FRESHWATER FISHES OF ALASKA

Their Biology, Distribution and Value

by

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FOREWARD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory (CERL).

The primary mission of the Corvallis Laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This monograph assembles and organizes under one cover a vast amount of information about freshwater fishes of Alaska that was previously scattered in various, and at times obscure, sources. This valuable contribution to the knowledge of fishery biology will be utilized by many scientific disciplines.

A. F. Bartsch
Director, CERL

ABSTRACT

A summary of knowledge of the freshwater fishes of Alaska is provided. Covered are 56 species in 34 genera and 15 families, including strictly freshwater species, anadromous forms and those which normally are marine but which occasionally or regularly enter fresh water. For each species, a brief description is given, followed by discussion of its range and abundance, its general biology and its importance to man, as far as presently known.

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SECTION 1

INTRODUCTION

Since 1961 the author has studied the taxonomy, biology and distribution of various Alaskan freshwater fishes. These studies, combined with those of graduate students at the University of Alaska and related projects of undergraduates, resulted in the accumulation of extensive notes and manuscripts based on original investigations and a comprehensive file of references.

With the rapidly increasing industrialization of Alaska, an oil pipeline nearly ready to go into operation, a gas pipeline proposed and the increasing need for environmental impact statements, it seemed imperative to make this accumulation of data on fishes available. Those who plan projects, those who execute them, and those who determine feasibility, cost/benefit ratios, and probable environmental effects need as much accurate information as possible.

This monograph includes information on all fishes known to occur regularly or occasionally in the fresh waters of Alaska. Some species are strictly freshwater forms, never entering the sea. Others are anadromous, spending part of their lives in salt or brackish water and part in fresh water. Still others are normally marine forms which regularly or occasionally enter rivers. A few of this last group have not yet been recorded from fresh water in the State of Alaska but are included because they are known from this environment in other parts of their ranges. Discussion for each species includes a technical description, the distribution and abundance, a summary of the biology and behavior as far as known and a brief discussion of its importance to man. No attempt has been made to provide keys or other methods for identification, or a glossary of ichthyological terminology, since this information is available in McPhail and Lindsey (1970), Scott and Crossman (1973) and Morrow (1974).

SECTION 2

LAMPREYS--FAMILY PETROMYZONTIDAE

The lampreys are a primitive group of fish-like animals. Characteristically, they have no jaws, the mouth being a round, suctorial opening on the ventral side of the head and containing numbers of horny teeth. There is only a single nostril, located on the dorsal side of the head just before the eyes. The gill openings appear as a row of seven round holes on each side of the head, behind the eyes. The body is long and eel-like, with no paired fins. The dorsal fin is in two parts, the anal one, and both are more or less confluent with the caudal fin. The dorsal fin is larger and better developed in males than in females, while the anal fin is well developed in females but is almost non-existent in males. The skeleton is entirely of cartilage and contains no bone.

Some species of lampreys are parasitic on fishes. They attach themselves to the host with the oral sucker, rasp away the skin and scales with their horny teeth and suck the body juices. Parasitism appears to be found chiefly in species which are anadromous and is confined almost entirely to the marine phase of the life history. Non-parasitic species are much smaller and generally have blunt rather than sharp teeth.

PACIFIC LAMPREY

Entosphenus tridentatus (Gairdner)

DISTINCTIVE CHARACTERS

The Pacific lamprey is characterized by the presence of three (rarely only two) large, sharp teeth on the supraoral bar, and three sharp cusps on each of the central lateral tooth plates.

DESCRIPTION

Body elongate, eel-like, more or less cylindrical anteriorly, compressed posteriorly. Depth about 7% of total length. Head moderate, its length about 15% of TL. Snout rounded, its length about 66% of head length. Eye round, small, its diameter about 19% of head length, about equal to postorbital distance (from posterior edge of eye to anterior margin of first gill opening). A single nostril on median dorsal line just in front of eyes, in a short tube. Oral sucker round to oval. Gill openings 7, their vertical height about 60% of eye diameter, spaces between openings averaging a little less than half eye diameter (43-53%). Fifty eight - seventy four myotomes between last gill opening and anus. Anus at anterior end of anal fin. A slender, fairly prominent genital papilla present in males.

Teeth

Supraoral bar with three (rarely only two, the center one reduced or absent) large, sharp points. Lateral tooth plates with three sharp points on each of the central plates. A row of posterial teeth present. Tongue with 15-25 small, fine teeth, all about the same size. Infraoral bar with 5-8 points.

Fins

Two dorsal fins, placed far back on body, the anterior one lower and shorter than the posterior, the two fins separated by a notch. Dorsal fins higher in males than in females. Caudal fin more or less pointed, lower lobe larger than upper, the lobes joined to dorsal and anal fins. Anal fin rudimentary, virtually absent in males. No paired fins.

Color

Adults fresh from the sea are usually blue-black to greenish above, silvery to white below. Spawning adults become reddish brown.

Size

Reaches a length of 760 mm (30 in) and a weight of about 1/2 kg (1 lb).

RANGE AND ABUNDANCE

The Pacific lamprey has been recorded from Alaskan waters from Nome (UAFC #1119), St. Matthew Island, Wood River, Unalaska Island and southward. It is also known from Hokkaido Island, Japan. One was taken from the stomach of a whale captured off Bering Island, near the Kamschatkan Peninsula. On the American side of the Pacific, the range extends from the northern Bering Sea south to southern California. This lamprey is fairly abundant throughout its range.

HABITS

Adults return from the sea and run upstream in fresh water in the spring and summer, showing considerable ability to overcome obstacles such as dams and waterfalls. In this, they hold on with their oral suckers to the smooth face of the obstruction, then let go and swim vigorously upward and catch a new hold. This procedure is repeated until the obstacle has been passed. At the time of upstream migration, the lampreys are not yet sexually mature. They spend the following fall and winter in the streams, often burrowing into the stream bottom. Spawning takes place in the spring following the migration into fresh water. The spawning areas are usually in the upper reaches of the streams, most often in fine gravel at the upper ends of riffles. The nest is a shallow pit, about 550 mm in diameter, and is dug by both males and females. In this activity, each lamprey affixes itself to a stone by means of its oral sucker, then both members of a pair thrash about with their bodies, disturbing the fine sand and debris which are carried downstream by the current. They may also pick up small stones with their suckers and carry them out of the nest.

In the spawning act, the female attaches herself to a stone and the male fastens his sucker on the head of the female. The two arch and twist their bodies towards each other, the male more or less wrapping his body around that of the female. This brings the male's genital papilla in close proximity to the genital pore of the female. The two then vibrate and eggs and sperm are released. A large female may produce up to about 100,000 eggs. The adults die soon after spawning.

The small, whitish eggs fall to the bottom of the nest, where the parents leave them. Hatching occurs a week or two after spawning, the time depending largely on temperature. The newly hatched larvae (ammocoetes) are blind and have no sucking disc. They remain for several years more or less buried in the fine sand and mud of the stream bottom, feeding by filtering plankton and tiny particles of algae and debris from the water. Finally, they metamorphose into the adult form and go to sea. A number of landlocked populations are known, in which the adults remain in fresh water throughout their entire lives (Pletcher, 1963).

During the marine life, the adults are parasitic, attaching themselves by means of the oral sucker to the bodies of larger fishes. With their sharp, horny teeth, they rasp through the scales and skin of the host and feed on the blood and body fluids. They will probably attack any fish of suitable size, but are particularly known to parasitize the various species of salmons and trouts. Adults do not feed in fresh water. In turn, the lampreys are fed upon by many predacious fishes such as pike, trout, salmon and so on.

IMPORTANCE TO MAN

The Pacific lamprey is of greatest importance as a parasite of more desirable fishes. It is not known whether this lamprey actually kills a significant number of fishes, but certainly a fair percentage are found bearing scars which may be attributable to E. tridentatus. The Pacific lamprey is not marketed, but there is no reason to think that it is any less edible than the European lampreys, which have long been considered a delicacy.

ARCTIC LAMPREY

Lampetra japonica (Martens)

DISTINCTIVE CHARACTERS

Two large teeth on the supraoral bar, only two points on the central pair of lateral tooth plates, and the presence of a row of posterial teeth distinguish *L. japonica*.

DESCRIPTION

Body elongate and eel-like, depth about equal to width anteriorly, becoming compressed posteriorly, depth about 7% (5.8-9.1%) of total length. Head short, about 12.4% (11.7-13.3%) of total length. Snout rounded anteriorly, its length about 66% (55-68%) of head. Eye round, its diameter 20% (15-28%) of head, 135% (114-152%) of postorbital distance. The eye is relatively larger, over 20% of head, in specimens under about 150 mm total length, while in individuals over about 200 mm the eye is only 15-17% of head length. The eye-postorbital relationship, however, appears to remain constant. Nostril on median dorsal line, just before eyes, in a short, fairly prominent tube. Oral sucker more or less round. Gill openings 7, approximately round, their diameter about 36% (22-62%) of eye. Spaces between gill openings averaging a little more than half eye diameter. Sixty-five - eighty myotomes between last gill opening and anus. Anus located at anterior end of anal fin. A slender, fairly prominent genital papilla present in males, barely developed in females.

Sensory pores on head region, each in a small tubercle, as follows: Laterally on each side a row of about six pores extending backward from tip of snout; a row of about nine from ventral margin of eye dorsally and anteriorly; a row of about seven posteriorly from postero-dorsal margin of eye. On dorsal side, a transverse row, often broken, of four to six pores across top of head at level of posterior margin of eye; two rows of widely spaced pores extending backwards from just anterior to first gill opening, the more dorsal row reaching somewhat behind last opening, the more lateral row reaching the last opening. On ventral side, a fairly prominent row more or less encircling posterior part of oral sucker; two rows from behind oral sucker to about the level of the fourth gill opening.

Teeth

Supraoral bar normally with two large points (rarely a small third central point). Lateral tooth plates with two points on central pair. A row of posterial teeth present. Tongue with a large median tooth point and six or seven small points on each side. Infraoral bar with 5-10 usually blunt points.

Fins

Two dorsal fins, anterior one lower than posterior, arising far back on body, the fins separated from each other by at least a definite notch, higher in males than in females. Caudal fin with lower lobe somewhat larger than upper, the fin joined to both dorsal and anal fins. Anal fin small, in males represented only by a low ridge.

Color

Variable, from brown to olive or grayish above, paler beneath.

Size

Known to reach a length of over 600 mm (about 2 ft), but generally rather smaller. The strictly freshwater, non-anadromous form rarely exceeds 180 mm (7 in).

RANGE AND ABUNDANCE

In Alaska, the Arctic lamprey ranges from the Kenai Peninsula north to the Arctic coast and east as far as the Anderson River in Canada. It has also been found on St. Lawrence Island. Inland, it ranges up the Yukon River into the Yukon Territory, and is also present in the Kuskokwim and Tanana river drainages. World-wide, this species is almost completely circumpolar, from Lapland south to the Caspian Sea, eastward to Kamschatka, south to Korea, and eastward across North America to the Northwest Territories of Canada.

Abundance varies locally and seasonally. Large numbers are known to ascend the lower Yukon River, and the population in the Naknek River also seems to be relatively large. A small population is known to spawn in the Chaktanika River a few kilometers below the Elliott Highway bridge.

HABITS

Relatively little is known of the life history of this species. In the Naknek River of Alaska, and doubtless in other areas as well, the population appears to be composed of both anadromous and strictly freshwater forms. The Chatanika population is probably strictly freshwater, while those of the lower Yukon seem to be mostly anadromous. Both the anadromous and the freshwater forms are reported to be parasitic. Spawning takes place in the spring. Both males and females engage in nest-building, removing pebbles and small rocks from the stream bottom by picking them up with their suckers and depositing them downstream from the nest, or by attaching themselves to a large rock and thrashing violently, thus raising small stones and silt which are carried downstream by the current. Nests are located out of the main current, in water from a few centimeters to nearly a meter deep, flowing at between 0.16 and 0.3 meters per second. In the breeding act, the male attaches himself by means of his sucker to the head of the female. The two arch their bodies and the male wraps himself around the female so that his genital papilla is close to her genital pore. Both members of the pair vibrate rapidly and eggs and sperm are extruded into the nest. Occasionally, two males may mate simultaneously with a single female. Females will mate several times before their egg supply is exhausted, usually with several males. A large female may produce more than 100,000 eggs.

Time for development of the eggs is probably a few weeks. The larvae (ammocoetes) apparently spend at least one and possibly two years in this stage, for in the Naknek River two distinct size groups have been observed. Upon metamorphosis, the young adults descend the stream either to the sea or to lakes or larger rivers. Adults are parasitic on many species of fishes, attaching themselves to their hosts by means of the oral sucker, rasping through the skin and scales and sucking the blood and body fluids. Host species which have been recorded include sockeye salmon (Oncorhynchus nerka), pink salmon (O. gorbuscha), chum salmon (O. keta), chinook salmon (O. tshawytscha), starry flounder (Platichthys stellatus), pygmy whitefish (Prosopium coulteri) and three-spine stickleback (Gasterosteus aculeatus) (Berg, 1948; Birman, 1950; Heard, 1966; McPhail and Lindsey, 1970). It is probable that this lamprey will parasitize any species of fish, providing only that the individual is of suitable size.

Length of life is unknown.

IMPORTANCE TO MAN

The Arctic lamprey is probably of no direct importance to man. It is possible that lamprey parasitation may have a bad effect on the health of the host, but, at least in the Naknek River, there is no evidence that this species has had an adverse effect on the fisheries (Heard, 1966). In the Yukon River, lampreys were formerly taken in large numbers with dip nets and used for food (Evermann and Goldsborough, 1907). However, at the present time this species is but little utilized for any purpose, although a market for smoked lampreys might well be developed.

RIVER LAMPREY

Lampetra ayresi (Gunther)

DISTINCTIVE CHARACTERS

The river lamprey has two large teeth on the supraoral bar, a large middle tooth on the tongue, three points (rarely two) on each central lateral tooth plate, and no posterial teeth.

DESCRIPTION

Body elongate, eel-like, nearly cylindrical as far back as the dorsal and anal fins, where it becomes compressed. Depth about 8-11% of total length. Head moderate, 12.5% (11-14%) of TL. Snout rounded, its length about 60% of head. Eye large, round, its diameter about 145% (100-200%) of postorbital. Nostril on median dorsal line, barely in front of eyes, in a short tube. Gill openings 7, their vertical height about 24% of eye diameter, spaces between openings equal to about 50% of eye. Trunk myotomes usually 65-71, average 68, rarely as low as 60, between last gill opening and anus. Anus at anterior end of anal fin. A slender anal papilla present in males.

Teeth

Supraoral bar with two sharp points. Three lateral tooth plates on each side, the central ones with three points, the others with two. Tongue with a large, triangular central tooth and about seven small ones on each side. Infraoral bar with 7-10 (average 9) teeth. No posterial teeth.

Fins

Two dorsal fins, the anterior the lower, the fins separate in non-breeding individuals but coming in contact at spawning. Caudal fin pointed, lobes about equal, lower lobe joined to anal. Anal fin virtually absent in males.

Color

Dark brown or brownish grey on sides and back, belly whitish, silvery around head, gill openings and lower sides. Caudal fin with a band of dark pigment inside its margin, symmetrical on both lobes.

Size

This is a rather small lamprey, maximum length about 311 mm (1 ft). Average length seems to be about 170 mm (6 1/2 in) (Vladykov and Follett, 1958).

RANGE AND ABUNDANCE

The river lamprey is confined to the west coast of North America, from as far south as San Francisco Bay (Vladykov and Follett, 1958) north to Tee

Harbor, 24 km northwest of Juneau, Alaska (Scott and Crossman, 1973). It does not appear to be particularly abundant anywhere within its range.

HABITS

Like most parasitic lampreys, *L. ayresi* is anadromous. Spawning occurs in the spring (in late April through May in California). Spawning behavior has not been described, nor is the length of larval or adult life known. Egg numbers per female have been estimated at 37,288 for a specimen 175 mm long, and 11,398 for one of 230 mm. These numbers resulted in estimates of 5,108 and 5,428 eggs per gram of ovary, respectively. The river lamprey is known to parasitize small coho and kokanee salmon, and is in turn eaten by other fishes such as ling cod (Vladikov and Follett, 1958).

IMPORTANCE TO MAN

As with other lampreys, the importance of this species is indirect, in that it parasitizes more desirable fishes. However, its limited abundance makes it of little concern.

WESTERN BROOK LAMPREY

Lampetra richardsoni Vladykov and Follett

DISTINCTIVE CHARACTERS

The very blunt teeth, the lack of a distinct median tooth on the tongue and the lack of posterial teeth distinguish this species from others found in Alaska.

DESCRIPTION

Body elongate and eel-like, more or less cylindrical anteriorly but becoming compressed posteriorly. Depth of body about 7% of total length. Head short, about 12.5% of total length. Snout rounded anteriorly, its length about 60% of head. Eye small, round, diameter about 2.3% of total length, about equal to postorbital distance. A single nostril on dorsal median line of head, a short distance before eyes, in a short, fairly prominent tube. Oral sucker round, its diameter about 59-60% of snout length. Gill openings 7 on each side. Trunk myotomes 60-67 between last gill opening and anus. Anus just before anal fin. A small but obvious genital papilla in males. The number and arrangement of the sensory pores on the head seem to be as in *L. japonica*.

Teeth

Two broad, blunt teeth on supraoral bar. Two blunt teeth on each lateral tooth plate. About five blunt teeth on tongue. Infraoral bar with about seven blunt teeth. No posterial teeth.

Fins

Two dorsal fins, the anterior lower than the posterior, arising well back on body. Fins separate from each other in young, but come together and at least touch (may fuse) with onset of sexual maturity. Caudal fin joined to both dorsal and anal fins. Anal fin small, represented in males only by a low ridge.

Color

Sides and back dark grayish to brownish, ventral side of body whitish. Caudal fin and posterior tip of body conspicuously dark.

Size

This is quite a small species, the largest specimen recorded being only 154 mm (about 6 in) long. Ammocoetes range up to 175 mm (Vladykov and Follett, 1965).

RANGE AND ABUNDANCE

In Alaska the western brook lamprey has been recorded only from McDonald Lake, on the Cleveland Peninsula in southeastern Alaska just north of Yes Bay. However, it ranges southward in coastal streams in British Columbia, Washington and Oregon as far south as the Umpqua River, near Reedsport, Oregon. It is not particularly abundant anywhere, as far as is known.

HABITS

Nothing is known of the biology of this species. Presumably, its life history is like that of other non-parasitic lampreys, in which the larvae burrow into the bottoms of brooks or hide under stones, hence are not easily discovered. The adults do not feed and probably do not live more than a few months. They die after spawning.

IMPORTANCE TO MAN

This species is of no importance to man, except for its scientific and aesthetic interest. It probably contributes a minor portion of the food of predacious fishes, insects, etc., wherever it is found.

SECTION 3

STURGEONS--FAMILY ACIPENSERIDAE

This group includes some of the largest fishes in the world, some exceeding 1,000 kg (a ton) in weight and 6 meters (20 ft) in length. They are heavy fishes, with more or less cylindrical bodies, a flat, extended snout and a toothless, protrusible mouth on the under side of the snout, with four barbels in front of it. The tail is upturned, like that of sharks, with the upper lobe notably longer than the lower. The body shows five rows of large, bony plates; a dorsal row along the back, a lateral row on each side, and two ventro-lateral rows. The plates are sharp-pointed in the young, but become blunt in adults. The skin between the plates appears naked but actually bears patches of fine denticles. The head is covered by bony plates. The first ray of the pectoral fin is heavy and ossified. The two species of sturgeon found in Alaska are anadromous, spending most of their lives in the sea but breeding in fresh water. Other species are confined to fresh water.

GREEN STURGEON

Acipenser mediostris Ayres

DISTINCTIVE CHARACTERS

A single row of 1 to 4 bony plates along the mid-ventral line between the anus and the anal fin, and about 33-35 dorsal rays characterize the green sturgeon.

DESCRIPTION

Body rather robust, more or less five-sided in cross-section, depth about 10% of total length. Head flattened, its length about 25% of total length. Snout produced, flattened, somewhate concave in profile. Mouth small, transverse, protrusible, on ventral side, toothless. Four sensory barbels in front of mouth, their bases nearer to mouth than to tip of snout. Eyes small, round. Gill rakers 18-20. Body with five longitudinal rows of bony, keeled plates, the keels sharp-pointed in young but becoming more blunt and rounded in older individuals. Plates in one dorsal row of 8-11 plates, two lateral rows of 23-30 plates, and two ventro-lateral rows of 7-10 plates each. Skin between plates with numerous small, rough plates or denticles. A single row of 1-4 small bony plates on ventral mid-line between anus and origin of anal fin.

Fins

Dorsal arising at posterior third of total length, usually with 33-35 rays. Anal originating under posterior part of dorsal, 22-28 rays. Pectoral origins low on body, just behind gill openings, fins large and rounded. Pelvic fins arising near anus. Caudal heterocercal, lower lobe about 3/4 as long as upper.

Color

Generally olive to dark green, lower parts more or less whitish green. A longitudinal olive green stripe on side between lateral and ventro-lateral plates, another on mid-ventral surface. Fins grayish to pale green.

Size

Reaches a length of over 2 meters (7 ft) and a weight of about 160 kg (350 lb) (Dees, 1961).

RANGE AND ABUNDANCE

In Alaska, the green sturgeon has been found as far north as the northwest side of Unalaska Island in the Aleutians, but it is rather uncommon in the state (Wilimovsky, 1964). The range extends southward along the Pacific coast of North America to southern California, with two specimens recorded from just south of Los Angeles (Roedel, 1941; Norris, 1957). It has also been reported from Ensenada, Baha California (Miller and Lea, 1972). On the western side of the Pacific, this species ranges from the Amur River south to Hokkaido, Peter the Great Bay and Kunsan, Korea. The area of greatest abundance seems to be from the Columbia River in Washington and Oregon to the Fraser River in British Columbia.

HABITS

Very little is known of the biology of the green sturgeon. The little information available suggests that its life history is like that of other anadromous sturgeons. However, it is not known to ascend streams to any great distance. It is most commonly found in estuaries, in the lower reaches of large rivers and in salt or brackish water off river mouths.

The green sturgeon probably spawns in fresh water. It is captured in nets and by anglers in the lower Columbia and Fraser rivers in late summer to winter. Presumably, these fish move into the fresh water in the late summer and fall to spawn the following spring.

Green sturgeon may undertake considerable movements in the ocean. Three fish tagged in 1954 in San Pablo Bay, California, near the mouth of the Sacramento River, were recovered one to four years later in Oregon. One was recaptured in Winchester Bay, the other two in the lower Columbia River (Chadwick, 1959).

Nothing is known of growth rates, age, etc.

Food of the green sturgeon probably consists largely of bottom-dwelling invertebrates and small fishes. There is one report of a green sturgeon having fed on sand lance (Anon., 1954).

IMPORTANCE TO MAN

The green sturgeon is virtually unutilized in North America, although it is taken commercially in the Bering Sea by Russian fishermen (Magnin, 1959). As a food fish, the green sturgeon is considered inferior. The flesh is said to be dark, with a strong, disagreeable taste and an unpleasant odor. It was once thought to be poisonous. At least in the past, the roe was not utilized (Jordan and Evermann, 1908). The green sturgeon does not seem to be particularly common, although occasional concentrations (feeding aggregations?) may be encountered. One such was reported off Kyuquot Sound on the northwest coast of Vancouver Island, where 75 fish were taken in a single day (Anon., 1954).

WHITE STURGEON

Acipenser transmontanus Richardson

DISTINCTIVE CHARACTERS

Two rows, each of 4-8 bony plates along mid-ventral line between anus and anal fin, and about 45 rays in the dorsal fin serve to distinguish the white sturgeon.

DESCRIPTION

Body elongate, sub-cylindrical, depth about 10% of total length. Head more or less conical, somewhat flattened above, its length 19-23% of total length. Snout moderately produced, blunt, relatively shorter in adults than in young. Eyes small. Nostrils prominent. Mouth wide, transverse, protractile and toothless, located on ventral side of head below eyes. Four tactile barbels on ventral side of snout in front of mouth, a little closer to tip of snout than to mouth. Gill rakers 34-36. Body with five longitudinal rows of keeled, bony plates. Dorsal row 11-14, lateral rows 38-48, ventrolateral rows 9-12. Rarely there may be a secondary row on each side between the dorsal and lateral rows (Bajkov, 1955). Skin between plates with numerous, rather inconspicuous, stellate tubercles. Two rows of 4-8 plates each on ventral side between anus and anal fin.

Fins

Dorsal fin originating near posterior third of total length, 44-48 rays. Anal origin under posterior part of dorsal, the fin with 28-31 rays. Pectoral fins arising low on body, just behind gill openings, upper rays longer than lower, first ray notably enlarged and bony. Pelvic origins slightly before anus. Caudal heterocercal, upper lobe about twice as long as lower.

Color

Generally gray or brownish above, paler below. Fins gray.

Size

The largest freshwater fish in North America, the white sturgeon is reputed to attain a length of 6 meters (20 feet) and weight to over 860 kg (1,900 lb). However, the heaviest documented specimen weighed 630 kg (1,387 lb) (Hart, 1973).

RANGE AND ABUNDANCE

Pacific coast of North America, from Ensenada, Baha California in the south (Miller and Lea, 1972) north to the Gulf of Alaska. Found in rivers and estuaries, and in the sea to as deep as 122 meters (400 ft). Most abundant in and around the mouth of the Columbia River. It has been suggested that the Lake Iliamna "sea monster" may be a large white sturgeon. Not common in Alaska.

HABITS

The white sturgeon is anadromous, although some individuals apparently spend much of their lives in fresh water. Mature fish enter the estuaries and lower reaches of large rivers any time from fall to early spring, although the majority seem to leave the sea in the spring. Upstream migration begins in April or May, with spawning taking place in May and June in most areas (Bajkov, 1951).

Some fish may move great distances, as far up the Columbia River as Flathead Lake, Montana (Brunson and Block, 1957). Such fish may well start their upstream migration earlier (perhaps even the previous year) and spawn later than fish moving shorter distances.

Spawning areas are said to be in swift water over rocky bottoms. Water temperature during the spawning period has been reported as 8.0-16.7°C (Scott and Crossman, 1973).

First spawning occurs at about 10 years of age for males, 11 to 12 years for females of southern stocks (Carlander, 1969; Pycha, 1956). In the Fraser River, males mature at 11 to 22 years, females at 26 to 34 (Semakula and Larkin, 1968). Adults return to the sea after spawning, but do not breed annually. Intervals of 2-9 years may occur between breeding periods in the Fraser River stock (Semakula and Larkin, 1968).

Fecundity varies with the size of the individual, from a few hundred thousand eggs in small females to about 2,000,000 or more in the largest adults. Ovary weights may reach more than 110 kg.

The eggs are brown in color. They are sticky and adhere to the stream bottom. Time required for hatching is unknown. Growth of the young is quite rapid for the first few years. One-year-old fish from San Pablo Bay, California, averaged about 260 mm total length, five-year-olds about 800 mm. After the 8th year, the fish grew at a fairly constant rate of 50-60 mm per year. Similar growth rates were found in white sturgeon of the Fraser River (Pycha, 1956; Semakula and Larkin, 1968).

Adult white sturgeon may reach great size, but very large fish are rare nowadays. The average weight of net-caught fish seems to be on the order of 16-25 kg. However, around the turn of the century, very large fish appear to have been more common. One of 862 kg (1,900 lb) was supposed to have been taken at Astoria, Oregon. Another (possibly the same fish) of about 908 kg (2,000 lb) was supposed to have been exhibited at the Chicago World's Fair in 1893, but neither the specimen nor records of it now exist (Jordan et al, 1930; Gudger, 1942). Other large white sturgeon include one of 817 kg (1800 lb) from the Fraser River at Mission, B.C., sometime before 1897, one of 630 kg (1,387 lb) from the Fraser at New Westminster in 1897, and one of 583 kg (1,285 lb) and 3.81 m long (12 ft, 6 in) from the Columbia River at Vancouver, Washington in 1912 (Clemens and Wilby, 1946, 1961; Gudger, 1942).

The maximum age recorded for the white sturgeon is 82 years (Carlander, 1969). Extrapolation of data given by Pycha (1956) suggests that the very large fish mentioned above must have been on the order of 100 years old, possibly older.

The white sturgeon spends much of its life in the sea, where it is thought to remain fairly close to shore. It is known from depths of 30 m or less and has been taken in salt, brackish and fresh waters with temperatures between 0° and 23.3°C. Migrations and movements in the sea are not well known, but they certainly exist, for a specimen tagged in San Pablo Bay, California, was recaptured about 10 months later at the mouth of the Columbia River, a minimum distance traveled of 1,056 km (Chadwick, 1959).

The white sturgeon is primarily an omnivorous scavenger, but seems also to be actively piscivorous, much more so than other sturgeons. Eulachon and lampreys appear to be favored foods, along with sculpins, sticklebacks, salmonids, crayfish, frogs, molluscs, insect larvae and various other organisms (Gudger, 1942; Merrell, 1961; Radtke, 1966; Carlander, 1969; Scott and Crossman, 1973). The young feed primarily on plankton, amphipods, shrimp and tendepedid larvae. Other food organisms include mysids, *Daphnia*, *Chaoborus* larvae, copepods and various immature insects (Carlander, 1969; Schreiber, 1961; Scott and Crossman, 1973).

IMPORTANCE TO MAN

Before about 1880, white sturgeon were utilized almost entirely in subsistence fisheries. As the Pacific salmon fisheries developed, the sturgeon came to be considered a nuisance. However, about 1886 or 1887, "an eastern firm" began to ship frozen sturgeon to eastern markets. The enterprise was successful, and by 1892 the Oregon landings from the Columbia River were in excess of 1,498,000 kg (3,300,000 lbs). The greater part of the flesh was smoked after arrival in the east, the air bladder made into isinglass, the eggs into caviar. Indeed, every part of the fish was used, even the backbone (McGuire, 1896). This state of affairs did not last long. By 1897 the total catch for Washington and Oregon had dropped to just under 629,142 kg (1,386,000 lb), and by 1900 had declined further to a mere 55,152 kg (121,500 lb). The fishery continued at a low ebb until the mid-1940's, when catches began to rise. Current landings (1970) are on the order of 227,000 kg (500,000 lb). The catch from the Fraser River has averaged about 13,600 kg (30,000 lb) annually since 1941 (Hart, 1973).

Flesh of the white sturgeon is highly esteemed, either fresh or smoked, and the eggs make excellent caviar. However, there is no demand for isinglass nowadays.

SECTION 4

HERRINGS--FAMILY CLUPEIDAE

This is a large family, containing about 70 genera and more than 150 species, but only two members, the Pacific herring, Clupea harengus pallasi, and the American shad, Alosa sapidissima, are found in Alaska.

Characteristically, the members of this group have slender, compressed bodies, although some are short and deep and a few are sub-cylindrical. The scales are cycloid and in most are extremely deciduous. The ventral side of the body is compressed to a sharp edge, usually serrate. There is no lateral line. The mouth is large, teeth small or absent in almost all. The dorsal fin is located about at the mid-length of the body and there is no adipose fin. The caudal fin is forked.

This is one of the most important of the families of fishes from the human economic standpoint. Vast numbers are taken for food, fresh, canned, smoked, pickled, etc. Other species are utilized for fish meal and oil. The smaller species and the young of the larger ones serve as food for a tremendous variety of large fishes, aquatic mammals, birds and turtles.

PACIFIC HERRING

Clupea harengus pallasi Valenciennes

DISTINCTIVE CHARACTERS

The Pacific herring may be distinguished from the American shad by the origin of the dorsal fin about mid-way between the tip of the snout and the base of the tail (further forward in the shad); the body depth 25% or less of the length (more in the shad); and the presence of teeth on the vomer bone (absent in the shad).

DESCRIPTION

Body elongate, compressed, its depth less than 25% of total length. Head compressed, its length about equal to body depth. Snout moderate, about equal to eye diameter. Eyes round, adipose lids present. Mouth fairly large, no teeth on jaws but a patch of fine teeth on vomer in roof of mouth. Gill rakers long, those at angle of gill arch about as long as eye diameter, fine, 63-73, the number apparently increasing with size of fish. Lateral line absent.

Fins

D. 15-21, origin of fin about equidistant between tip of snout and base of tail. A. 14-20. P_1. 17-19. P_2. 8-9, abdominal in position, each with a fleshy axillary process above its origin. Caudal fin forked.

Scales

Large, cycloid, deciduous, 38-54 rows along side of body. On mid-ventral line, scales modified, with moderate keels on those before pelvic fins, strong keels between pelvics and anal.

Color

Dark blue to olivaceous above, shading to silver below.

Size

Said to reach 38 cm (15 in) in Alaskan waters, but the average is probably around 25 cm (10 in).

RANGE AND ABUNDANCE

On the North American coast, the Pacific herring is found from northern Baha California (Miller and Lea, 1972) to Bathurst Inlet in the eastern Beaufort Sea (Richardson, 1836). Commercial fisheries exist as far south as San Francisco, but the region of greatest abundance is along the coasts of British Columbia and southeastern and central Alaska.

On the western side of the Pacific, this herring ranges from the Japanese islands and Korea north and west to the Laptev Sea on the arctic coast of Siberia. Very closely related forms are found still further west in the Kara Sea, Barents Sea and White Sea (Andriyashev, 1954; Nikolskii, 1961).

Although generally considered a marine species, the Pacific herring occasionally enters estuaries. Freshwater, landlocked races have been reported from Japan (Fujita and Kokubo, 1927). On this basis, the Pacific herring is included here.

HABITS

The Pacific herring spawn from December to July. The winter spawning occurs at the southern end of its range, around San Diego, California, and occurs progressively later in the year in more northern populations (Schaefer, 1937; Scattergood et al, 1959; Barraclough, 1967). In Alaska, most spawning activity goes on between mid-March and mid-April in southeastern; April-May in Prince William Sound; and May-June around Kodiak Island (Scattergood et al, 1959). Spawning has been recorded in the Bering Sea near St. Michael's in June (Nelson, 1887). Spawning activity is roughly related to temperature and occurs at water temperatures between 3.0 and 12.3°C. It is uncertain whether the herring of the Chukchi and Beaufort seas are self-sustaining populations or represent migrants from farther south.

The eggs are 1.2-1.75 mm in diameter after being spawned. Fecundity is related to size and age, and northern fish appear to produce more eggs than do southern ones of the same size (Nagasaki, 1958), although there is considerable variation among populations (Katz, 1948). Average egg numbers along the coast of North America range from a little over 8,000 in two-year-old fish from southern British Columbia to more than 59,000 in seven-year-olds (Nagasaki, 1958). A fish from Peter the Great Bay, near Vladivostok, was reported to contain more than 134,000 eggs (Katz, 1948, citing Russian data).

Spawning of the Pacific herring appears to be a mass proposition, with no definite pairing of males and females, although Rounsefell (1930) described the male following "a few inches behind the famale covering the attached eggs with a stream of milt."

Spawning takes place in shallow water, from the very edge of the high tide line to a depth of about 7 meters (23 ft), most commonly over vegetation such as eel grass or Fucus, or on brush, pilings, rocks, etc. In the spawning act, the female turns on her side, fins extended and body nearly rigid. Vibrating her tail, she moves slowly forward, her vent brushing the eel grass or other substrate, depositing her eggs as she goes. The posterior edge of the vent is equipped with a fleshy lobe which blocks extrusion of the eggs. Brushing the vent against the substrate pulls this lobe out of the way, allowing the eggs to escape. The female remains on her side for 2-5 seconds, then resumes upright posture. This procedure is repeated again and again until all the eggs have been laid, which may take several days (Schaefer, 1937). While the females are depositing their eggs, the males in the area are releasing milt. The milt mixes and spreads in the water, fertilizing the eggs, and the whitish, milt-filled water may extend for several miles along the shore.

The eggs are sticky and adhere to whatever they touch. They hatch in about 10 days at the usual temperatures, yielding yolk-sac larvae about 7.5 mm (0.3 in) long. Feeding begins two weeks or less after hatching, as soon as the yolk has been absorbed. The first foods are mainly copepods, invertebrate eggs and diatoms. The young fish are in turn eaten by various filter-feeders such as pilchards, and entanglers like jelly fishes, as well as by young salmons.

During this early growth period, the young herring may be dispersed by waves and currents. Those which are carried out to sea apparently perish and this off-shore transport seems to be the major cause of mortality at this time (Stevenson, 1962). Those not carried out to sea subsequently congregate in suitable shallow bays, inlets and channels (Hourston, 1958, 1959). By the end of the summer, the young may be as long as 10 cm (4 in). They move into deeper water in the fall and virtually disappear from the fishing grounds for the next couple of years.

After the first year or two, northern herring grow faster than do those from California. They also live longer and get bigger. The oldest California herring was a 9+, but a 19+ has been recorded from Alaska. Most herring in the Alaskan catch are between 4 and 9 years old (Rounsefell, 1930; Miller and Schmidtke, 1956).

As the fish grow, larger food items become more important in the diet. Copepods remain important to the young, but the diet also includes euphausiids, amphipods, cladocerans, decapod and mollusc larvae, etc. Adults exhibit a similar diet, but also eat larger crustaceans and a wide variety of small fishes. In turn, adult herring are preyed upon by virtually every animal large enough to eat them - dogfish and other sharks, salmon, cods, mackerel, squid, seals and sea lions and man.

Pacific herring usually move offshore in the winter and back onshore for spawning, but apparently do not undertake extensive coastwise migrations. Mixing of local populations is relatively rare, so particular groups can be recognized by certain physical characteristics all the way from Alaska to southern California.

IMPORTANCE TO MAN

The Pacific herring has never rivaled its Atlantic relative in terms of tonnage landed, but it is nevertheless a significant part of the fisheries of the North Pacific. Along the Siberian coast, "the annual catch exceeds 6,000,000 centners" (300,000,000 kg) (Andriyashev, 1954). High production values for the North American coast are generally slightly lower. Almost all the North American herring catch comes from Alaska and British Columbia.

The Alaskan herring fishery began in the late 19th century. Statistics for 1882 show landings of 1,363,636 kg (3,000,000 lb). Over the next 34 years, the catch fluctuated between 2.5 and 14.6 million kg (5.6-32.1 million lb), averaging about 6.6 million kg (14.5 million lb). The majority of the catch went into salted herring in various forms. World War I increased the demand for Alaska salt herring and catches increased accordingly. By the mid-1920's, however, the Alaskan salteries could no longer compete, either in price or in quality of product, with the resurgent European industry. Nevertheless, a great expansion of the reduction industry led to further increased landings. From 1924 to 1941, Alaskan landings were more than 45.5 million kg (100 million lb) per year, peaking at more than 118.6 million kg (261 million lb) in 1937. For the next 10 years or so, catches again varied widely, then, beginning in the early 1950's, dropped rapidly to their present low level. This has been ascribed to a sudden paucity of fish, increased competition from foreign sources and other factors such as greater profit in other fisheries, which attracted operators away from herring. Probably all three were important. In recent years, the Alaskan herring fishery has produced between 4.5 and 9.1 million kg (10-20 million lb) annually, most of it being used for bait (Anderson and Power, 1946, 1957; Anderson and Peterson, 1953; Power, 1962; Lyles, 1969; Anonymous, 1971, 1972, 1973; Browning, 1974).

AMERICAN SHAD

Alosa sapidissima Wilson

DISTINCTIVE CHARACTERS

The American shad is easily distinguished from similar-appearing Alaskan fishes by the rather pointed lower jaw which fits into a deep notch in the upper jaw; the coarse, curved, radiating striae on the gill cover; and the row (sometimes two or even three rows) of dark spots on the upper sides behind the head.

DESCRIPTION

Body compressed, fairly deep, depth 30-37% of standard length. Head moderate, compressed, its length 23-28% of SL. Snout moderate, 27-32% of head length. Eye about equal to snout, adipose lids well developed. Mouth terminal, lower jaw fitting into a notch in upper jaw in adults, but this notch lacking in young less than about 150 mm long. Upper jaw (maxilla) reaches middle of eye in young, to below posterior margin of eye in adults. Teeth absent, or at best few and small in adults, present but minute on jaws and mid-line of tongue in young specimens. Gill rakers long and slender, those at angle of gill arch shorter than snout in young but longer than snout in adults, number increasing with age and size, 26-43 on lower limb in young, 59-73 in adults. Lateral line absent.

Fins

Dorsal elevated anteriorly, margin slightly concave, its origin slightly forward of pelvic bases, rays 15-19, usually 17 or 18. No adipose dorsal. Anal long and low, 20-23 rays. Pectorals small, low on sides, 14-18 rays. Pelvics with 9 rays. A pelvic axillary process present. Caudal deeply forked, upper and lower lobes about equal.

Scales

Moderately adherent, cycloid, with crenulate borders, 52-62 rows along middle of side, 15-16 between pelvic base and dorsal origin. Ventral scutes well developed, 20-22 before pelvics, 14-17 behind.

Color

Metallic greenish or bluish above shading to silvery on sides and belly. A row of dark spots on upper part of sides behind head, sometimes a second, rarely a third row below the first. Fins pale to greenish, dorsal and caudal dusky in large specimens, tips of caudal sometimes dark.

Size

The largest North American member of its family, the shad reaches a length of 760 mm (30 in) and a weight of 6.4 kg (14 lb). However, the average weight of adult shad is probably around 2-2.5 kg (4.5-5.5 lb). Females are usually larger and heavier than males.

RANGE AND ABUNDANCE

The normal range of the shad on the east coast is from the St. Lawrence River and Nova Scotia south to the Indian River, Florida. It has been reported from as far north as Bull's Bay, Newfoundland. On the Pacific side, the shad ranges from Todos Santos Bay, Baha California, to southeastern Alaska, with strays north and west to Cook Inlet, Kodiak Island and Kamschatka.

In the Major portions of its range, the shad is quite abundant, but it is quite scarce in Alaska. Fishermen in southeastern pick up a few in the salmon nets every year, but, as far as is known, there are no breeding populations of shad in the state.

HABITS

The shad is anadromous, spending most of its life in the sea but returning to freshwater streams to breed. Some spawn almost immediately on entering fresh water, while others may undertake fairly long journeys, as much as 630 km (394 mi) upstream to their favored spawning grounds (Hildebrand, 1963). Timing of the run is governed by water temperature. The shad enter the rivers when the temperature is between 10 and 13°C. Hence, in the southern part of the range, spawning may occur as early as March, but not until late June at the northernmost end.

Spawning usually takes place in the evening, between dusk and 10 p.m., on sandy or pebbly shallows. No nest or redd is made. The fish pair and swim close together, side by side, releasing eggs and milt. A single female may require several evenings to complete spawning, as all eggs apparently are not shed at once. The eggs are slightly denser than water, non-adhesive, and drop loosely and singly to the bottom, where they lodge in crevices between the pebbles. Fecundity estimates range from 116,000 to 616,000 eggs per female, with egg number directly related to the size and age of the individual fish. Early estimates of average egg counts of about 30,000 and maximum 156,000 apparently referred to hatchery egg-takes in the late 19th century. On the Atlantic coast, fish in the southern part of the range produce more eggs than do northern fish, but it is not known if this also holds true along the Pacific coast (Lehman, 1953; Davis, 1957).

The spent fish return to the sea immediately after spawning. They begin to feed while still in fresh water and may recover a good deal of fat before reaching the sea. Adult shad return to fresh water year after year to spawn in their natal streams (Hollis, 1948; Talbot and Sykes, 1958; Cheek, 1968).

The fertile eggs, about 3.5 mm (0.14 in) in diameter and pale pink to amber in color, hatch in 12 to 15 days at 12°C, 11 days at 13.3°C, 6 to 8 days at 14 to 17°C, and only 3 days at 23.3°C (Rice, 1884; Ryder, 1884b; Leim, 1924). The young are about 9-10 mm long at hatching. The yolk sac is absorbed in 4-5 days and the young begin to feed 10-12 days after hatching. The first food consists primarily of copepods and chironomid larvae (Ryder, 1884a; Leim, 1924), but as the young fish grow they take larger and larger particles. They have doubled their length, to about 20 mm, in three to four weeks, by which time the fins are fully developed and metamorphosis is virtually complete. A young shad about 50 mm (2 in) long closely resembles the adult, except that the body is more slender, the shoulder spots are not developed and the ventral scutes are more prominent. Adult fish feed on copepods, mysids, shrimps, barnacle larvae, ostracods, amphipods, insects and, rarely, small fishes (Bigelow and Schroeder, 1953; Hildebrand, 1963).

Growth proceeds rapidly during the summer in fresh water. By the time the young fish move downstream in the fall, they are between 37 and 112 mm (1.5-4.5 in) long. Growth rate of the young in salt water is unknown. However, on the basis of back-calculations made in scale studies, the lengths at various ages are approximately as follows: 1+, 12.7-19.3 cm; 2+, 22.9-29.5 cm; 3+, 25.4-37.6 cm; 4+, 37.6-42.9 cm; 5+, 40.4-48.3 cm; 6+, 51.3 cm (LaPointe, 1958; Cheek, 1968). Growth rates vary from one population to another. Shad attain at least 11 years, but age determinations on old fish are difficult because of the extensive regression of the edges of the scales at spawning (Cating, 1953).

After leaving the natal streams, the young shad spend 3-4 years in the sea. Sexual maturity is usually attained in the fourth year for males, the fifth for females, and spawning occurs annually thereafter. An exception seems to lie in fish of the southern Atlantic states, from North Carolina south, which spawn but once and then die (Cheek, 1968).

Aside from the spawning migrations, little is known of the movements of the shad. Atlantic fish, from Chesapeake Bay northward, congregate in the Gulf of Maine after spawning and presumably winter in deep water off the mid-Atlantic coast (Talbot and Sykes, 1958). What happens with Pacific populations is unknown, but, at least in the early years following the first transplants, the Pacific shad must have wandered considerably.

The American shad was first introduced into Pacific waters in 1871, when about 10,000 eggs were placed in the Sacramento River, California, at Tehama, on 26 June. Another 35,000 eggs were planted on 2 July 1873, and between 1876 and 1880 almost 600,000 more were added to the Sacramento. Plants were made in the Columbia River basin (910,000) in 1885 and 1886. Additional plants, totalling more than 9.6 million eggs, were made in the Colorado River and in Utah and Idaho between 1873 and 1891, but these seem to have been unsuccessful (Smith, 1896). Shad appeared at Vancouver Island, B.C., in 1876 (McDonald, 1891; Clemens and Wilby, 1946), in the Stikine River near Wrangell, Alaska in 1891 (Smith, 1896), and by 1904 had reached Cook Inlet, Alaska (Evermann and Goldsborough, 1907). In 1926 and again in 1937, single individuals were taken at Kodiak Island (Welander, 1940). Expansion southward also took place, with shad found near San Diego in 1916 (Starks, 1918) and in Todos Santos Bay, Baha California, Mexico, in 1958 (Claussen, 1959). Occasional specimens are taken in Kamschatkan waters (Nikolskii, 1961). Thus, although the shad normally returns to the natal stream, it has been something of a wanderer in the new environment of the Pacific.

Despite the rapid expansion of range, however, shad have never been more than strays in Alaska. The statement by Evermann and Goldsborough (1907) that "The cannery at Fairhaven took one about July 1, 1903, and the fishermen at Birch Point got about 3,000 in one day" has at times been taken to indicate that shad were once abundant in Alaska. However, there is no Birch Point in the state, and Fairhaven, near Juneau, was not officially named until 1962 (Orth, 1967). The Fairhaven and Birch Point referred to by Evermann and Goldsborough are undoubtedly at Bellingham, Washington.

IMPORTANCE TO MAN

The shad is an important sport and commercial fish on the east coast, with total commercial landings in excess of 4.5 million kg (9.9 million lb) in most years. Pacific coast landings are about a third of this figure as a rule. As a sport fish, the shad is highly regarded in the east, for it readily takes a fly or small spinner and is a game fighter. Because of its tender mouth, light tackle is imperative. Oddly enough, there is relatively little sport fishing for shad on the west coast. Because of its scarcity in the state, the shad is of no importance in the Alaskan fisheries, either sport or commercial.

SECTION 5

SALMONS, TROUTS, CHARRS, WHITEFISHES AND GRAYLING -- FAMILY SALMONIDAE

The salmonoids are freshwater or anadromous fishes, mostly medium to large sized, with more or less round to moderately compressed bodies. The fins are all soft-rayed and a dorsal adipose fin is present. Scales are cycloid, with a distinct, elongate axillary scale or process present at the base of each pelvic fin. The mouth may be large and well-toothed to small and toothless. The swim-bladder is connected to the esophagus. Pyloric caeca are numerous. Sexual dimorphism is often apparent at spawning time.

The group is conveniently divided into three subfamilies: Coregoninae, the whitefishes and ciscoes; Salmoninae, the salmons, trouts and charrs; and Thymallinae, the graylings.

The Salmonidae is the dominant family of fishes in the northern parts of Europe, Asia and North America, with a number of species reaching the high Arctic. Various members of the group, especially the Pacific salmons, genus *Oncorhynchus*, are of great commercial importance, while others, as the trouts (*Salmo*), charrs (*Salvelinus*), and grayling (*Thymallus*) are noted chiefly as sport fishes.

Characteristically, the Salmoninae have small scales, 115-200 along the lateral line; well developed teeth on jaws and vomer; a truncate caudal fin (forked in the lake trout); and prominent parr marks on the young (absent in pink salmon).

The Coregoninae possess relatively large scales, not more than 100 along the lateral line; teeth are small and weak, or absent; and parr marks are absent except in the genus *Prosopium*.

The Thymallinae, with only the arctic grayling, *Thymallus arcticus*, present in Alaska, agree generally with the Coregoninae, but parr marks are present in the young and the dorsal fin of adults is greatly enlarged, especially in mature males.

INCONNU OR SHEEFISH

Stenodus leucichthys (Güldenstadt)

DISTINCTIVE CHARACTERS

The inconnu is easily distinguished from other coregonines by the large mouth, the protruding lower jaw, and only 13-17 gill rakers on the lower limb of the first gill arch.

DESCRIPTION

Body elongate, little compressed. Depth 20-23% of total length, deepest just behind pectoral fins. Head long, 24-28% of total length, depth of head about half its length. Snout prominent, about 23% of head length. Eye round, its diameter averaging about 15% of head length. Nostrils with a double flap between openings on each side. Mouth large, lower jaw protruding, maxillary reaching at least to vertical through middle of eye. Teeth very small in velvet-like bands on anterior portion of both jaws and on tongue, vomer and palatines. Gill rakers 17-24. Branchiostegals 9-12. Lateral line scales 90-115. Pyloric caeca 144-211. Vertebrae 63-69.

Fins

D. 11-19, the fin high and pointed. A. 14-19. P_1. 14-17. P_2. 11-12, axillary process well developed. Caudal fin forked.

Scales

Large, cycloid.

Color

Overall color silvery, with the back usually greenish, bluish or pale brown. Silvery white below. Dorsal and caudal fins with dusky margins, other fins pale.

Size

Up to 27 kg in the Kobuk River, Alaska (Alt, 1969), to 28.6 kg in the Mackenzie River (Dymond, 1943) and to 40 kg in Siberia (Wynne-Edwards, 1952).

RANGE AND ABUNDANCE

In Alaska, the inconnu is known from the Kuskokwim, Yukon, Selawik and Kobuk drainages. It is found in the Yukon and its tributaries all the way from the mouth to Teslin Lake, but apparently does not ascend the Tanana much beyond Fairbanks. It migrates up the Koyokuk River at least as far as Alatna. Except for a few reported from the Meade River, it is not found north and east of the Kobuk River. In Canada, the inconnu is present in most of the MacKenzie drainage and east to the Anderson River.

The inconnu ranges westward across Siberia to the White Sea, south to Kamschatka. Another subspecies is present in Caspian Sea drainages.

Because of its migratory habits, the abundance of the inconnu is both local and seasonal. However, within these limits it is abundant in most areas where it is found.

HABITS

Inconnu spawn in the fall, late September and early October, in Alaska at water temperatures of 1.4-4.6°C. The spawning grounds are located in clear, fairly swift streams, over bottom composed of differentially-sized gravel and sand under 1-3 m of water. Spawning takes place in the evening, usually beginning about dusk and continuing well into the night. In the spawning act, a female, accompanied by a male (rarely by two or more males), rises to the surface near the upstream end of the spawning grounds. She moves rapidly across the current, usually in an upright position but sometimes tilted almost horizontal with the abdomen upstream, extruding eggs as she goes. This activity lasts 1-3 seconds. The male, meanwhile, stays below the female. The eggs, averaging about 2.5 mm in diameter, sink to the bottom through the cloud of sperm released by the male and are fertilized as they sink. Apparently, differentially-sized gravel on the stream bottom is important in insuring that the eggs lodge in the bottom and are not carried away by the current.

After completing a spawning pass, the female drifts downstream. She may repeat the spawning act over the downstream portion of the spawning area, or may move upstream to the head of the grounds before releasing more eggs. It is not known how many spawning passes are required to extrude all the eggs, but Alt (1969) noted one female which released eggs six times in a single pass. Since large females may contain as many as 400,000 eggs, several passes are undoubtedly needed to complete a spawning.

Development of the eggs is slow. The young hatch in late February to April and are about 7 mm long. The yolk sac is absorbed in a week to 10 days and the young inconnu then feed actively on plankton. Growth rates of the early young are unknown. Eggs are easily handled under hatchery conditions, but mortality of the young after absorption of the yolk sac has so far been virtually 100% (LaPerriere, 1973; K. Alt, Alaska Dept. Fish Game, pers. comm.) On the other hand, Russian workers apparently have had good success with hatchery rearing of inconnu (Karzinkin, 1951; Nikolskii, 1961).

The distribution of young fish appears to differ from one drainage to another. In the Kobuk and Selawik rivers, and indeed in most areas, they are probably swept downstream by spring floods. Alt (1969) found no fish younger than 4+ in the Kobuk and Selawik rivers. On the other hand, he found young of the year, as well as 1+ and 2+ fish, in the upper Yukon, and Fuller (1955) believed the young remained for two years in rivers emptying into Great Slave Lake.

Growth of the young is quite rapid for the first two years of life. One-year-olds in Alaska are 110-150 mm long, with two-year-olds averaging about 200 mm. Growth subsequently slows down. At five years, Alaskan inconnu average about 430 mm in total length; at 10 years, about 700 mm; and at 15 years, about 960 mm. The largest fish reported by Alt (1969) was a 19+ of 1,190 mm from the Kobuk River. His oldest specimen, a 20+ from the Selawik area, was 1,120 mm long.

The inconnu is known to hydridize with other coregonids, doubtless due more to the broadcasting of eggs and sperm than to interspecific or intergeneric pairing. Known hybrids include those with Coregonus nelsoni (Alt, 1971c), C. autumnalis (Kuznetsov, 1932; Dymond, 1943) and C. muksun (Kuznetsov, 1932).

As with most fishes, the food of the inconnu changes with the age and size of the individual, as well as with the time of year. The very young post-larvae feed almost exclusively on plankton of various sorts, but soon graduate to insect larvae and larger zooplankton. In the upper Yukon River and in the Ob River of Siberia, inconnu begin to feed on fish in their first year (Vork, 1948; Alt, 1965), but in Great Slave Lake they apparently do not do so until about four years old (Fuller, 1955).

Adults feed mostly on fish, especially the least cisco, Coregonus sardinella. Also important are the isopod, Mesidotea entomon, and the mysid, Mysis relicta. Other foods include king salmon fingerlings, several species of coregonids, lampreys, charr, smelt, blackfish, suckers, burbot, chubs, sticklebacks, sculpins and the nymphs and larvae of several orders of insects. The last are eaten almost exclusively by the smaller fish (Fuller, 1955; Alt, 1965; 1969). The food habits vary with locality and time of year. In Selawik Lake, C. sardinella was the major food item of large inconnu in early spring, while smaller fish fed heavily on small coregonids and invertebrates. In the latter part of June, Mesidotea and small coregonids became more important to inconnu of all sizes, as did the rainbow smelt, Osmerus mordax (Alt, 1969).

The inconnu of Alaska constitute five rather distinct populations. The Minto Flats and the upper Yukon River groups are year-round residents, wintering in the large rivers and moving relatively short distances to clear streams to spawn. The Minto Flats population spawns chiefly in the Tolovana and Chatanika Rivers, with a few entering the Chena River and other clear streams. The fish of the upper Yukon apparently utilize almost every major tributary.

Fish of the Kuskokwim and lower Yukon rivers overwinter in the delta areas of these streams, while the Kobuk-Selawik population spends the winter in the brackish waters of Selawik Lake and Hotham Inlet. These fish may move as far as 670 km up the Kobuk River, while those from the mouth of the Yukon travel 1,600 km to spawn in the Alatna River (Alt, 1971b, 1973a).

Upstream migration from the wintering areas begins at ice breakup. The early movements appear to be associated with feeding, but, the time depending on the distance to be travelled, this soon becomes a definite migration to the spawning area. The true spawning migration may last only a few weeks, or, as with the lower Yukon fish, may take as long as four months. During this spawning migration, the inconnu feed little, if at all, but, unlike salmon, they are still in good condition when they reach the spawning grounds in late September. They appear to utilize excess visceral fat during the migration (Alt, 1969).

Spawning takes place in late September and early October, when the water temperature is between 1.4 and 4.6°C. Following spawning, there is a fairly rapid downstream migration to the wintering grounds, where the inconnu again commence to feed. It is not certain whether inconnu spawn annually or at longer intervals. Russian fish appear to spawn only every third or fourth year (Nikolskii, 1961). Alt (1969) found two stages of gonad development in mature fish at Selawik and suggested that this might indicate spawning every other year. On the other hand, he felt that all mature fish in the Kobuk River were spawners. It may be that non-spawners do not migrate very far upstream.

IMPORTANCE TO MAN

Wherever it is found, the inconnu is prized for sport, subsistence or commercial purposes. It is an excellent sport fish. Its fighting qualities and size make it a trophy worthy of any angler's best endeavors. As food, it is likewise excellent. The flesh is white, sweet, slightly oily. It has not always enjoyed a high reputation, however, for Richardson (1823) wrote that it was "disagreeable when used as daily food."

Subsistence fisheries of considerable magnitude exist along the Kobuk, Selawik, lower Yukon, Koyokuk and Kuskokwim rivers. In the early 1960's, the subsistence catch on the lower Yukon was on the order of 5,000 fish annually, while the Kuskokwim produced about 1,600 - 1,700. No data are available for the Koyokuk, but statements from residents of Hughes suggest that the subsistence take on that river is in excess of 2,000 fish a year. The greatest subsistence fishery is in the Kobuk-Selawik area, where Alt (1969) estimated a catch of 19,240-22,000 fish in 1965. This represents something like 50,000 kg, of which about 900 kg were sold commercially.

The only commercial fishery for Alaskan inconnu is in the Kotzebue area. This fishery has produced up to 45,000 kg per year (Wigutoff and Carlson, 1950). The total catch, both subsistence and commerical, from northwest Alaska in 1965 was estimated at 34,200 - 37,000 fish, or nearly 90,000 kg.

Commercial fisheries for inconnu also exist in Great Slave Lake, with annual yields on the order of 144,000 kg (Sinclair et al, 1967), and in the rivers of Siberia. The annual catch from the latter region between 1936 and 1940 was reported as about 4.15 million kg per year (Nikolskii, 1961).

LEAST CISCO

Coregonus sardinella Valenciennes

DISTINCTIVE CHARACTERS

Adults of the least cisco are easily distinguished from those of other Alaskan ciscoes by the lower jaw protruding slightly beyond the upper when the mouth is closed, and by the dusky to black pelvic fins. The latter characteristic, however, does not appear until the fish are about 150 mm long, so identification of the young is sometimes difficult.

DESCRIPTION

Body slightly to moderately compressed, its greatest depth 19-24% of total length. Head rather short, less than 25% of total length. Snout about 25% of head length. Eye round, large, 26-32% of head length. Nostrils with a double flap between the openings. Mouth moderate, lower jaw protruding slightly beyond upper when mouth is closed. Maxillary reaching backward to below anterior half of eye. No teeth on jaws, vomer or palatines, but a patch of small teeth present on tongue. Gill rakers long and slender, 42-53 on first arch. Branchiostegal rays 8-9. Lateral line with 78-98 pored scales.

Fins

D. 12-14, rather high and falcate. Dorsal adipose fin present. A. 11-13. P_1. 14-17, narrow. P_2. 8-12, a distinct axillary process present. Caudal fin forked.

Scales

Moderately large, cycloid. Statements that "spawning males probably develop tubercles along the sides" (McPhail and Lindsey, 1970) are in error. At least in interior Alaska, spawning tubercles are not developed by either sex.

Color

Brownish to dark greenish above, silvery below.

Size

The least cisco is known to reach fork length of at least 413 mm in interior Alaska (Kepler, 1973). Scott and Crossman (1973) gave 419 mm (total length or fork length?) for Canadian fish, while Nikolskii (1961) indicated a maximum size of 420 mm and 500 g for fish from Siberia.

RANGE AND ABUNDANCE

Present in most streams and lakes of Alaska north of the Alaska Range, from Bristol Bay to the arctic coast. The least cisco is present throughout the Kuskokwim and Yukon drainages, ranges south in the Mackenzie to Fort Simpson and eastward along the arctic coast of Canada to Bathurst Inlet and Cambridge Bay. McPhail and Lindsey (1970) noted its presence on Victoria and Banks islands in the Arctic Ocean. Westward, the range extends across the Bering Strait and Siberia as far as the White Sea.

The least cisco is one of the more abundant freshwater fishes of Alaska, but because of its migratory habits the abundance is seasonal.

HABITS

The least cisco spawns in late September and early October. Spawning takes place at night, with peak activity between 2000 hours and midnight. The spawning grounds in the Chatanika River, near Fairbanks, are confined to a stretch of river from 16 km below to 12 km above the Elliott Highway bridge. Individual spawning areas vary in size from 100-800 m in length and 15-22 m in width. Water depth ranges between 1.3 and 2.6 m, with average velocity of about 0.5 m/sec. Surface temperatures during the spawning period are between 0° and 3°C (Kepler, 1973). The stream bottom in the spawning areas is composed of gravel with a little sand.

In the spawning act, a female swims almost vertically upwards, with her ventral side upstream. She is joined by as many as five males (usually only one or two), who swim upward close to the female. As the spawners approach the surface, eggs and milt are released. A small cloud of milt can sometimes be seen as the fish enter the upper 20-30 cm of water. The fish break the surface, fall over backwards and swim back to the bottom of the pool. It is not known whether a female deposits all her eggs in one night, or whether two or more nights are required.

The eggs, somewhat less than 1 mm in diameter and cream to yellow in color, sink to the bottom where they lodge in crevices in the gravel. They are not adhesive. Fecundity varies between 9,800 and 93,500 eggs per female, averaging about 54,350. Egg number is more closely related to age than to size of the individual (Kepler, 1973). The Chatanika River ciscoes are more fecund than those of Siberia, for Nikolskii (1961) gave only 23,600 as the maximum egg count for fish from the Yenisei River.

The eggs over-winter in the gravel and hatch early in the spring. By mid-June, large numbers of young of the year, which may be up to 40 mm long, are moving downstream to deeper, slower water (Townsend and Kepler, 1974).

Males first become sexually mature at age 2+, with the majority maturing at 3+. Females begin to mature at 3+ (rarely 2+), but most mature at 4+. A large, mature female may weigh as much as 2.5 kg (5.5 lb) (Alt, 1971a)

Occasional hybrids between least cisco and Alaska whitefish occur (UAFC 2173), but despite the fact that the two species spawn more or less simultaneously in the same areas and have similar breeding behavior, such hybrids are rare.

The maximum age attained in most populations seems to be between 8 and 11 years (Cohen, 1954; Nikolskii, 1961; Kepler, 1973), although Scott and Crossman (1973) mentioned that ages approaching 26 years have been recorded in specimens from Victoria Island, N. W. T.

Growth rates vary widely from place to place, and even within the same habitat. Although stream-dwelling, migratory populations are generally stated to grow faster and live longer than lake-dwelling, non-migratory fish (McPhail and Lindsey, 1970; Scott and Crossman, 1973), Cohen (1954) found that the anadromous fish at Point Barrow were slower growing and thinner than a non-migratory population in Ikroavik Lake. To further confound the situation, a second population in Ikroavik Lake was slower growing and shorter lived than the first two.

Kepler's (1973) data on spawning females from the Chatanika River yield the following average fork lengths at ages from 2+ to 8+: 2+, 311 mm (2 fish); 3+, 316 mm (4); 4+, 333 mm (15); 5+, 370 mm (12); 6+, 383 mm (5); 7+, 413 mm (1); 8+, 405 mm (2). Alt (1971a), on the basis of back-calculating from scales, gave the following fork lengths at the end of each year of life for Chatanika River fish: 1, 120 mm; 2, 208 mm; 3, 261 mm; 4, 304 mm; 5, 337 mm; 6, 364 mm; 7, 387 mm; 8, 410 mm.

Although lake-dwelling populations appear to be non-migratory, those living in streams or reaching brackish water undertake considerable movements to reach or leave their spawning grounds. As already noted, young of the year move off the spawning grounds shortly after spring break-up. The upstream spawning migration of adults begins in early July in the Chatanika River and is completed by late September.

Least cisco feed primarily on various types of zooplankton, including various small copepods, cladocerans, mysids and the adults and larvae of a variety of insects. Plant material may also be eaten. The ciscoes normally do not feed during the spawning run. (Nikolskii, 1961; Furniss, 1974; Morrow et al, 1977).

Least cisco are preyed upon by many predators, including eagles, hawks, kingfisher, pike, inconnu, lake trout, burbot, man, and, no doubt, any others capable of catching them. The eggs may be eaten by grayling and Alaska whitefish during spawning (Morrow et al, 1977).

IMPORTANCE TO MAN

In North America, the least cisco is relatively unimportant. It is taken by subsistence fisheries in Alaska and northern Canada, usually as an incidental in nets set primarily for other whitefishes, pike or grayling. A small sport spear fishery exists in the Chatanika River in interior Alaska.

Least cisco is an important commercial fish in Siberia. Annual landings in the late 1930's were in excess of 1,000,000 kg (2,200,000 lb) (Nikolskii, 1961).

As a food fish, the least cisco is generally considered somewhat inferior to the humpback whitefishes. However, it is a very good fish, with firm, tasty meat.

BERING CISCO

Coregonus laurettae Bean

DISTINCTIVE CHARACTERS

The pale pelvic and pectoral fins distinguish the Bering cisco from the least cisco, while the lower number of gill rakers on the lower portion of the first gill arch (18-25 vs 26-31) distinguish it from the arctic cisco.

DESCRIPTION

Body rather elongate, slightly compressed. Depth about 20% of total length. Head moderate, 22-25% of total length. Snout 20-25% of head length. Eye about equal to snout, round. Nostrils with a double flap between the openings on each side. Mouth moderate, terminal, upper and lower jaws equal. Maxilla reaching backward to middle of eye. Usually no teeth on jaws, but weak teeth present on maxilla in young and a few small teeth rarely present on lower jaw of adults. A small patch of teeth present on tongue. Gill rakers 18-25 on lower portion of first gill arch, total count on first arch 35-39. Branchiostegals 8-9. Lateral line with 76-95 pored scales.

Fins

D. 11-13, rather high and falcate. Dorsal adipose fin present. A. 12-14. P_1. 14-17. P_2. 10-12. Caudal fin forked.

Scales

Cycloid, fairly large.

Color

Generally brownish to dark green on back, silvery on lower sides and belly. Anal, pelvic and pectoral fins pale, caudal and dorsal dusky.

Size

The largest known, recorded by Alt (1973b,c), was a female of 480 mm fork length from the lower 500 m of Hess Creek, Alaska. The average size of adults is about 300 mm (1 ft).

RANGE AND ABUNDANCE

The Bering cisco is found from Bristol Bay north and east to the mouth of the Oliktok River on the arctic coast of Alaska. It is present in the Yukon River as far upstream as Fort Yukon, and also in the Porcupine River. It has also been found at the mouth of Ship Creek, Knik Arm, at Anchorage, Alaska (SU 41858, now in the Ichthyological Collection of the California Academy of Sciences,(McPhail, 1966)),in Tolugak Lake in Anaktuvuk Pass in the Brooks Range (UAFC 617,618), and was found in 1972 in the Kenai River on the Kenai Peninsula of Alaska (K. T. Alt, Alaska Dept. Fish Game, pers. comm.).

Throughout its range it is fairly abundant, at lease seasonally, for Alt (1973b) reported up to 18 a day taken in a fish wheel at Rampart, on the Yukon River, in September 1972.

HABITS

Very little is known of the biology of the Bering cisco. Most of the following is derived from Alt (1973b,c).

Spawning runs begin in the spring. Most of the Bering ciscoes apparently winter in salt or brackish water near river mouths, but the presence of potential spawners well up the Yukon and Kuskokwim rivers suggests that some populations may spend the winter in fresh water, far from the sea. Bering cisco were first observed well inland in 1968 and 1969, when one (UAFC 2176) was taken in the Chatanika River, near Fairbanks, and seven (UAFC 632) at Rampart, on the Yukon River. Two more specimens (UAFC 617, 618) are from Tolugak Lake in Anaktuvuk Pass. Subsequently, Alt (1973b) found Bering cisco in the Porcupine River, 1,400 km from the mouth of the Yukon; in the Yukon River at Fort Yukon; and in the South Fork of the Kuskokwim River, 840 km from the ocean.

Spawning probably takes place in the fall, but spawning behavior and the location of the spawning grounds are unknown. From the distribution of the fish in June, it may be presumed that the spawning grounds are in clear-water streams tributary to major rivers. Dymond (1943) mentioned C. laurettae X Stenodus leucichthys hybrids, but the location whence the specimens came, the Mackenzie River delta, suggests strongly that they were actually hybrids between the arctic cisco, C. autumnalis and the inconnu.

Alt (1973b) stated that the majority of his specimens from Hess Creek were 4+ to 6+ and were mature. His fish from Port Clarence and Grantley Harbor were mostly 2+ and 3+ immatures, as well as a few adults, which showed slower growth than the Hess Creek fish, possibly because of a shorter growing season. Mean fork lengths at age were, for Hess Creek: 4+, 344 mm; 5+, 354 mm; 6+, 373 mm; 7+, 405 mm; 8+, 446 mm; and for the Port Clarence-Grantley Harbor fish: 3+, 241 mm; 4+, 263 mm; 5+, 285 mm; 6+, 313 mm; 7+, 350 mm.

As noted above, Bering cisco undertake extensive spawning migrations. Presumably they move downstream after spawning. The precise extent of the migrations is unknown.

The Bering cisco, like other ciscoes, apparently does not feed on its spawning runs. All the fish examined from the Yukon and Kuskokwim rivers (June through September) had empty stomachs. By contrast, fish taken at Port Clarence-Grantley Harbor had fed on invertebrates and small cottids (Alt, 1973b,c). McPhail and Lindsey (1970) listed amphipods as food of the Bering cisco.

IMPORTANCE TO MAN

The Bering cisco is little utilized. Small numbers are taken for subsistence use by gill net and fish wheel in the Yukon and Kuskokwim rivers. Similar utilization probably exists wherever subsistence fishing and the Bering cisco coincide.

ARCTIC CISCO

Coregonus autumnalis (Pallas)

DISTINCTIVE CHARACTERS

Pale pelvic fins, a terminal mouth and 41-48 gill rakers on the first arch serve to distinguish the arctic cisco.

DESCRIPTION

Body elongate, slightly compressed. Depth 20-23% of total length. Head moderate, somewhat less than 25% of total length. Snout about 25% of head, a little longer than eye diameter. Eye round, 20-24% of head. Nostrils with a double flap between the openings. Mouth moderate, jaws toothless in adults (a few weak teeth may be present in very small young), a patch of teeth on tongue. Maxilla extends backward about to middle of eye. Gill rakers 41-48 on first arch. Branchostegals 8-9. Lateral line with 82-110 pored scales.

Fins

D. 10-12, fairly high, slightly falcate. Dorsal adipose fin present. A. 12-14. P_1. 14-17. P_2. 11-12. Caudal forked.

Scales

Moderately large, cycloid, 82-110 pored scales in lateral line.

Color

Brown to dark greenish above fading to silvery on sides and belly. Fins pale.

Size

Specimens up to 640 mm total length and up to 2,685 g weight have been reported from the Lena River in Siberia (Berg, 1948). However, North American specimens generally are much smaller, averaging somewhere in the neighborhood of 350-400 mm long (Roguski and Komarek, 1971) and perhaps a kilogram (2.2 lb) in weight.

RANGE AND ABUNDANCE

In North America, the arctic cicso is found along the arctic coast of Canada and Alaska from the southeastern end of Victoria Island westward to Point Barrow and south in the Mackenzie to the Liard River. It ranges westward across arctic Siberia to the White Sea. Due to its migratory habits, it is abundant seasonally.

HABITS

The arctic cisco is truly anadromous. It seems to be much more tolerant of salt water than most coregonids, for it has been taken in water up to 22 ppt salinity (Roguski and Komarek, 1971). The upstream spawning run takes place in the summer and may cover as much as 1,000 km (1,600 miles) (Nikolskii, 1961). Spawning occurs over gravel in fairly swift water. The eggs are broadcast and left to fend for themselves. Mature females may produce as many as 90,000 eggs (Berg, 1948). After spawning, the adults return downstream. The arctic cisco occasionally hybridizes with the inconnu (Kuznetsov, 1932; Dymond, 1943).

The young probably hatch in the spring and descend the rivers to estuaries, as do other ciscoes.

Little is known of growth rates in North America. Roguski and Komarek (1971) and Kogl (1971) have provided data on 65 specimens from the Beaufort Sea and the Colville River delta, as follows: Age I, 114-115 mm fork length; II, 136 mm, III, 233 mm; IV, 297 mm; V, 317 mm; VI, 325 mm; VII, 373 mm; VIII, 414 mm. This is somewhat faster growth than was listed by Berg (1948) for Yenisei River ciscoes. The fish become mature at about six years of age and apparently do not breed every year (Nikolskii, 1961; Roguski and Komarek, 1971).

The arctic cisco shows a wide range in its feeding and has been found to eat mysids, copepods, amphipods, isopods, chironomids and other insects and a variety of small fishes (Nikolskii, 1961; Kogl, 1971).

IMPORTANCE TO MAN

In North America, the Arctic cisco is used primarily in subsistence fisheries, and these may be of considerable magnitude. The fish are caught "in abundance" during August at Barter Island, where it is preferred over charr (Furniss, 1974). A small commercial fishery on the Colville River delta takes about 11,000 kg (24,200 lb) per year, about 60% of the total catch of all species there (Winslow and Roguski, 1970). The arctic cisco is an important component of the fisheries along the Mackenzie River (Wynne-Edwards, 1952) and it is an important commercial fish in Siberia and the eastern parts of northern USSR (Nikolskii, 1961).

PYGMY WHITEFISH

Prosopium coulteri (Eigenmann and Eigenmann)

DISTINCTIVE CHARACTERS

The pygmy whitefish is distinguished by its bluntly rounded snout, less than 70 pored scales in the lateral line and 14-33 pyloric caeca.

DESCRIPTION

Body elongate, round in cross-section. Depth about 17% of fork length. Head moderate, its length about 22% of fork length. Snout short, broadly rounded as seen from above. Eye large, round, diameter usually greater than snout length, a notch present in lower posterior portion of adipose lid. Nostrils with a single flap between the openings. Mouth small, subterminal, maxillary reaches to anterior portion of eye. No teeth on jaws, vomer or palatines, but a small patch of fine teeth present on tongue. Gill rakers short, the longest 6.5-9% of head length, 12-21 on first arch. Branchiostegal rays 6-9. Lateral line with 50-70 pored scales.

Fins

D. 10-13, a small adipose dorsal fin present. A. 10-14. P_1. 13-18. P_2. 9-11, axillary process present. Caudal fin forked.

Scales

Large, round, cycloid.

Color

Brownish, often with greenish tints, above; sides silvery, belly white. A row of about 11 large, round parr marks along sides of young, persisting in all but the largest adults.

Size

This is the smallest of the Alaskan coregonids. The largest specimens recorded were only 271 mm fork length (McCart, 1965) and most are scarcely half that size.

RANGE AND ABUNDANCE

The pygmy whitefish has a most remarkably discontinuous distribution. It is known from Lake Superior; from parts of the Columbia, Fraser, Skeena, Alsek, Peace, Liard and upper Yukon systems in Washington, Montana, British Columbia and the Yukon Territory; and from the Chignik, Naknek and Wood river systems in southwestern Alaska. It is not known outside of North America. Wherever it is found, it seems to be quite abundant.

HABITS

Details of breeding behavior are unknown. Spawning takes place at night in late fall and early winter (November-December) at water temperatures of about 4°C or colder. Spawning grounds appear to be on gravel in lake shallows and in streams. Presumably, the eggs are broadcast, settle into interstices in the gravel and hatch the following spring. In the Bristol Bay region, the eggs are about 2.4 mm in diameter (Heard and Hartman, 1966), somewhat larger than the 2.0 mm reported for Lake Superior fish (Eschmeyer and Bailey, 1955). Egg number varies between 103 and 1153 per female in Bristol Bay fish, a greater average number than in Lake Superior fish.

Growth of the pygmy whitefish is very slow and shows considerable variation from one population to another. In general, females grow faster than males, although in some populations the males grow faster during the first year (Eschmeyer and Bailey, 1955). In Brooks Lake, Alaska, the average three-year-old fish was about 70 mm fork length, while in South Bay, Naknek Lake, the same aged fish averaged about 116 mm. The maximum age recorded for fish in the Naknek system was 5+ (Heard and Hartman, 1966), but ages up to 9+ have been noted in Maclure Lake, British Columbia (McCart, 1965).

The pygmy whitefish does not make extended migrations. However, it does move on to the spawning areas in the early winter and presumably back into deeper water after spawning.

Food of the pygmy whitefish includes a rather wide variety of items. Listed as most important in the Naknek system were cladocerans, dipteran (chiefly Chironomidae) larvae and pupae, adult Diptera, and nymphs of Plecoptera. Other items included diatoms and other algae, pelecypods, nematodes, arachnids and fish eggs (Kendall, 1921; Heard and Hartman, 1966). In Lake Superior, ostracods and amphipods were the principal foods (Eschmeyer and Bailey, 1955). The pygmy whitefish feeds almost exclusively during daylight hours. In its feeding, the pygmy whitefish makes "short distinct jabs or darts, apparently at specific food items, such as insect larvae, when picking up mouthfuls of bottom material." They may also rise off the bottom and take specific items from the current (Heard and Hartman, 1966).

There is a distinct positive correlation between the diet and the average size of individuals in a population. Groups in which insects are the dietary mainstay average much larger than those in which zooplankton is the chief food (Heard and Hartman, 1966). McCart (1970) found high and low gill raker count forms in Aleknagik, Naknek and Chignik lakes in Alaska and suggested that these represented sibling species. The high count form was found almost exclusively in deep water, fed on plankton and grew more slowly. By contrast, the low count form was found in both shallow and deep water, ate mostly insects and grew faster. However, the difference in growth rates through age IV in Chignik Lake does not appear to be significant. More careful analyses of larger samples are needed.

As noted above, the pygmy whitefish is found in both deep and shallow water. In Lake Superior, it was reported as most abundant at depths of

46-71 m (Eschmeyer and Bailey, 1955; Dryer, 1966). In the Naknek system, the species was found at depths to 168 m but was also abundant in the shallows (Heard and Hartman, 1966). McCart (1970) found that, in Chignik Lake, beach seine samples were composed entirely of the low gill raker count form, while in gill nets set at 30 m or deeper, the high count form accounted for 36.2% of the fish taken.

IMPORTANCE TO MAN

The pygmy whitefish is of no direct importance to man. It is too small and scarce and of too limited distribution to be a profitable object for any kind of fishery. However, it is undoubtedly fed upon by predatory fishes such as charr, pike, burbot, etc., and may contribute to the overall scheme of competition. In this respect, it is interesting to note that the pgymy whitefish attains its greatest size in waters where there is no competition from other coregonids (McCart, 1965).

ROUND WHITEFISH

Prosopium cylindraceum (Pallas)

DISTINCTIVE CHARACTERS

The narrow, rather pointed snout, more than 70 pored scales in the lateral line, and 50 or more pyloric caeca distinguish the round whitefish.

DESCRIPTION

Body elongate, cylindrical, slender. Depth 15-20% of fork length. Head relatively short, its length averaging about 20% of fork length. Snout short, about 22% of head, pointed as seen from above. Eye round, its diameter equal to or less than snout length, notch present in membrane below posterior edge of pupil. Nostrils with a single flap separating the openings on each side. Mouth small, upper jaw overhanging lower, maxilla reaches about to anterior margin of eye in adults, a little farther back in young. Teeth restricted to a small patch of embedded teeth on tongue, also present on bases of gill rakers. Gill rakers short, 14-21. Branchiostegal rays 6-9 on each side. Lateral line with 74-108 pored scales. Pyloric caeca 50-130.

Fins

D. 11-15, an adipose dorsal fin present. A. 10-13. P_1. 14-17. P_2. 9-11. Caudal fin forked.

Scales

Fairly large, cycloid, nuptial tubercles prominent on lateral scales of breeding males, but only feebly developed in females.

Color

Bronze dorsally, sometimes with a greenish tinge. Sides silvery, belly silvery white. Fins of most Alaskan specimens are more or less colorless or slightly dusky. Scott and Crossman (1973) reported the pectoral, pelvic and anal fins to be amber colored, becoming orange at spawning time. The young are marked with three rows of rather well-defined parr marks. One row lies along the lateral line, a second row (sometimes ill-defined) just above the first, and a third row just below the mid-line of the back. The spots of this third row often coalesce across the mid-dorsal line.

Size

The largest on record is a specimen of 561 mm total length from Great Slave Lake (Scott and Crossman, 1973). The round whitefish is known to reach a weight of 2 kg (Keleher, 1961) and has been reported as reaching "about 5 pounds" (2.27 kg) in Lake Superior (Koelz, 1929).

RANGE AND ABUNDANCE

The round whitefish is found throughout mainland Alaska from the Taku River, near Juneau, north to the arctic coast. It ranges eastward across Canada to the western shores of Hudson Bay. A discontinuity in range exists in Manitoba and northern Ontario, and the species is again present in the Great Lakes (except Lake Erie), eastward to New Hampshire and Maine, south to Connecticut and north to the arctic coast of Labrador. In Asia, the round whitefish ranges west to the Yenisei River, south to Kamschatka.

The round whitefish is fairly abundant wherever it is present, although it usually does not occur in such large numbers as some of its relatives.

HABITS

Spawning occurs in the late fall, late September through October, in interior Alaska, but not unil November or December in more southern parts of the range. Spawning appears to be an annual affair, with many fish breeding in successive years, even in the arctic (McCart et al, 1972). The spawning beds are located on gravelly shallows of rivers and the inshore areas of lakes. Inshore and upstream migrations have been observed (Harper, 1948; Normandeau, 1969) at spawning time and are probably characteristic. However, fish in interior Alaska do not seem to show the concentrated migrations characteristic of ciscoes and humpback whitefish. According to Normandeau (1969), the fish swim in pairs during spawning, a single male with each female. Details of spawning behavior have not been described, but probably resemble those of the pygmy whitefish, *Prosopium coulteri*. In that species, the fish contact each other and rest on the bottom for 2-4 seconds, emitting eggs and milt, then separate (Brown, 1952). The eggs of the round whitefish are known to be broadcast and to receive no parental care. Females produce between 1,000 and 12,000 eggs, with the average between 5,000 and 6,000 (Bailey, 1963; Normandeau, 1969; Furniss, 1974). The size of ovarian eggs varies with locality. In New Hampshire, unfertilized eggs averaged 2.7 mm in diameter (Normandeau, 1969), but Furniss (1974) found ovarian eggs of Alaskan fish to be only 1.0-1.8 (average 1.2) mm in diameter. The eggs absorb water after fertilization and may reach diameters of 3 to almost 5 mm in a few hours. The eggs are yellow to orange, demersal, though not sticky, and settle into crevices in the rocks and gravel of the bottom. Time of development has been reported as about 140 days at 2.2°C in New Hampshire (Normandeau, 1969), and presumably is not much different in Alaska. The young hatch out as sac fry. In two to three weeks, the yolk has been absorbed and the young have left the spawning grounds.

Growth rates vary from one locality to another. Lake Michigan fish grow very rapidly, reaching a total length of about 500 mm in seven years (Mraz, 1964a). By contrast, in Elusive Lake, in the Brooks Range of Alaska, this length is not achieved until the age of twelve. The oldest known round whitefish is one of 16+ from Shainin Lake, Alaska (Furniss, 1974). Sexual maturity is reached at about five years in the southern parts of the range, but not until age seven in the Brooks Range of Alaska (Furniss, 1974).

Except for the spawning movements already mentioned, the round whitefish apparently does not migrate.

Food of the round whitefish is primarily the immature stages of various insects, especially Diptera and Trichoptera. Adult Trichoptera are also important, as well as gastropods, *Daphnia* and fish eggs (Martin, 1957; Loftus, 1958; Normandeau, 1969; Furniss, 1974). In some areas, the round whitefish is considered a serious predator on the eggs of lake trout (Martin, 1957; Loftus, 1958).

IMPORTANCE TO MAN

The round whitefish was formerly taken in considerable quantities in the Great Lakes. In the late 1920's, annual catches from northern Lake Michigan were on the order of 90,900-163,200 kg (Mraz, 1964a), but present day catches are much smaller, primarily because of the relatively small size of the fish and an uncertain supply. In Alaska, the round whitefish is of some importance in freshwater subsistence fisheries. It is occasionally smoked in strips and sold as "squaw candy."

BROAD WHITEFISH

Coregonus nasus (Pallas)

DISTINCTIVE CHARACTERS

The broad whitefish is set off by its short gill rakers, which are less than 1/5 as long as the interorbital width, and the rounded to flat profile of the head.

DESCRIPTION

Body elongate, compressed, especially in large specimens, sides rather flatter than in most other whitefishes. Depth of body 23-31% of fork length in adults, more slender in young. Head short, 15-20% of fork length, dorsal profile rounded to flat (may be slightly concave in large specimens). Snout blunt, rounded (sheep-nosed) in profile, short, its length about equal to or less than diameter of eye. Eye small, 12-16% of head length. No notch in adipose lid. Nostrils with a double flap between openings. Mouth small, upper jaw overhanging lower, maxilla reaching posteriorly about to below anterior edge of eye. No teeth, except for a small patch of weak teeth on base of tongue. Gill rakers 18-25, blunt, short, longest less than 1/5 (13-19%) of interorbital width. Branchiostegals 8-9. Lateral line with 84-102 pored scales.

Fins

D. 10-13, dorsal adipose fin present and fairly large. A. 11-14. P_1. 16-17. P_2. 11-12. Caudal fin forked.

Scales

Large, cycloid. Males develop prominent breeding tubercles on lateral scales at spawning time, these only weakly developed in females.

Color

Olive brown to nearly black on back; sides silvery, often with a gray cast; belly white to yellowish. Fins usually grayish in adults, pale in young.

Size

This species is the largest of the Alaskan whitefishes. It is reported to reach weights up to 16 kg in the Kolyma River of Siberia (Berg, 1948), but most mature fish run around 2-5 kg. One of 715 mm weighing 5.7 kg from the Yenisei River is mentioned by Berg (1948). The largest Alaskan specimen known is a fish of 670 mm fork length from the Colville River at Umiat (Alt and Kogl, 1973).

RANGE AND ABUNDANCE

The broad whitefish is found throughout Alaska from the Kuskokwim River north to the arctic coast. It is present in the Yukon River from the mouth to the headwaters. In the Tanana River drainage it is known from Minto Flats and the Tolovana, Chatanika and Chena rivers and probably occurs further upstream as well. It is present in most, if not all, of the rivers draining into the Bering, Chukchi and Beaufort seas. The range extends eastward to the Perry River, Northwest Territories, westward across Siberia to the Pechora River, south to the Bay of Korf and to the Penzhina River on the Sea of Okhotsk. It is fairly abundant seasonally, though apparently not as numerous as some of its relatives.

HABITS

Little is known of the biology of the broad whitefish. Although the adults are more or less anadromous, those reaching the sea apparently do not venture far from brackish water. Upstream spawning runs begin as early as June and may extend into September or even later (Kogl, 1971; Alt and Kogl, 1973; Kepler, 1973; Townsend and Kepler, 1974). Spawning actually takes place from September through October, possibly even into November. Wynne-Edwards' (1952) statement that "The broad whitefish spawns in the rivers in August..." is probably based on a misinterpretation of the timing of the spawning runs. Except that spawning takes place in streams with gravel bottoms, nothing is known of the breeding habits. Presumably they are similar to those of other coregonids. The ovarian eggs are pale yellow to milky white in color and up to 4 mm in diameter (Berg, 1948; Nikolskii, 1961). Young hatch in the spring and move downstream. Adults apparently move downstream after spawning and over-winter in deep parts of the rivers or in estuaries.

Growth is relatively slow, especially in the arctic. Berg (1948) mentioned lengths of 500-530 mm at eight years for fish from the Kara and Kolyma regions, but in the Colville River, Alaska, the average length of eight-year-olds was under 400 mm (Kogl, 1971). Broad whitefish from the Minto Flats area grow at about the same rate as the Siberian fish (Alt and Kogl, 1973). Maximum age recorded is 15 years (Alt and Kogl, 1973), although Nikolskii (1961) stated that "The age limit of this fish exceeds 15 years."

The broad whitefish appears to be mainly a bottom feeder. It is known to eat chironomids, snails, bivalve molluscs (Kogl, 1971), mosquito larvae (Berg, 1948) and crustaceans (Scott and Crossman, 1973).

IMPORTANCE TO MAN

The broad whitefish is an unimportant commerical species in Siberia, where pre-World War II catches averaged 40,000 kg per year. In North America, however, it is utilized almost exclusively in subsistence fisheries. A commercial fishery in the Colville River delta takes about 7,000 kg per year. Despite its lack of utilization, the broad whitefish is an excellent food fish.

HUMPBACK WHITEFISHES

"Coregonus clupeaformis complex"

This group of three closely related species forms a most confusing assemblage, for almost the only means by which they can be separated one from another seems to be the modal number of gill rakers in large samples. The form here called Coregonus pidschian has average gill raker counts of 21-23, with range from about 17 to 24 or 25 in individual specimens. Coregonus nelsoni averages 24 or 25 (mode usually 25) with a range of 22-27, while Coregonus clupeaformis has modal counts of 26 or more, with range of individual counts from 24 to 33. Fisheries biologists in Alaska have applied one or another of these names to humpback whitefish throughout the state, all too often without adequate samples for proper identification. Hence, distributional records are often of little value.

There appear to be some differences in ecological relationships among the three species. C. clupeaformis is primarily a lake-dwelling form. C. nelsoni is mostly a stream dweller, only rather rarely being encountered in lakes. It seems, also, to be intolerant of salt water. C. pidschian apparently is truly anadromous, at least in some areas, and may over-winter in the sea near river mouths.

ALASKA WHITEFISH

Coregonus nelsoni Bean

DISTINCTIVE CHARACTERS

Gill rakers longer than 20% of interorbital width, 22-27 total gill rakers on first arch (modal counts 24 or 25) and a pronounced hump behind the head in adults are the distinctive marks of the Alaska whitefish.

DESCRIPTION

Body moderately compressed, sides rather flat. Depth of body usually 25% or more (up to 33%) of fork length in adults, increasing in larger fish. Head short, less than 25% of fork length. Dorsal profile of head distinctly concave behind eyes in adults due to the prominent nuchal hump. Snout 27-35% of head length. Eye small, its diameter 20-25% of head length, no notch in lower posterior part of membrane. Nostrils with a double flap between openings. Mouth rather small, upper jaw over-hanging lower, maxilla reaching backwards to below anterior third of eye. A few weak teeth present on premaxilla in young, no teeth on jaws in adults. A few small teeth present on tongue. Gill rakers 22-27, average total counts around 24 or 25. Longest raker longer than 20% of interorbital space. Branchiostegals 8-10. Lateral line with 77-95 pored scales.

Fins

D. 11-13. Dorsal adipose fin well developed, often larger in males than in females. A. 10-14. P_1. 15-17. P_2. 11-12. Caudal fin forked.

Scales

Cycloid, fairly large, well-developed nuptial tubercles on lateral scales of males, but less strong in females.

Color

Dark brown to midnight blue above, paling to silver on sides and white beneath. No parr marks in young.

Size

Up to at least 532 mm fork length in the Chatanika River, Alaska (Alt, 1971a).

RANGE AND ABUNDANCE

The precise distribution of Alaska whitefish is uncertain, primarily because of the difficulty of identifying the three species of humpbacked coregonids which occur in Alaska. However, as far as can presently be determined, the Alaska whitefish seems to be pretty well confined to the Yukon and its tributary drainages, where it is to be found all the way from Nulato to the Canadian border. It is present in the Tanana River and the Koyokuk River and their tributaries and in Lake Minchumina. Specimens which may be of this species have been reported from the Unalakleet and Wulik rivers. Possible C. nelsoni are known from the Alsek, Copper and Susitna systems, the upper parts of the Yukon River in Canada, the lower reaches of the Mackenzie River and several lakes in western Canada (Lindsey, 1963a,b; Lindsey et al, 1970; McPhail and Lindsey, 1970).

The Alaska whitefish is locally and seasonally abundant during the summer and fall. Throughout the rest of the year, the fish apparently disperse widely.

HABITS

The Alaska whitefish spawns from late September through October in interior Alaska. Spawning areas are in clear, moderately swift streams with fairly clean gravel bottom. In the Chatanika River, these areas are from 100 to 800 m long, 15-22 m wide, 1.3-2.6 m deep, with water velocities of about 0.5 m per second. Water temperatures at spawning are between 0° and 3°C (Kepler, 1973). Average fecundity of 20 mature females five to ten years old and 395-520 mm fork length was about 50,000 eggs. Fecundity was not closely correlated with age or size of the fish (Townsend and Kepler, 1974).

The spawning act is similar to that of the least cisco. A female begins to swim vertically towards the surface, belly upstream. She is joined by a male (sometimes two, rarely three). Eggs and milt are extruded as the fish approach the surface of the water. The fish break the surface, fall away from each other and return to the bottom of the pool. In contrast to the least cisco, the Alaska whitefish spawns actively both at night and in the daytime. The yellow to orange eggs, with an average diameter of 2.1-2.3 mm, drift down to the bottom where they lodge in crevices in the gravel. The exact time of incubation is unknown. However, young of the year have been taken in June and July, so presumably the young fish hatch out in late winter or early spring.

The Alaska whitefish of the Chatanika River grow rapidly during their early years. A one-year-old averages about 120 mm fork length. By the age of five, the fish average between 350 and 400 mm fork length, and at ten years about 485 mm. The oldest so far recorded is a 12+ of 532 mm fork length. Sexual maturity is reached between the ages of three and five years (Alt, 1971a; Townsend and Kepler, 1974).

The Alaska whitefish of the interior undertakes fairly extensive upstream and downstream movements. Upstream migration, apparently the beginning of the spawning run, may start as early as late June. The migration seems to be rather indefinite at first, but becomes marked as the season progresses and more fish approach breeding condition. By September, schools of up to several hundred fish are on or close to the spawning areas. Following the completion of spawning, the majority of the fish move downstream, but a few may over-winter in deep pools near the spawning grounds. The young of the year move down stream in their first year of life and as a rule do not return to the spawning areas until they are sexually mature.

Alaska whitefish generally return to the same spawning grounds year after year. Townsend and Kepler (1974) found that five fish tagged in 1972 were present on the same grounds in 1973. On the other hand, these same investigators noted far fewer tag returns that were expected and suggested that this might indicate either increased mortality of tagged fish or non-consecutive spawning. The recent (October 1975) recovery at Nenana of an Alaska whitefish tagged in the Chatanika River in 1974 (Townsend, pers. comm.) suggests that some fish may wander far from their natal streams. Apparently all fish do not return each year to the same spawning areas.

Hybrids of Alaska whitefish and sheefish (inconnu) are known (Alt, 1971c). The two species spawn at the same time and in the same places. Because of the differences in breeding behavior, hybridization is probably not the result of inter-generic pairing but due rather to simultaneous broadcasting of sex products in the same area. Occasional hybridization occurs also between the Alaska whitefish and the least cisco (UAFC #2173).

Alaska whitefish feed primarily on immature stages of insects, notably Diptera and Trichoptera. Although they generally do not feed during the latter part of the spawning run, this is not always so. On occasion they will feed heavily on eggs of the least cisco (Morrow et al, 1977).

IMPORTANCE TO MAN

The Alaska whitefish is an excellent food fish but is virtually unutilized. Its major importance lies in the subsistence fisheries, but even here it falls far short of the various salmons. A small sport fishery in the Chatanika River is estimated to take up to 500 fish yearly by spearing at night (Kepler, 1973), and similar small spear fisheries exist at other locations in Alaska. Small commercial fisheries have operated in some of the lakes of the Copper River drainage, but the take has not been large (Williams, 1968). The young are utilized by predatory fishes such as pike and burbot (Alt, 1968), and by other predators such as kingfishers, mink, otter, etc.

HUMPBACK WHITEFISH

Coregonus pidschian (Gmelin)

DISTINCTIVE CHARACTERS

Gill rakers longer than 20% of interorbital width, 19 to 24 or 25 gill rakers with average counts of 22 or 23, and a pronounced hump behind the head in adults distinguish the humpback whitefish.

DESCRIPTION

See description of C. nelsoni. Except for the gill raker counts, there are no known morphological differences of any significance. It is our impression, as well as that of several fisheries biologists in the Fairbanks Office of the Alaska Department of Fish and Game, that pearl organs are far fewer in number and are less well developed in C. pidschian than in C. nelsoni. Specimens from the Kobuk River (author's observation) and from Highpower Creek and the Kolitna River in the Kuskokwim system (K. Alt, pers. comm.), all taken in early October, had few pearl organs.

RANGE AND ABUNDANCE

The humpback whitefish is to be found in most of the Alaskan rivers that empty into the Bering, Chukchi and Beaufort seas. It ranges throughout the Kuskokwim River drainage, and well above Umiat in the Colville. Alt and Kogl (1973) found it at Umiat in July, whence it is presumed that the spawning grounds in that river must be much farther upstream. In the Yukon, on the other hand, it apparently is confined to the lower reaches, where it has been recorded from Marshall. Its range extends eastward along the Arctic coast at least to the Sagavanirktok River, westward across Siberia to the Kara Sea. Throughout its range, it is quite abundant during the spawning concentrations, but the fish apparently disperse at other times of the year.

HABITS

Humpback whitefish appear to be truly anadromous, though it is not known how far the over-wintering fish move from the river mouths. They have been taken in the Beaufort Sea several miles offshore off the Colville and Sagavanirktok rivers, as well as in Kotzebue Sound, off Nome, and around the mouths of the Yukon and Kuskokwim rivers. In the Kara Sea of western Siberia, they have been taken well out in the northern parts "which are characterized by high salinities" (Berg, 1948). Upstream spawning migrations may be extensive. Fish tagged in the Kuskokwim River below Bethel have been recovered at Medfra and Telida on the North Fork, the latter representing a migration of not less than 1,280 km. Possible C. pidschian have been found in the Yukon River at Fort Yukon and in the Porcupine River (K. Alt, Alaska Dept. Fish and Game, Fairbanks, pers. comm.), but their origin remains unknown. Other populations seldom venture far upstream and still others may never go to sea at all (Berg, 1948).

The spawning run generally begins in June and spawning usually occurs in October. However, these fish have been found spawning under the ice in the Kuskokwim River near Bethel as late as 15 November (Alt, pers. comm.) and similar phenomena have been recorded in Siberia (Berg, 1948). Spawning behavior has not been described, but presumably is similar to that of the Alaska whitefish. Sexual maturity is attained at 4-6 years of age. Ovarian eggs are reported as 1.2 mm in diameter in Siberian fish (Nikolskii, 1961). Fecundity of females varies from one population to another and with the size of the fish. The general range is from about 8,000 to nearly 50,000 eggs per female. The young presumably hatch in the late winter and spring, subsequently moving downstream, to return as mature adults four to six years later.

The young feed mainly on zooplankton, but adults feed mostly on molluscs, crustaceans and chironomid larvae (Nikolskii, 1961).

Growth rates vary greatly from place to place and even in different sections of the same river (Nikolskii, 1961). In Alaska, fish in arctic rivers, such as the Colville, Kobuk and Agiakpuk, grow much more slowly than do those in the Kuskokwim and lower Yukon drainages. Humpback whitefish from the first three rivers average about 267 mm fork length at 5 years and 405 mm at 10 years, while those from the latter areas average 347 and 445 mm at the same ages (K. Alt, Alaska Dept. Fish and Game, Fairbanks, pers. comm.).

IMPORTANCE TO MAN

The humpback whitefish of Alaska is of little direct importance except in local subsistence fisheries. A commercial operation on the Colville River delta takes about 1,000 fish annually (Alt and Kogl, 1973). However, this fish is an important commercial species in Siberia (Berg, 1948; Nikolskii, 1961).

LAKE WHITEFISH

Coregonus clupeaformis (Mitchill)

DISTINCTIVE CHARACTERS

The lake whitefish is differentiated from the other two humpbacked whitefishes of Alaska by its higher gill raker count, 26-33 total.

DESCRIPTION

See description of C. nelsoni. Except for the gill raker counts, there are no known morphological differences of any significance.

RANGE AND ABUNDANCE

The lake whitefish is widely distributed across Canada and northern United States, from the upper Yukon and Northwest Territories south to Montana, Minnesota and the Great Lakes, east to New England, Quebec and Labrador. Knowledge of its distribution in Alaska is uncertain, due to the confusion with closely related species. However, it has been recorded with reasonable certainty from Paxson and Crosswind lakes in the Copper River drainage and from Lake Louise and the Tyone lakes in the Susitna drainage (Williams, 1968; Van Wyhe and Peck, 1969). Lindsey et al (1970) showed a possible record of lake whitefish from Old John Lake at the head of the Sheenjek River, but it was based on only two specimens (Lindsey, pers. comm.). Wherever it is found, the lake whitefish is quite abundant, especially when schooled up for spawning.

HABITS

Breeding behavior of the lake whitefish is similar to that of the Alaska whitefish, except that spawning generally takes place in inshore regions of lakes. Stream populations, of course, utilize the rivers and creeks. Spawning takes place over rocky or gravelly bottom in depths of 1 to 3 m. A female and one or more males rise to the surface, extrude eggs and milt, then descend separately towards the bottom. Spawning occurs at night (Bean, 1903; Hart, 1930; Everhart, 1958). Adults breed annually in the southern parts of the range, but apparently only every other year or even every third year in the arctic and sub-arctic (Kennedy, 1953).

Fecundity varies greatly from one population to another, averaging around 50,000 eggs per female, with a reported range from less than 6,000 to more than 150,000. Spawning occurs from October to December, depending on locality, and seems to be associated with water temperatures of about 6°C or less. Hatching normally occurs in late April. Development of the eggs takes 140 days at 0.5°C and this seems to be the optimum temperature for the eggs. In laboratory studies, none survived at 0° or at 12°C. Mortalities through hatching increased from 27% at 0.5° to 41%-42% at 2-6°, 81% at 8° and 99% at 10°C. Abnormalities also increased from 0 at 0.5-2°C. to 50% at 10°C (Price, 1940).

The larvae are 11-14 mm long at hatching and grow rapidly during the summer. In Lake Huron, the larvae are close inshore from soon after break-up to the end of the summer (Faber, 1970), often associated with emergent vegetation. They stay at or near the 17°C isotherm (Reckahn, 1970), descending with it to the metalimnion. Van Wyhe and Peck (1969) found similar movements of young-of-the-year "lake whitefish" in Paxson Lake, Alaska.

Growth slows abruptly in September so that by the end of October the larvae are about 120 mm long. This slowing of growth is associated with descent into the colder water of the hypolimnion.

Growth rates vary with locality and population. Average total lengths at age, covering a wide variety of localities in the U. S. and southern Canada, are: 1 year, 130 mm; 2, 216 mm; 5, 386 mm; 10, 511 mm; 15, 627 mm (Carlander, 1969). By contrast, "lake whitefish" in Paxson Lake, Alaska, had the following age-length relationships: 1, 40 mm; 2, 77 mm; 5, 202 mm; 10, 373 mm; 15, 460 mm (Van Wyhe and Peck, 1969). Maximum age reported is a fish of 28 years from great Slave Lake (Kennedy, 1953), while the largest is a fish of 19 kg taken in Lake Superior in 1918 (Van Oosten, 1946). If the length-weight relationship given by Dryer (1963) for Lake Superior whitefish can be applied to this specimen, then the fish must have been on the order of 1,350 mm total length. The next largest known weighed just over half as much, 10.9 kg (Keleher, 1961).

The lake whitefish appears to be a rather sedentary fish, at least in the Great Lakes. Tagging studies (Budd, 1957; Dryer, 1964) indicate that the majority of fish stay within 16 km of their spawning grounds, although one fish in Lake Huron was recaptured 240 km from the point of release. There seems, also, to be a tendency towards movement in definite directions, although no well-defined routes were determined (Budd, 1957). In general, movement of lake whitefish in large lakes consists of (a) travel from deep to shallow water in the spring; (b) movement back into deep water during the summer as the shoal water warms; (c) migration back to the shallow water spawning areas in the fall and early winter; and (d) post-spawning movement back to deeper water.

Within each of the Great Lakes, and probably in most large lakes, the lake whitefish forms more or less discrete populations. These are usually characterized by different growth rates rather than by morphological differences (Budd, 1957; Roelofs, 1958; Dryer, 1963, 1964; Mraz, 1964b). It is not known whether these populations are genetically distinct or are environmentally produced. In any case, the lack of migratory habits probably tends to keep them separate.

Food of the lake whitefish varies with size and age of the fish, the location and the type of food available. The initial food of the young consists of copepods, later on of cladocerans. By early summer they begin to feed on bottom organisms, but Cladocera, especially Bosmina, remain a dominant food item for some time (Reckahn, 1970). Adults feed mainly on benthic organisma, but pelagic and semi-pelagic forms also are important. Kliewer (1970) found a significant negative correlation between gill raker length and the proportion of benthic food, but a strong positive correlation between the number of gill rakers and the amount of benthic food. He listed the following food items for lake whitefish from the Cranberry Portage area in northern Manitoba: Pelecypods, gastropods, amphipods, Diptera (tendipedid larvae and pupae, culicid and ceratopogonid larvae), Ephemeroptera, Trichoptera, Megaloptera, plant material, fish eggs, Hirudinea, Cladocera, Copepoda, mysids, Hemiptera (Corixidae), Hymenoptera, fishes. In Paxson Lake, Alaska, adult whitefish were seen to prey upon young sockeye salmon until the fry grew too big for the whitefish (Van Wyhe and Peck, 1969).

Although extensive hatchery programs for the propagation of lake whitefish have been carried on for years on the Great Lakes and other places, there is no evidence to show that these programs have ever influenced the strength of year-classes (Koelz, 1929; Christie, 1963). Weather seems to be the most important factor. Cold water temperatures, below 6°C, at spawning time, followed by a steady (non-fluctuating) decrease to 0.5°C, and warm temperatures at hatching time produce the strongest year-classes (Christie, 1963; Lawler, 1965a).

IMPORTANCE TO MAN

The lake whitefish has long been one of the most valuable freshwater species in North America. Environmental deterioration, depletion of the stocks and other factors led to a decline in yield from the 5,500,000 kg per year of the 1880's to the 700,000 kg per year of the 1920's (Koelz, 1929), but in the late 1960's the catch was increasing. In 1970, the U.S. and Canada landings from the Great Lakes and the international lakes amounted to 1,690,500 kg (Anonymous, 1973). In addition, there are considerable Canadian fisheries in the northern lakes, such as Lake Winnipeg and Great Slave Lake. In Alaska, however, the lake whitefish is virtually unutilized. Attempts at commercial fishing for lake whitefish have been made in Crosswind Lake in the upper Copper River drainage, and in Lake Louise and Tyone Lake in the upper Susitna. These have not been especially successful (Williams, 1968).

CUTTHROAT TROUT

Salmo clarki Richardson

DISTINCTIVE CHARACTERS

The cutthroat trout is distinguished by having a red to orange mark on the underside of each lower jaw, numerous small black spots over most of the body, and a patch of small teeth (basibranchial teeth) behind the tongue between the gills.

DESCRIPTION

Body elongate, terete, little to moderately compressed, greatest depth about 25% of FL, deeper in large specimens. Head about equal to body depth. Snout rounded to slightly pointed, longer than eye diameter, especially in spawning males. Eye round, its diameter about 22% of head length. Mouth terminal, large, upper jaw reaching well behind eye in adults. Teeth caniniform, well developed, present on both upper and lower jaws, tongue, head and shaft of vomer, and palatines. A patch of minute teeth usually present between gills behind base of tongue. Gill rakers 14-22. Branchiostegals 10-12. Lateral line decurved anteriorly, 116-230 pores. Pyloric caeca 27-57.

Fins

D. 8-11. Adipose dorsal present. A. 11-13. P_1. 12-15. P_2. 9-10, a distinct axillary process present. Caudal slightly forked.

Scales

Cycloid, small, 116-230 (usually 120-180) along lateral line.

Color

Body dark greenish on back and upper sides, olivaceous on middle sides fading to silvery below. Often a pinkish sheen on gill covers. Numerous small black spots on back and sides, these extending to or almost to belly. Spots also present on dorsal, anal and caudal fins. Adipose fin usually with several spots, edge of adipose with an incomplete black border. Fins of a uniform ground color, no white or colored borders. Underside of lower jaw with a yellow to red (usually red) slash in the skin folds of each side. Freshly sea-run fish usually more bluish, with silvery sides, inconspicuous spots, and the red jaw marks inconspicuous or absent.

Size

The largest cutthroat known was a fish of the interior subspecies (*S. clarki lewisi*) taken in Pyramid Lake, Nevada, in 1925. This specimen was 991 mm (39 in) long and weighed 18.6 kg (41 lb). However, the average coastal cutthroat (*S. clarki clarki*) of 5 or 6 years of age will be only 250-380 mm (10-15 in) long.

RANGE AND ABUNDANCE

The coastal cutthroat ranges from the northern parts of Prince William Sound, Alaska, south to the Eel River in Northern California, and is to be found in most of the streams emptying into the Pacific within those limits. It has been widely introduced into various streams and lakes within its natural range, as well as into a few lakes in eastern North America.

Its abundance is irregular. In some streams it may be the most numerous sport fish present, while other streams support only small populations. Its willingness to strike a lure, coupled with its low fecundity, leads to adverse response to heavy fishing pressure.

HABITS

Coastal cutthroat spawn early in the spring, from April to mid-May in southeastern Alaska (Baade, 1975). In some parts of its range, the cutthroat may spawn as early as February (Scott and Crossman, 1973).

Spawning takes place in small gravel-bottomed streams, as a rule (Sumner, 1953, 1962; Baade, 1957; Lowry, 1965; Dewitt, 1954), but may go on in the main stream of small drainages (Jones, 1975). At spawning time, the male courts the female by nudging her and coming to rest beside her and quivering. Having chosen the site for her redd or nest, the female begins to dig out the egg pit in typical salmonid fashion. Heading upstream she turns on her side, presses her tail against the bottom and gives five to eight vigorous upward flaps of the tail. This sucks silt, debris and pebbles out of the bottom whence they are carried downstream by the current. Digging in this fashion continues every few minutes, with occasional interruptions, until the pit is deep and clean enough for egg laying. Such a pit is usually 100-150 mm (4-6 in) deep and not quite as long as the fish. Two to four hours seems to be the usual time required to dig the redd.

Meanwhile, the male takes no part in the digging. He is very attentive to the female, courting her and driving away intruders.

When the pit begins to take shape, the female tests it frequently by sinking down into the pit and feeling around the stones with the tip of her anal fin. Finally, she settles into the pit, with her anal fin pushed into the gravel and her head and tail arched upwards. The male joins her at once, both fish open their mouths and become rigid, quiver slightly, and eggs and milt are extruded.

The fish now leave the pit, the female moves to its upstream end and begins to dig again. The gravel she disturbs is carried down into the pit, covering the eggs. She continues digging until the entire pit is filled and the eggs well covered, a process requiring 40 minutes to an hour (Smith, 1941). The new pit, upstream of the first, may also be used for spawning, or the female may seek out a new spot and repeat the entire process. Both male and female cutthroat may spawn with one or more members of the opposite sex. Spawning goes on both in daylight and at night.

Fecundity varies with the size of the individual and with locality. Egg numbers up to 6,500 have been reported from Wyoming, but Alaskan fish average something less than 1,000 eggs per female (Baade, 1957; Jones, 1975).

The eggs, 4.3-5.1 mm in diameter, hatch in six to seven weeks and the fry remain in the redd for one or two weeks longer before they become free-swimming. The young are only about 15 mm (0.6 in) long at hatching, but grow quite rapidly. Growth rate varies tremendously with stock and locality, but overall, the young average 50-75 mm (2-3 in) long by the end of September. By the end of the first year of life, most of the fish are around 100-150 mm (4-6 in) long. At age 3, Alaskan fish average about 179 mm (7 in); 4, 210 mm (8 1/4 in); 5, 254 mm (10 in); 6, 309 mm (12 in); 7, 332 mm (13 in); and 8, 380 mm (15 in) (Jones, 1973, 1975). Farther south, growth rates are faster. About 90% of the years growth occurs between April and September (Cooper, 1970). Most young cutthroat do not go to sea until they are two or three years old. Most populations of coastal cutthroats are dominated by fish 4-7 years old. Sexual maturity is reached in the second or third year of life, with males generally maturing earlier than females. The young fish usually stay in the stream for one or two years before going to sea, but some populations may never go to sea at all. In sea-going populations, the freshwater life may be as long as eight years for rare individuals (Sumner, 1962; Jones, 1975).

The outmigration to the sea takes place in late spring and summer (mid-April to July), with the peak of movement in late May and early June (Baade, 1957; Jones, 1973, 1975), but in the southern part of the range the migration may be several months earlier (Lowry, 1965). Most movement goes on at night on moderate stream flows. Extreme high or low water inhibits migration. In general, the larger fish migrate to sea earlier in the season than do the smaller ones. Cutthroat stay in the sea for 12 to 150 days in southeastern

Alaska, those migrating earliest staying out the longest. It is possible that some individuals may stay at sea for a year or more, as seems to be true of some southern populations. However, most of the Alaskan cutthroats seem to go to sea annually and to stay there a relatively short time (Baade, 1957; Armstrong, 1971a; Jones, 1973, 1975). Most of the fish seem to stay fairly close to the home stream, but tagged fish have been recovered as far as 70 km (44 miles) from the mouth of the home stream (Jones, 1973).

Mortality of smolts (fish going to sea for the first time) is extremely high, 98% or more between the beginning of the outmigration and their return (Sumner, 1953, 1962).

The return migration from the sea to fresh water takes place in the summer and fall, with peak movement in September (Armstrong, 1971a; Jones, 1973, 1975). In Alaskan waters, this in-migration takes place mostly at night on moderate stream flows, but in Oregon streams the cutthroat appear to move most actively during periods of high water and later in the year (Sumner, 1953; Lowry, 1965). It is apparent that this migration pattern is not firmly associated with spawning, for in Petersburg Creek, Alaska, over half the incomers are immature (Jones, 1973).

Post-spawning mortality in northern Oregon averaged 68.4% over a four-year period, and ranged from a low of 54% to a high of 89%. Of the upstream migrants, 68.4% had not spawned previously, 26.6% had spawned once, 4.5% twice, and only 0.5% had spawned three times (Sumner, 1962). In Blue Lake, northern California, only 5-10% survived to a second spawning, and these fish produced significantly fewer eggs than did first-time spawners (Calhoun, 1944). Post-spawning mortality has not been studied in Alaskan cutthroats.

The food of the cutthroat varies with locality and time of year. Fish from Eva Lake on Baranof Island, Alaska, had fed chiefly on insects and young salmon during the late summer; on sticklebacks, insects and gastropods in winter; mainly on insects during the outmigration; and on amphipods and young salmon while at sea. Near Ketchikan, Alaska, cutthroats fed on salmon eggs and fry, insect larvae and sculpin eggs in the spring; on insects, sculpins, coho fry and leeches in summer; and chiefly on salmon eggs in the fall. Oregon fish were reported to eat aquatic and terrestrial arthropods, frogs, earthworms, crayfish, small fishes and fish eggs (Baade, 1957; Lowry, 1966; Armstrong, 1971).

Cutthroat trout prefer relatively small streams (watershed less than 13 km^2), with gravel bottoms and gentle gradients (Hartman and Gill, 1968). However, they may also be present in the sea, estuaries, lakes, and in alpine lakes and streams to over 4,375 m altitude. The residents of these high altitude habitats, however, belong to the inland subspecies.

IMPORTANCE TO MAN

The cutthroat trout is an important sport fish wherever it occurs. Although generally considered inferior to the rainbow trout, it is nevertheless a hard fighter, but does not jump as much as the rainbow. The cutthroat will take a wide variety of lures - spinners, spoons, flies both wet and dry, and small plugs. Cutthroats are raised commercially in southwestern United States, mainly for introduction into private ponds. The flesh is orange-red and of excellent flavor.

RAINBOW TROUT

Salmo gairdneri Richardson

DISTINCTIVE CHARACTERS

Black spots on the sides, back and on dorsal and anal fin, a reddish band along the side (absent in sea-run fish) and no basibranchial teeth on the base of the tongue serve to distinguish the rainbow trout.

DESCRIPTION

Body elongate, moderately compressed, greatest depth varying, according to locality and size of fish, from about 21% to nearly 30% of standard length (19-28% of fork length). Head about 20% of FL, larger in breeding males, especially steelhead. Snout round, a little longer than eye diameter, but much extended in breeding males. Eye round, about 20% of head length in females and non-breeding males. Mouth large, terminal, slightly oblique, maxilla reaching to or well behind posterior edge of eye. Teeth caniniform, well developed on both jaws, head and shaft of vomer, palatines and tongue. No teeth on basibranchials at base of tongue. Gill rakers 15-22. Branchiostegals 8-13 on each side. Lateral line with 100-150 pored scales, slightly curved anteriorly, straight on most of sides and tail. Pyloric caeca 27-80.

Fins

D. 10-12, dorsal adipose fin present. A. 8-12. P_1. 11-17. P_2. 9-10, axillary process present. Caudal broad, slightly indented in small, but quite square-edged in large specimens.

Scales

Small, cycloid, the size and number variable in different populations.

Color

Extremely variable according to locality, sexual condition and size of fish. In general, top of head, back and upper sides dark blue to greenish or brownish. Lower sides silvery, whitish or pale yellow. Belly silvery white to grayish. Cheek and gill cover pinkish, sides with a band of bluish pink to rose red, not present in fish fresh from the sea (steelhead). This band reddest in spawning or recently spawned out fish, especially males. Back and upper sides with many small, black spots, which may extend well down on lower sides. Dorsal and caudal fins profusely spotted with black. Adipose fin with black spots and a black border. Other fins with few spots, dusky or unmarked. In some populations inhabiting Briston Bay drainages, red to orange marks present on lower jaw, resembling cutthroat trout. Stream resident fish may retain parr marks as adults.

Size

Although in most areas a rainbow of 1 or 2 kg (2-5 lbs) is considered a very good fish, they are known to attain much greater size. The largest taken by angling was a fish of 16.8 kg (37 lbs) from Lake Pend Oreille, Idaho. A fish of 19.1 kg (42 lbs) was recorded from Corbett, Oregon (Field and Stream Magazine, March, 1960) and one of 23.6 kg (52 lbs) from Jewel Lake, B. C. (McPhail and Lindsey, 1970).

RANGE AND ABUNDANCE

The original native range of the rainbow is from the Kuskokwim River in Alaska south to northern Mexico near Ciudad Durango, about 24°N, westward in Alaska to Port Moller on the Alaska Peninsula (160° 34' 30" W). The entire range is west of the continental divide except for the headwaters of the Peace River in British Columbia and the Athabasca River in Alberta.

Rainbow and steelhead have been introduced into every continent and most major islands of the world. Rainbow trout have been planted virtually all over North America, with the result that the species is now present in every state of the U. S. except Louisiana, Mississippi and Florida, and in every province and territory of Canada except the Northwest Territories (MacCrimmon, 1971).

The rainbow is not native to interior Alaska (north of Alaska Range), but has been planted in a number of lakes, ponds and gravel pits in the Fairbanks area and near Big Delta, as well as Summit Lake. Lost Lake, about 48 km from Big Delta, was rehabilitated in 1951 and received the first plant of young rainbows in 1952. Alaska was thus the last state to practice planting rainbow trout. These first plants were made with fish raised from eggs imported from Idaho and Montana, as this was less expensive than taking eggs of native fish. (Marvich, 1952; Marvich and McRea, 1953; Marvich et al, 1954.)

HABITS

The rainbow trout is basically a spring spawner, with the majority breeding between mid-April and late June (Lindsey et al, 1959; Hartman, 1959; Hartman et al, 1962). However, various populations may spawn as early as November or December (Dodge and MacCrimmon, 1970) or as late as August, and fish have been bred in Idaho hatcheries to spawn in the fall. When these latter were transplanted to warm temperatures (up to 17°C) in California, they were able to spawn twice a year, summer and winter (Hume, 1955).

Spawning takes place in streams, usually on a riffle above a pool. Most spawning occurs at temperatures between 10° and 13°C, but early spawners in the north may encounter temperatures as low as 5.5°C, while southern fish have been known to spawn when water temperature was 17°C. Breeding behavior is typically salmonid. The male courts the female by coming in contact with her, sliding over her back, rubbing her with his snout, vibrating beside her and pressing against her. When the female has selected a site for the redd, she turns on her side and gives several strong, upward flips of her tail. This displaces sand and gravel which is washed downstream by the current.

Repeated digging soon results in a pit somewhat longer and deeper than her body. Meanwhile, the attendant male has been courting her and driving off rival males, although a subordinate male may also be in attendance. These processes may go on both in daylight and at night.

When the redd is finished, the female drops down into the pit. The dominant male joins her, the bodies of the two parallel and close together. Both fish open their mouths, quiver, and extrude eggs and milt for a few seconds. The subordinate male often participates in the spawning also. The eggs fall into the interstices in the gravel, where they are fertilized. From one or two hundred to as many as 1,000 eggs may be dropped in a single nest. Fecundity per female ranges from as low as 200 (Needham, 1938) to as high as 12,749 eggs, the latter from specially selected stock (Buss, 1960). Average fecundity is on the order of 3,250 eggs per female, with younger and smaller fish producing fewer eggs than larger, older fish. The number of eggs produced depends in part on adequate nutrition. Insufficient food, such as may be effected by overly large populations and excessive intra-specific competition, leads to follicular atresia of the eggs, although the eggs which survive are of normal size (Scott, 1962). As soon as the spawning act is completed, the female moves to the upstream edge of the redd and digs again. The displaced gravel is carried downstream and covers the eggs. The whole process is repeated, either with the same or other males, until the female's egg supply is exhausted.

The eggs average between 3 and 5 mm in diameter and are pink to orange in color. Time of development varies with temperature, ranging from as little as 18 days at 15.5°C to 101 days at 3.2°C (Embody, 1934; Wales, 1941; Knight, 1963). Under most natural conditions, development to hatching takes 4 to 7 weeks. The alevins require 3 days to more than 2 weeks to absorb the yolk sac completely, but normally begin to feed about 15 or 16 days after hatching, even though some yolk may still be unabsorbed. The young emerge from the redds in mid-June to mid-August for spring (April-May) spawners.

Survival of eggs is directly correlated with the velocity of ground water passage through the redd and with the amount of dissolved oxygen in this ground water (Coble, 1961). It has been found that wood fibers in the water do not affect the survival of eggs but have pronounced adverse effects on growth and survival of young fish (Kramer and Smith, 1965).

Subsequent life history varies greatly according to environmental conditions and the genetic make-up of the population. Stream-resident fish generally stay in the natal stream. By contrast, the young of lake-resident fish usually move up or down stream to the lake in a few days to several months. However, rainbows introduced into the Finger Lakes of New York have been found to stay as long as 4 years (usually 1 or 2) in the streams before moving down to the lake (Hartman, 1959). Movement of the young appears to be associated with water temperature. In cold water, less than 13°C, the fry rarely contact the bottom during the hours of darkness, and are carried downstream. By contrast, in warmer waters (over 14°C), the young fish make frequent contact with the bottom and tend to stay more or less in one area. Upstream movements are associated with rapid increases in water temperature (Northcote, 1962).

Growth rates and growth patterns vary tremendously. Genetic composition, type and availability of food, temperature, type of habitat and geographical area all come into play. Sexual maturity is usually reached at two years or older (rarely in the first year by some males) or as late as six years of age in some females. In general, age at maturity is between 3 and 5 years, with males usually maturing a year earlier than females. The size at sexual maturity is equally variable. Mature individuals from small streams may be only about 150 mm (6 in) long, while steelhead or fish in large lakes may be as long as 400 mm (about 16 in). Maximum age seems to be about 9 years (Sumner, 1948).

Many rainbow trout spawn more than once. Particularly if environmental conditions are good, rainbows may spawn annually for up to five successive years (Hartman, 1959). The percentage of repeat spawners in a population varies widely, from 5% to 57%. In general, larger and older females are less likely to survive spawning than are smaller, younger ones, and males less likely to survive than females (Hartman, 1959; Hartman et al, 1962; Withler, 1965). Survival to subsequent spawning seems to be inversely related to the number of spawners entering a stream (Hartman, 1959).

Although the rainbow is generally considered a cold-water fish, with a preferred temperature of about 13°C (Garside and Tait, 1958), it can tolerate fairly warm water, and indeed seems to grow best at about 21°C. The upper lethal temperature is 24°C (Black, 1953).

The migratory patterns of rainbows are as varied as the populations and the areas in which they are found. In general, stream-dwelling rainbows tend to be non-migratory and to spend their entire lives in relatively short sections of the stream. Lake-dwelling fish migrate into the spawning streams in the spring, those going to inlet streams a month or more later. Both groups move back into the lake 3 to 6 weeks after leaving it. This return seems to be triggered by rising temperature. In Loon Lake, B. C., the return to the lake occurred when the water temperature reached 10°C (Hartman, et al, 1962).

Steelhead undertake the greatest movements of any form of rainbow trout. After 1-4 years (usually about 2) of stream life, the steelhead run down stream in the spring and summer and enter the sea. Here they may stay from a few months to as much as 4 years before returning to the natal stream to spawn. Most of the freshwater movement, both up and downstream, goes on at night (French and Wahle, 1959). At the time of the first downstream migration, the young fish lose their parr marks and become silvery, the smolt stage. This change in color is the result of increased activity of the thyroid gland (Robertson, 1949). The younger fish adapt readily to sea water, but the longer the period of freshwater life the longer the period of adaptation which is required (Houston, 1961). The return migration may take place in spring-summer (May-August) or in the winter (December-March). The fish of the latter group are nearly ripe and spawn that same spring. By contrast, the spring-summer fish stay almost a year in fresh water and spawn the following spring. At spawning, these fish are typical rainbows, with the usual red band along the side and the males with a well-developed kype. By contrast, winter fish show little, if any, sexual dimorphism (Smith, 1960). Spring-run fish in California have been reported to spawn in the late autumn (Briggs, 1953; Shapovalov and

Taft, 1954). This division into spring-summer runs and winter runs appears to be genetically controlled. It is probable that the evolution of the two types has come about in response to stream barriers which are passable only during periods of high water (Withler, 1965).

Rainbows resident in fresh water generally do not migrate very far. Stream-resident fish, in particular, may spend their entire lives within a few kilometers of the place where they were hatched. Lake residents generally do not move about much in the lake, but may move up to 60 to 70 km, especially up inlet streams. Steelhead, however, move extensively, undertaking upstream migrations of hundreds of kilometers in large rivers such as the Columbia. Steelhead introduced into Great Lakes drainages of Michigan have been known to travel as much as 1320 km in 8 months through the lakes. Regardless of strain, rainbows exhibit a high degree of homing. Better than 90% of surviving migrants return to the home stream (Taft and Shapovalov, 1938; Lindsey, et al, 1959).

Food habits of rainbow and steelhead seem to depend as much on size and availability of food items as on any preference on the part of the fish. In general, fish in fresh water feed on various invertebrates, especially the larvae and adults of dipteran insects, and crustaceans such as *Gammarus*, but plankton, various insects, snails, and leeches also may be eaten. Other fishes may be eaten by adult rainbows, and the availability of fish may be necessary for the rainbow to reach maximum size. Steelhead in the sea are known to feed heavily on squid and fishes (Reimers, et al, 1955; Le Brasseur, 1965; Scott and Crossman, 1973).

Because of its popularity as a sport fish, the rainbow has been widely introduced, and many populations are maintained at levels suitable to anglers only by continued stocking. Planted hatchery fish, especially in fast-moving streams, have a regrettable tendency to die off in a relatively short time, yielding but poor returns to the angler (Randle and Cramer, 1941; Burns and Calhoun, 1966). At least some, and perhaps a major, part of the die off results from the inability of the fish to cope with the continued vigorous swimming necessary in fast water. As a result, glycogen reserves are used up faster than they can be replaced, blood lactate reaches very high levels (four or more times above the level found in surviving fish), blood pH drops to 6.9 or less, and death ensues (Black, et al, 1962; Hochachka and Sinclair, 1962; Jonas, et al, 1962; Miller and Miller, 1962).

IMPORTANCE TO MAN

It is safe to say that *Salmo gairdneri* is one of the most sought after sport fishes in North America, and probably the most important of all sport fish west of the Rockies. It takes both flies and lures, fights hard and leaps frequently. The flesh is of high quality, both in texture and flavor. Rainbows are raised for eating purposes in a number of hatcheries in the U. S., as well as in Europe and Japan, and a few thousand cases of steelhead are canned annually from fish taken by commercial salmon fishermen. The economic value of the sport fishery is not to be sneezed at. Anglers spend vast sums for tackle, bait, lodging, travel, etc., in order to fish for rainbows and steelhead. In the Copper River (tributary to Lake Iliamna), Alaska, sport fishermen in 1972 spent $125,552.18 to catch 3,621 rainbows, for an average cost of $35.50 per trout! (Siedelman, et al, 1973.)

BROOK TROUT

Salvelinus fontinalis (Mitchill)

DISTINCTIVE CHARACTERS

The combination of dark green marbling on the back and dorsal fin and the red spots with blue halos distinguish the brook trout.

DESCRIPTION

Body elongate, only slightly compressed, its greatest depth 20-28% of total length, generally deeper in larger, sexually mature individuals. Head longer than in most other American charrs, 22-28% of total length. Snout more or less rounded, longer than eye diameter, 25-38% of head length. Eye round, its diameter 15-22% of head length. Mouth large, terminal, maxilla reaching well behind eye in adults, only to posterior edge of eye in young. Breeding males often develop a kype. Teeth caniniform and well developed on upper and lower jaws, head of vomer (but absent from shaft), palatines and tongue. Gill rakers 14-22. Branchiostegals 9-13, usually one less on right side than on left. Lateral line with 110-130 pored scales.

Fins

D. 10-14, adipose dorsal fin present. A. 9-13. P_1. 11-14. P_2. 8-10, an axillary process present. Caudal fin nearly straight (hence the old popular name "squaretail") or with a shallow indentation.

Scales

Cycloid, minute, in about 230 rows in a mid-lateral series.

Color

Varies, but generally more or less as follows: Back greenish to brownish, marked with paler vermiculations or marblings which extend onto the dorsal fin and sometimes the caudal also. Sides lighter, marked with numerous pale spots and some red spots, each of the latter surrounded by a blue halo. Anal, pelvic and pectoral fins with a white leading edge followed by a dark stripe, rest of fins reddish. In spawning fish, especially the lower sides and fins become red. Sea-run fish are dark green above, with silvery sides, white belly and very pale pink spots.

Size

The largest known is a fish of 6.6 kg which was 700 mm long, taken in the Nipigon River, Ontario, in 1916. In most areas, fish as large as 1-1.5 kg are considered large. Occasionally, fish over 7 kg have been reported, but these have invariably turned out to be arctic charr.

RANGE AND ABUNDANCE

The native range of the brook trout is from Ungava Bay in northern Quebec to New Jersey and southern Pennsylvania in the lowlands, still farther south to northern Georgia in the Appalachian highlands; from the easternmost tip of Newfoundland west to eastern Minnesota and Manitoba, where it reaches north along the west coast of Hudson Bay to the Churchill River. It has been widely introduced into the western states and provinces, as well as to other parts of the world such as South America, New Zealand, Asia and Europe. In Alaska, brook trout were introduced into southeastern in 1920 (MacCrimmon and Campbell, 1969), with plantings continuing into the 1950's (Anonymous, 1953). Unfortunately, it hybridizes readily with the native Dolly Varden and the resultant hybrid is inferior to both the parent species (Baade, 1962). It also has a distressing tendency to overpopulate in some situations, resulting in large numbers of stunted fish which are of no interest to anglers.

HABITS

The brook trout spawns in the fall of the year, from late August in the far north to as late as December in the southern part of the range, at water temperatures between about 3° and 9°C. Maturation of sex products appears to be stimulated by lessening day length and falling temperatures (Henderson, 1963). Artificial manipulation of day length, beginning in mid-January, in hatchery situations has resulted in fish becoming ripe as early as the first week of August. Fish subjected to this treatment produced smaller than normal, but more numerous, eggs. The treatment was highly successful with two year old fish, less so with older ones (Corson, 1955).

Spawning takes place over gravelly bottom, most often in fairly shallow streams, but sometimes also in lakes at locations where there is upwelling of ground water. The presence of springs seems to be essential and may be the most important factor in the choice of a spawning site (White, 1930; Hazzard, 1932; Webster, 1962). Gravel size on spawning beds has been noted to vary from coarse sand to stones 75-100 mm in diameter, and apparently is unimportant as long as ground water seepage is present.

Courtship begins with a male attempting to guide or drive a female towards suitable spawning gravel. A ripe, receptive female makes close visual inspection of the gravel and, having chosen a spot, begins to dig the redd. She turns on her side and, with powerful upthrusts of her tail, lifts gravel, silt, etc., from the bottom. The smaller and lighter particles are swept away by the stream current, but the larger ones settle at once to the bottom, building a mound just downstream from the pit. Repeated digging forms a depression from 100 to 150 mm (4-6 in) deep. The female tests the pit from time to time with her anal, caudal and pelvic fins. Meanwhile, the male continues his courtship activities, darting alongside of her and quivering, swimming over and under her and rubbing her with his fins. He spends most of his time, however, in driving off other males, in which the female assists.

When the pit suits the female, she drops her anal fin deeply into it and arches her tail. The male comes beside her, both fish open their mouths and quiver, and eggs and milt are deposited in the pit. This process takes about one second and up to about 800 eggs may be dropped at one time (Greeley, 1932). Due to the depth of the pit, quiet water and gentle eddies are present at the bottom, which hold the eggs and the cloud of sperm in place or spread the latter upstream and laterally (Smith, 1941; Needham, 1961).

After spawning, the female at once begins to cover her eggs, but the method is very different from that used by most salmonids. She goes to the mound of gravel which has formed at the downstream edge of the redd and begins a sinuous movement, using the tips of her anal and caudal fins to sweep small pebbles upstream into the nest. The eggs are quickly covered, after which the female circles the pit, continuing to sweep in this manner for about half an hour. Only after the eggs are well covered does she go to the upstream end of the nest and again begin the characteristic salmonid digging of a new redd (Smith, 1941; Needham, 1961).

In Alaska, the brook trout may hydridize with the native Dolly Varden, with results which are a credit to neither parent species (Baade, 1962). The brook trout has been experimentally crossed with kokanee and with brown, rainbow and lake trout. Survival of offspring is virtually nil in the first three crosses. Brook trout X lake trout crosses produce viable offspring called "splake", but survival and fertility are lower than for either parent species (Buss and Wright, 1956; 1958; Crossman and Buss, 1966). It is not known whether the brook trout X Dolly Varden hybrids are fertile.

The eggs are large, 3.5-5.0 mm in diameter after spawning. The number of eggs produced is directly related to the size of the female. The average number varies from 100 eggs for a fish of about 150 mm to 5,000 for a fish of 565 mm (Vladykov, 1956; Wydoski and Cooper, 1966).

Hatching time varies with temperature, but usually occurs in late winter. At 5°C, 100 days are required, but normal, though slower, development occurs at temperatures as low as 1.7°C. The upper limit appears to be about 11.7°C (Embody, 1934; Bigelow, 1963).

The young fish remain in the gravel until the yolk sac has been absorbed. They emerge in April or May when they are about 38 mm long. They stay on the redd for a few days and may burrow into the gravel if frightened, but soon disperse. Scales begin to form at a length of about 50 mm. Survival to this stage is good, averaging about 16.4% (3.6-42.4%) in one series of observations (Smith, 1947).

Growth is rapid during the first summer. By the end of September, the young may be as much as 100 mm long and weigh about 10 grams. Subsequent growth rates vary with locality, temperature, food supply and the genetic composition of the population. The most rapid growth takes place in May, slows through the summer and goes on at a minimal level from September until spring (Cooper, 1951).

Sexual maturity may be reached as early as one year of age, but most usually in the second year. All fish are mature at three years (Wydoski and Cooper, 1966).

The brook trout is a relatively short-lived fish. Few wild individuals survive more than five years, although there are reports of introduced fish reaching 15 years of age in California (McAfee, 1966).

Most brook trout are more or less stable residents in streams or lakes, where they prefer temperatures below 20°C. On the east coast of North America, general upstream movements have been observed in early spring, summer and late fall, downstream movements in late spring and fall (White, 1941, 1942; Smith and Saunders, 1958, 1967). Some fish, popularly known as "salters", run to sea in the spring as stream temperatures rise. They stay at sea for up to three months, feeding and growing, but never venturing more than a few kilometers from the river mouths. Their return to fresh water apparently is related to freshets in the main river and there is a definite homing tendency to the tributaries of origin within the drainage (White, 1941, 1942; Bigelow, 1963).

Brook trout eat a most amazing variety of food organisms, ranging from copepods, eaten by the young, to small mammals (mice, voles and shrews) by large adults. The most important items are insects of all sorts, both aquatic and terrestrial. Other foods include Cladocera, spiders, worms, leeches, crustaceans, molluscs, fishes, amphibians and mammals (Clemens, 1928; Ricker, 1930, 1932; Wadman, 1962). The most intensive feeding and best growth occur at temperatures of about 13°C (Baldwin, 1957).

IMPORTANCE TO MAN

The brook trout is one of the most important sport fishes in North America. It is angled for with all types of sport gear by people from all walks of life. In addition, it is amenable to pond culture and large numbers are raised in private ponds for commercial sale, either for food or for stocking.

LAKE TROUT

Salvelinus namaycush (Walbaum)

DISTINCTIVE CHARACTERS

The lake trout is easily distinguished by its color, whitish or yellowish spots on a dark green to grayish background; its deeply forked tail; and the numerous (93-208) pyloric caeca.

DESCRIPTION

Body elongate, more or less terete. Depth usually 18-26% of TL, but much deeper in some populations, especially those which feed largely on molluscs. Head fairly long, 21-28% of TL. Snout long, 26-36% of head length. Eye rather small in adults, 12-20% of head length. Mouth terminal, large, maxilla reaching well behind eye in adults, snout protruding beyond lower jaw when mouth is closed. Teeth caniniform, present on both jaws, on head but not shaft of vomer, on palatines, tongue and basibranchials. Gill rakers 16-26. Populations of lake trout which feed mostly on plankton tend to have more gill rakers than those which are mainly piscivorous. Branchiostegals 10-14, usually more on left than on right. Lateral line with 116-138 pores, slightly curved anteriorly. Pyloric caeca numerous, 93-208, mostly 120-180.

Fins

D. 8-10. Adipose dorsal present. A. 8-10, P_1. 12-17. P_2. 8-11, a small axillary process present. Caudal deeply forked.

Scales

Small, cycloid.

Color

Back and sides usually dark green liberally sprinkled with whitish to yellowish (never pink or red) spots. Ground color varies from light green to gray, brown, dark green or nearly black. Belly white. Pale spots present on dorsal, adipose and caudal fins and usually on base of anal. Sometimes orange-red on paired fins and on anal, especially in northern populations. Anterior edge of paired and anal fins sometimes with a white border. At spawning time, the males develop a dark lateral stripe and become paler on the back (Royce, 1951).

Size

The lake trout is the largest member of the genus Salvelinus. The angling record is a fish of 29.5 kg (65 lb) from Great Bear Lake, N.W.T. The largest known came from Lake Athabasca and weighed 46.4 kg (102 lbs) (Canadian Dept. Fisheries, 1961).

RANGE AND ABUNDANCE

The lake trout is widely distributed in northern North America and has been introduced into other parts of the world such as Scandinavia, South America and New Zealand. Its natural range in North America corresponds closely with the limits of Pleistocene glaciation (Lindsey, 1964). It is generally absent from lowland regions such as the Yukon-Kuskokwim valleys in Alaska and the Hudson Bay-James Bay lowlands of Canada. The range extends from the Alaska peninsula east to Nova Scotia, south to northern New York and Pennsylvania and the Great Lakes, north to the islands of the Canadian arctic. The species is intolerant of salt water (Boulva and Simard, 1968) and has made its way only across narrow stretches of the marine environment. However, it has been found on Southhampton Island (Manning, 1942), and Baffin, King William, Victoria and Banks islands (Scott and Crossman, 1973).

In the more isolated parts of its range, the lake trout is abundant, but in many other areas, especially the Great Lakes, it has become rather scarce, except where maintained by artificial propagation and careful management.

HABITS

Like most charrs, the lake trout spawns in the fall. The exact time varies with latitude and temperature. Over the entire range, spawning activity occurs as early as late August and early September in the far north, e.g., Great Bear Lake and certain lakes in northern Alaska (Miller and Kennedy, 1948a; McCart et al, 1972) to as late as December in the southern parts of the range (Royce, 1951).

Spawning takes place over clean, rocky bottom in depths from as little as a meter or even less (Merriman, 1935; Martin, 1957; Rawson, 1961) to as deep as 36 m (Eschmeyer, 1955). Virtually all lake trout spawn in lakes, but a few populations are known to spawn in streams tributary to Lake Superior (Loftus, 1958). Conversations with residents of Kobuk, Alaska, suggest that a few lake trout may spawn in the Kobuk River. However, this has not been verified.

Spawning takes place mostly at night, with peak activity between dusk and 9 or 10 p.m. (Royce, 1951; Martin, 1957). During the day, the fish are more or less dispersed away from the spawning beds, but return in numbers in the late afternoon. Males reach the spawning beds first and spend time cleaning the rocks. This they do by twisting their tails and bodies over the bottom and by rubbing the rocks with their snouts. This activity by a group of males cleans an area of several tens of square meters. When the females arrive, a few days after the males, they are courted by the males. A male butts the side of the female, follows her, and may swim beneath her, brushing her vent with his dorsal fin. At this time, the males become pale on their backs and develop a dark stripe on each side and dark areas around the head (Royce, 1951; Martin, 1957).

During and following courtship, the males attempt to spawn with the females. One or two males approach a female, press against her sides with vents close together and then quiver. Both sexes have their mouths open and the male's dorsal fin is erect. On occasion, as many as seven males and three females may engage in a mass spawning act (Royce, 1951). The spawning act lasts only a few seconds and is probably repeated many times before a female has voided all her eggs. Fecundity varies from a few hundred to more than 17,000 eggs per female, the number of eggs increasing with the size of the fish (Eschmeyer, 1955).

Spawning is an annual affair in southern areas, but evidence indicates that it occurs only every other year in Great Slave Lake and only every third year in Great Bear and some other lakes of the high arctic (Miller and Kennedy, 1948a; Kennedy, 1954; Furniss, 1974).

The large eggs, 5 to 6 mm in diameter, fall to the bottom and lodge in crevices and crannies among the rocks. Incubation requires 15-21 weeks or more, depending on temperature, and hatching normally occurs between mid-February and late March (Eschmeyer, 1955; Martin, 1957). The newly hatched young are about 16 mm long, with an exceptionally large yolk sac. Buds of the pelvic fins and elements of the anal and caudal are already present (Fish, 1932). Growth is usually good during the summer and by September or October the young fish are about 60-70 mm long. Subsequently, growth rates vary widely from place to place, according to water temperature, altitude, type and amount of food available, and the genetics of the fish. Most growth occurs during the summer, with some northern populations growing only from June to September (Kennedy, 1954). Overall, age I fish average about 200 mm TL; age V, 450 mm, 874 g; age X, 728 mm, 3,240 g; age XV, 964 mm, 7,631 g. The slowest growing lake trout are those of Great Bear Lake, N.W.T., and of Itkillik and Campsite lakes in Alaska. Ten-year-olds from Great Bear Lake average only 406 mm TL, age XC, 528 mm, age XX, 678 mm. A 37 year old fish was 1,046 mm TL and weighed 15.4 kg (Miller and Kennedy, 1948a). What appears to be the oldest known was a fish of 927 mm and 12.5 kg estimated to be 42 years old taken in Chandler Lake, Alaska, in July 1973 (Furniss, 1974). Another aged at 41 years was reported from the west coast of Hudson Bay (Sprules, 1952). Fish from the two Alaskan lakes had even slower growth rates when calculations were based on otoliths. However, when calculations were based on scales, growth rates of Itkillik Lake fish were quite comparable to those from Great Bear Lake (McCart, et al, 1972). Growth of lake trout in other Alaskan lakes is generally better than in Great Bear Lake but below the general average (Roguski and Spetz, 1968; Van Wyhe and Peck, 1969; Furniss, 1974).

Sexual maturity is generally reached around the seventh year, but may be achieved as early as age 5 or as late as 13. Males usually mature a year earlier than females.

Although the lake trout can hardly be called migratory, in that whole populations do not undertake movements in definite directions, it is definitely a solitary wanderer. Tagged fish in Lake Superior have been recovered up to 408 km (255 mi.) from the point of release. In other areas, lake trout wander throughout the lake, the extent of their movements apparently limited chiefly by the size of the body of water. Smaller fish tend to move shorter distances than do larger fish (Eschmeyer et al, 1953; DeRoche and Bond, 1957; Rawson, 1961). Dispersal begins shortly after spawning. By spring, the fish are wide spread, and as the water warms above 10°C., they tend to go into deeper water and to congregate below the thermocline during the summer. (Martin, 1952; Rawson, 1961; Dryer, 1966). With the approach of fall, the fish return to the spawning beds. They show a marked tendency to return to their natal spawning areas, although stocked fish may utilize artificial spawning beds (Eschmeyer, 1955; Hacker, 1957; Loftus, 1958, Martin, 1960). The newly hatched fish move off the spawning areas and into deep water a month or so after hatching, and apparently stay there for some time.

As with most fishes, food habits vary with age and size of the fish, locality and the food available. Total diet includes a wide variety of such items as zooplankton of various sorts, insects, spiders, clams, snails, many kinds of fish, plant material such as Nostoc, sponges, amphibians, worms, shrews, mice. The very young fish subsist almost entirely on small crustacean plankters of various sorts. As size increases, larger organisms such as Mysis, Pontoporeia and insect larvae become of major importance. Mature lake trout in most areas feed almost exclusively on fishes (Hildebrand and Towers, 1927; Dunbar and Hildebrand, 1952; Hacker, 1957; Kimsey, 1960; Rawson, 1961; Martin, 1970). Coregonids appear to be particularly important in most places and to provide superior nourishment for the lake trout. In Lake Opeongo, Ontario, a shift to coregonids from other kinds of fish resulted in faster growth, greater weight, older age at maturity and larger and more numerous eggs (Martin, 1970).

Some populations of lake trout feed on plankton throughout their lives. This may be due to unavailability of forage fish, or perhaps to a genetic characteristic of the trout. Such fish tend to have more numerous and longer gill rakers, and often develop accessory rakers on the medial side of the gill arch (Martin and Sandercock, 1967). Plankton-feeding lake trout grow more slowly, mature earlier and at smaller size, die sooner, and attain smaller maximum size than do their fish-eating counterparts (Martin, 1966). Seasonal changes in food habits, probably in response to availability, have been observed in several areas. In Lake Superior, coregonids made up the major food in fall and early winter, but were replaced by smelt in February and March, with cottids, mysids and insects most common in late summer (Dryer, et al, 1965). A similar situation prevailed in certain lakes in Ontario, where again fishes were eaten more commonly in winter (Martin, 1954).

Lake trout are not known to produce natural hybrids with other species of Salvelinus, perhaps because of their unique spawning habits. However, artificial crossing of female lake trout and male brook trout yields viable offspring, called "splake." These splake grow more rapidly than either parent species, are fertile and are known to reproduce naturally (Martin and Baldwin, 1960).

Lake trout are highly susceptible to pollution, especially from such insecticides as DDT. This substance accumulates in the yolk and fatty tissues and concentrations of less than 3 ppm produce mass mortalities of the alevins following yolk-sac absorption (Burdick et al, 1964).

IMPORTANCE TO MAN

The lake trout was formerly one of the mainstays of the Great Lake fisheries, with landings up to nearly 7,000,000 kg in 1940 (Fiedler, 1943). However, with the entrance of the sea lamprey, Petromyzon marinus, into these waters, and the extensive use of insecticides such as DDT, the stocks declined drastically and annual catches now amount only to about 190,000 kg (Anonymous, 1975). It is still an important commercial species in Canada, especially in the Northwest Territories, but even here, free of the lamprey, landings have declined by a third in recent years (Scott and Crossman, 1973).

As a sport fish, the lake trout is well regarded. It fights hard, though not spectacularly, and the large size attained makes it a trophy worthy of any angler's skill. The flesh is usually of a yellowish creamy color, but may be anything from white to orange, depending, at least in part, on diet. Regardless of color, lake trout is excellent as human food.

ARCTIC CHARR

Salvelinus alpinus (Linnaeus)

DISTINCTIVE CHARACTERS

The arctic charr is distinguished by the presence of 23 to 32 gill rakers and 35 to 75 pyloric caeca, and the presence of pink to red spots, the largest usually larger than the pupil of the eye, on the sides and back.

DESCRIPTION

Body elongate, more or less terete, compressed posteriorly. Depth about 20% of TL, but highly variable, depending on time of year, sex, size, and state of maturity. Head moderate, 22-25% of TL. Snout rounded, its length usually equal to or longer than eye diameter. Eye more or less round, large, diameter averaging about 23% of head length, but highly variable. Mouth large, terminal, maxilla reaching nearly to posterior margin of eye in small specimens, to well behind eye in large fish, especially in spawning males. Teeth caniniform, in an irregular single row on each jaw and palatines. A patch of teeth present on head of vomer. Teeth on tongue 10-24, in two rows. Gill rakers 23-32 on first arch. Branchiostegal rays 10-13. Lateral line with 123-152 pored scales, slightly decurved anteriorly. Pyloric caeca 35 to 75.

Fins

D_1. 12-16 (10-12 major rays). Adipose dorsal fin present. A. 11-15 (8-11 major rays). P_1. 14-16. P_2. 9-11, axillary process present.

Scales

Small, cycloid.

Color

Highly variable, depending on location, time of year and degree of sexual development. In general, the back is dark, usually brownish but sometimes with a greenish cast. The sides are lighter colored, belly pale. Sides and back are liberally sprinkled with pink to red spots. The largest spots along the lateral line are usually larger than the pupil of the eye. Leading edges of pectoral, pelvic and anal fins, and sometimes the caudal, with a narrow white margin. Fins pale in young fish, dorsal and caudal dark in adults, but other fins light. Spawning adults, especially males, are brilliant orange-red to bright red on the ventral side and on pectoral, pelvic and anal fins. Young Arctic charr have about 11 dark parr marks on each side.

Size

The largest arctic charr known is one of "over 27 pounds (12.2 kg)" from the Tree River, N.W.T. (Scott and Crossman, 1973). However, average size is much less than this. Arctic charr in Lake Aleknagik, Alaska, run about 1 to 2 kg. Fourteen fish taken in a small gill net in Campsite Lake at the head of the Kuparuk River, Alaska, in August 1973, averaged less than 1 kg, but others, taken on hook and line in the same lake, ran up to 5 kg. Thirty four charr from Chandler Lake, Alaska, taken by gill net in July 1973, ranged in weight from 569 to 2196 grams (Furniss, 1974).

RANGE AND ABUNDANCE

Distribution of the arctic charr is circumpolar in arctic and sub-arctic regions, with isolated relict populations in cold lakes south of the normal range. In North America, the species ranges from the Aleutian Islands, the Alaska peninsula and Kodiak Island north to the Arctic Ocean as far north as Discovery Harbor, Lady Franklin Bay, Ellesmere Island (82°42'N according to Günther, 1877, but more recently listed as 81°42'N, 65°20'W in the Gazeteer of Canada, 1971), and thus is the most northerly of all salmonids. The general distribution is circumpolar reaching south to New England, the British Isles, isolated locations in the Alps and Siberia, and the islands of Japan. In most areas where it is present, the arctic charr is abundant, though this abundance is often highly localized.

HABITS

Spawning occurs in the fall of the year, usually over gravel shoals in lakes, but sometimes in quiet pools in streams close to a lake. In lakes of the North Slope of the Brooks Range, Alaska, spawning may begin as early as late August or early September, while farther south it may not take place until November or December. Water temperatures range from about 3°C to nearly 13°C.

The male fish are territorial, guarding their areas and driving off intruding males with considerable vigor. However, as soon as the females begin to show spawning behavior, the males pair with them and lose interest in their territories. The female invades the male's territory and at first may be attacked by the male. She persists, however, and makes visual examination of the bottom. With head and tail bent downwards and eyes directed towards the bottom, she swims slowly about until she finds a suitable spot. During this period, she may attack nearby fish of either sex. When a suitable spot has been found, the female begins to dig the redd. This may start with powerful swimming movements, pushing water backwards and carrying away sand and loose debris. More often, however, digging begins in the typical salmonid fashion. The female turns on her side and gives a few strong, upward flaps of her tail, thus displacing the lighter particles, sand and small gravel. After each spell of digging, the female swims forward, circles around and returns to about the same spot to dig again. Digging occurs about once a minute. Depending largely on the size of the bottom particles, the completed redd varies from a fairly deep pit to a clean spot on large stones.

While the female digs the redd, the male courts her by circling around her, then gliding along her side and quivering. In intensive courtship, the verticle and pelvic fins are erected and the male opens his mouth. During courtship, the male develops a dark band along the side and across the top of the head, while the back becomes pale.

When the redd is completed, the female tests it with her erected anal fin, bends head and tail upward, opens her mouth and quivers. The male joins her, assuming a like position, and eggs and sperm are ejected. The fish then swim forward out of the nest, often still ejecting sex products. This act may be repeated up to five times before the female begins to cover the eggs. She does this by swimming about the redd, sweeping the gravel with her anal and caudal fins. This sweeps the eggs into the nooks and crannies of the gravel. The female then digs at the edge of the pit, covering the eggs and beginning the next redd.

Spawning apparently takes place at almost any time of the day or night, although most apparently occurs during the day. Males often mate with more than one female, taking the second mate after the first has exhausted her eggs. Occasionally a female may mate successively with two or more males (Fabricius, 1953; Fabricius and Gustafson, 1954).

Several days are usually required for a female to deposit all her eggs. Depending upon the size of the fish, a female may produce as few as a couple of hundred to as many as four or five thousand. The eggs are fairly large, 3.5 to 5.5 mm in diameter, yellowish to orange in color. Time of development seems to vary widely according to conditions and stock. Under hatchery conditions at 4.4°C, hatching may occur in 60-70 days (Bigelow, 1963), while in the northwestern part of the Hudson Bay area "eggs are still visible at break-up in the following spring, probably hatching soon after open water appears." (Sprules, 1952). The situation in Alaskan waters is not known.

The young are about 17 mm long at hatching. Subsequent growth rates depend largely on temperature and the abundance of food. In Swedish hatcheries, average lengths of 97 mm at the end of the first year, 123 mm at the end of the second, and 137-216 mm at the end of the third have been reported (Bigelow, 1963). Growth under wild conditions is much slower. In the eastern Canadian arctic, 5 year old fish averaged from 130 to 382 mm fork length; 10-year-olds from 363 to 584 mm; and 15-year-olds from 553 to 671 (Sprules, 1952; Grainger, 1953; Andrews and Lear, 1956). In Chandler Lake, in Alaska's Brooks Range, 10 year old fish averaged 424 mm FL, 14-year-olds 537 mm (Furniss, 1974). The arctic charr is thus a very slow growing fish. It is known to achieve an age of at least 24 years (Grainger, 1953).

Some populations of arctic charr, particularly in Europe, Siberia and eastern Canada, are anadromous, running to sea shortly after break-up in the spring and returning to fresh water in late summer and early fall. Other populations, especially lake-dwelling fish, remain in fresh water all their lives and do not migrate. In Alaska, it appears that all arctic charr are of the fresh water, lake-dwelling type. The species has been reported as being anadromous in most rivers from Bristol Bay to Barter Island. However, examination of numerous specimens and published data shows that these anadromous fish are the northern form of the Dolly Varden, *Salvelinus malma* (Morrow, unpublished).

The food of the arctic charr is varied, mostly according to what is available. In Chandler Lake, Alaska, insects, especially Diptera, were most important. Arctic charr feed heavily on young sockeye salmon in the Karluk and Wood River lakes systems in Alaska (DeLacy and Morton, 1943; Thompson, 1959; personal observations). Other foods reported from various parts of the world include fishes, crustaceans, molluscs, nereid worms and their own young.

IMPORTANCE TO MAN

The arctic charr is an important sport fish in the Canadian Arctic and in Scandinavia, as well as in the Wood River lakes of Alaska. Canadian eskimos rely heavily on it for food in some regions. It is fished commercially in various locations in northern Canada, Greenland, the Scandinavian countries and Siberia. The flesh is of excellent quality and commands a good price. Red-meated fish are preferred over those with pink or white flesh, and are priced accordingly. Frozen arctic charr are shipped to gourmet restaurants in most of the larger cities of the world. Canned charr is another high priced delicacy. However, the arctic charr is slow-growing and there is some doubt as to whether many populations can withstand heavy exploitation. There are a number of examples of serious depletion in only a couple of years (Andrews and Lear, 1956).

DOLLY VARDEN

Salvelinus malma (Walbaum)

DISTINCTIVE CHARACTERS

The Dolly Varden is identified by the lack of worm-like marbling on the back, the presence of pink or red spots on the sides, 11-26 gill rakers, and 13-35 (rarely up to 39) pyloric caeca.

DESCRIPTION

Body elongate, rounded. Depth about 20% of FL. Head moderate to fairly long, 15-28% of FL, longest in breeding males. Snout rounded, about equal to eye in small fish, longer in adults, especially breeding males. Eye round or nearly so, about 20% of head length. Mouth large, terminal, upper jaw reaching about to vertical through hind margin of eye in small fish, well behind it in large ones. Well developed caniniform teeth present on both jaws, head (but not shaft) of vomer, palatines and tongue. Zero-44 small teeth on base of tongue (basibranchials). Gill rakers 11-26, average numbers 17-19 in the southern form, 21-23 in the northern. Branchiostegals 10-15, usually one more on left than on right. Lateral line with 105-142 pored scales. Pyloric caeca 13-35, rarely to 39.

Fins

D. 13-16 (10-12 major rays). Adipose dorsal present. A. 11-15 (9-12 major rays). P_1. 14-16. P_2. 8-11, usually 9, a small axillary appendage present. Caudal fin emarginate.

Scales

Small, cycloid.

Color

Extremely variable according to locality, size of fish and degree of sexual maturity. Very young parr are usually brownish with 8-11 (12) dark parr marks, the sides and back showing small red spots, the fins pale to dusky. Fish in salt water or just entering fresh water may be dark above, with silvery sides sprinkled with pale or pink spots. Breeding fish become dark greenish black above and on the upper sides. Males in breeding condition turn bright orange to red on the lower sides and belly. Pectoral, pelvic and anal fins usually have white or creamy leading edges followed by a black or red line. Dorsal and caudal fins usually dusky or brownish. Largest spots on sides usually smaller than pupil of eye.

Size

The largest Dolly Varden known was 103 cm (40.5 inches) long and weighed 14.5 kg (32 lbs).

RANGE AND ABUNDANCE

Definition of the range of the Dolly Varden is difficult because it has, in the past, been confused with at least two other species, the arctic charr, Salvelinus alpinus, and the bull trout, S. confluentus (McPhail, 1961; Cavender, pers. comm.). The range in North America, as presently known, extends from the arctic coast of Alaska and probably of western Canada as well, south to northern California, eastward into Nevada, Idaho, Montana and Alberta. At least some of the eastward records will undoubtedly turn out to be S. confluentus. The Dolly Varden is widely distributed throughout Alaska, where both anadromous and apparently non-anadromous populations are to be found in clearwater streams. The presence of northern type Dolly Varden in the lower Susitna drainage and of southern type in the upper Tanana has undoubtedly been brought about by headwaters exchange between the Nenana and Susitna in the one case, the Slana and the Little Tok in the other (Morrow, unpublished).

On the western side of the Pacific, Dolly Varden are found from the Chukhotsk Peninsula south to Japan and Korea.

Wherever found, the Dolly Varden is usually abundant, although, because of its migration patterns, the abundance may be seasonal.

HABITS

The life history of the Dolly Varden is fairly complex and the account is not simplified by the fact that different populations seem to behave differently. The vast majority of Dolly Varden are anadromous, but some populations, especially in interior Alaska, apparently spend their entire lives in freshwater streams.

Spawning takes place in the fall, from late August to the latter part of November (Armstrong, 1967; Yoshihara, 1973). Spawning behavior is similar to that of other members of the genus. The male courts the female by swimming around and beside her, pressing against her and quivering. The female selects the nest site on clean gravel, the stones being from 6 to 50 mm in diameter. The redd is located in fairly strong current, usually near the center of the stream in water 0.3 m or more deep. Preferred water temperature in southeastern Alaska seems to be around 5.5°-6.5°C (42°-44°F). She digs the redd in typical salmonid fashion, turning on her side and giving several strong upward flips of her tail, thus dislodging the gravel and debris which are carried downstream. While the female is preparing the redd, the male continues to court and drives off intruding males. When the redd is finished, both fish drop into it, press against each other with arched backs and open mouths, quiver and expell the sex products. This procedure lasts about 5 seconds, and may be repeated several times before the female begins to cover the eggs. Covering is accomplished by the female who swims along the edge of the redd, sweeping small pebbles and other particles into it with her tail and anal fin. Later she may dig again in typical salmonid fashion and further cover the eggs while preparing a new nest (Needham and Vaughan, 1952; Blackett, 1968). Sexual dimorphism is apparent at this time. Females develop an extended and swollen ovipositor. Males, at least of anadromous populations, develop a pronounced kype, which begins to return to normal along in November.

The mature eggs are 4.5-6.0 mm in diameter, orange-red and demersal. Egg number per female varies with stock and location. Southern Alaskan Dolly Varden produce from 739 to 5,968 eggs. Fish in streams of the Arctic coast may surpass 6,000 eggs (Nagata, 1967; Blackett, 1968; Yoshihara, 1973). Development to hatching requires about 4 months (129-136 days) at 8.5°C (Blackett, 1968), but as long as 7 months along Alaska's north slope (Yoshihara, 1973). The newly hatched young, about 15-20 mm long, remain in the gravel until the yolk sac has been absorbed, a period of 60-70 days. On emergence they are about 25 mm long.

The young begin to feed actively as soon as they emerge from the redd. The major foods are various winged insects and the larvae of mayflies and midges, but other insects and various small crustaceans are also consumed (Karzanovskii, 1962). These newly emerged fry tend to stay on the bottom in pools or eddies, relatively inactive except when feeding. Growth rates vary tremendously from area to area and population to population. Thus, in Eva Creek, in southeastern Alaska, young fish reach only about 63 mm at 1 year, 78 mm at 2, and 100 mm at 3 (Heiser, 1966; Blackett, 1968). By contrast, young fish at nearby Hood Bay, on Admiralty Island, and on Prince of Wales Island, achieve 90 mm at 1 year, 154 mm to 182 at 2, and over 200 mm at 3 years (Reed, 1967; Armstrong, 1967). Dolly Varden in rivers of the north slope grow at intermediate rates (Roguski and Komarek, 1971; Yoshihara, 1973). The young Dolly Varden usually spend three or four years in the creek before going to sea. These young fish going to sea are typical smolts. The parr marks have disappeared and the fish are silvery.

Subsequently, greatest annual growth takes place between May and September of each year, while the fish are in salt water. Some of these fish may double their weight in this short time (Revet, 1962; Heiser, 1966). The Dolly Varden of southeastern Alaska appear to grow more slowly than those of the Arctic rivers. At six years of age, arctic fish run about 50 mm longer than those from southeastern areas, and at 10 years the difference is nearly 80 mm. Typical lengths at various ages for northern fish are 3 years, 164 mm; 5 years, 329 mm; 8 years, 470 mm; 10 years, 517 mm (Reed, 1967b; Armstrong, 1967; Rogushi and Komarek, 1971; Kogl, 1971; Yoshihara, 1973). Whether this difference reflects food conditions or a genetic difference between the northern and southern forms of Dolly Varden is not known.

Sexual maturity is achieved at 4 to 6 years in the southern form, but not until 7 to 9 in the northern (Blackett, 1968; Yoshihara, 1973).

The migration pattern of the Dolly Varden is rather complex. In southeastern Alaska, a migration of smolts and adults out of the over-wintering lakes begins in early spring and continues into July. After a stay in the sea of as little as a couple of weeks or as long as seven months, they return to spawn in the stream and over-winter in the lake. Thus, some fish are still moving out while others are already returning to freshwater. Some may enter non-lake streams to spawn, then leave and enter a lake-stream system to over-winter. Homing to the over-wintering lake is on the order of 40-50%, with the remaining over-wintering fish of unknown origin (Revet, 1962; Armstrong, 1965a).

Migrations of the northern form are not at all well known. Such data as are available indicate that the outmigration of smolts, mostly 3 or 4 year olds, occurs immediately after break-up. In arctic rivers, adults probably over-winter either in deep pools or springs in the river, or in the estuary. It is possible that at least some may spend the winter in the sea. The return migration back into the streams begins in August, with peak movement of spawners in the last week of that month, but continuing at least well into September. Non-spawners tend to enter freshwater a few weeks later than spawners. The northern Dolly Vardens apparently spawn only about every third year in these arctic rivers, whereas in southeastern Alaska spawning is probably an annual affair (Roguski and Komarek, 1971; Kogl, 1971; Yoshihara, 1973; Furniss, 1974).

The Dolly Varden is known to hybridize with the brook trout in some lakes of southeastern Alaska where the latter species has been introduced. The hybrids are said to be inferior to both parent species.

Movement in salt water is usually more or less coastwise in southeastern Alaska. However, this impression may well be due to the arrangement of islands and channels in the area. Within these confines, however, tagged Dolly Varden have been recovered as much as 115 km (72 miles) from the point of release (Armstrong, 1965a). Northern Dolly Varden of unknown origin have been taken in the Bering Sea at least as far west as 170° W (Hanavan and Tanonaka, 1959).

Dolly Varden in southeastern Alaska reach 10 to 12 years of age, although there is a rapid reduction in numbers after age 5, perhaps because of post-spawning mortality (Heiser, 1966). Northern fish, especially those along the Arctic coast, tend to live longer. The majority of spawners are 8 or 9 years old, and one of 18 years has been recorded (Yoshihara, 1973). A hatchery fish in California was reported to have reached its 20th year (Shebley, 1931).

The diet of the Dolly Varden varies with the size and age of the fish, location, time of year and local availability of food items. As already noted, the young fry feed chiefly on insects and small crustacea. Stream food of both rearing fish and adults also consists largely of various insects, spiders and annelids, as well as snails, clams, fish eggs and various small fishes. In estuaries and at sea, the food of the adults consists largely of small fishes and invertebrates, including smelts, herring, young salmon, sand lance, greenlings, sculpins, flounder larvae, cods, as well as amphipods, decapods, mysids, euphausiids, brachiopods, polychaetes, megalopids, and isopods. In the high Arctic, mysids seem to be the most important food, with fish second (Townsend, 1942; Roos, 1959; Lagler and Wright, 1962; Narver and Dahlberg, 1965; Armstrong, 1965b, 1967, 1971b; Yoshihara, 1973).

IMPORTANCE TO MAN

The Dolly Varden has long been reviled by salmon fishermen, canners and others (some of whom should have known better) as an eater of salmon spawn and a most serious predator on young salmon, especially sockeye (see, for example, Ohmer 1929a, b; Rounsefell, 1958). Despite the fact that a few bold biologists began to refute this shortly after the turn of the century (Chamberlain, 1907), it was not until the 1940's that it became apparent that the Dolly Varden did not deserve its bad reputation and that, at least in some areas, the real culprit was the closely related arctic charr (DeLacy and Morton, 1943). Dolly Varden do eat salmon eggs and young salmon on occasion. However, the eggs are "drifters", washed out of the redd or dug up by later spawners, which would not survive anyhow (Chamberlain, 1907; Reed, 1967a; Armstrong, 1967). With respect to young salmon, especially sockeye, other predators appear to be much more important than Dolly Varden. Removal of more than 20,000 predaceous fishes from Cultus Lake, B.C., led to a 1 1/3 times increase in sockeye survival (Foerster and Ricker, 1941). However, the Dolly Varden made up less than 5% of the predators, so could scarcely have accounted for much of the increase. In other places, such species as coho salmon, rainbow and cutthroat trout, squawfish and sculpins have been shown to be much more serious predators on salmons than the Dolly Varden (Chamberlain, 1907; Pritchard, 1936b; Ricker, 1941; Armstrong, 1965b; Reed, 1967a). Dolly Varden certainly will eat young salmon when they are abundant and concentrated (Bower and Fassett, 1914; Pritchard, 1936b; Ricker, 1941; Hartman, et al, 1962; Armstrong, 1965b; Thompason and Tufts, 1967; McCart, 1967), but in most places the damage has been grossly exaggerated.

For many years a bounty was paid in Alaska for Dolly Varden tails in the hope of decreasing the Dolly Varden population and thus enhancing the survival of young salmon. While this practice may have served to enhance the income of native fishermen, it did little, if anything, towards accomplishing its stated purpose. The bounty was finally eliminated in 1941.

As a sport fish, the Dolly Varden will take many artificial lures, especially shiny spoons and spinners, and also flies. They fight gamely, though not spectacularly, seldom jumping, and are not as strong as rainbow trout of comparable size. However, Dollies generally are quite a satisfactory sport fish.

For many years, Dolly Varden were taken incidental to the salmon fisheries of southeastern and western Alaska and in some years as much as 91,528 kg (over 201,000 lbs) were marketed fresh, frozen, canned or pickled (Bower, 1919). In recent years, however, landings have been miniscule, only two or three thousand kilograms (5,000 lbs) a year (Anonymous, 1975). The Dolly Varden is an important part of the subsistence fisherey in many areas of northern Alaska.

ANGAYUKAKSURAK CHARR

Salvelinus anaktuvukensis Morrow

DISTINCTIVE CHARACTERS

The angayukaksurak is distinguished from its closest relative, the Dolly Varden, by the more numerous rays in the dorsal, anal, pectoral and pelvic fins; and in having more lateral line pores and parr marks. The angayukaksurak is easily separated from the arctic charr by the fewer gill rakers and pyloric caeca.

DESCRIPTION

Body elongate, sub-cylindrical anteriorly, somewhat compressed posteriorly. Depth 18-24% of SL. Head moderately large, its length 20-29% of SL. Snout longer than eye diameter, 27.6% (24-31%) of head length. Eyes nearly round, the horizontal axis a little longer than the vertical, 19% (16-23%) of head. Nostrils double, the anterior one with a flap around its posterior margin. Mouth large, upper jaw reaching nearly to posterior margin of eye in young, well behind eye in adults. Teeth small, caniniform, in a single, irregular row on each jaw and palatine. Vomerine teeth in a V-shaped patch on head of vomer, ends of patch usually separated by a wide edentate space from anterior palatine teeth. Tongue teeth 4-13, in two widely separated rows. Gill rakers about 21 (18-23). Branchiostegals 9-12 on left, 9-11 on right, usually one more on left than on right. Lateral line straight, with 135 (127-152) pores. Pyloric caeca 28 (24-32).

Fins

D. 14-17, adipose dorsal present. A. 13-15. P_1. 13-15. P_2. 10, rarely 9, small axillary process present. Caudal only slightly indented, 19 principal rays.

Scales

Small, cycloid.

Color

Deep, velvety black on back and sides, paler below. Small, fiery red spots on back and sides, spots smallest and most numerous on back. Largest spots smaller than pupil of eye. Some or all spots may be surrounded by a blue to pale halo. Leading edges of dorsal, anal and pelvic fins cream to yellow. All rayed fins dark, without spots or marks. Adipose fin paler, with a dark posterior margin.

Size

The angayukaksurak does not reach large size. The largest known is the holotype, only 278.5 mm FL.

RANGE AND ABUNDANCE

Known only from headwaters situations in the Brooks Range, Alaska. Here it is distributed somewhat discontinuously from Howard Pass eastward to the Romanzoff Mountains, specifically: Western part of Howard Pass; Killik River; Ikiakpuk (Ekokpuk) Creek, Giant Creek, Contact Creek, Loon Lake Creek, all in the John River drainage; Tolugak Lake, Kanayut (Shainin) Lake, Willow Creek in the Anaktuvuk River drainage; Chandler River; North Fork, Koyukuk River; Hula Hula River; Aichilik River (Walters, 1955; S. Paneak, pers. comm.; personal obvervations).

HABITS

Virtually nothing is known of the biology of the angayukaksurak. It is found only in small headwater streams. In the winter, it congregates in springs, where there is a constant flow of water, and is reported to spawn in the springtime (Simon Paneak, Anaktuvuk Pass, pers. comm.). This report is borne out by the appearance of the gonads of the topotype series, which was taken in December. The angayukaksurak is extremely slow-growing. Five specimens taken in October, 1968 were 230 to 275 mm FL and were 6 to 9 years old. Dolly Varden of the same age from the same general area are about twice that size (Winslow, 1969).

IMPORTANCE TO MAN

At present, the angayukaksurak is important only as a rare species, a zoological curiosity. In the old days, however, it was important to the inland Eskimos as an emergency source of winter food (S. Paneak, pers. comm.).

PINK SALMON

Oncorhynchus gorbuscha (Walbaum)

DISTINCTIVE CHARACTERS

The pink salmon is distinguished from its relatives by the presence of large, black spots on the back and on both lobes of the caudal fin. The young have no parr marks.

DESCRIPTION

Body elongate, fusiform, slightly compressed. Depth about 22% of FL in females and non-breeding males. Breeding males develop a great hump behind the head, so that body depth is about 1/3 of FL. Head moderate, about 20% of FL, but much longer in breeding males, which develop an elongate, hooked snout. Snout about 30% of head in females, nearly 50% in breeding males. Eyes rather small, round, in advance of posterior end of maxilla. Mouth terminal, slightly oblique, breeding males with a pronounced kype. Teeth caniniform, well developed on both jaws, head and shaft of vomer, on palatines and tongue. No teeth on basibranchials. Gill rakers moderate, 24-35 on first arch. Branchiostegals 9-15 on each side. Lateral line with 147-205 pored scales. Pyloric caeca 95-224.

Fins

D. 10-15, a large adipose dorsal fin present. A. 13-19. P_1. 14-17. P_2. 9-11, axillary process present.

Scales

Cycloid, small.

Color

Pink salmon in the sea are steely blue to blue-green on the back, silver on the sides and white on the belly. Large, oval black spots present on back, adipose fin and on both lobes of caudal fin. Breeding males become dark on the back, the sides red with brownish-greenish blotches; females similarly but less distinctly colored.

Size

The pink is the smallest of the Pacific salmons. The greatest size achieved is about 750 mm (30 in) and 6.4 kg (14 lbs), but most run from 1-3 kg, with the average a bit less than 2 kg (about 4 lbs).

RANGE AND ABUNDANCE

The pink salmon is found from La Jolla, California (Miller and Lea, 1972) north to the Arctic Ocean. The range extends eastward to Kidluit Bay in the McKenzie River delta, westward across northern Siberia to the Lena River, south along the Asian coast to Korea and Kyushu, Japan. It is most abundant in the central parts of the north-south range.

Pink salmon have been introduced along the Atlantic coast from Maryland north to Newfoundland. The northern introduction apparently survived for some years, but seems to have disappeared recently (Hart, 1973). An accidental introduction into a tributary of Thunder Bay, Lake Superior, in 1956, seems to have survived. Introductions have been made into several European areas and one stock is said to have survived (Scott and Crossman, 1973).

HABITS

Adult pink salmon move into streams from the sea any time from June to late September, depending largely on location. As a rule they do not go far upstream and in many areas spawning occurs in the lower tidal areas. Even though the eggs and alevins are unable to adapt to salt water (salinity 31.8 o/oo), they can withstand exposure to it for a day or more without serious harm (Weisbart, 1968). This is, of course, much longer than the periods of high tide during which intertidal redds are exposed to sea water. However, some groups may ascend rivers such as the Kushokwim and Yukon for as much as 160 km (100 mi), while in Siberia pink salmon ascend the Amur River as much as 600 km (375 mi). Spawning takes place in mid-July in the lower Yukon, but generally in late August to October in areas to the south.

Spawning behavior is typically salmonid. The female prepares the redd by turning on her side, pressing her caudal fin against the bottom and giving several strong flaps with her tail. This dislodges silt, debris and small gravel which are carried downstream by the current. Repeated digging results in a pit somewhat longer than the female and perhaps as deep as the depth of her body, but may be as long as 915 mm (3 ft) and up to 457 mm (1.5 ft) deep. The male takes no part in digging the redd, but spends most of his time driving off intruding males. When the redd is finished, male and female drop into it, erect their fins, open their mouths, vibrate and release eggs and sperm. Pairing is usually on a 1:1 basis, but up to six males have been seen to spawn with a single female (Wickett, 1959). All pink salmon die after spawning.

The large (about 6 mm diameter) orange-red eggs fall into the interstices of the gravel and are fertilized by the milt. The eggs are covered with gravel as the female subsequently digs a new nest at the upstream edge of the previous one. Each female may produce as few as 800 or as many as 2,000 eggs. In general, larger fish have more eggs, but fish from small runs are said to be more fecund than those of the same size from large populations (Nikolskii, 1952). Development requires 61 to about 130 days, depending largely on temperature. The young hatch out in late December through February and remain in the gravel until spring. Mortality within the redd occurs chiefly before the eyed stage, and survival from spawning to emergence from the gravel shows a strong inverse correlation with the number of adult spawners (Hanavan, 1954; Hunter, 1959). The alevins have a large yolk sac. The yolk sustains them while they remain buried in the gravel through the winter. Usually in April or early May the yolk is fully absorbed and the young fry, now 30-45 mm long, wriggle up through the gravel. Almost immediately afterward, they begin to move downstream to the sea. Most of the fry swim downstream at night, staying at or close to the surface of the water. Migrations of up to 16 km (10 miles) may be accomplished in a single night. In short streams or from spawning areas near the river mouth, the migration to the sea may be accomplished in a single night. If not, the fry hide in the gravel during the day and resume their downstream movement the next night (Neave, 1955). Sometimes the fry become daylight-adapted, school and no longer hide during the day. This is particularly apparent in fry which have been migrating for several days (Hoar, 1956). In southeastern Alaska, this outmigration begins in March, peaks in mid-May, and ends by mid-June. The young fish are about 30 mm long at this time. They stay in the estuary for about a month, growing to a length of about 40 mm, then follow the salinity gradient within the estuary (Thorsteinson, 1962; McInerney, 1964), and move off, generally staying fairly close to shore. Larger fry tend to migrate first, so schools farthest from the river mouth tend to be made up of larger individuals than schools closer to the river. Within a school, the larger fry are usually found on the offshore side of the school. When the fry have reached a length of 60-80 mm (2.4-3.2 in), they move offshore (Le Brasseur and Parker, 1964).

The life-cycle normally takes two years, though rare three-year fish have been found (Turner and Bilton, 1968). It is probable that these fish are sterile. Mortality during early sea life is fairly high, 2-4% per day for the first 40 days. In the subsequent 410 days, this drops off, resulting in an average sea mortality of 0.4-0.8% per day. These rates are highly variable, however, with sea survival computed at about 2-22% and probably averaging about 5% (Neave, 1953; Parker, 1966).

During their oceanic life, pink salmon from the southern part of the range tend to remain in a broad band of ocean more or less parallel to the coast. Alaskan pinks, on the other hand, may be found in most of the northeast Pacific, from Bering Strait southwestward to about Kiska Island in the Aleutians, thence more or less southeasterly to the California coast (Hart, 1973).

In the sea, the young feed chiefly on copepods and Larvacea (Oikopleura). As the fish grow, there is a shift towards amphipods, euphausiids, and fishes. Other items include ostracods, decapod larvae, cirripeds and tunicates (Levanidov and Levanidova, 1957; Le Brasseur, 1966b; Manzer, 1969).

After spending about 18 months in the sea, the adults return to spawn in their natal stream. The pink salmon is less certain in its homing than the other Pacific salmons, and there is a certain degree of wandering. Pink salmon have been found spawning in streams as much as 640 km (400 miles) from the natal stream.

In general, the upstream run seems to be triggered by high water. A significant correlation has been found between the number of fish entering a stream each day, the daily water level in the stream and the daily rainfall in the area. But if water levels are too high and the current too strong, the fish stay in eddies and wait for a drop to suitable current strength (Pritchard, 1936a).

The males are usually larger than the females and tend to precede the females in entering fresh water. Early running females tend to be larger than late arrivals (Skud, 1955). Due to the two-year life cycle, the runs in odd-numbered and even-numbered years are genetically separated, often with observable, though minor, morphological differences. Thus, in British Columbia, the adults of the odd-year cycle are consistently larger than those of the even-year runs (Godfrey, 1959).

The pink salmon occasionally hybridizes in nature with the chum. Artificially produced hybrids show characteristics of both parent species rather than being intermediate between the two. The hybrids exhibit the size of the chum, but have a short (two or three year) life cycle. Most of the hybrids returned as two-year-olds, a group in which males outnumbered females by as much as 4.2:1. In those returning as three-year-olds, the sex ratio was reversed.

The pink-chum hybrid is fertile, but data are not available to indicate whether or not self-sustaining populations could be established (Simon and Noble, 1968).

IMPORTANCE TO MAN

Until World War I, the pink salmon was of negligible importance in North America, either for subsistence or commercial use. Demands for food during the war led to rapid growth of the fishery. The pink salmon is the most numerous of the Pacific salmons and the annual pack in North America runs into several millions to tens of millions of kilograms annually. The U. S. catch in recent years has ranged from a low of 23,509,545 kg (51,721,000 lbs) in 1967 to a high of 53,528,181 kg (117,762,000 lbs) in 1970. Alaska's share of these catches has run between 88.1% and 99.96%, but the per pound price paid to Alaskan fishermen is usually somewhat less than the U. S. average. The pink salmon is considered only slightly better than the chum and is priced accordingly. Thus, while pinks have, since 1967, made up from 23.9-41.9% of the total pack, they have accounted for only 12.9-26.8% of the total value. Virtually all the catch is canned.

About twenty years ago it was discovered that pink salmon in the sea will take a trolled lure. Since that time a small sport fishery for them has developed (Scott and Crossman, 1973).

CHINOOK SALMON

Oncorhynchus tshawytscha (Walbaum)

DISTINCTIVE CHARACTERS

The small black spots on the back and on both upper and lower lobes of the caudal fin, and the black gums of the lower jaw serve to distinguish the chinook salmon.

DESCRIPTION

Body elongate, fusiform, laterally compressed in adults. Depth about 25% of fork length. Head moderate, its length about 20% of fork length, longer in breeding males. Snout blunt, less than 33% of head in females and immature males, but elongate and turned down in breeding males. Eye small, nearly round. Mouth terminal, slightly oblique, upper jaw reaching well behind eye. In breeding males, both jaws elongate and curve anteriorly, forming a kype. Teeth canine-like, present in both jaws, on head and shaft of vomer, on tongue and on palatines; anterior jaw teeth notably enlarged in breeding males. Gill rakers 16-30, wide spaced and rough. Branchiostegals 13-19. Lateral line with 130-165 pored scales. Pyloric caeca numerous, 90-240, usually about 140-180.

Fins

D. 10-14, adipose dorsal fin present. A. 13-19. P_1. 14-17. P_2. 10-11, axillary process present. Caudal emarginate.

Scales

Cycloid, small.

Color

Fish in the sea are dark greenish to blue-black on top of head and back, the lower sides and belly silvery to white. Numerous small, dark spots present along back and upper sides and on both lobes of caudal fin. Gum line of lower jaw black. In fresh water, with the approach of breeding condition, the fish change to olive brown, red or purplish, the color change more marked in males than in females.

Size

This is the largest of the Pacific salmons. The largest officially recorded came from Petersburg, Alaska, and weighed 57.3 kg (126 lbs), but another has been reported at 61.4 kg (135 lbs). In most areas, however, 90-104 cm (35-41 in) and 12-18 kg (26-40 lbs) would be the maximum size range. The average Cook Inlet chinook is about 750 mm long for males, 855 mm for females, and weighs 7-9 kg (Yancey and Thorsteinson, 1963).

RANGE AND ABUNDANCE

Spawning populations of chinook salmon are to be found all the way from the Ventura River in southern California north to Point Hope, Alaska. It is rare in streams south of San Francisco Bay, but has been taken in the sea, as strays, as far south as La Jolla (Hubbs, 1946). At the northern end of the range, strays have been reported from the Coppermine River emptying into the Arctic Ocean at about 115°W. The marine adults range all across the northern Pacific Ocean and through the Bering Sea. Along the Asian coast, chinooks are known from the Anadyr River of northern Siberia south to Hokkaido in northern Japan (Schmidt, 1950). Asian populations are much smaller than those of North America (Nikolskii, 1961). Within its North American range, the chinook is most abundant from the Sacramento River to the Yukon River. However, because of its anadromous habits, this abundance is highly seasonal.

Chinook have been introduced into many areas outside their normal range, including the Great Lakes, eastern United States and Canada, Central and South America, Hawaii, northern Europe, Australia, Tasmania and New Zealand. Some of the Great Lakes transplants seemed to thrive at first, but sooner or later died out. Of all the introductions attempted, only those to New Zealand have resulted in self-sustaining populations (Davidson and Hutchinson, 1938).

HABITS

Adult chinook salmon return from the sea and move into freshwater streams to breed. The time of arrival at the main river mouth varies with geographic location and stock. In many streams in the southern part of the range (e.g., Columbia River, Fraser River) there are fairly well-defined early and late (spring and fall) runs, while farther north (e.g., Yukon River) there is only a single run, although it may be spread over a period of several months. The chinooks enter the Yukon in June and have reached the Canadian border by mid-to-late July. In Cook Inlet, chinooks may appear in the Susitna River as early as May, but most appear in late June and July (Yancey and Thorsteinson, 1963). As a rule, the fish entering fresh water earliest are those which will travel farthest upstream. Spawning takes place in July to early September in the Yukon drainage, but the season may continue into November or even December in the southern part of the range (Briggs, 1953; Scott and Crossman, 1973). Chinook utilize remarkably few streams for major spawning areas. In British Columbia, 50% of the spawning occurs in only 14 streams. In the United States, some 380 streams from California to Alaska are utilized, although this figure does not include the numerous tributaries of the Yukon and Kuskokwim rivers (Aro and Shepard, 1967; Atkinson et al, 1967).

On reaching the spawning area in the natal stream, the female selects the spot for her nest. She turns on her side and gives several powerful thrusts, up and down, with her tail. The gravel, sand and debris thus loosened from the bottom are carried downstream by the current. Repeated digging at the same spot at intervals of five to ten minutes produces a pit, the redd, which may be more than 3.5 m long and 35 cm deep, although usually it is only about 1.3 m long. The female drives off other females during the period of nest digging, but pays little, if any, attention to males. She is usually accompanied by a dominant and one or more subordinate males. The dominant male, in particular, drives off intruding males, although subordinates may undertake this activity if a new intruder arrives while the dominant male is engaged. During nest-digging, the male may court the female by coming to rest beside her and quivering; by swimming about over her, touching her dorsal fin with his body and fins; and occasionally by nudging her side gently with his snout (Schultz, 1938).

When the pit is finished, the female drops into it, pushing her vent well down toward the bottom of the pit. She is immediately joined by the dominant male, sometimes by one or more subordinate males as well. The fish open their mouths, quiver and eject the eggs and sperm. The female at once swims to the upstream edge of the nest and digs. The eggs are quickly covered with the gravel displaced from the new pit, and the whole process is repeated until the female has voided all her eggs, a process which may take several days. The male then leaves and may mate with another female. The female continues to dig for a week or more, the digging becoming haphazard and aimless as she weakens. She finally dies, as do the males.

Fecundity of females varies with the population and the size of the individual. Average number of eggs per female varies from about 2,600 to 8,500, with northern fish generally producing more eggs than southern. In Alaska, egg numbers range from 4,242 to 13,619 (Rounsefell, 1957; Yancey and Thorsteinson, 1963).

The eggs are large, 6-7 mm in diameter, orange-red in color and demersal. They hatch in 7-9 weeks in the southern part of the range, probably up to 12 weeks, or perhaps a little longer, in interior Alaska. The alevins remain in the gravel until the yolk sac has been absorbed, usually about 2-3 weeks after hatching, then work their way up through the gravel to become free-swimming, feeding fry.

The fry may go to sea after only three months in fresh water (fall-run fish in the Puget Sound area) (Mason, 1965), or may stay for as long as two (rarely three years) (Yukon River). Most chinooks stay one year in the stream before migrating. During this period, they feed chiefly on terrestrial insects, chironomids, corixids, caddis flies, mites, spiders, aphids, small crustaceans - virtually anything available to them, although they do not appear to eat fishes during their freshwater life. Growth is moderate during the freshwater life. By the end of the first year, the young chinooks are 100-150 mm long, and by the end of the second year they may exceed 200 mm.

As the time for migration to the sea approaches, the young fish "smolt-up", lose their parr marks and become silvery. They tend to seek deeper water and avoid light, and the major downstream movements occur at night (Meehan and Siniff, 1962). In the sea, the young fish remain for a time near shore, where they feed mostly on herring, sand lance, terrestrial insects, crustaceans and molluscs (Foskett, 1951). In some areas, there are seasonal changes in the diet, with euphausiids important in early spring with a shift to fishes in the summer (Prakash, 1962).

Some of the chinooks may remain close inshore throughout their life (Milne and Ball, 1958), but others undertake extensive migrations. Fish from California to British Columbia reach the outer waters of southeastern Alaska. Others from the same populations and from Alaskan streams go even farther, entering the Gulf of Alaska gyre and moving extensively across the north Pacific. In the spring of the year, they seem to be scattered across the north Pacific and in the Bering Sea, while during the summer their numbers increase in the Aleutian - western Gulf of Alaska region (Manzer et al, 1965). Many of the inshore fish in southeast Alaskan waters appear to be of local origin (Parker and Kirkness, 1951; Mason, 1965; Royce et al, 1968). During ocean life, growth is rapid, often averaging 0.5 kg per month. The chinooks feed largely on herring and sand lance, as well as on pilchards, walleye pollock, Pacific cod, tomcod, smelts, sand fish, rockfishes, sticklebacks, shiner perch, wolffish, anchovies, squid, euphausiids, amphipods and crab larvae (Pritchard and Tester, 1939, 1940, 1942). Sexual maturity is reached at ages of 2-7 years. Fall run fish from the Columbia River are mostly 3 and 4 year olds, but the spring run is dominated by 5 year olds. In the Yukon River, 6 year olds predominate.

The return from the sea begins in the winter, so that the first fish are near the river mouths by spring. Just how this oceanic movement is accomplished is not understood, but it may well be on the basis of inherited responses to electro-magnetic cues (Royce et al, 1968). The final year in the ocean is very important for the chinook to attain full growth, so much so that maximum harvest can be achieved only by harvesting mature fish (Parker, 1960).

Once in fresh water, the home stream is picked out through olfactory stimuli (Hasler, 1966). Despite the amazingly acute sense of smell, chinooks apparently do not respond to a wide variety of pollutants and are not deterred by them. On the other hand, minute amounts of extracts of mammalian skin (human hands, bear paws, deer feet, dog paws and sea lion meat) produce an immediate alarm reaction and a temporary halt to upstream migration (Brett and MacKinnon, 1952, 1954).

IMPORTANCE TO MAN

The chinook is a most important part of the native subsistence fisheries of Alaska and British Columbia, and in former times held a similar position in Washington, Oregon and northern California.

Commercially, most of the chinook catch is taken by trolling and is sold fresh or frozen. Some are taken by purse seines and gill nets, also, and most of these go to canneries. In terms of poundage, the chinook, along with the coho, is a relatively small part of the Alaska salmon catch. In recent years, Alaska has produced an average of about 5,319,432 kg (11,702,750 lb) per year, representing between 3.3 and 5.5% of the total Alaskan salmon catch. However, chinook is the highest priced of the salmons so the value of the catch is on the order of 10% of the total.

Chinooks are usually red-meated, but some are white-meated. Flesh color is probably genetically controlled. About 70% of the chinook of southeastern Alaska are of the red-meated form, the remaining 30% white. (Finger and Armstrong, 1965). The red chinooks command a higher price.

As a sport fish, the chinook is highly regarded wherever it is found. Its large size, fighting ability and eating qualities all make it a much-sought-after species. In the Strait of Georgia region of northern Washington and southern British Columbia, as many as 93,000 adult chinooks have been taken by anglers in a single year (Scott and Crossman, 1973). In southeastern Alaska, the Juneau and Ketchikan areas' sport catches account for 2,000 to 2,500 fish a year. Herring is the most popular bait in this region, with strip cut most successful followed by plug cut and whole herring. Spinning from drifting or anchored boats is the most successful method (Finger and Armstrong, 1965). Various artificial lures are also quite popular.

The viscera of chinook salmon, normally discarded, has a quite high vitamin A content and has been used successfully as food for hatchery fish. In this respect, it is said to be superior to beef liver (Butler and Miyauchi, 1947; Burrows and Karrick, 1947).

CHUM SALMON

Oncorhynchus keta (Walbaum)

DISTINCTIVE CHARACTERS

Chum salmon are distinguished by the lack of distinct black spots on back and tail and the presence of 18-28 short, stout, smooth gill rakers on the first arch.

DESCRIPTION

Body elongate, fusiform, slightly compressed. Depth about 25% of fork length, usually slightly deeper in mature males than in females. Head about 22% of fork length, but much longer in breeding males due to elongation of snout and lower jaw. Snout usually blunt, moderately long, about 35% of head length in females, but much longer in breeding males. Eye round, rather small. Mouth large, terminal. Jaws of breeding males develop noticeable hook or kype. Teeth caniniform, well developed on both jaws, head and shaft of vomer, palatines and tongue. Gill rakers short, stout, smooth, rather widely spaced, 18-28 on first arch. Branchiostegals 12-16 on each side. Lateral line with 124-153 pored scales. Pyloric caeca numerous, 163-249.

Fins

D. 10-14. Adipose dorsal present. A. 13-17. P_1. 14-16. P_2. 10-11, an axillary process present. Caudal truncate to slightly emarginate.

Scales

Small, cycloid.

Color

Large fish in the sea are dark metallic blue dorsally, becoming silvery on sides and belly. Fine dark speckling may be present, but no definite, large, black spots. At spawning, the fish become dirty red on the sides and dusky below, with greenish bars or mottlings on the sides. Females are less brightly colored than males.

Size

Known to reach 102 cm and 15 kg (40 in and 33 lb), but average size of mature fish in most places is about 60-70 cm and 4.5-6 kg.

RANGE AND ABUNDANCE

The chum salmon ranges from the Sacramento River in California (and as a stray as far south as Del Mar), north to the Arctic, east at least as far as the McKenzie and Anderson rivers, west along the arctic coast of Siberia to the Lena River, and south on the Asian coast to Korea and Japan. In North America, it is most abundant from the Columbia River to Kotzebue Sound. The Noatak and Kobuk rivers support runs estimated at about 1,000,000 fish each (Smith et al, 1966), but north of this area the runs are too small to be of more than incidental value.

HABITS

The chum salmon is typically a fall spawner, with the greatest spawning activity occurring in September and October in most localaties. However, the first spawning run in the Yukon appears in the lower river in June or even earlier, often before the ice goes out. A ripe male was found near Fairbanks in February, and spawning has been recorded as late (or early) as April on Vancouver Island (Wickett, 1964). In interior Alaska, the first spawners appear in the Chena River, near Fairbanks, in late July and the run is at its height about a month later. In the upper Yukon River, the major portion of the run passes Eagle in late August and early September. The Yukon River run of chums reaches to the headwaters in Teslin Lake, some 3,200 km from the mouth. In most rivers, however, chums do not travel far, seldom going more than 160 km or so upstream.

Spawning usually occurs over gravel 2-3 cm in diameter, but they have also been seen to use coarser stones, even bedrock covered with small boulders. In the upper Yukon drainage, and also in the Amur River in Siberia, at least some of the fish select spawning sites in springs or ground water seepages, presumably a protection against freezing of the redds (Birman, 1953; Kogl, 1965). In preparing the nest, the female faces upstream, turns on her side and gives several powerful flaps of her tail, thus displacing the smaller particles of the bottom which are carried away downstream by the current. Continued digging at the same spot produces an elongate pit somewhat longer than the fish and up to about 40 cm deep. The female drifts into the pit, which apparently stimulates the attending males. She is joined by the dominant male, both fish open their mouths, quiver and extrude the sex products into the nest. The female may then proceed to dig a new pit at the upstream end of the first one, covering the newly laid eggs as she does so. The process is repeated until all her eggs are shed. The males take no part in nest digging, but are aggressive towards each other. One male usually dominates the rest, driving them away from the nest site. However, a female may spawn with several males, and a male may mate with more than one female. After spawning is completed, the female remains near the nest and may continue digging, although in a haphazard, unorganized way. Fish of both sexes die a few days after spawning.

In the Amur River of Siberia, "summer" and "fall" runs are recognized. The "fall" fish are larger (average length 72-75 cm vs 58-61 cm) and more fecund (average 3,366 eggs per female vs 2,468) than the summer fish (Nikolskii, 1961). The chum of the Yukon and Kuskokwim Rivers, and possibly of other northern Alaskan streams, appear to correspond to the "fall" chum, while the fish utilizing streams of southeast Alaska and farther south resemble the Asian "summer" chum (Lovetskaya, 1948).

The eggs are large, up to 7 mm in diameter before fertilization (McPhail and Lindsey, 1970) and swell even further, to 8-9.5 mm after being fertilized (Mahon and Hoar, 1956). Major mortality of eggs seems to occur between fertilization and the eyed stage (Hunter, 1959). Hatching occurs from Demember to February in the more southerly parts of the range, depending largely on temperature. Time of hatching in interior and northern Alaska is not known, as it must take place while the streams are still ice-covered. However, eggs fertilized on 30 September and placed in artificial redds in the Chena River, near Fairbanks, hatched between 17 November and 31 December (Kogl, 1965). The alevins remain in the gravel until the yolk sac is absorbed, 60 to 90 days after hatching (Nikolskii, 1961). They then make their way up through the gravel and begin the migration to the sea. The young chums can stand temperatures up to about 23.8°C, but, with pinks, are the least resistant of the Pacific salmons to prolonged exposure to high temperatures (Brett, 1952). Young chum with only a short distance to travel probably do not feed until they reach the ocean. However, those which must spend several days to weeks on their journey feed actively on chironomid larvae, daphnids and bosminids and may attain significant growth before reaching the sea (Sparrow, 1968).

Most of this seaward movement is accomplished at night, the little fish hiding in the stream bottom during the day (Neave, 1955; Hoar, 1956). However, when the migrations are long, they may travel in daylight as well. The young chum may form schools while still in fresh water and always do so upon reaching the estuaries.

In the sea, the young chum, now up to 70 mm long, remain close to shore for several months before dispersing into the open ocean. Alaskan chum salmon occupy the Chukchi and Bering seas, westward along the Aleutian chain to about 178°E, south in the Gulf of Alaska to about 43°N, and eastward to the North American coast. Chums from the southern part of the North American range tend to stay in the Gulf of Alaska and regions along the coast to the south, while Asian chums may spread out through virtually the entire North Pacific Ocean. The fish are found from close to the surface down to at least 61 m. There is some indication of vertical diurnal movement, tending toward the surface at night and deeper during the day (Manzer, 1964). This is probably a response to movements of food organisms.

Growth is fairly rapid in the sea and the chums attain weights of 3.6-5.5 kg (8-12 lb) in three or four years. A large portion of this growth is accomplished during the final year in the sea, so much so that it has been estimated that high seas fishing for chum results in a net loss of total yield of more than 50% (Ricker, 1964). After three or four years in the sea, the adult chums return to spawn in the natal stream. The average time spent in the sea varies to some extent with geographical location. In general, fish from the southern part of the range return in their third or fourth year of life, while those from the Yukon (and probably other far northern rivers as well) are mostly in their fourth and fifth years (Gilbert, 1924; Chatwin, 1953). Fish which have only a short freshwater journey ahead of them may begin to show pale flesh, less oil, sexual dimorphism and spawning colors even before they enter the river. By contrast, fish facing a long freshwater trip are still silvery, the flesh red and oily, and the males have not yet developed a kype. The closer to the spawning grounds the fish are, the more pronounced are the secondary sex characters, spawning colors and loss of fats.

Upon reaching the sea, the young chum salmon feed largely on small crustaceans of many varieties, terrestrial insects and young herring (Foskett, 1951). In an experimental situation, copepods between 1.6 and 4.5 mm long were the preferred food, to the almost total exclusion of other items (Le Brasseur, 1966b). Farther at sea, the diet consists largely of copepods and tunicates (Larvaceae) (Manzer, 1969) as well as euphausiids, pteropods, squids and a variety of fishes. Upon reaching fresh water on the spawning run, the adults cease feeding. The digestive tract may undergo considerable shrinkage and degeneration at this time.

IMPORTANCE TO MAN

Although generally regarded as one of the less desirable species of salmon, the chum has always been an important source of food for native peoples, as well as for their dogs. Large numbers are still taken with gill nets and fish wheels and are smoked and/or dried for winter subsistence. The commercial fishery for chum began about 1893 on the Columbia River when scarcity of other species made the chum profitable (Craig and Hacker, 1940). However, the yellowish color and low fat content of the flesh make for a product less desirable than sockeye. The price for chums is scarcely higher than that for pinks. Still, the species is abundant and Alaskan landings in recent years have ranged between 10,300 and 25,416 metric tons (22.6 to 55.9 million lb) with values to the fishermen on the order of 10 to 13 cents a pound (Anonymous, 1971, 1972, 1973, 1974). Fluctuations in landings are in response to several factors, including abundance, price, and abundance of higher priced species. The chum salmon is not considered a sport fish. Nevertheless, chums will often take small spinners and the angler equipped for Dolly Varden or grayling who hangs a chum will find he has tangled with a worthy opponent.

COHO SALMON

Oncorhynchus kisutch (Walbaum)

DISTINCTIVE CHARACTERS

The coho is characterized by the presence of small, black spots on the back and on the upper lobe only of the caudal fin, and by the lack of dark pigment along the gum line of the lower jaw.

DESCRIPTION

Body elongate, streamlined, somewhat compressed. Depth 22-25% of FL, deepest in adult males. Head about equal to body depth, longer in breeding males. Snout bluntly pointed, about 33% of head in adult females, about 40% in breeding males. Eye small, round. Mouth terminal, gape reaches well behind eye; upper and lower jaws of breeding males hooked (kype). Teeth sharp, well-developed, present on both jaws, head and shaft of vomer, palatines and tongue, but not on basibranchials. Gill rakers 18-25 on first arch, rough, widely spaced. Branchiostegals 11-15. Pyloric caeca 45-114. Lateral line nearly straight, 112-148 pored scales.

Fins

D. 9-13, a slender adipose dorsal present. A. 12-17, first ray longest in young, resulting in a curved outer margin. P_1. 13-16. P_2. 9-11, axillary process present.

Scales

Cycloid, small.

Color

Fish in or fresh from the sea are dark metallic blue or greenish on the back and upper sides, brilliant silvery on mid- and lower sides, white below. Small, black spots present on back and upper sides and on upper lobe of caudal fin. Fish in breeding condition turn dark to bright green on head and back, bright red on the sides, the belly often dark. Females are less brightly colored than males.

Size

The size record was long held by a fish of 14.1 kg (31 lb) caught in 1947 in Cowichan Bay, B. C. However, a fish of 15 kg (33 lb) was taken recently in the Manistee River, Michigan (Scott and Crossman, 1973). Usual weights of adults are between 2.7 and 5.4 kg (6-12 lb). Such fish are usually between 630 and 900 mm (2-3 ft) long.

RANGE AND ABUNDANCE

The natural range of the coho is from Monterey Bay, California (and apparently as strays in the sea as far south as Chamalu Bay, Baja California) north to Point Hope, Alaska, westward across the Bering Sea to the Anadyr River in Siberia and south along the Asian coast to Japan. In addition to the Great Lakes introductions mentioned above, cohoes have also been planted in east coast waters from Maine to Maryland. A few populations apparently have survived in New Hampshire. California, Oregon, Washington, Alaska and Alberta have planted cohoes in lakes to provide sport fishing. These plants are strictly "put and take", for the planted fish do not spawn and the stocks must be renewed periodically. Despite the fact that the returns to anglers represent but a small percentage of the number of young fish planted, the cohoes provide a significant portion of the sport catch in these waters.

Cohoes are nowhere as numerous as are chums, pinks and sockeyes. Nevertheless, in most areas the coho probably should be considered as at least moderately abundant. Abundance is, of course, seasonal, depending on the arrival of the spawning run. At other times of the year, adult anadromous coho are scarce to absent.

HABITS

Coho salmon may enter fresh water on their spawning run any time from mid-summer to winter. As a rule the winter (December-January) entries occur in the southern parts of the range, with appearance in fresh water becoming progressively earlier to the north (Briggs, 1953; Shapovalov and Taft, 1954; McHenry, 1973). The preferred streams are usually short, coastal streams, but coho salmon are known to spawn in Yukon River tributaries several hundred kilometers from the sea. Initial entrance of the fish into fresh water seems to be triggered by a rise in river level, and possibly also by a rise in water temperature (Briggs, 1953; McHenry, 1973).

On arrival at the spawning area, the female selects a suitable spot and begins to dig the redd. She turns on her side, facing upstream, and gives several powerful flips of her tail. The currents and suction so generated raise debris, silt, sand and pebbles off the bottom to be carried downstream by the current. Repeated digging in the same spot at intervals of 2-5 minutes produces a pit somewhat longer than the fish and usually 200-250 mm deep. The female is aggressive towards other females, driving them away vigorously.

The attendant male takes no part in nest digging, but usually stays slightly downstream and to one side of the female. He courts her by occasionally swimming close to her side, sometimes coming to rest beside her and quivering; by swimming over her and touching her dorsal fin with his body and fins; and by gently nudging her side with his snout (Schultz, 1938). The male drives off other males from the nest site.

When the pit is finished to the satisfaction of the female, she drops into its deepest part. The male joins her at once. The two fish, side by side in the pit, open their mouths, quiver, and expell the eggs and sperm. The eggs drop to the bottom of the pit, lodging in crevices between the stones, and are fertilized by the cloud of milt. The female immediately moves to the upstream edge of the nest and starts digging a new pit. The gravel so removed is carried downstream and covers the eggs just deposited.

Nest digging and spawning continue at intervals for several days to a week, until the female has deposited all her eggs. The male then leaves and may seek another female. The spent female usually continues to dig, but weakly and irregularly, until she dies.

The number of eggs a female deposits varies with the size of the fish, the stock and sometimes the year. Numbers have been reported from 1,440 to 5,700; the average is probably between 2,500 and 3,000.

The eggs are fairly large, 4.5-6.0 mm in diameter, orange-red in color. Development time varies with temperature, but usually takes 6-7 weeks. Development periods up to 115 days have been reported from Asia (Nikolskii, 1961). The young remain in the gravel until the yolk sac has been absorbed (2-3 weeks or more), then emerge as free swimming fry and begin feeding.

The coho fry feed mainly on terrestrial insects, especially Diptera and Hymenoptera. Hemiptera (aphids) and Thysanoptera (thrips) may also be important. The diet may also include mites, beetles, collembola, spiders and a little zooplankton. Feeding at this period involves shore-oriented cruising by individuals and schools, at least when the fish are in a lake (Mason, 1974a). As the young fish grow, they take larger food items and often become serious predators on young sockeye salmon. In Chignik Lake, Alaska, young coho have been found to eat seven times as many sockeyes as do Dolly Varden, and in other localities may be equally serious predators (Pritchard, 1936b; Ricker, 1941; Roos, 1960; Reed, 1967a).

The young coho normally spend a year in fresh water before going to sea, although some may go to sea at the end of the first summer and others may stay two or even three years in fresh water. Fish which stay more than two years in fresh water may become sexually mature without ever going to sea. However, these "residuals" never spawn, hence all residuals are the offspring of anadromous parents. Early migration may be the result of over-crowding (Mason, 1974b). Summer carrying capacity of a stream can be greatly increased by supplemental feeding, but this benefit is lost if winter capacity cannot be increased as well (Mason, 1974c).

During their life in freshwater streams, the young coho stay almost entirely in pools, avoiding riffle areas. They soon become strongly territorial, defending their space against other coho and against other salmonids (Hartman, 1965).

After a year in fresh water, the young begin to turn silvery ("smolt up"), avoid light and seek deeper water. They move downstream, usually at night, and reach the sea in the spring to early summer.

When the young fish reach the sea, they tend to stay fairly close to shore at first, feeding chiefly on planktonic crustacea of various sorts. As they grow larger, the fish move farther and farther from the home river and feed on larger organisms. Most coho in the sea feed chiefly on herring, with sand lance second in importance. Fishes make up 70 to 80% of the food, the remainder being invertebrates (Pritchard and Tester, 1943; Prakash, 1962). Some populations, however, remain on the crustacean diet. Such fish generally do not get as big as those that change to a fish diet (Prakash and Milne, 1958).

The oceanic movements of coho in the southern part of the range seem to be chiefly coastwise, and some fish apparently never venture far from land (Milne and Ball, 1958; Allen, 1965). By contrast, northern fish, particularly those from Alaskan streams, spread out all across the north Pacific and into the Bering Sea. It has been shown that these fish travel "downstream" in the Alaskan gyre and other major current systems, making one complete circuit per year (Manzer et al, 1965; Royce et al, 1968).

Having spent two or three years in the ocean and reached full adulthood, the coho now return to their natal stream to spawn. As a rule, 85% or more of the fish return to the proper stream. The mechanism by which they make the return journey through the open ocean is not known, but it has been suggested that inherited responses to electro-magnetic cues are involved (Royce et al, 1968). Once in the river, the fish home, apparently on the basis of olfactory cues, to the tributary from which they migrated. The place of return apparently is impressed on the fish at the time of smoltation, so that fish transplanted as yearlings will return to the transplant location rather than to the place where they were reared (Donaldson and Allen, 1958).

IMPORTANCE TO MAN

Although the coho does not rival the sockeye, pink or chum in terms of numbers, it is nevertheless an imporatnt part of the fisheries of the Pacific coast of North America. Alaskan landings alone in recent years have averaged about 4.8 million kg per year, with an annual value to the fishermen of about $2,700,000. The fish are taken by purse seine, gill net or trolling and are canned, mild-cured, smoked, or sold fresh or frozen. Frozen coho is a luxury item on the east coast.

In addition to its commercial value, the coho is highly regarded as a sport fish. It is taken in the sea by anglers using trolling lures of various sorts. It is also taken in fresh water on large flies, spoons, spinners and various sorts of bait.

The coho was introduced into Michigan waters of the Great Lakes in the spring of 1966. The fall of the same year, Michigan commercial fishermen started catching jacks of up to 1 kg or heavier, and an angler caught a coho of 3.2 kg. The fish spread rapidly and successfully, aided by further introductions in other lakes. In the first nine months of 1970, U. S. anglers in the Great Lakes took 320,000 kg of coho salmon. The coho of the Great Lakes grow rapidly, utilizing the enormous populations of smelt and alewife for food, and by the time they are three year old adults they average about 2.5 kg in weight (Scott and Crossman, 1973).

SOCKEYE SALMON AND KOKANEE

Oncorhynchus nerka (Walbaum)

DISTINCTIVE CHARACTERS

The sockeye is distinguished by having 30-40 long, fine, serrated, closely spaced gill rakers on the first arch, and by lacking definite spots on back and tail.

DESCRIPTION

Body elongate, fusiform, somewhat compressed laterally. Depth of body about 20% of FL, somewhat deeper (about 25% of FL) in spawning males. Head about 22% of FL, longer in breeding males due to elongation of the jaws and development of the kype. Snout rather long, about 40% of head in females and immature males, considerably longer in breeding males. Eye round, small, about 10% (8-16%) of head length. Mouth large, terminal, reaching well behind eye. Teeth canine-like, well developed, present on both jaws, palatines, head and shaft of vomer, and on tongue. Gill rakers long, slender, serrated and close set, 30-40 on first arch. Branchiostegals 11-16. Lateral line straight, with 120-150 pored scales. Pyloric caeca 45-115.

Fins

D. 11-16, a dorsal adipose fin present. A. 13-18. P_1. 11-21. P_2. 9-11, axillary process present. Caudal fin emarginate.

Scales

Small, cycloid, the margins often resorbed in spawning fish.

Color

Pre-spawning fish are dark steel-blue to greenish blue on the top of head and back, the sides silvery, belly white to silvery. There are no definite spots on the back, although some fish may have dark speckling and there may be some irregular marks on the dorsal fin. At spawning, the head of the males becomes a bright green to olive green, with black on the snout and upper jaw, lower jaw whitish, and the whole body turns brilliant red. The dorsal adipose and anal fins turn red, the paired fins and tail generally grayish to green or dark. Various populations may show less brilliant colors, and a few turn dull green to yellowish, with little if any red. Females are generally less brilliantly colored than males.

Size

The sockeye is known to reach at least 840 mm and 7 kg (33 in and 15.5 lb), but the average fish in most areas will be in the neighborhood of 650 mm and 3-5 kg (25 in and 6-11 lb). The kokanee is much smaller, averaging about 350 mm and 0.5 kg (14 in and 1 lb) or less.

RANGE AND ABUNDANCE

The sockeye salmon ranges from the Klamath River in California and Oregon north to Point Hope, Alaska. Stragglers have been reported from Bathurst Inlet in the Canadian Arctic Ocean. The most northerly population of any size is that of Salmon Lake on Alaska's Seward Peninsula. Sockeye have been taken in the Yukon River as far upstream as Rampart (UAFC #2023). On the Asian side of the Pacific, sockeye are known from the Anadyr River in Siberia south to Hokkaido, Japan. The abundance of sockeye varies tremendously from place to place. The greatest centers are in the Fraser River system in British Columbia and in the Bristol Bay system - the Kvichak, Naknek, Ugashik, Egegik and Nushagak rivers of Alaska. In good years, the runs to these areas may be in the tens of millions of fish. The kokanee is known from Japan and Siberia on the Asian side, and in North America from the Kenai Peninsula in Alaska, south to the Deschutes River in Oregon. It has been introduced widely into the Great Lakes, New England, various western and mid-western states, and California. Kokanee may be extremely abundant in some lakes, while in others the populations are small. There seems to be no particular explanation.

HABITS

The adult sockeyes return to their natal streams during the summer and fall, July to October in most areas, but as late as December in the southern part of the range. Spawning occurs almost exclusively in streams with a lake connection, although a few populations spawn in lakes and a very few in streams with no lake. Lake spawners tend to breed later in the year than do stream spawners, but this is by no means universal.

As with other salmons, the female selects the site and digs the nest. Nest digging is accomplished by the female facing upstream, turning on her side on the stream bottom and giving several powerful strokes with her tail. This disturbs debris, sand and gravel, which is carried downstream by the current. Repeated digging at the same spot produces a pit somewhat longer than the fish and as much as 400 mm (16 in) deep (Hanamura, 1966). The nest is usually constructed where the bottom is of fine gravel, but may be over large pebbles of 5-10 cm diameter or even amongst large rocks. In the last case, no proper nest is dug (Ricker, 1966). Preferred sites have less than 10% of the gravel larger than 75 mm in diameter, about 50% between 25 and 75 mm, and the remainder smaller than 25 mm (Hoopes, 1962). During preparation of the nest, the female is attended by a dominant male and often by several subordinate males as well. The female is aggressive towards other females and sometimes towards the subordinate males. The male is aggressive towards other males.

Between digging acts, the female often rests over the pit. The dominant male courts her by approaching her from behind, gently nudging her side with his snout, then coming to rest beside her and quivering. He may also swim over her, brushing her dorsal fin with his body and fins.

When the nest is completed, the female drops into it with her vent and anal fin well down in the deepest part of the pit. The male at once comes close beside her, both fish arch their bodies, open their mouths, quiver and extrude the eggs and sperm. One or more subordinate males may come to the other side of the female and join in the spawning. Three to five days are normally required to deposit all the eggs.

The eggs, which are bright orange-red in color and 4.5-5 mm in diameter, fall into crevices in the gravel at the bottom of the nest, where they are fertilized by the male's milt. A female may deposit 500-1,000 eggs in a single nest. Having done so, she moves to the upstream edge of the nest and digs again. The gravel so disturbed is carried into the nest, covering the eggs, and a new nest is dug just upstream from the previous one. The female usually produces between 2,500 and about 4,300 eggs, and will occupy 3-5 nests. She may spawn with several dominant males, and a male may breed with several females. All adult sockeye die after spawning.

Development of the eggs takes 6-9 weeks in most areas, the time depending largely on water temperature, but may require as long as 5 months (Hart, 1973). Hatching usually occurs from mid-winter to early spring and the young emerge from the gravel in April to June. There is strong positive correlation between intra-gravel water flow and egg survival. Deposition of silt in the redd, reducing water flow, may result in heavy mortality of the eggs. Oxygen consumption by the alevins in the nest is considerably higher than by eggs, further emphasizing the need for adequate flow (Cooper, 1965).

Upon emerging from the gravel, the fry at first tend to avoid light, hiding in the stones and gravel of the stream bottom during the day and emerging at night. In a few populations, the fry go to sea during their first summer, but the vast majority spend one or two years in a lake before migrating, with rather rare cases of three or even four years in freshwater (Margolis, et al, 1966). The young sockeye in inlet streams go downstream to the lake, while those hatched in outlets swim upstream. The mechanisms of these different responses are unknown, but appear to be genetically controlled.

Once in the lake, the young fish spend the first few weeks close to shore, feeding largely on ostracods, _Bosmina_ and insect larvae. Subsequently, the fish become pelagic and move offshore, where they feed on plankton in the upper 20 m or so. The major food items during the summer are _Calanus_ and _Bosmina_, with the latter preferred by the younger fish (Hoag, 1972). The abundance of the fry is positively correlated with the abundance of adult spawners, and their growth through June is correlated with water temperature and an abundant food supply (Nelson, 1964; Narver, 1966; Rogers, 1973). Experimental fertilization of lakes to increase the standing crop of plankton has resulted in up to 30% greater size of under-yearling sockeyes. However, the increase in plankton was much greater. Apparently the upper layers of water are too warm for the young sockeye in July and August, leading to underutilization of the food (Le Brasseur and Kennedy, 1972; Barraclough and Robinson, 1972).

After a year in the lake (two years in most Bristol Bay areas), the young sockeye lose their parr marks, turn silvery ("smolt up") and migrate downstream to the sea. Smoltification is largely dependent on size, rather than age, and the threshold size seems to be determined by the genetics of the particular stock. Early-spawning adults tend to produce a greater percentage of age I smolts than do late spawners (Narver, 1966). In the Wood River system of Alaska, the first smolts to migrate are age II, which are probably late migrants from the upper lakes which encountered a temperature block and were forced to spend a second year in the lake (Nelson, 1964). In other systems, however, age II smolts seem to be the usual thing. Peak outmigration in the Bristol Bay region occurs in June, beginning when water temperatures reach about 4°C (38-39°F). Most of the migrants move at night, especially between 10 and 11 p.m. (Nelson, 1964), but schools of smolt leave the Agulowak River for Lake Aleknagik all day long in mid-July (personal observations), and in Babine Lake, British Columbia, the main movements are at dawn and dusk (Groot, 1965). The migrating smolts show well-directed orientation towards the lake outlet and travel 5-8 km/day in the lake, farther on bright days than on cloudy ones. During the course of the migration, the orientation shifts according to the orientation of the bodies of water traversed. Various mechanisms, including responses to celestial phenomena, polarized light and the immediate surroundings seem to be involved (Groot, 1965).

Once in the sea, the young sockeye stay fairly close to shore at first, feeding mainly on various zooplankters, but also on small fishes (Manzer, 1969). As the fish get bigger and stronger, they head out to sea. Fish from areas south of the Alaska Peninsula head out into the Alaska Gyre in the Gulf of Alaska. Those from Bristol Bay and northward go through the eastern and central Aleutian passes into the Gulf. By late winter, the sockeyes are spread in a band across the North Pacific south of 50°N. In late spring, the young fish move north to between 50°N and the Aleutians, from about 160°W to 170° or 165°E. This appears to be an important feeding area, the major foods of the sockeye being amphipods, copepods and squid (Le Brasseur, 1966a). The following winter, the fish separate into those which will mature the following spring and those which will spend another year or more in the sea. The early-maturing fish stay north of 50°N, while the others repeat the previous year's journey. In the following spring, the mature fish head back to their natal streams, while the immatures continue to repeat the oceanic circuit (Thorsteinson and Merrell, 1964; Manzer et al, 1965; Margolis et al, 1966; Royce et al, 1968; French and Bakkala, 1974).

Most sockeye from British Columbia areas spend one year in fresh water and two in the sea, returning to spawn in their fourth year of age. However, farther north, two years in fresh water and two or three in the sea are common.

Hence, many Alaskan sockeye return in their fifth or sixth years. However, the four year cycle is generally prevalent.

Growth of the sockeye in the ocean is rapid, especially in the final year. Because of this growth pattern, the inshore fishing practiced along the North American coast is the most efficient harvesting of the resource. Catching the fish at sea in the year before they mature results in loss of yield of 50 to 65% (Ricker, 1962).

The landlocked form of the sockeye is called kokanee. It differs from the anadromous sockeye chiefly in spending its entire life in fresh water and in reaching a much smaller maximum size.

Kokanee, wherever they are native, have been derived from anadromous sockeye populations and each kokanee population apparently has evolved independently from a particular sockeye run (Ricker, 1940; Nelson, 1968a). Offspring of kokanee occasionally become anadromous, and sockeye offspring sometimes will not go to sea. The life span of the kokanee varies from two to seven years in different stocks. The fish is confined to lake-stream systems and spends most of its life in the lake, analagous to the sea life of the sockeye. They are much smaller than sockeye, averaging about 300 mm long in most places, although fish of over 600 mm have been recorded (Kimsey, 1951). Spawning time and behavior of the kokanee are like those of the sockeye (Schultz and students, 1935; Schultz, 1938). However, related to their small size, fecundity is much lower, on the order of 300-500 eggs per female.

Kokanee are either weak swimmers, or, more likely, lack the strong urge to swim upstream so characteristic of the salmons. At any rate, small barriers effectively stop their migrations (Seeley and McCammon, 1966). Spawning usually takes place in inlet or outlet streams, though sometimes in lakes near the shore (Lorz and Northcote, 1965). All kokanee die after spawning.

Kokanee are mainly plankton feeders throughout their lives. At least in some lakes, there is seasonal variation in the type and quantity of food eaten. They feed most heavily in June and October, less through the summer, in Nicola Lake, B.C. Diaptomids dominated the food in the spring, chironomids in the summer and Daphnia in the fall (Northcote and Lorz, 1966).

IMPORTANCE TO MAN

The sockeye salmon is one of the most important of the Pacific salmons. Its flesh is of the highest quality, and although it is not as abundant as the pink and chum, the higher price it commands makes it the real "money fish" in the salmon industry. The kokanee is primarily a sport fish, generally well accepted by anglers, despite its small size. Like the sockeye, the kokanee is excellent as food. It has been fished commercially in Lake Pend Oreille, Idaho. It is also well regarded in some areas as a forage fish for large trout, but in other places is looked upon as a competitor with the trout.

ARCTIC GRAYLING

Thymallus arcticus (Pallas)

DISTINCTIVE CHARACTERS

Adult grayling are distinguished by the greatly enlarged dorsal fin and the small mouth with fine teeth in both jaws. Juveniles may be separated from coregonids of similar size by the presence of narrow, vertically elongate parr marks. These are round or absent in coregonids.

DESCRIPTION

Body elongate, somewhat compressed. Greatest depth at origin of dorsal fin, depth about 20% FL. Head short, about 17% of FL. Snout about equal to or a little less than eye diameter, 21-25% of head length. Eye large, round, about equal to snout. Mouth terminal, small, maxilla reach about to middle of eye. Teeth small, present on both jaws, tongue (may be missing in large adults), palatines and head of vomer. Gill rakers 16-23 on first arch. Branchiostegals 8-9 on each side. Lateral line straight. Pyloric caeca 18-21.

Fins

D. 17-25, greatly enlarged in adults, especially in males. Adipose dorsal fin present. Dorsal fin of adult males reaches adipose fin when depressed; shorter in females. A. 11-15. P_1. 14-16. P_2. 10-11, rather long, reaching anal in adult males, shorter in females. A small axillary process present. Caudal fin forked, lower lobe often longer than upper.

Scales

Cycloid, fairly large, 77-103 pored scales in lateral line.

Color

Back dark purply blue to blue gray, sides silvery gray to blue, sometimes with a pinkish wash, with scattered dark spots on sides, these more numerous in young. A dark longitudinal stripe along lower sides between pectoral and pelvic fins. Dorsal fin dark with narrow purple edge, rows of reddish to orange and/or purple to green spots on body of fin. Pelvics dark with irregular diagonal orange-yellow stripes. Adipose, dorsal, anal, caudal and pectoral dusky to dark.

Size

The largest grayling known is one of 759 mm and 2.7 kg (29 7/8 in, 5 lb, 15 oz) from the Katseyedie River, Northwest Territories. However, in most areas the average angler-caught fish would be on the order of 300-350 mm (10-14 in) long and weigh 450-700 grams (1-1 1/2 lb).

RANGE AND ABUNDANCE

The grayling is common throughout Alaska and northern Canada, from the west side of Hudson Bay to the western shores of Alaska. It is present in the headwaters of the Missouri River above Great Falls, Montana, and ranges northward from central Alberta. To the west, it is present on Saint Lawrence Island and on the Asian mainland west to the Kara and Ob rivers of Siberia, south to the upper Yalu River.

The grayling has been introduced into a number of lakes in southeastern Alaska, as well as into mountainous areas of Colorado, Utah and Vermont.

HABITS

Grayling spawn early in the spring, immediately after break-up. In interior Alaska, they begin to congregate at the mouths of clearwater tributaries in April, and may start upstream through channels cut in the ice by surface runoff (Reed, 1964). The fish run upstream to the spawning grounds, sometimes a matter of more than 160 km, as soon as the streams open. Spawning takes place from mid-May to June, with no particular preference for substrate, although sandy gravel seems to be used most often, perhaps because of prevalence.

The males establish a territory which they defend against intruding males by erecting the dorsal fin, opening the mouth, and assuming a rigid posture. Persistent intruders may be rushed and driven off. Rarely, females may be attacked. At spawning, the male follows a female, courting her with displays of his dorsal fin. He then drifts over beside her and folds his dorsal fin over her back. Both fish arch, vibrate and release eggs and milt. They may gape, also. No redd is constructed, but the vibrations of the tails during the spawning act stir up the substrate and produce a slight depression (Laird, 1928; Wojcik, 1955; Kruse, 1959; Reed, 1964; Bishop, 1971).

The eggs are orange in color and about 2.5 mm in diameter but quickly swell to about 2.7 mm on hardening (Reed, 1964). During the next few days, they continue to swell and after three or four days are about 3.5 mm in diameter (Ward, 1951). Egg number varies with size of the individual and the stock, with counts as low as 416 and as high as 12,946 recorded (Brown, 1938b). Development to hatching requires 11 days to three weeks, depending on temperature (Lord, 1932; Brown, 1938b; Nelson, 1954; Bishop, 1971). The young, which have been described as resembling "two eye-balls on a thread" (Schallock, 1966), begin feeding the 3rd or 4th day after hatching, and all are feeding actively by the 8th day (Lord, 1932; Brown and Buck, 1939). Growth is rapid during the ensuing summer. By September, the young of the year are about 100 mm (4 in) long. In general, growth is somewhat faster in the southern part of the range than in the northern, but rates may vary widely from tributary to tributary within a single drainage (Miller, 1946; Kruse, 1959; Reed, 1964). At age I, grayling of interior Alaska average about 148 mm (5.8 in) in fork length; at age II, 192 mm (7.6 in); age III, 228 mm (9 in); age IV, 265 mm (10.4 in); age V, 304 mm (12 in). A 300 mm grayling will weigh between 200 and 250 grams (about 1/2 lb).

Following the spawning migration, the adult grayling move away from the spawning areas, generally but not always going farther upstream, and take up more or less permanent summer residence in pools (Schallock, 1966; Vascotto, 1970). Territoriality and social hierarchy develop quickly in each pool, with the largest and strongest fish occupying the most advantageous positions near the head of the pool, the smaller subordinate fish farther downstream, and the smallest of all occupying the foot of the pool without any territories.

Territories are established and maintained through a series of ritualistic "challenge displays," involving seven distinct steps. First, an "invader" moves up parallel with a "defender." 2. Both fish then lie still, with dorsal fins folded. 3. The invader drifts sideways toward the defender until they are less than 1 cm apart. 4. One fish, usually the invader, moves forward about 15 cm and bends the body so that the inside of the curve is presented to the head of the defender. 5. The invader drifts toward and beneath the defender. 6. The invader rises towards the defender, who drifts back. 7. Either (a) the defender keeps on retreating and leaves the territory, or (b) the defender moves around the invader and the pattern is repeated, with the roles reversed. Once territories and hierarchies have become firmly established in a pool, the ritual rarely goes beyond the third stage (Vascotto, 1970; Vascotto and Morrow, 1973).

The establishment and use of the territories is related to the feeding habits of the grayling. Virtually the entire diet is composed of insects, larvae, pupae and adults, which are taken drifting. The majority of these are aquatic forms which have been disturbed from the bottom by one means or another and thus become part of the benthic drift. The grayling is primarily a surface and mid-depth feeder and does not generally feed on the bottom except in the fall, when benthic drift is much reduced. (Brown, 1938a; Reed, 1964; Vascotto, 1970; Vascotto and Morrow, 1973).

A downstream migration occurs in mid-September. The fish leave the smaller tributaries and the vast majority move downstream to over-winter in deep water. A few stay in the major clear-water streams and apparently over-winter in the deeper pools (Schallock, 1966).

IMPORTANCE TO MAN

The grayling is one of the most important sport fishes of Alaska and northern Canada. It also makes a significant contribution to subsistence fishing in some remote areas.

SECTION 6

SMELTS--FAMILY OSMERIDAE

The Osmeridae is a group of small fishes which rarely, if ever, exceed about 30 cm (1 ft) in length. They are related to the salmons, but differ morphologically from that group chiefly in having no axillary process at the base of the pelvic fins; the lower jaw is longer than the upper; the head is, in general, smaller; the body is more slender, and there are few or no pyloric caeca.

The smelts are slender-bodied, silvery or dull, and have forked tails. Sexual dimorphism, usually in the form of nuptial tubercles, appears at spawning time.

Smelts may be entirely freshwater, anadromous or marine in their life history. Spawning usually takes place in fresh water or on beaches, although a few species spawn in the sea.

The smelts are generally quite abundant, at least during the spawning season, and are of considerable economic value.

LONGFIN SMELT

Spirinchus thaleichthys (Ayres)

DISTINCTIVE CHARACTERS

The longfin smelt is distinguished by the long upper jaw, reaching at least to below the middle of the eye in adults; fine teeth in a single row on vomer and palatine bones; and 38-47 gill rakers on the first arch.

DESCRIPTION

Body elongate, slender, compressed, its depth 14-20% of fork length. Head short, 20-25% of FL. Snout 22-28% of head. Eye fairly large, its diameter about equal to snout length. Mouth large, oblique, lower jaw projecting beyond upper when mouth is closed, upper jaw reaching backwards at least to below middle of eye in adults, shorter in young. Teeth small, fine, present on both jaws, tongue, vomer and palatines. Gill rakers long, 38-47 on first arch. Branchiostegal rays 7-8. Lateral line incomplete, 14-21 pored scales, reaching not quite to below dorsal fin. Pyloric caeca 4-6.

Fins

D. 8-10, moderately high, origin near middle of body length. Adipose dorsal fin present. A. 15-19. P_1. 10-12, reaching to origin of pelvic fins. P_2. 8, origin under anterior edge of dorsal fin. Paired fins with tubercles on upper sides in breeding males. Caudal fin forked.

Scales

Moderately large, cycloid, 55-61 (rarely 62 or 63) in a midlateral row. Tubercles present in breeding males.

Color

Dusky to olive or olive brown above, sides and belly silvery white. Fin rays usually dusky, membranes clear.

Size

Up to as much as 200 mm (8 in), but average adults are about 150 mm (6 in) or a bit less.

RANGE AND ABUNDANCE

The longfin smelt is found along the coast of North America from San Francisco Bay (Rutter, 1908) north to Prince William Sound, Alaska, where it has been found near Hinchinbrook Island at 60°12'N, 146°15'W (Dryfoos, 1961). The record from the Nushagak River in the Bristol Bay area of Alaska (Gilbert, 1895) is an error which has been uncritically accepted even by some modern authors, even though Hubbs (1925) long ago pointed out that the specimens in question were pond smelt, *Hypomesus olidus*. Within this range, the species is locally and seasonally abundant, appearing chiefly during the spawning runs.

HABITS

Extraordinarily little is known of the biology of the longfin smelt. The fish are anadromous, although a few landlocked populations are known. Spawning runs occur between October and December in most areas, with a few populations breeding as late as February. Details of spawning have not been recorded, but it is known to take place in streams not far from the sea. Fecundity varies from 535 eggs in small females of a landlocked stock to more than 23,600 for large anadromous fish. Average fecundity for anadromous females is said to be about 18,000 eggs. The eggs, about 1.2 mm in diameter, hatch in 40 days at 6.9°C. The newly hatched larvae are 7-8 mm long. They probably spend considerable time in fresh water, as young fish up to 72 mm long have been taken in the Fraser River (Hart and McHugh, 1944). Year old fish average about 75 mm, while two-year-old males are about 106 mm, females about 110 mm long. Sexual maturity is reached at the end of the second year of life. Most individuals die after spawning, although a few females apparently survive to three years. It is not known whether or not these three-year-olds have already spawned at the age of two. Members of landlocked populations apparently do not reach as great a size as do sea-run fish.

In the sea, the fish apparently stay fairly close to shore. They are taken in shrimp trawls at depths to 41 meters in the winter time. Food of the smelt in the sea consists of small crustaceans, especially euphausiids, copepods, and cumaceans, while in fresh water the young feed on a small, shrimp-like crustacean, *Neomysis mercedis* (Hart and McHugh, 1944), small, bottom-dwelling crustaceans and insect larvae (Hart, 1973).

IMPORTANCE TO MAN

This smelt is but little utilized. Fish in the sea are reported to have a good flavor, but the supply is limited and the species is lumped with other smelts in the market (Hart, 1973). The longfin smelt is often abundant during the spawning run, but at this time the flesh is soft and oily and spoils quickly (Scott and Crossman, 1973).

POND SMELT

Hypomesus olidus (Pallas)

DISTINCTIVE CHARACTERS

The small mouth, teeth in two rows on vomer and palatines, and 51-62 mid-lateral scales distinguish the pond smelt.

DESCRIPTION

Body elongate, somewhat compressed. Depth 16-24% of standard length. Head short, 20-25% of standard length. Snout short and blunt, its length usually a little less than eye diameter. Eye round, moderate, diameter equal to 20-30% of head length. Mouth small and oblique, lower jaw protruding beyond upper when mouth is closed; maxillary reaching to below pupil. Small, pointed teeth present on both jaws and on tongue, in two rows on vomer and palatines. Gill rakers long and slender, 26-34 on first arch. Branchiostegal rays 6-8 on each side. Lateral line incomplete, 7-16 pored scales, reaching scarcely beyond tip of pectoral fin. Pyloric caeca 0-3, rarely 4, usually 2.

Fins

D. 7-9, its anterior edge slightly before middle of standard length. Adipose dorsal fin present. A. 12-18, usually 12-16. P_1. short, 10-12, rarely 13. P_2. 8, arising below or ahead of origin of dorsal fin. Caudal fin forked.

Scales

Large, cycloid, 51-62 in a mid-lateral series. Males develop breeding tubercles on scales, as well as on head and fin rays.

Color

Light brown to olive green above, with a metallic silvery band along middle of sides. Ventral regions silvery white. Fins pale.

Size

Reported to reach 185 mm (7 1/2 in) in the Anadyr River (Andriyashev, 1954). Most North American adults are 100-150 mm (4-6 in) in total length.

RANGE AND ABUNDANCE

In Asia, the pond smelt is found from Wonsan, Korea, north to the Chukhotsk Peninsula, westward to the Alazaya River in Siberia. It is also present on Hokkaido Island, Japan, and on Sakkalin. An isolated population is present in Lake Krugloe in the Kara Sea drainage (Ivanova, 1952). In North America, the pond smelt is known from the Copper River north along coastal regions to the Kobuk River in Alaska, and from the Mackenzie drainage as far upstream as Great Bear Lake in northern Canada.

The pond smelt is often extremely abundant in suitable ponds and streams (Turner, 1886).

This species (or possibly the closely related H. transpacificus japonicus) was introduced into a number of reservoirs in California, but only one of the introductions, that in Freshwater Lagoon, Humboldt County, seems to have been at all successful (Wales, 1962).

HABITS

Spawning occurs in shallow water in streams or ponds, over pebbly bottoms in streams but often in littoral areas of ponds where the bottom is covered by organic debris (Jordan and Evermann, 1896; Nikolskii, 1956; Narver, 1966). Time of spawning is late April to May in Asia, but not until June in the Copper River and certain lakes in Alaska. On the spawning grounds, females outnumber males by about 3 to 1. Each female produces 1,200 to nearly 4,000 eggs. The eggs are about 0.75 mm in diameter at fertilization, but quickly swell to about 0.95 mm on contact with the water. They are demersal and sticky, adhering to whatever they touch. Like other smelt eggs, those of the pond smelt form a short pedicle from the inverted outer coat. However, about two days after fertilization the egg breaks off the pedicle and thereafter develops pelagically (Nikolskii, 1956). This pelagic development has not been reported by other authors. Hatching occurs on the 11th day at temperatures between 11 and 15°C, (Nikolskii, 1956) but not until the 18th - 24th day at 10°C (Narver, 1966).

The larvae are 4-5 mm long, with a well developed yolk sac. They begin to feed almost immediately after hatching, even before the yolk sac is absorbed, feeding on minute crustaceans and rotifers (Sato, 1952). When they are about 10 mm long, the young school up and move close to shore. They tend to stay in this region for most of the summer, moving into deeper water with the approach of fall. After a month of planktonic life, the young are about 20 mm long, and reach 30 to 40 mm by the end of the summer (Nikolskii, 1956). During this time, the larval population may decline drastically, but the cause is unknown (DeGraaf, 1974).

Pond smelt are about 60 mm (2.4 in) long at the end of the first year of life, about 80-100 mm (3-4 in) at the end of the second year. Apparently only a few survive beyond three years of age. Sexual maturity is reached at the end of the second year of life in most populations, although in some Japanese populations, spawning occurs at age 1+, with virtually no survivors. Most pond smelt are 50-70 mm long by the end of the first year, 70-90 mm at age 2, 90-110 mm at 3, and about 120 mm at 4 years of age. The last two age groups are extremely scarce.

A unique population of pond smelt is reported from an unnamed lake on the arctic coastal plain of Yukon Territory at 69° 18' N, 138° 57' W (DeGraaf, 1974). If the age determinations are correct, a few of these fish may survive to 9 years. The growth rates given are extra ordinarily slow, with 1+ fish smaller than young-of-the-year from other places; five-year-olds no longer than one-year fish from Black Lake, Alaska; and the supposed eight and nine year old fish about the same length as Black Lake 2+ fish.

Pond smelt do not migrate as a rule. However, within a lake or pond, the adult fish generally stay on the inshore spawning areas in spring and early summer, later moving offshore. Young-of-the-year follow the same patterns, while immature fish stay in the pelagial regions all summer. There may be outmigrations to other parts of the drainage system if population are high in relation to the abundance of food (Narver, 1966).

Food of the pond smelt is virtually exclusively zooplankton. Very young fish feed largely on rotifers, while adults take larger zooplankton such as copepods and cladocera, as well as insects and, occasionally, algae (Sato, 1952; Nikolskii, 1956).

IMPORTANCE TO MAN

The pond smelt is of no direct importance to man, due chiefly to its limited distribution. Where it is present, it is of value in subsistence fisheries (Turner, 1886). They are doubtless used locally in Asia as well as in Alaska.

It has been suggested (McPhail and Lindsey, 1970) that, since the adults feed mainly on zooplankton, they may sometimes be important competitors with young sockeye salmon.

SURF SMELT

Hypomesus pretiosus (Girard)

DISTINCTIVE CHARACTERS

The surf smelt is distinguishable from other species of *Hypomesus* by its mid-lateral scale count of 66-73, and the presence of 4-7 pyloric caeca.

DESCRIPTION

Body elongate, slender, slightly compressed. Depth 14-22% of fork length. Head rather short, 19-21% of fork length. Snout moderate, about 30% of head length and about equal to interorbital width. Eye round, its diameter about equal to snout length. Mouth rather small, upper jaw (maxilla) reaching to below front half of eye. Teeth small, pointed, present on both jaws. Gill rakers 31-36 on first arch. Branchiostegal rays 7-8. Lateral line short and incomplete, reaching about to tip of pectoral fin. Pyloric caeca 4-7.

Fins

D. 8-10, its origin above or slightly behind middle of body length. A small, sickle-shaped adipose fin present. A. 12-16. P_1. 14-17, slightly longer in males than in females. P_2. 8, origin below or behind front of dorsal fin. Caudal fin forked.

Scales

Cycloid, 66-73 in a mid-lateral series. Scales are deciduous and easily removed.

Color

In males, the back is dull olive to brownish, the belly yellowish-silver. Females are brighter, more metallic green above and silver on the belly. Both sexes have a bright silver band along the middle of each side, which becomes dark in preserved specimens.

Size

The surf smelt reaches a length of about 254 mm (10 in) in California (Roedel, 1953) but the maximum size of northern fish seems to be about 200-230 mm (8-9 in).

RANGE AND ABUNDANCE

Along the coast of North America from Long Beach, California in the south (Miller and Lea, 1972) to Chignik Lagoon in southwestern Alaska (Phinney and Dahlberg, 1968). A single specimen was taken in Herendeen Bay, on the north side of the Alaska Peninsula, in the summer of 1976 (I. Warner, Alaska Dept. Fish and Game, Kodiak, pers. comm.). On the western side of the Pacific, another subspecies ranges from southern Kamchatka to Korea.

The surf smelt is most abundant in the central part of its range, especially in Puget Sound and adjacent regions. Good runs occur in Alaska as far north as Prince William Sound. In the Columbia River to Puget Sound area, the surf smelt is fished not only for sport but also commercially. Landings of smelt contribute significant amounts to the fisheries of Oregon, Washington and British Columbia. However, abundance is far from uniform. In Puget Sound, for example, 57.3 linear km (35.8 mi) of beach are used by spawning smelt, but only 9.8 km produce more fish than the remaining 47.5 km.

HABITS

The surf smelt, as its name suggests, spawns along beaches in light to moderate surf. The spawning period for all populations stretches from May to March, according to locality and population (Yap-Chionggo, 1941). At spawning time, schools of smelt approach the beach, the females appearing a few days before the males. Spawning is most frequent on a falling afternoon or evening high tide, and takes place from extreme low tide line to more than half-way up the beach (Thompson et al, 1936; Yap-Chionggo, 1941). Other observers have found surf smelt spawning most actively within one to one and one half hours before or after the flood (Loosanoff, 1937). At spawning, large numbers of males mill about near the edge of the surf. When a female is seen, numbers of males pursue her and try to get into spawning position. If she swims into deeper water, the males desert her. A ripe female, however, moves up the beach, accompanied by 1-5 males who swim parallel to and slightly behind her. The males press against the female, sometimes tilting their bodies to bring male and female vents close together. As they reach shallow water, 25-50 mm (1-2 in) deep, the fish bend and vibrate, releasing eggs and sperm, then retreat to deeper water. Spawning may take place on both incoming and outgoing waves (Schaefer, 1936). The spawning act lasts only 5-10 seconds and may be repeated on several successive waves. A female usually requires several days to deposit all her ripe eggs, which number from about 1,500 to over 36,000 (Schaefer, 1936), depending on the race and size of the female. Females normally contain several size-groups of eggs at any given time and apparently spawn more than once in a single season. Although the female releases only a few eggs at a time, the males emit rather large quantities of milt, so that the water may become slightly milky on a heavily used beach. Preferred beaches are those not exposed to strong sun and composed of coarse sand and fine gravel 2.5-4 mm (0.1-0.16 in) in diameter. Suitable-sized substrate particles appear to be a most important factor in the selection of a spawning beach.

The eggs, about 1.0-1.2 mm in diameter after water-hardening and pale yellow in color, are sticky and adhere to the particles of gravel. Shortly after fertilization, the outer membrane ruptures and turns inside out, adhering to the egg at the point where it sticks to the substrate and forming a short pedicel. Wave action buries the eggs, usually to a depth of 25-100 mm (1-4 in) but sometimes to as deep as 300 mm (1 ft).

Incubation requires 8-11 days at 12.2-15.5°C, but three or four times as long at 7.5-8.5°C. Once development is complete, hatching requires the stimulus of wetting, which is accomplished by the incoming tide. The young are 3-6 mm (0.1-0.24 in) long at hatching, transparent, with yellow eyes and a small yolk sac. They are positively phototropic and swim actively towards the light. Thirteen days after hatching they are about 7 mm long.

Very little is known of the subsequent life history. Young smelt 33 mm (1.4 in) closely resemble the adults and may go up rivers, where they feed on Diptera and Ephemeroptera. Presumably those fish which do ascend rivers return to the sea very shortly, for only a few specimens have been taken in fresh water. One was recorded from the Sandy River, 16 km (10 mi) east of Portland, Oregon (Mc Allister, 1963).

The surf smelt matures at one to two years of age, at a minimum length of 90 mm (3.5 in), with males maturing earlier than females. Within a single age group, larger fish mature and spawn earlier in the season than do smaller ones (Schaefer, 1936; Loosanoff, 1937). Maximum life is about two years for males, three for females.

Nothing is known of the movements of the surf smelt. They disappear, presumably offshore, as young and re-appear inshore as mature adults.

IMPORTANCE TO MAN

The surf smelt is one of the minor constituents of the total commercial fisheries of the west coast of North America. Total landings run to several hundred thousand kg per year and it is considered the smelt in British Columbia. As food, it is considered a delicacy, being of fine flavor and texture. The size of the sport catch is unknown, but it is probably quite large.

EULACHON

Thaleichthys pacificus (Richardson)

DISTINCTIVE CHARACTERS

Large canine teeth on the vomer and 18-23 rays in the anal fin distinguish the eulachon.

DESCRIPTION

Body elongate, slender, slightly compressed in females; thicker dorsally than ventrally (cross-section more or less pear-shaped) in adult males. Depth 15-20% of standard length. Head short, 20-26% of standard length, rather prominent concentric striae present on gill covers. Tubercles present on heads of breeding males, poorly developed or absent in females. Snout fairly long, 25-28% of head length. Eye round, small, its diameter 50-66% of snout length. Mouth oblique, large, maxilla reaching to or behind posterior margin of eye in adults. Small, pointed teeth present on both jaws, tongue and palatines. A pair of moderately large canine teeth on vomer. All teeth tend to be lost at spawning. Gill rakers long, about 66% of eye diameter, 17-23 on first arch. Branchiostegals 6-8. Lateral line complete, with 70-78 pored scales. Pyloric caeca 8-12, quite long.

Fins

D. 10-13. Dorsal adipose fin present, sickle shaped. A. 18-23. P_1. 10-12. P_2. 8. Caudal fin forked. Pectoral and pelvic fins longer in males than in females, pelvic fins of males may reach anus but always much shorter than this in females. All fins with well developed breeding tubercles in ripe males, these poorly developed or absent in females.

Scales

Cycloid, rather small. Well-developed breeding tubercles present on adult males, but tubercles only poorly developed on females.

Color

Brown to dark bluish dorsally, fading to silvery white or white ventrally. Fins immaculate, although pectorals and caudal often dusky.

Size

Maximum length about 225 mm (9 in) fork length (Taranetz, 1933), but most not over 200 mm (8 in).

RANGE AND ABUNDANCE

The eulachon ranges from Bodega Head, California (Odemar, 1964), north along the coast of North America to Bristol Bay, Alaska and westward in the Bering Sea to the Pribilof Islands. It is seasonally abundant in all the streams utilized for spawning.

HABITS

The eulachon is anadromous, spending most of its life in the sea but returning to freshwater streams to spawn. There is evidence, based on significant differences in meristic characters such as numbers of vertebrae, indicating that eulachon return to their natal streams (Hart and McHugh, 1944). The spawning run occurs in the spring, beginning in mid-March in the southern part of the range and extending well into May at the northern end. Males predominate in the early part of the run, but may be equaled or exceeded by females later. The fish apparently do not feed in fresh water (McHugh, 1939; Hart and McHugh, 1944).

Spawning takes place over coarse sand and pea-sized gravel in water up to about 7.6 m deep. Water temperature at spawning time is usually between 4.4 and 7.8°C (McHugh, 1940; Smith and Saalfeld, 1955). The eggs are about 0.8 - 1.0 mm in diameter and a female produces from about 17,000 to as many as 60,000 eggs. Fecundity increases with the size and age of the individual. Shortly after the egg is extruded, its outer membrane splits, separates from the inner membrane and turns inside out, remaining attached to the inner membrane at one point and thus forming a short stalk. The free edges of the broken membrane are sticky and easily become attached to the bottom substrate. Hatching occurs after 30-40 days of incubation at 4.4 - 7.2°C, but in less than three weeks at 9.4 - 12.8°C. The larvae are transparent, only 4-5 mm long. They are weak swimmers, stay near the bottom of the stream and are soon carried downstream to salt water. In the sea, the young fish become distributed in the scattering layer of coastal waters, where food is abundant. Food of the youngest fish seems to be mainly copepod larvae. Later young, 25-50 mm long, have a more varied diet, including phytoplankton, copepod eggs and adults, mysids, ostracods, barnacle larvae, cladocerans, worm larvae and the smaller larvae of the eulachon itself (Hart, 1973, citing unpublished studies by Barraclough). Juvenile eulachon feed heavily on euphausiids, which are abundant in these waters. By mid-winter (December-February) the young fish average about 66 mm (2.6 in)long and by the time they are a full year old they are about 80 mm (3.1 in) long. Subsequent growth is much slower. Two year old fish average not quite 90 mm, 3+ about 117 mm and 4+ about 154 mm in April. Adult eulachon in the sea feed on plankton, mostly euphausiids and cumaceans (Hart and McHugh, 1944; Smith and Saalfeld, 1955; McAllister, 1963; Barraclough, 1964).

Little else is known of the marine life of the eulachon. Occasional commercial catches of this smelt in near-shore waters suggest that the fish do not travel far offshore, but probably move about at no great distance from the natal river.

Sexual maturity may be attained at the end of the second year of life in some populations, not until the end of the third year in others. Most smelt die after spawning, but some survive and may spawn a second time. The spawning run from the sea begins when river water temperatures rise to about 4.4°C, but the fish stop running if the temperature exceeds 7.8°C. Most of the runs occur in the larger rivers, such as the Columbia and Fraser, although smaller streams reaching the sea may also have eulachon population. The spawning grounds may be in the major rivers themselves or in tributaries. Some of the spawning areas in the Columbia River are above Vancouver, Washington, more than 160 km from the ocean.

IMPORTANCE TO MAN

In Washington and Oregon, commercial fisheries exist which take more than 454,000 kg (1,000,000 lb) per year. A fishery of similar size formerly existed in British Columbia, but landings at present are much smaller. Eulachon are important in the subsistence fisheries, and have been for many years (Swan, 1881). Today, the native fishery in British Columbia probably takes more fish than does the commercial fishery in that province (Scott and Crossman, 1973).

The flesh of the eulachon contains a high percentage of oil which can be rendered down to a fatty material with color and consistency much like lard. This fat was highly prized by the Indians of the Pacific Northwest. The fat content is so high that, when dried, the fish can be burned directly or with a wick threaded through it, hence the name "candle fish".

Today the eulachon is utilized principally as food, either for humans or for commercially reared fur animals. The flavor is good and the eulachon has a high place among gourmet food fishes. Indeed, it has been called "unsurpassed by any fish whatsoever in delicacy of the flesh..." (Jordan and Evermann, 1908).

The eulachon is also important indirectly. When eulachon are congregated off river mouths preparatory to beginning their spawning runs, they are fed upon heavily by all sorts of predatory fishes, including halibut, cod and salmon, as well as by such marine mammals as finback whales, porpoises, sea lions and seals. The eulachon thus forms an important link in the food chain between the small animals of the zooplankton and the large carnivores.

RAINBOW SMELT

Osmerus mordax (Mitchill)

DISTINCTIVE CHARACTERS

One or more large canine teeth on the vomer (often missing in spawning fish), 11-16 anal rays, and the front of the dorsal fin above or ahead of the bases of the pelvic fins distinguish the rainbow smelt from other Alaskan osmerids.

DESCRIPTION

Body elongate, compressed, slender, its depth about 12-19% of total length. Head moderate, its length 16.5-23% of total length. Snout pointed, elongate, longer than eye diameter. Eye large, round, its diameter 17.5-24% of head length. Mouth large, lower jaw longer than upper; maxilla reaches to middle of eye or farther back. Teeth well developed, canine-like, present on both jaws, tongue, vomer and palatines, the anterior teeth on tongue and vomer enlarged. Gill rakers long, slender, 25-36 on first arch. Branchiostegals usually 7 on each side, rarely 5, 6 or 8 on one or both sides. Lateral line incomplete, with 14-28 pored scales. Pyloric caeca 4-8.

Fins

D. 8-11, its origin ahead of base of pelvic fins. A small adipose dorsal fin present. A. 12-16. P_1. 11-14, shorter than head. P_2. 8. Caudal fin forked.

Scales

Cycloid, fairly large, thin and deciduous, 62-72 in a mid-lateral series. Prominent nuptial tubercles present on scales of spawning males, absent in females.

Color

Pale green to olive dorsally, silvery below, a bright, metallic silvery band along sides. Sides often with purple, blue or pink iridescence. Fins colorless, sometimes with faint speckling.

Size

Reported up to 340 mm TL in the Anadyr River of Siberia (Berg, 1948), but North American smelt apparently only rarely exceed about 250 mm. The average rainbow smelt in commercial catches is about 150 mm long with a weight of about 30 grams.

RANGE AND ABUNDANCE

The range of the rainbow smelt along the Pacific coast of North America is from Barkley Sound, Vancouver Island, north along the coast of British

Columbia and Alaska through Bristol Bay, thence north to the Arctic coast and east to Cape Bathurst. The species is also known from St. Lawrence Island. On the Asian side, the rainbow smelt may be found from Korea and northern Japan to the Anadyr Peninsula and westward to the White Sea. Rainbow smelt are also native to the east coast of North America, from northern New Jersey north to Hamilton Inlet on the northern coast of Labrador and westward in a number of lakes and streams in Quebec and Ontario (Dymond, 1937; Bigelow and Schroeder, 1963). References to rainbow smelt as far south as Virginia appear to be in error (Low, 1896; Backus, 1957; Bigelow and Schroeder, 1963).

Smelt were introduced into Michigan waters from Maine, beginning in 1906. Early plantings were unsuccessful, but a plant of 16,400,000 eggs in Crystal Lake, Benzie County, made in 1912, took hold and appears to be the ancestors of most or all smelt in the western Great Lakes (Hankinson and Hubbs, 1922; Creaser, 1926; Savage, 1935). Introductions into New York waters were probably responsible for smelt in Lake Ontario, for they appeared there some years before they were taken in Lake Erie (Mason, 1933).

Wherever it is present, excepting perhaps the most extreme ends of its range, the rainbow smelt is abundant, although, because of its migratory habits, the abundance is local and seasonal.

HABITS

Little, if anything, is known from direct studies of the rainbow smelt of the Pacific coast. Most of the following account is derived from studies of east coast and Great Lakes populations. Presumably the life history of Pacific coast smelts does not differ greatly from this.

Like other osmerids, the rainbow smelt is a spring-time spawner. The adult fish begin to congregate near stream mouths early in the spring, often long before the ice goes out (Rupp, 1959). In most areas, the majority of the fish are first-time spawners, usually two years old. These constitute half to two thirds of the run, with three-year-olds another 25-30% and the rest older fish (McKenzie, 1964). Movement into the streams begins when water temperatures reach 2-4°C or higher. Warm days and cool nights seem to enhance the spawning migrations (Hoover, 1936). As a rule, the upstream run is short, a few miles to sometimes only a few hundred yards above the head of the tide and some may even spawn in brackish water behind barrier beaches or in the tidal zone of estuaries (Bigelow and Schroeder, 1963; McKenzie, 1964). In the Yenisei River of Siberia, however, upstream migrations of more than 1,000 km have been observed (Berg, 1948), and to at least 320 km in the St. Lawrence River in Canada (Magnin and Beaulieu, 1965).

The movement from lake or river to the spawning grounds is usually made at night, although daytime spawning has been observed (Rupp, 1959). In most populations, there appears to be an influx of fish just after dusk, followed by a second group running around 2 a.m., (Creaser, 1926; Hoover, 1936; Baldwin, 1950). As a rule, the males appear earliest, the females following an hour or so later. Spawning seems to be initiated, at least in part, by the presence of the proper sex ratio in the group, which has been indicated as being no more than four males to one female (Hoover, 1936; Rupp, 1965). In the spawning act, which takes place over sandy gravel, pebbles and rocks, the fish crowd together, all headed upstream. They move laterally, in somewhat exaggerated swimming movements. Contact between males either brings about no reaction or a separation of the two fish, but when a male and female contact each other, eggs and milt are released. It has also been reported that the male pushes the female to the bottom or into shallow water after contact has been made (Hoover, 1936), but this action does not seem to be general. Apparently the prominent nuptial tubercles on the sides of the males provide a tactile stimulus which serves the individual in discriminating between the sexes. Females also may have nuptial tubercles on the top of the head and along the base of the dorsal fin, but they are poorly developed and are located in positions where they could not function in the manner described (Hoover, 1936; Richardson, 1942; Rupp, 1965).

In the spawning act, a female deposits only about 50 eggs at a time (Hoover, 1936). Since the eggs are quite small (0.8-1.0 mm), a single female produces a large number, from 1,700 to 69,600 (Langlois, 1935; Hoover, 1936; Bert, 1948; Bailey, 1964; McKenzie, 1964). It thus requires many spawning acts, spread over several hours each night for several nights, to deposit all eggs.

Following each evening's activity, most of the fish drift, tailfirst, downstream to the larger body of water whence they came to the spawning grounds. Some, mostly males, may remain in the spawning stream during the day, but they avoid light as much as possible.

The larger members of an age group ripen earlier in the season than do smaller ones, and older fish ripen earlier than younger. Hence the spawning season may extend over several weeks, or even months, with newly ripe fish coming in as the spawned out fish leave. Because of this correlation of spawning time with age and size, the average size of the fish tends to decrease as the run progresses.

Many of the spawned-out fish, especially males, die after spawning, but those which survive will spawn again the following year. Sexual maturity is achieved at the end of the second or third year of life. Since a few fish may live to six years, some obviously spawn several times during their lives (Creaser, 1926; Bailey, 1964).

Spawning is not always confined to streams, for rainbow smelt have been observed breeding in shallows along lake shores. Here the fish come inshore in small schools and swim about over rather restricted areas, apparently without any distinct pairing. The composition of the schools changes constantly, for individual fish apparently engage in spawning activities for only 15-30 minutes at a time, then leave the school (Lievense, 1954; Rupp, 1965).

Whenever spawning takes place, the eggs settle quickly to the bottom. Within 15-30 seconds of exposure to water, they become sticky and adhere to whatever they touch. As with the eggs of other smelt, the outer cover ruptures and turns inside out, adhering to the egg at one point, so that the egg is held above the substrate on a tiny pedestal. Hatching occurs in about 29 days at 6-7°C, 25 days at 7-8°C, 19 days at 9-10°C, 11 days at 12.2°C and 10 days at 15°C (Hoover, 1936; McKenzie, 1964). Density of eggs on the spawning grounds varies tremendously, according to the number of adults using the area. Greatest production of larvae results when the density of eggs is on the order of 100,000 - 130,000 per square meter. Under these conditions, average survival to hatching is on the order of 0.5-2%. Major causes of mortality are mechanical crushing, abrading, dislodging by waves and currents, and fungus infections. However, year-class abundance is not related to the number of larvae produced. Factors affecting the post-hatching survival of the young apparently are more important than the number of fish hatched (McKenzie, 1947, 1964; Rothschild, 1961; Rupp, 1965).

The young are about 5-6 mm long at hatching and are transparent. Being weak swimmers, they are soon carried downstream to the lake or estuary. They reach a length of about 40 mm in 3-4 months (Gordon, 1961; Bigelow and Schroeder, 1963). Growth rates vary tremendously from one population to another. However, averages, compiled from a number of sources, yield the following approximate average lengths at various ages: 1+, 111 mm; 2+, 167 mm; 3+, 190 mm; 4+, 218 mm; 5+, 228 mm; and 6+, 242 mm. Females grow faster, get bigger and live longer than do males (Creaser, 1926; Beckman, 1942; Warfel et al, 1943; Baldwin, 1950; McKenzie, 1958; Bailey, 1964).

Except for the spawning runs, the rainbow smelt apparently does not undertake definite migrations. Fish which go to sea stay within 8-10 km of shore and probably do not stray far along the coast from the estuary (Bigelow and Schroeder, 1963).

Although the rainbow smelt apparently returns to the river system in which it was hatched, return to the spawning streams, both by first-time spawners and by older fish, is often not precise. The degree of homing seems to vary from one population to another and may be genetically controlled (McKenzie, 1964; Rupp and Redmond, 1966).

Food of young-of-the-year smelt is mostly copepods and cladocerans, as well as rotifers, eggs, and algae. Adults in saltwater feed on decapod and mysid shrimps, copepods, amphipods and small fishes, as well as small shellfish of various sorts, crabs, squid and worms. The diet in fresh water includes the same major groups; copepods, amphipods, cladocerans, mysids and small fishes, as well as various insects, especially Ephemeroptera and Diptera nymphs and larvae. Feeding virtually ceases during spawning (Creaser, 1926, 1929; Kendall, 1927; Beckman, 1942; Baldwin, 1950; Gordon, 1961; Bigelow and Schroeder, 1963).

IMPORTANCE TO MAN

In areas where it is sufficiently abundant, such as the Great Lakes region of the U. S. and Canada, and the New England states, the rainbow smelt is an important part of both the sport and commercial fisheries. Since 1960, the commercial catch by the U. S. and Canada in the Great Lakes and the international lakes has been between 4,500,000 and 9,000,000 kg annually, averaging about 6,800,000 kg per year, with a value of about $0.07 per kg. These fish are taken mainly by otter trawls, traps and gill nets. In the New England states, landings of smelt reached 550,000 kg in 1889, but declined to a yearly average of only 215,250 kg in the period 1951-1954, and to an average of only 69,700 kg yearly for 1969-1971. This decline is probably caused in part by lessened abundance caused by obstructions in and pollution of streams and in part by the high price commanded by New England smelts, about ten times the price of Great Lakes fish (Bigelow and Schroeder, 1963; Anonymous, 1972, 1973, 1974).

Great Lakes catches were formerly much greater, but an epidemic, ascribed to either bacterial or viral agents, decimated the population in 1943-1944, causing an estimated loss to the commercial catch of nearly 23,000,000 kg for the 1943-1946 fishing seasons (Van Oosten, 1947). Other epidemic die-offs, particularly in New England, have been ascribed to the microspridian parasite *Glugea hertwigi* (Haley, 1952).

The rainbow smelt is also a popular sport fish. It is taken by dip-netting or with hook and line, the latter being especially popular in winter through the ice. Sport catches in the U. S. are estimated to equal or exceed the commercial landings.

As food, the rainbow smelt is highly esteemed, and has been ever since white men came to North America. Its flesh is firm and tasty.

The rainbow smelt was not always considered an asset in lakes where it was introduced, as it was thought to be a serious predator on and competitor with various native fishes, and often fouled the nets of fishermen in the days before it became marketable. However, there appears to be no evidence that smelt in the Great Lakes have had any adverse effect on other species (Gordon, 1961).

The rainbow smelt is too scarce in Alaska to be of any great importance, although it undoubtedly enters subsistence fisheries from time to time.

SECTION 7

MUDMINNOWS AND BLACKFISH--FAMILY UMBRIDAE

The five living species in this family, belonging to three genera, were previously classified in two or three separate families. Current ichthyological thinking lumps them all together in one group. The family is strictly northern hemisphere in its distribution. One species is found in eastern Europe, two more are known from eastern and central North America, another from northwestern Washington, and the fifth, *Dallia pectoralis*, is found in Alaska and western Siberia.

All members of the family are small, elongate fishes with rounded tails and rather broad, flattened heads. They live in small, muddy ponds and quiet streams with abundant vegetation. They are of no commercial value, but the Alaska blackfish may be used for food for both dogs and people.

ALASKA BLACKFISH

Dallia pectoralis Bean

DISTINCTIVE CHARACTERS

The short, flattened snout; dorsal and anal fins far back; pectoral fins of about 33 rays and pelvic fin of only 3 rays identify the Alaska blackfish.

DESCRIPTION

Body elongate, cylindrical anteriorly but compressed posteriorly. Depth of body about 16% of total length. Head short, blunt, somewhat flattened, about 20% of TL. Snout short, near 20% of head. Eye small, round, its diameter usually somewhat less (75%) than snout length. Mouth large, broad, lower jaw protruding, maxillary reaches behind middle of eye. Small, sharp teeth present on lower jaw, premaxilla, palatines and head of vomer. No teeth on maxilla or tongue. Gill rakers 9-12, short. Branchiostegal rays 7-8 on each side. Lateral line with minute pores, 76-100 scales in mid-lateral series. No pyloric caeca.

Fins

D. 10-14, located far back on body. A. 12-16, more or less under dorsal. P_1. 32-36, edge of fin round. P_2. usually 3, the fins very small and located just before anus. Caudal fin broad, rounded.

Scales

Cycloid, small, more or less imbedded in skin.

Color

Dark green or brown above and on upper sides, pale below with dark speckles, four to six irregular dark bars or blotches on sides. Fins with dark brownish speckling. Dorsal, anal and caudal with pale margins, these margins pink to red in spawning males.

Size

In most of its normal habitat, the blackfish rarely exceeds about 200 mm in length. However, in the Yukon-Kuskokwim delta, fish up to about 255 mm are not uncommon. In the area around Anchorage, Alaska, fish up to 304 mm and 366 g have been recorded (Trent and Kubik, 1974) and one specimen of about 330 mm is known (Alaska Dept. Fish & Game, Anchorage).

RANGE AND ABUNDANCE

The Alaska blackfish is found in lowland areas in eastern Siberia, St. Matthew, St. Lawrence and Nunivak islands in the Bering Sea, and in Alaska. On the mainland of Alaska, its natural range is from the Colville River delta on the Arctic coast east and south to the central Alaska Peninsula near Chignik. It is present in the Yukon-Tanana drainage as far upstream as Big Eldorado Creek, near Fairbanks. Wherever it is present, it is usually quite abundant.

The Alaska blackfish was introduced successfully to St. Paul Island in the Pribilofs, unsuccessfully to Ontario. It was accidentally introduced into Hood-Spenard lakes at the Anchorage airport in the early 1950's and has thrived there. Subsequently, it spread via interconnecting waterways and illicit transplants to a number of other lakes in that area, where it creates a serious problem in the management of the sport fisheries for rainbow trout.

HABITS

Little is known of the biology of the Alaska blackfish. Spawning occurs in the spring and summer, beginning soon after break-up in May and continuing into July in the interior of Alaska, but apparently taking place only in late July in the Bristol Bay area (Blackett, 1962; Aspinwall, 1965). Upstream movement appears to coincide with a rise in water temperature to 10-15°C (50-59°F) (Blackett, 1962). Spawning has not been observed, but the eggs, about 1.5-2.3 mm in diameter, are probably deposited in vegetation at the bottom of shallow ponds and quiet streams (Nelson, 1887; personal observations). Females deposit from about 40 to about 300 eggs, the number increasing with the size of the fish. Spawning of a particular female probably goes on over a period of several days, possibly longer, with only a few eggs being extruded at each spawning act. At any rate, partially spawned females have been found during most of the spawning season. Nearly ripe ovarian eggs are yellow and opaque, but are not capable of being fertilized. Fully ripe eggs are nearly transparent. The fertilized eggs are demersal and extremely sticky. Females normally contain two sets of eggs, the large, mature ones about 2 mm in diameter, and a larger number of small "recruitment" eggs, which average less than 1 mm in diameter. These are presumably the eggs which will be spawned the following year.

Development to hatching requires about 10 days at 12-13°C (ca 54°F) under experimental conditions. The young are about 5.7 mm long at hatching and have a large yolk sac. By the tenth day post-hatching, the young are about 9 mm long and the yolk sac has virtually disappeared. By the 22nd day, the little fish are about 12 mm long and are beginning to take on the characteristics of the adults. At 20-21 mm, reached in about 44 days, metamorphosis is virtaully complete (Aspinwall, 1965). Subsequent growth in the first year of life is fairly rapid, but later slows. In interior Alaska and the Anchorage area, the blackfish reach about 64 (50-95) mm by age 1, 108 (76-146) mm at age 2, 138 (115-160) mm at age 3 and 178 (155-200) mm at 4. By contrast, fish from Lake Aleknagik in the Bristol Bay area grow very slowly.

A two year fish was only 36 mm long. A three was 50 mm, a four 63 mm, and one of 8 years was only 135 mm long. Sexual maturity is reached at 2 or 3 years of age, so some females probably spawn several times during their lives (Blackett, 1962; Aspinwall, 1965; Chlupach, 1975).

The blackfish does not undertake extensive movements, as far as is known. Its migrations appear to be limited to inshore or upstream movements to spawning grounds in the spring of the year, and (presumably) reverse migrations to deeper water in the fall.

Blackfish feed almost exclusively on small invertebrates. The smaller individuals subsist mostly on copepods and Cladocera, shifting, as they grow larger, to insects and small fishes. Hemiptera are especially important, but the diet also includes Diptera larvae, Trichoptera larvae, Ephemeroptera, Odonata, ostracods, molluscs, annelids and even algae (Ostdiek and Nardone, 1959; Chlupach, 1975). They also eat smaller members of their own kind. Because of their hardiness, their ability to tolerate crowding and low oxygen, and their diet, Alaska blackfish make tough competitors for rainbow trout wherever the two co-exist.

Blackfish are renowned for their cold tolerance, but despite the old story of frozen fish being eaten by dogs, thawed by the heat of the dogs' stomach and then vomited up alive (Turner, 1886), they cannot withstand complete freezing. Fish have survived exposure to -20°C for up to 40 minutes, and can survive for a few days after complete freezing of parts of the body, even the head. However, complete freezing results in death (Borodin, 1934; Scholander et al, 1953). Blackfish can also withstand complete anoxia for up to 24 hours if the temperature is 0°C (Bonnet, unpublished research).

IMPORTANCE TO MAN

The Alaska blackfish was formerly a most important source of food for the native peoples and their dogs. In the early 1880's, it was estimated that not less than 103.5 tons were taken annually in the Yukon-Kuskokwim delta alone, with 69 tons taken from October through December. Total harvest all along the coast was estimated at not less than 155 tons, and it was felt that double this amount might be a more realistic estimate (Nelson, 1884). Nowadays, however, such use has decreased greatly, although unknown quantities of blackfish are still utilized in some of the more remote villages.

The Alaska blackfish makes an interesting aquarium fish, but it shoud be noted that possession or export is prohibited by law unless a permit is secured.

SECTION 8

PIKES--FAMILY ESOCIDAE

The pikes are elongate, somewhat compressed fishes, with elongate, flattened snouts and large, sharp teeth. Five species in one genus are distributed in the northern hemisphere. One species is confined to Siberia, three are endemic to eastern North America, and the fifth, the northern pike, *Esox lucius*, is of circumpolar distribution.

Pikes are carnivores, their diets consisting mainly of other fishes. They are classified as game fishes in North America, although the smaller members of the family might not be so considered by some people. They are quite edible when properly prepared, and commercial fisheries for northern pike are important in the larger lakes of Canada and the United States. The muskellunge reaches the largest size of any of the six species, with an angling record of 31.8 kg (69 lb 15 oz). Next largest is the northern pike.

NORTHERN PIKE

Esox lucius Linnaeus

DISTINCTIVE CHARACTERS

The pike is easily recognized by its long, flat, "duck-bill" snout; large mouth with many large, sharp teeth; and the rearward position of the dorsal and anal fins.

DESCRIPTION

Body elongate, slender, moderately compressed, its depth 10-17% of total length. Head long, 25% or more of total length. Snout elongate, flattened, 40-47% of head length. Eye round, large, near middle of head length and close to dorsal surface. Mouth large, maxilla reaches to eye, lower jaw often projects beyond upper. Usually five large sensory pores on each side of lower surface of lower jaw. Large sharp canine teeth on lower jaw, head of vomer and inner edge of palatines. Smaller sharp, curved teeth on premaxilla, tongue, vomer and palatines, as well as on basi-/-and pharyngobranchials behind tongue. Gill rakers present only as patches of sharp teeth on gill arches. Branchiostegals 14 or 15 on each side. Lateral line with 55-65 pored scales, these scales notched posteriorly. Scales rows along middle of sides 105-148. No pyloric caeca.

Fins

D. 17-25 soft rays, fin located far posterior. A. 14-22, located under and arising a little behind dorsal fin. P_1. 14-17, low on body, base arising under opercle. P_2. 10-11, low on body, about at middle of total length. Both P_1 and P_2 rounded, paddle-shaped. Caudal fin slightly forked.

Scales

Cycloid, moderately small, with numerous pitted scales scattered over body.

Color

In adults, back and sides dark grayish-green to green or dark brownish, sides with numerous yellow spots arranged in irregular longitudinal rows. Scales usually with a tiny gold spot at edge. Belly and ventral surface of head creamy white. Dorsal, anal and caudal fins green to yellowish, sometimes more or less orange or reddish, marked with dark blotches. Pectoral and pelvic fins dusky. Head dark green above, pale below, an inconspicuous dark line running below eye.

Color of young pike is similar to that of adults except that the sides are marked with irregular pale vertical bars instead of spots, and the eye-bar is usually more conspicuous.

A color variant is the so-called "silver pike". Here the color is grayish green or deep blue on the back through silvery gray on the sides to creamy white below. There are no spots or bars on the sides, although pale marks may be present on the caudal peduncle. The fins are marked with small dark spots concentrated along the rays. This color variant is a genetic mutant that breeds true. It was first reported from the area near Sharbot Lake, Ontario (Prince, 1898), and subsequently has been found in north-central United States; in Ontario, Manitoba and Mackenzie in Canada; Sweden; and Alaska. It is said to be much hardier than the ordinary form (Eddy and Surber, 1947; Lawler, 1960, 1965b; Bartholomew et al, 1962).

Size

The northern pike in North America reaches at least 133 cm (4 ft) in length and 22.3 kg (49 lb) in weight. The angling record is a specimen of 21 kg (46 lb 2 oz) and 133 cm (52.5 in) length from Sacandaga Reservoir, N.Y. A pike said to have weighed "about 45 pounds" (20.5 kg) was taken near Circle, Alaska, in the early 1960's. European pike apparently get bigger than those of North America. There are authentic records of pike up to 26 kg (57 lb 3 oz) from Ireland and Scandinavia (Scott and Crossman, 1973) and an apparently authentic record of a 34 kg (74 lb 13 oz) fish from Lake Il'men' in Russia (Berg, 1948).

In most areas, the average pike caught by anglers will run between 1 and 3 kg (2-6.6 lb) weight. A fish of over 7 kg (15 lb) is a very good one and one of more than 11 kg (24 lb) would be considered rather remarkable.

RANGE AND ABUNDANCE

The northern pike is circumpolar in fresh water. It is present widely in Europe as far south as Spain and northern Italy, with an east-west distribution from the British Isles to the Pacific shores of Siberia. In North America, the pike ranges from western Alaska to eastern Canada (though absent from the Keewatin Peninsula) and from the Arctic coast south to Nebraska, Missouri, southern New England. Except in the Ahrnklin River drainage in Alaska and the headwaters of the Alsek and Taku rivers in Yukon Territory and British Columbia, pike do not occur naturally west of the continental divide. Pike have been introduced into a number of places in the United States, and the introductions are a nuisance or a blessing, according to one's point of view. Recent illegal transplants by private individuals have placed pike in the Susitna River drainage in Alaska.

HABITS

Pike spend the winter in relatively deep water in lakes and rivers. With the approach of spring, they begin to move inshore or upstream to the marsh areas where they spawn. This movement usually occurs soon after the ice goes out (Clark, 1950), but may start even before that in far northern areas (Cheney, 1972). Most of this movement to the spawning grounds takes place at night (Franklin and Smith, 1963). Spawning does not begin until water temperatures in the shallows reach about 6-9°C (43-48°F) (Bennett, 1948; Clark, 1950, Cheney, 1971).

The spawning grounds are marshy areas, with shallow water, emergent vegetation and a mud bottom covered with a vegetation mat. Suitable vegetation and quiet water seem to be the most important factors in the choice of spawning areas. Actual spawning occurs in water less than 51 cm (20 in) deep, with most activity in water of less than half that depth (Clark, 1950). A male (sometimes two or three males) courts a female by pushing with his snout against her head and pectoral region. If the female is not yet ripe or is spawned out she repels the male by turning her head to one side and straightening with a jerk. She may also adopt the threat posture, with branchiostegals lowered, back arched, paired fins spread downward. Although pike are not territorial or monogamous, a male attending a female may threaten other males with this same posture.

If the female is receptive, the two fish swim about side by side, apparently oriented eye to eye. At mating, both fish lower the branchiostegals and swimming speed increases. The male flaps his caudal fin towards the female, then swings the caudal sharply away from her and brakes with his paired fins. This thrusts his vent close to that of the female, and he ejects milt. At the same time, the female erects her pelvic fins, thrusts her caudal fin towards the male, and, by powerful contractions of her abdominal muscles, ejects some eggs. The final return of the caudal fins to normal position mixes eggs and sperm, and scatters the eggs. Only a few eggs, 5 to 60, are released at a time. The spawning act is repeated every few minutes for up to several hours, after which the fish rest for some time before resuming spawning. During this resting period, both male and female may take new mates, or they may continue together for several days until the female's eggs are all extruded. Spawning occurs only during daylight, and reduced light, as from cloud cover or ripples on the water reduces spawning activity. Excessively cold nights have the same effect (Svärdson, 1949; Clark, 1950; Fabricius and Gustafson, 1958). The spawned out adults may stay on the spawning grounds for as long as 3 1/2 months, but most leave within 6 weeks.

The eggs are 2.5-3.0 mm in diameter, tan to yellow in color. Egg number increases with the size of the fish, from as few as 2,000 in fish of about 33 cm (14 in) to nearly 600,000 in a fish weighing 14.5 kg. Ripe females contain both large, ripe eggs and minute, immature eggs which will ripen the following year. Thus, new eggs continue to develop during the life of the individual. Some of the immature eggs are resorbed between spawning periods, as are all of the residual mature eggs (Carbine, 1944). Fertilization is usually highly efficient. After fertilization, the eggs settle to rest on the weeds or the bottom. Development time to hatching varies inversely with temperature. At 6°C, 23-29 days are required, but at 18°C, only 4-5 days. Mortality rates of the eggs tend to increase with increasing temperatures (Swift, 1965). The newly hatched larvae are 6.5-9.3 mm long and have a yolk sac but no mouth. The mouth develops at 10.5-12 mm, by which time the yolk sac is absorbed. Active feeding begins when the young fish are 11-13 mm long about 10 days after hatching (Franklin and Smith, 1960). Early foods are various entomostracan zooplankters, especially copepods and cladocerans. As the little fish grow, they shift to insect larvae and nymphs, mainly Tendepedidae, then to fish and other small vertebrates. By the time they are about 50 mm (2 in) long, the little pike are feeding almost exclusively on fish (Hunt Carbine, 1951; Mateeva, 1955; Franklin and Smith, 1970, 1963).

When the young have reached a length of about 20 mm, they begin to move out of the marshes. Movement is in the daytime and is positively correlated with light intensity. Mortality from the fertilized egg to migrant fry is heavy, as much as 99.9%. Competition for food, predation and cannibalism are the most important factors here. Water quality also may be important, as the fry are rather sensitive to extremes of pH and the concentrations of carbonate and bicarbonate (Hunt and Carbine, 1951; McCarraher, 1962; Franklin and Smith, 1963).

Growth of the young is rapid, about 0.5 mm per day for the first 20 days, about 2 mm per day for the next 30 days, and about 1 mm per day for the next 40 days. The fastest growers are those which first make the shift to a fish diet. These young are especially likely to become cannibals. One fish of only 23 mm had eaten another young pike of 16 mm (Hunt and Carbine, 1951). The fastest growing fish may achieve a length of 446 mm (17.5 in) and a weight of 460 grams (1 lb) by mid-October. This represents growth in length at the rate of 2.6 mm per day from hatching, and in weight of 2.69 grams per day (Carbine, 1945).

Growth remains rapid in the first year, although it depends on temperature and the availability of food. Subsequently, as with most fishes, the growth rate slows (Rawson, 1932; Van Engel, 1940; Lagler, 1956; McCarraher, 1959; Cheney, 1972). Pike appear to require less food for maintenance than do most fishes and are therefore able to convert a relatively large portion of their ration into growth. After maintenance requirements have been met, 1 gram of food will produce 0.437 grams of pike, a ratio of 2.29:1. Peak maintenance requirements occur in late spring, then decline and remain low through the winter, rising again in the spring (Johnson, 1966). This cycle appears to be related to the energy requirements of reproduction.

Growth rates tend to be faster in the warmer, southern parts of the range than they are in the far north, but northern fish live longer. However, even within a relatively small area, growth is highly variable from one body of water to another. The average size of fish of a given age may vary by a factor of 2 or even more, and the difference between the largest and smallest may represent almost a full order of magnitude. In the Minto Flats area of interior Alaska, pike reach average lengths of 140 mm (5.5 in) by September of their first year of life, 186 mm (7.3 in) as 1 year olds, 287 mm (11.3 in) at 2 years, 555 mm (21.9 in) at 5 years, 801 mm (31.5 in) at 10 years; and 990 mm (39 in) at 21 years. These growth rates are rather faster than those found in Great Bear, Great Slave, Lesser Slave, and Athabasca lakes in northern Canada, or in a number of small lakes in the upper Tanana River drainage in Alaska (Miller and Kennedy, 1948b; Cheney, 1972).

Adult pike feed almost exclusively on fish, the kinds eaten depending largely on what is available. The variety of species eaten is tremendous and often includes smaller pike. Other organisms included in the diet include water fowl, frogs, small mammals such as mice and shrews, crayfish and insects. In Alaska, coregonids appear to be the major food item, followed by by small pike, blackfish, burbot and suckers, as well as insects, especially Odonata naiads. In general, pike seem to eat whatever they can catch and swallow (Lagler, 1956; Lawler, 1965b; Cheney, 1971). Digestion of fish food is fairly rapid at usual summer temperature, with digestion 50% complete in 20 hours. Birds, on the other hand, require a much longer time, almost 130 hours for 50% digestion, due, no doubt, to the protection provided by the feathers (Solman, 1945; Seaburg and Moyle, 1964). Pike are believed to be serious predators of young waterfowl. This is no doubt true in some places, but not in others. In the deltas of the Saskatchewan and Athabasca rivers in Canada, pike were estimated to eat nearly 10% of the young ducklings, but in the Seney National Wildlife Refuge in Michigan, only 0.2% of the pike stomachs examined contained waterfowl (Solman, 1945; Lagler, 1956).

Pike do not, as a rule, undertake long migrations, although occasional individuals may move considerable distances. In the Minto Flats, in interior Alaska, 36% of the fish tagged moved more than 10 miles during the summers. The Minto Flats lakes become anoxic in winter and the pike must travel considerable distances to find suitable wintering areas. One fish moved 288 km (180 mi) downstream in 10 months (Cheney, 1971).

Different populations of pike often show statistically significant differences in such things as the numbers of fin rays, lateral line pores and vertebrae. These differences may indicate isolation in separate glacial refuges. However, since such differences have been found in lakes only 32 km (20 miles) apart and draining into the same river, even interpretation is open to question. There is certainly no strong evidence to indicate subspeciation (Morrow, 1964; McPhail and Lindsey, 1970; Cheney, 1972).

IMPORTANCE TO MAN

The pike enjoys a most varied reputation. In some areas it is considered a nuisance, scarcely worthy of the name fish, but in other regions it is highly regarded and attracts large numbers of anglers and dollars. Pike will take a large variety of lures and live baits. They put up a strong fight at first, but it is usually of fairly short duration. They seldom jump, but will often rear out of the water, shaking their heads and all too frequently throwing the hook. Much of the reason behind the pike's poor reputation as a sport fish is too heavy gear. Taken on light tackle, pike give very good accounts of themselves. A short wire leader is a necessity, as the pike's sharp teeth are all too liable to cut a line.

On the commercial side, the pike is unimportant in the United States. Landings from 1960 through 1970, almost entirely from the Great Lakes, averaged only a bit more than 79,500 kg (175,000 lb) per year. On the other hand, the Canadian catch runs on the order of 2,273,000 kg (5,000,000 lb) per year, much of which is exported to the United States. Pike are usually sold fresh, generally in the round or gutted and beheaded.

For eating purposes, pike are delicious. The meat is white, flakey and flavorful. The so-called "muddy" taste of which some people complain is confined to the skin. If the fish be thoroughly scaled, scrubbed and washed, the muddy taste is eliminated. But it is better and easier to skin the fish.

Another complaint against pike is its boniness. The dorsal ribs or Y-bones are only lightly fastened to the backbone and tend to come loose in the meat. However, with a very sharp knife and a little practice, it is easy to cut boneless filets of pike and thus eliminate the problem.

Pike are often used as farm-pond fish, particularly in combination with blue gills. They seem able to crop the forage fish at such a rate that the latter cannot overpopulate and become stunted.

SECTION 9

MINNOWS--FAMILY CYPRINIDAE

This is the largest of all families of fishes, including some 275 genera and more than 1500 species. They are virtually world-wide in their distribution, being absent only from Australia, South America and Greenland. They are of variable shape, but generally are moderately elongate. They have no spines in the fins, although some forms, such as carp, may have the first one or two rays of the dorsal and/or anal fin stiffened and spine-like. Sexual dimorphism is often marked in the spawning season, when the males may develop breeding tubercles and/or bright colors. The larger species, such as carp, are used for human food in some parts of the world. However, most members of the family are small and find their chief value as forage for larger fishes.

LAKE CHUB

<u>Couesius plumbeus</u> (Agassiz)

DISTINCTIVE CHARACTERS

The spineless fins, normal jaws, and tiny barbet at the corner of the mouth distinguish the lake chub from other Alaskan fishes.

DESCRIPTION

Body elongate, slender. Depth 14-21% of total length. Head short, about 19-22% of total length, relatively longest in young fish. Snout moderate, rounded, a little shorter than eye diameter. Eye round, about 25% (20-33%) of head. Mouth fairly small, slightly oblique, upper jaw usually extending slightly beyond lower anteriorly and reaching posteriorly about to anterior edge of eye. A small but well developed barbel near posterior end of maxilla. No teeth in jaws, but pharyngeal (throat) teeth well developed, usually 2, 4-4, 2, but variable. Gill rakers short, 4-9 on first arch. Branchiostegals 3 on each side. Lateral line with 53-79 pores, usually 56-69.

Scales

Cycloid, small, those on back often smaller than those on sides. Breeding adults develop nuptial tubercles on the head and along the back of the dorsal fin as well as on the upper parts of the pectoral fins and on the breast. These tubercles are better developed in males than in females.

Color

Brown to greenish above, silvery below. A rather indistinct dark or lead-colored band along sides, often extending forward on to head in small specimens. Lower sides and belly often with fine dots of dark pigment. In some populations, breeding males develop bright orange-red patches on sides of head and at bases of pectoral fins (Richardson, 1944), but the presence of this color varies from place to place. So far, orange patches have not been found in Alaskan lake chubs.

Size

Known to reach 227 mm (8.94 in) total length in northern Quebec (Scott and Crossman, 1973), but most are 50-100 mm (2-4 in) long.

RANGE AND ABUNDANCE

The lake chub is strictly North American. It ranges from interior Alaska east to Nova Scotia and from the Arctic coast at the McKenzie River delta and Ungava Bay south to New England and the Great Lakes, except Lake Erie. Scattered, isolated populations are present in Iowa, Nebraska, Wyoming, Colorado, Montana and the Dakotas. In Alaska, the lake chub seems to be confined to the Yukon-Koyokuk-Tanana-Porcupine drainage, from about Nulato on upstream. Wherever it is present at all, the lake chub is usually one of the more abundant fishes.

HABITS

Despite the fact that the lake chub is wide-spread and common, very little is known about it. Spawning apparently occurs in the spring and summer, as early as April in the southern part of its range and as late as August in the far north (McPhail and Lindsey, 1970; Scott and Crossman, 1973). Spawning occurs in shallow water over rocky or gravelly bottoms in rivers and smaller streams (Allin, 1953; McPhail and Lindsey, 1970), the fish moving out of lakes or deeper parts of streams in large schools for this purpose. No nest or redd is built, nor do the adults guard the eggs (McPhail and Lindsey, 1970). In Lake Superior, the lake chub occasionally hybridizes with the longnose dace, Rhinichthys cataractae (Hubbs and Lagler, 1949). The eggs are yellowish in color. A female of 70 mm length was estimated to contain about 500 eggs (Richardson, 1935). Nothing has been reported of spawning behavior or rate of development of eggs and young. In Pyramid Lake, Alberta, one year old chubs averaged about 28 mm long, 2-year-olds 48 mm, 3-year-olds 71 mm, and 4-year-olds 114 mm (Rawson and Elsey, 1950). Lake chubs are thought to mature at 3 or 4 years of age, seldom surviving beyond 5 years, in central British Columbia. Females apparently grow faster and live longer than do males (McPhail and Lindsey, 1970).

Young lake chub feed primarily on zooplankton, chiefly cladocerans and copepods, while older fish eat mostly insect larvae and algae. Large chubs may also take small fishes (Simon, 1946; Rawson and Elsey, 1950; McPhail and Lindsey, 1970; Scott and Crossman, 1973).

The lake chub inhabits all sorts of waters - lakes, clear streams, heavily silted rivers. In general, it seems to be most common in fairly shallow water, but may move into deeper parts of lakes during hot weather. In some areas, as Great Bear Lake, NWT, it is found only in streams, in others it seems to utilize stream habitats only for spawning, while in still other places it inhabits streams almost exclusively (Hubbs and Lagler, 1949; Allin, 1953; Personius and Eddy, 1955; Johnson, 1975). In interior Alaska, in the Tanana and upper Yukon drainages, it is much more common in the heavily-silted main rivers than in the clear tributaries (personal observation).

The lake chub has been classified as a sight feeder, since it has large optic lobes and relatively few taste buds (Davis and Miller, 1967). However, since it is so common in heavily-silted rivers, where visibility is virtually nil, other mechanisms for finding food must also be present.

IMPORTANCE TO MAN

The lake chub is of little direct importance. In some regions, anglers use it extensively for bait. It is said to be a nuisance in some trout fisheries, for it takes bait or fly readily and "it is almost impossible to make a cast without catching one of these minnows" (Allin, 1953). Lake chub, in view of their diet, distribution and abundance, are probably an important forage species, but confirmatory data are lacking.

In Ontario streams, the lake chub is sometimes taken and eaten by smelt fishermen who do not recognize it (Scott and Crossman, 1973). It has been cold-smoked, with satisfactory results (Lantz, 1962).

SECTION 10

SUCKERS--FAMILY CATOSTOMIDAE

These fishes are elongate, mostly subcylindrical, with a ventrally-placed, protrusible mouth and no teeth in the jaws. They feed by swimming slowly along the bottom, sucking up the bottom debris, including therein the small insect larvae and other invertebrates that live on or in the bottom. Some of the suckers may reach considerable size, up to several kg.

There are about 65 species of suckers, all but two of them found only in North America. One of the remaining species is endemic to southern China, while the other, the longnose sucker of North America, is also present in eastern Siberia.

Suckers are generally considered more of a nuisance than anything else, especially by trout fishermen. They are popularly supposed to do great damage to the eggs of other fishes, but the supposed extent of this damage is probably greatly exaggerated. The larger species, especially the longnose sucker and white sucker, are taken commercially in the Great Lakes and the large Canadian lakes and are marketed as "mullet". Suckers make excellent bait for large game fish such as pike and bass.

LONGNOSE SUCKER

Catostomus catostomus (Forster)

DISTINCTIVE CHARACTERS

The ventrally-placed sucking mouth with thick, papillose lips distinguishes the longnose sucker from all other Alaskan fishes.

DISCRIPTION

Body elongate, nearly cylindrical. Depth of body greatest somewhat forward of dorsal fin, 14-19% of TL. Head long, about 20% of TL, top of head rounded and scaleless. Snout long, 38-48% of head length, ending anteriorly in a rounded point. Eye round, small, its diameter about 22-31% of snout length. Mouth ventrally located, behind tip of snout, protrusible. Lips, especially upper, thick and papillose. No teeth in jaws. Pharyngeal teeth numerous, comb-like, in single rows. Gill rakers short, 23-30 on first arch. Branchiostegals 3 on each side. No proper, well-differentiated stomach, no pyloric caeca. Lateral line complete, inconspicuous, with 90-120 pored scales.

Fins

D. 9-11. A. 7, P_1. 16-18. P_2. 10-11. Caudal moderately forked, the tips slightly rounded.

Scales

Cycloid, small.

Color

Adults may be reddish brown, dark brassy green or gray to black above, paler on the lower sides, the ventral parts white. Young fish are usually dark gray with mottling of paler color on the back. Young of the year are gray with small black spots. Breeding males are usually dark above with a brilliant reddish stripe along each side, while females are greenish gold to copper, with a less brilliant red stripe. The breeding males show prominent tubercles on the rays of the anal and caudal fins, and also on the head.

Size

The longnose sucker is reported to reach a length of 643 mm (25 in) and a weight of 3.3 kg (7.26 lbs) (Keleher, 1961), but the usual run of fish are much smaller.

RANGE AND ABUNDANCE

The longnose sucker ranges from New England to Labrador in the east, westward through the Great Lakes, the northern part of the Mississippi-Missouri system and the Columbia to the west coast. It reaches the Arctic Ocean in northeastern Labrador, but is absent from the arctic coast of Canada from Ungava to the Horton River. Present throughout the rest of mainland Canada (except Nova Scotia and eastern Labrador) and Alaska, but absent from the islands along the Pacific and Bering coasts and from the arctic islands. Found also in eastern Siberia from the Yana to the Anadyr rivers.

In North America, the longnose sucker is abundant throughout the northern part of its range, especially in the northwest.

HABITS

Breeding occurs in the spring, as early as May in the southern part of the range, as late as July in the far north. Spawning runs begin after water temperatures have reached 5°C, with greatest intensity occurring at temperatures above 10°C (Rawson and Elsey, 1950; Brown and Graham, 1954; Geen, et al, 1966). The fish move from lakes into inlet streams or from slow, deep pools into shallow, gravel-bottomed portions of streams. Spawning occurs only during daylight hours most commonly over gravel of 0.5-10 cm diameter, in shallow water 10-60 cm deep with a current of 30-45 cm/sec (Geen et al, 1966). At spawning time, the males lie close to the bottom in the current of the spawning area and show no aggressive behavior, while the females stay along the banks and in still water. In the breeding act, a female swims out to the males, 2-4 of whom escort and crowd around her. Dorsal fins erect, the males clasp the female with their pelvic fins and vibrate their anal fins against her. There is considerable thrashing about for a few seconds during which eggs and sperm are released. No nest is built. After a spawning, the female returns to quiet water. She may spawn many times in an hour, with the same or different males. A single female may produce up to 60,300 eggs (Harris, 1962; Geen et al, 1966). Fish which have moved out of a lake to spawn generally return to the lake a few days after spawning is completed. However, river-resident fish may stay on or near the spawning area for much of the summer.

Post-spawning mortality of adults is on the order of 10-30%. Many fish spawn in two or even three consecutive years, while others may skip one or two years between spawnings (Geen et al, 1966).

The eggs are about 3 mm in diameter, yellow in color, adhesive and demersal, sinking to the bottom and lodging in crevices in the gravel. Development to hatching takes one to two weeks, according to temperature. The young are about 8 mm long at hatching and remain in the gravel for one to two weeks. In some areas, a nocturnal, downstream movement of fry begins as soon as the fish emerge from the gravel. However, in interior Alaska at least some of the young stay in the streams all summer.

Growth rates vary tremendously from place to place, apparently correlated more with food supply than with temperature. In Great Slave Lake, young of the year may reach 80 mm FL by the end of August, but in Yellowstone Lake they are less than half that length (Brown and Graham, 1954; Harris, 1962). Similar variations in growth rates are continued through later years of life. Even in a single population, the largest fish of a given age may be twice as long as the smallest. Age determinations by means of scales, which often underestimate the true age (Geen et al, 1966), have given the following age-length relationship for suckers from the south end of Great Slave Lake, one of the faster growing populations recorded (Harris, 1962): 2 yrs, 179 mm; 5 yrs, 306 mm; 10 yrs, 496 mm; 15 yrs, 557 mm.

Age at maturity increases with latitude. Sexual maturity is achieved at 2 years by males, 3 years by females in Colorado, 4 and 5 years in Yellowstone Lake, but not until 9 or 10 years of age in Great Slave Lake. The oldest fish on record is one of 19 years from the northern part of Great Slave Lake (Brown and Graham, 1954; Hayes, 1956; Harris, 1962).

Except for movement to and from the spawning areas, the longnose sucker apparently does not undertake any definite migrations. During the summer, fish in interior Alaskan streams appear to wander more or less at random, some going upstream, some down. The general trend of movement is down stream, however, so that by October no suckers remain the the upper reaches or on the spawning areas.

The longnose sucker feeds almost entirely on material found on the bottom. The fish swim slowly along, their protrusible lips touching the bottom in a way which suggests that the papillae have a sensory function. Food is sucked into the mouth and swallowed. In streams, major food items of the adults include algae and other plants, Diptera, Ephemeroptera, Trichoptera, Coleoptera, spiders, molluscs. Lake-dwelling adults feed mainly on various crustaceans, especially cladocerans and amphipods, as well as insect larvae and nymphs. Diptera and Ephemeroptera are the most important of these. Occasionally, large adult suckers will feed upside down on terrestrial insects floating on the surface of eddies. The very young fish seem to feed chiefly on cladocera and insects.

The longnose sucker is reputed to destroy the spawn of other fishes, especially trout. Undoubtedly, fish eggs are eaten when available, but, as far as trout eggs are concerned, these are undoubtedly "floaters", which were washed out of the redd or were dug up by subsequent spawners (Stenton, 1951).

IMPORTANCE TO MAN

Utilization by man of the longnose sucker ranges from zero to extensive. In many areas, it is a major source of dog food. In the Great Lakes and the Canadian lakes, considerable amounts are landed and marketed, together with other suckers, as "mullet". The flesh is said to be firm, white, flaky and sweet, although bony. This may be true of fish taken in the winter, but the flesh of spawning fish is soft and glutinous and has an unpleasant taste.

Because of the similarity in food habits, longnose suckers are important competitors with trout and other desirable sport fish. An intensive gill netting program to remove longnose suckers from Pyramid Lake, Alberta, resulted only in improved growth of young suckers and did not improve angling success (Rawson and Elsey, 1950).

SECTION 11

TROUT-PERCHES--FAMILY PERCOPSIDAE

This family, which includes only two species, gets its name because the fish have some of the characteristics of the trouts and some of the characteristics of the perches. They have, for example, a dorsal adipose fin and abdominally placed pelvic fins, like the trouts; but there are one or two spines in the dorsal, anal and pelvic fins and the scales are ctenoid, like the perches.

The trout-perches are known only from North America. One species, the sand roller, is found in Washington, Oregon and Idaho. The other, the trout-perch is wide-spread over much of the northern U. S. and Canada.

Trout-perches are important forage species for larger fishes.

TROUT-PERCH

Percopsis omiscomaycus (Walbaum)

DISTINCTIVE CHARACTERS

The combination of a dorsal adipose fin; small, weak spines in the dorsal and anal fins; rough, ctenoid scales; and pectoral fins reaching well behind the bases of the pelvic fins distinguishes the trout-perch from all other Alaskan freshwater fishes.

DESCRIPTION

Body elongate, terete, noticeably heavier anteriorly. Greatest depth just behind head, about 18% of TL. Head large, more or less conical, its length 22-27% of TL. Snout long, rounded anteriorly, 30-38% of head length. Eye round, large, 22-27% of head. Mouth small, subterminal, maxillary not reaching eye. Teeth small, bristle-like, in bands on lower jaw and premaxilla. No teeth elsewhere in mouth. Gill rakers short, stubby mounds with small teeth, 8-13 on first gill arch. Branchiostegals 5-7, usually 6, on each side. Lateral line nearly straight with 41-60 pored scales. Pyloric caeca 7-14.

Fins

D. I-III (usually II), 9-11, adipose dorsal fin present. A. I, 5-8. P_1. 12-15. P_2. 8-9. Caudal forked.

Scales

Rather large, ctenoid, noticeably rough to the touch when brushed from tail to head. No scales on head or nape.

Color

Pale yellowish to silvery, often almost transparent. A row of about 10 dark spots along midline of back, 10 or 11 along lateral line, another row of spots high on sides above lateral line. Fins transparent.

Size

The maximum size attained in the southern part of the range is said to be about 200 mm (8 in). In most areas, however, the largest are only about half this size. Alaskan specimens have run up to about 80 mm.

RANGE AND ABUNDANCE

Trout-perch are found in North America. They range from the Del-Mar-Va peninsula north to the shore of Hudson's Bay, west through West Virginia, Tennessee and Missouri, northwesterly in the Mississippi drainage to the prairie provinces and north eastern British Columbia, northward in the Mackenzie drainage to the Arctic coast and down the Porcupine and Yukon Rivers almost to the mouth. In Alaska, it has been found at the mouths of the Tatonduk, Kandik and Charlie rivers, at Circle and Nulato, and at the mouth of the Andreafsky River (UAFC #327; Morrow, 1965; McPhail and Lindsey, 1970).

The trout-perch appears to be rare in Alaska (Morrow, 1965), but in other areas it is an abundant species. In Heming Lake, Manitoba, the population of adult fish was estimated at 2929-3636 fish per hectare (Lawler and Fitz-Earle, 1968).

HABITS

Spawning takes place in late spring and summer. In Red Lake, Minnesota, spawning fish were found from early June to mid-August (Magnuson and Smith, 1963), while in Heming Lake, Manitoba, most spawning occurred in the latter half of May (Lawler, 1954). In Lake Erie, ripe individuals have been taken from early May to mid-August (Scott and Crossman, 1973). Ripe fish were taken at Circle, Alaska, on June 28 (McPhail and Lindsey, 1970).

At spawning time, adults move inshore to shallow water, or into shallow tributaries of lakes (Magnuson and Smith, 1963; Langlois, 1954). Males generally dominate the spawning population, sometimes by as much as 10:1. Some populations breed almost exclusively at night (Magnuson and Smith, 1963), but others show no diurnal variation (Lawler, 1954). In the spawning act, two or more males cluster with a single female within four or five inches of the surface. They press close to the female, often breaking the surface of the water, and eggs and milt are released. The eggs are yellowish in color, about 1.5 mm in diameter before fertilization, demersal and sticky. They sink to the bottom and adhere to whatever they settle upon. Water hardened eggs are about 1.9 mm in diameter. Females 60-78 mm FL produce 210-728 eggs, larger fish having more eggs (Lawler, 1954). Spawning has been observed in water with temperatures between 4.5° and 17°C (Lawler, 1954). Hatching occurs in about one week at 20°-23°C (Lawler, 1954; Magnuson and Smith, 1963). Because Alaskan streams are so much colder than this, it is probable that trout-perch eggs here require at least twice as long to hatch.

The young are about 5.5 mm long at hatching. They have a prominent yolk sac, a large head with a prominent, pointed snout and a small, inferior mouth, an oval eye, and are unpigmented save for a number of large, black, stellate chromatophores on the yolk sac. By 7 mm in length, the yolk sac has been absorbed and only a few large pigment cells are present on the right side of the stomach region. All fins except the pelvics are well-developed by the time the larvae are 9.5 mm long; the pelvics are just beginning to appear at this stage. The young trout-perch leave the shallows and move out into deep water about three weeks after hatching (Magnuson and Smith, 1963). The young fish at 50 mm is completely transformed and is fully scaled (Fish, 1932). By the end of the first growing season, they may achieve lengths of 50-84 mm, although Alaskan fish appear to grow much slower than this. Average length at one year of age is about 81 mm; at two years, 94 mm; at three, 102 mm; and at four, 115 mm. Females grow faster and live longer than males. Males apparently do not survive beyond the third year (Trautman, 1957; Magnuson and Smith, 1963).

Males begin to mature in their second summer (age 1+), but most females do not mature until a year later. This difference in age at first maturity apparently accounts, at least in part, for the predominance of males in the spawning populations. Spawning groups are composed of 25-31% one-year-olds, 61-71% two-year-olds, 4-8% three-year-olds and 0-1% four-year-olds (Lawler, 1954; Magnuson and Smith, 1963). There is often (usually?) heavy post-spawning mortality. Amongst 2-year-olds, 96% of the males and 67% of the females die after spawning; for 3-year-olds, 100% of males and 96% of females; and all four year old females (Magnuson and Smith, 1963).

Trout-perch are typically found in fairly deep water, 10-61 m, in lakes, or in long, deep pools in streams. They move into shallow water for spawning. Diurnal movements are rather noticeable, for the trout-perch spends the day either in deep water (in lakes) or under cut-banks, roots, debris, etc. (in streams), moving into the shallows to feed at night. Major foods are algae (Microcystis), Cladocera, amphipods and the larvae of Chironomids and mayflies. Small fishes are sometimes eaten in the winter (Nurnberger, 1930; Langlois, 1954; Trautman, 1957).

IMPORTANCE TO MAN

The trout-perch is of no direct importance to man. However, it is an important forage fish for larger carnivores wherever it is abundant. It is known to be a major food for such fishes as pike, burbot, wall-eye, lake trout and others. Its habit of feeding in the shallows, then moving to deep water where it, in turn, is fed upon by larger fishes, may make it an important factor in nutrient transfer, especially in stratified lakes (Lawler, 1954; Langlois, 1954; McPhail and Lindsey, 1970).

SECTION 12

CODFISHES--FAMILY GADIDAE

The codfishes are a large family, most marine. They have large heads, wide gill openings, two or three dorsal fins and one or two anal fins, with no spines in any fins, and usually have a small barbel at the tip of the chin.

Cods are mostly northern hemisphere marine fishes, some of which enter fresh water. One species, the burbot, is strictly freshwater and has a circumpolar distribution in the northern hemisphere. A few species are known from the southern oceans.

The larger forms are very important food fishes and are the objects of wide-spread and intensive commercial fisheries.

BURBOT

Lota lota (Linnaeus)

DISTINCTIVE CHARACTERS

The long second dorsal fin, at least six times as long as the first, and a single barbel on the chin distinguish the burbot.

DESCRIPTION

Body enlongate, robust and nearly round anteriorly, strongly compressed behind anus. Depth 13-15% of total length. Head flattened, broad, its length 19-20% of total length. Snout long, 27-33% of head length. Each nostril in a prominent tube. Eye small, its diameter about 30% of snout length. Mouth terminal, large, upper jaw reaching to below eye. A single, prominent barbel present at tip of lower jaw. Teeth small and numerous, in bands on jaws and head of vomer. Gill rakers short, 7-12 on first arch. Branchiostegals 6-8 on each side.

Fins

D_1. short, 8-16 rays. D_2. long, at least six times length of D_1, with 60-80 rays, joined to caudal. A. 58-79, joined to caudal. P_1. 17-21, the fin short and rounded. P_2. 5-8, second ray elongate and filamentous. Caudal fin rounded.

Scales

Minute, cycloid, embedded in the skin.

Color

Yellowish through brown to dark olive green above and on sides, color generally darker in northern regions but also depending to some degree on the color of the local environment. Sides blotched and mottled with pale and dark shades, ventral parts usually pale yellow or white. Pelvic fins pale, others dark and mottled.

Size

Reported up to 34 kg (75 lb) and 1,524 mm (5 ft) long in Alaska (Turner, 1886; Dall, 1898), but the angling record for the state is only 10.2 kg (22.5 lb). The average angler-caught fish probably weigh in the neighborhood of 0.5-1 kg (1-2 lbs).

RANGE AND ABUNDANCE

The burbot is circumpolar in the northern hemisphere. It is present, in one or another of several subspecies, all across northern North America from about 40°N to the Arctic Ocean, excluding only coastal Quebec and Labrador and the northeastern part of Keewatin. In Europe and Asia it is to be found from the Pacific (though not on Kamschatka) to the Atlantic, but is missing from northern Scandinavia, Scotland and Ireland. Throughout its range it is moderately to extremely abundant. In some of the lakes of north-central North America, burbot are so numerous as to be a nuisance to commercial gill-netters (Hewson, 1955).

HABITS

Burbots are winter spawners. The gonads begin to enlarge in August, but spawning does not begin until well into winter. Depending on geographical location, the actual spawning period may be from as early as mid-December to as late as early April, with most populations breeding in January or February (Cahn, 1936; Bjorn, 1940; Hewson, 1955; Mac Crimmon, 1959; Lawler, 1963; Chen, 1969). In Alaska, as in most other areas, spawning apparently occurs in late January and February (Chen, 1969). In the spawning act, which is difficult to observe, since it goes on at night under the ice and the fish show strong negative phototrophism, the burbot congregate in moderately shallow water, 0.3 to more than 1.5 m (1-5 ft) deep but sometimes in 18-20 meters (Clemens, 1951b), over bottom composed of clean sand, gravel and stones. The males reach the spawning area first. At breeding, males and females form a great globular mass of fish, individuals pushing toward the center and releasing eggs or sperm (Cahn, 1936), or at least milling around close together (Mac Crimmon, 1959). There is no pairing, although Fabricius (1954) observed definite pairing of European burbot in an aquarium.

Burbot mature at 2-4 years of age in the southern part of the range, but not until six or seven years in interior Alaska (Chen, 1969). An average adult female will produce between 500,000 and 750,000 eggs, with numbers up to nearly 1,500,000 having been recorded (Bjorn, 1940; Lawler, 1963; Chen, 1969). Egg size seems to be quite variable, from a diameter of 1.7 mm in Lake Erie to as little as 0.5 mm in Heming Lake, Manitoba. The eggs of interior Alaskan fish range between 0.71 and 0.87 mm (Fish, 1932; Lawler, 1963; Chen, 1969). The eggs are not sticky, but are demersal and contain an oil globule. After being spawned, they settle to the bottom and develop without any care from the parents. Development time varies with temperature, possibly also with the particular population. At 6.1°C, hatching occurs in about 30 days, but 71 days are needed at temperatures between about 0 and 3.6°C (Bjorn, 1940; Mac Crimmon, 1959).

The newly hatched larvae are only 3-4 mm long, colorless, transparent and without a yolk sac. Fin rays begin to appear in the dorsal, anal and caudal fins at about 10 mm. By the time the young are about 19 mm long, fin rays are present in all fins, the chin barbel is present and the little fish is readily recognized as a burbot (Fish, 1932). Young burbot at this stage of development have been found in the Chena River, interior Alaska, in June (Chen, 1969).

Growth rates are quite variable from place to place. As a generality, it may be said that fish in the northern part of the range tend to grow more slowly and to live longer than fish in more southern regions, although there are exceptions. Males tend to be shorter lived than females and to grow more slowly after age 10. Typical lengths at various ages for burbot in interior Alaska are: 1+, 136 mm; 2+, 185 mm; 3+, 238 mm; 4+, 283 mm; 5+, 355 mm, 10+, 595 mm; 15+, 715 mm; 20+, 871 mm; 24+, 972 mm (Chen, 1969). Fish from lakes Erie, Simcoe and Winnipeg, for example, grew much faster than Alaskan fish, but those from Heming Lake, Manitoba, grew more slowly, at least after the first year (Clemens, 1951b; Hewson, 1955; Mac Crimmon, 1959; Lawler, 1963). Chen's 24 year old fish seems to be the oldest on record. In general, it appears that relatively few burbot reach an age much beyond 15 years.

The burbot is usually a resident of fairly deep water, whether in lakes or in rivers. In lakes, burbot have been taken as deep as 213 m (700 ft), and seem to be confined to the hypolimnion in the summertime. River fish tend to congregate in deep holes throughout the year, except at spawning. Optimum temperature for burbot is reported as 15.6-18.3°C (Scott and Crossman, 1973).

Migratory patterns of burbot are inadequately known. The fish are generally rather sedentary and do not move about very much. However, there do appear to be definite movements toward spawning areas, although as a rule these are individual movements rather than migrations of a whole school together. They also may move into shallow water to feed at night in the summer. Burbot have also been observed to make post-spawning runs up river, apparently for feeding (Mac Crimmon, 1959).

In its food habits, the burbot is an omnivorous carnivore, although displaying strong preference for a fish diet. Young Alaskan burbot in their first and second years feed mostly on insect larvae, especially Plectoptera and Ephemeroptera, and on small sculpins, Cottus cognatus. Beginning in the third year, at a length of about 180 mm, there is a steady shift towards fishes of all sorts and away from invertebrates. From about age 5 on (355 mm TL), fishes of various sorts compose 67-90% of the food, with invertebrates making up less than 12% (Chen, 1969). In more southerly climes, the dependence on invertebrates seems to change at about the same age (5 years) but at a much larger size (500 mm).

The list of food items is a long one, depending at least in part on what is available. In addition to those items already mentioned, it includes molluscs, asellids, Mysis, Pontoporeia, Gammarus, Trichoptera, and crayfish, as well as cisco eggs, mice, shrews and at least 20 species of fishes. Young burbot are an important food of large burbot (Nurnberger, 1930; Van Oosten and Deason, 1938; Clemens, 1951a; Mac Crimmon and Devitt, 1954; Hewson, 1955; Beeton, 1956; Bonde and Maloney, 1960; Lawler, 1963; Chen, 1969). Two fish taken by the author in the Tanana River near Tetlin Junction, Alaska, in the early 1960's had adult bank swallows in their stomachs.

IMPORTANCE TO MAN

The burbot makes up a relatively small part of the freshwater fish catch of the United States. Maximum landings (over 277,000 kg per year) occurred in the late 1940's and early 1950's, since declining slightly to an average of 173,600 kg (382,000 lb) per year for the six years 1968-1973. Most of this catch comes from the Great Lakes and the international lakes, although since 1968 the upper Mississippi basin has supplied about 25% of the total. The price has fluctuated widely during this time, from less than $0.02 to more than $0.11 per pound. Fish from the Mississippi drainage generally commands a higher price than fish from the Great Lakes. Almost all U. S.-caught burbot is used for food, either for men or for animals (Anonymous, 1971-1976). Attempts to popularize the burbot in Canada have thus far met with but little success (Scott and Crossman, 1973). Burbot are an important commercial product in Siberia (Nikolskii, 1961).

As a food fish, burbot has enjoyed a mixed reputation. Early explorers in the Canadian Arctic ate it "...only in times of great scarcity" (Richardson, 1836), but the same author also noted that "When well bruised and mixed with a little flour, the roe can be baked into very good biscuits...". The liver is also considered a delicacy, at least in Europe, and is used as a pate for canapés, as well as fried or smoked and eaten for itself. Burbot liver oil contains as much vitamins A and D as does cod liver oil (Branin, 1930). Actually, burbot is an excellent food fish, for its flesh is white, flaky, of good flavor and almost boneless. The repulsive appearance of the fish apparently militates against its popularity.

In Alaska, small numbers of burbot are taken for subsistence. Sport fishermen probably take more than do the subsistence fisheries. Icefishing for burbot in winter is reasonably popular and more and more anglers are learning that a burbot on light tackle is a worthy opponent at any time of year.

ARCTIC COD

Boreogadus saida (Lepechin)

DISTINCTIVE CHARACTERS

The distinctive characters of the Arctic cod are the three dorsal and two anal fins; the lower jaw as long as or slightly longer than the upper; the minute chin barbel; and the forked caudal fin.

DESCRIPTION

Body slender, elongate. Depth about 15% of fork length, greatest depth just behind head. Head moderate, 24-27% of fork length. Snout rather long, about 30% of head length. Eye round, large, its diameter 25-33% of head. Mouth fairly large, terminal; rather small, sharp teeth in two rows in front of upper jaw, in one row on posterior part as well as on lower jaw and vomer, the teeth wide set. A very small barbel usually present at anterior tip of lower jaw, sometimes scarcely visible. Gill rakers long and slender, 37-46. Lateral line discontinuous. Pyloric caeca 20-37.

Fins

D_1. 10-14, rarely to 16. D_2. 14-17. D_3. 18-24. A_1. 15-20. A_2. 18-24. P_1. about 19. P_2. 6, the second ray notably elongate. Caudal fin forked, the tips of the lobes slightly rounded.

Scales

Cycloid, minute.

Color

Brownish or grayish brown above, sides above lateral line somewhat lighter, often with a yellow or purple tinge. Sides below lateral line, and ventral surface, silvery. Fine black dots scattered over body, most numerous on back. Fins dusky; dorsal and caudal with a narrow white edge; anal pale at base.

Size

One of the smallest of the cods, most adults about 130-160 mm (ca 5-6 in) long, the largest specimen known said to have been only 321 mm (Svetovidov, 1948). Weight to about 75 g (about 1 oz).

RANGE AND ABUNDANCE

The Arctic cod enjoys a circum-polar distribution in most of the Arctic Ocean, being absent only from the region just north of Scandinavia. On the Atlantic side of North America it has been found as far south as the St. Lawrence River (Vladykov, 1945) and even to the estuary of the Miramichi River, New Brunswick (McKenzie, 1953). It ranges throughout the Arctic Ocean across the arctic coast of Canada and Alaska, south in the Bering Sea to Norton Sound on the east side, to the Gulf of Anadyr on the west; westward along the Siberian coast to about 37-38°E; and north probably to the North Pole (Andriyashev, 1954). Although primarily a marine species, the Arctic cod seems to prefer the less saline waters, 15-30 parts per thousand salinity, and not infrequently runs far upstream in rivers. The Arctic cod is one of the most abundant fishes present in arctic seas (Bean, 1887a, b, c; Alverson and Wilimovsky, 1966). The density of juveniles in the eastern Chukchi Sea in September and October, 1970, was estimated at 28 fish per 1,000 m^3 of water, or about 700 kg of young fish per km^2 (Quast, 1974).

HABITS

The Arctic cod is a demersal species, the adults associated with some kind of substrate, either the sea bottom or the underside of ice packs. Its distribution is closely correlated with the presence of ice and/or lowered salinity. Sexual maturity is reached at 3-4 years of age, and the fish are reported to spawn only once in their lives (Nikolskii, 1961). The eggs are the largest of any gadid, 1.5-1.9 mm in diameter. The large eggs and the small size of the fish combine to produce low fecundity, 9,000-21,000 eggs per female. Spawning takes place from October to March, usually in January and February. At this time, the fish move close inshore, often in tremendous numbers. They may enter rivers, and spawning in fresh water has been recorded in Siberia (Svetovidov, 1948). The eggs are pelagic, floating in the surface waters.

Development to hatching requires several months. The first larvae, about 5 mm long, appear in May to July. The larval stage lasts about 2 months. Small individuals 5-9 mm long have been taken in Siberian waters in May. Larger larvae, 9-8 mm long, are known from near the west coast of Greenland north of 68°N in late June. Transition to the juvenile stage occurs at the end of summer at lengths of 30-50 mm (Jensen, 1926; Andriyashev, 1954; Rass, 1968; Quast, 1974).

The young-of-the year appear to be negatively phototrophic, avoiding light. They are much more numerous below 20 m depth than above. This may be a mechanism whereby the fish reduce predation by sea birds (Quast, 1974).

Growth of Arctic cod in the northern Bering Sea has been given as follows: 0+, 31 mm; 1+, 75-100 mm; 2+, 144-158 mm; 3±, 190-200 mmg; 4+, 220-230 mm. This is rather faster growth than is found in more southerly regions along the east coast of Siberia (Andriyashev, 1954).

Arctic cod apparently undertake onshore-offshore migrations, in part associated with spawning and in part with movements of ice. They are common along the edge of pack ice, where they are said to swim rapidly between the blocks and to hide in cracks in the ice. The Arctic cod shows strong preference for low temperatures. Eggs do well at 0°-2°C, larvae at 2°-5°C, and fry at 5°-7°C (Rass, 1968). Older fish prefer lower temperatures. Adults seem to be most abundant in water with temperatures around -1° to -1.85°C (McKenzie, 1953; Backus, 1957; Leim and Scott, 1966).

Arctic cod feed mostly on plankton. Larvae and young fry eat copepod eggs and larval stages. Adults have a more varied diet, with euphausiids and calanoid copepods (especially *Calanus*) as the most important items but also including amphipods, shrimps, fish eggs and small fishes (Svetovidov, 1948; Andriyashev, 1954; Leim and Scott, 1966; Ponomarenko, 1967; Hognestad, 1968).

IMPORTANCE TO MAN

The Arctic cod's chief importance to man is indirect. It is one of the major foods of many arctic marine animals, including fishes, seals, belugas, narwhals and birds. At Cape Thompson, Alaska, Swartz (1966) estimated that the sea bird colony consumed about 13,100,000 kg of fish per breeding season, of which the majority was Arctic cod.

Direct importance to man is relatively low. The Arctic cod is reported to be of low palatability. Hence, although it is fished commercially and in subsistence fisheries, especially by the Russians, most of the catch is used for animal food. The liver, however, contains up to 50% valuable oil.

PACIFIC COD

Gadus macrocephalus Tilesius

DISTINCTIVE CHARACTERS

Three dorsal and two anal fins, a long chin barbel (about 3/4 as long as eye diameter in young, longer than eye diameter in adults) and the space between the second and third dorsal fins shorter than the eye diameter distinguish the Pacific cod.

DESCRIPTION

Body elongate, nearly cylindrical anteriorly, more or less compressed posteriorly. Depth about 20% of total length, deepest below first dorsal fin. Head large and broad, its length 26-29% of total length. Snout blunt, long, about 33-37% of head length. Eye round, its diameter 50-65% of snout length. Mouth large, subterminal, lower jaw shorter than upper, maxilla reaches to below eye. Small, sharp teeth present on both jaws and on head of vomer, the outer row of jaw teeth larger than the others. Gill rakers 18-23 on first arch. Lateral line with a prominent arch under first and second dorsal fins, straight posteriorly, ends under third dorsal.

Fins

D_1. 13-15; D_2. 16-21; D_3. 15-21. A_1. 17-22; A_2. 16-20. P_1. 19-22; P_2. 6-7, second ray longest. Caudal fin truncate.

Scales

Cycloid, small.

Color

Quite variable, usually brownish or olive gray above, paler below, with numerous brown or grayish spots on sides and back. Yellow color phases are known. Fins dusky; dorsal, anal and caudal fins with white edges, wider on anals and caudal than on dorsal.

Size

Reaches a length of 1,200 mm (nearly 4 ft). Average size of trawl-caught fish is around 700-750 mm (27-29 in) with a weight of about 4.5 kg (10 lb).

RANGE AND ABUNDANCE

Pacific cod are found along the North American coast from southern California, off Santa Monica at 33° 59.5'S, north to Norton Sound and St. Lawrence Island in the Bering Sea. On the Asian side the species is present from the southeastern tip of the Chukhotsk Peninsula through the Anadyr Gulf and southward to the Yellow Sea (Popov, 1933; Andriyashev, 1937, 1954; Svetovidov, 1948; Pinkas, 1967). It is rare south of Oregon, however, becoming most numerous, as well as larger, in the northern part of the range. From Puget Sound on northward and well into the Bering Sea, Pacific cod are abundant and support commercial fisheries of considerable size. Cod appear to prefer temperatures between 6° and 9°C (Ketchen, 1961).

HABITS

Like other cod fishes, Pacific cod spawn in the winter, usually in January and February. Spawning grounds are in deep water, to as deep as 250 m (137 fath). The eggs are small, average diameter about 1 mm, and fecundity is high. Egg numbers tend to increase with the size of the fish. A female 400 mm long contains about 228,000 eggs while one of 800 mm may produce about 3,350,000. Egg counts as high as 5,700,000 have been recorded. The eggs are demersal, with specific gravity of about 1.050, and are adhesive at first. They lose their adhesiveness about 30 hours after fertilization. Development to hatching requires about 8-9 days at 11°C but 29 days at 2°C. Experiments have shown that the maximum numbers of larvae are produced at salinities of about 19 o/oo and temperatures of about 5°C (Andriyashev, 1954; Thomson, 1962, 1963; Forrester, 1964, 1969b; Forrester and Alderdice, 1966).

The larvae are 3.5-4.8 mml long at hatching and have a fairly large yolk sac which is absorbed in 6-10 days, the time depending on temperature. Early growth is rapid and by the end of the first year of life the young fish are 230-260 mm long. Subsequent growth is, of course, much slower, and quite variable with different locations and populations. Typical lengths for various ages are: 2+, 500 mm; 3+, 614 mm; 4+, 673 mm; 5+, 726 mm; 6+, 762 mm. Use of otoliths for aging Bering Sea cod gave much shorter lengths for corresponding ages. In contrast to most fishes, Pacific cod appear to grow just as fast in winter as they do in summer. Cod on the Asian side of the Bering Sea do not grow as fast as these eastern Pacific fish. Sexual maturity is reached at 2-3 years of age in the southern parts of the range, but about two years later in the northern areas. Maximum age attained is about 13 years, but in most areas few live beyond about 7 years (Svetovidov, 1948; Mosher, 1953; Andriyashev, 1954; Forrester and Ketchen, 1955; Ketchen, 1961, 1964; Forrester, 1969b).

Pacific cod do not, as a rule, undertake extensive migrations. They move inshore after spawning, to depths of 30-60 m; then, from late summer to mid-winter, move out into the deeper water (100-250 m) of the spawning areas. In at least some North American stocks, there appears to be a good deal of movement from one bank to another. Most of these migrations are relatively short, but at least one tagged fish was recovered about 125 km (200 mi) from the point of release (Andriyashev, 1954; Forrester and Ketchen, 1955).

Young cod, like so many young fishes, probably feed largely on copepods and similar organisms. Adults feed heavily on shrimps, herring, sand lance and crabs, in that order, but also take almost any kind of small fish available, as well as worms, euphausiids, amphipods, isopods, echinoids, octopus and even ducks (Cobb, 1927; Hart, 1949; Andriyashev, 1954; Forrester and Ketchen, 1955).

IMPORTANCE TO MAN

The Pacific cod is one of the more important secondary commercial fishes of the Pacific coast. Total landings in the U. S. and Canada run on the order of 5-10 million kg (11-22 million lb) annually. The fishery began in 1863, when Captain Turner, on the brig Timandra, brought a fare of salt cod to San Francisco from Sakhalin. A small fleet was organized and fished the same region two years later. Fishing off the Shumagin Islands, Alaska, began in 1867. Subsequently, nearly all the cod fishing was done in Alaskan waters and the fishery prospered. Catches rose, more or less steadily, to a peak level of 2-4 million fish (probably about 10-20 million kg or 20-40 million lb) in the 1920's. Nearly all the fish were landed at ports in Washington and California. Economic factors resulted in the decline of the Alaskan fisheries and the concommitant rise of the industry around British Columbia and Washington. By the late 1950's, the Alaska catch was no longer listed separately in the fisheries statistics and did not re-appear until 1973 when landings of 72,000 kg (158,600 lb) were reported (Power, 1962; Anonymous, 1976).

The entire catch was salted in the early days, and the oil was extracted from the livers (10,000 gallons in 1866). With the advent of modern freezing techniques, more and more of the catch is frozen and used for fish sticks and similar products. The liver oil contains large quantities of Vitamins A and D, and is quite comparable to liver oil of Atlantic cod in this respect. Oil derived from the viscera is 3-9 times as potent, but the average yield is less than 0.1 that of the liver (Pugsley, 1938). The development of synthetic vitamins has adversely affected the market for these products.

SAFFRON COD

Eleginus gracilis (Tilesius)

DISTINCTIVE CHARACTERS

The saffron cod is set off by the three dorsal and two anal fins, lower jaw shorter than upper, chin barbel not longer than 1/2 eye diameter, and the space between the second and third dorsal fins equal to or longer than the eye diameter.

DESCRIPTION

Body elongate, nearly round in cross-section anteriorly, slightly compressed posteriorly. Depth about 16% of total length. Head 21-25% of total length. Snout long, about 33% of head length. Eye round, moderate, its diameter about 18% of the head length, or 1/2 snout length. Mouth large, subterminal, lower jaw distinctly shorter than upper, maxilla reaching to below eye. Teeth small, slender, curved backwards, in several rows in upper jaw; in two rows in anterior part of lower jaw, a single row posteriorly. A patch of small teeth present on head of vomer. Gill rakers 14-24, usually about 20, on first arch. Lateral line curved in its anterior portion, ending posteriorly under second dorsal fin.

Fins

D_1. 11-15. D_2. 15-23. D_3. 18-21. A_1. 20-24. A_2. 19-23. P_1. 20. P_2. 6, the second ray produced. Caudal fin truncate or slightly emarginate.

Scales

Cycloid, small, about 157 in a mid-lateral series.

Color

Grayish brown to olive above, upper part of sides paler, sometimes with a silvery-violet shading, often mottled with indistinct darker blotches. Lower sides and belly yellowish to silver white. Fins dusky, dorsals and caudal with white edges.

Size

Length usually around 250-350 mm (10-14 in), but up to about 500 mm (20 in) and a weight of 1 kg (2.2 lb).

RANGE AND ABUNDANCE

Confined to the North Pacific Ocean and the Bering and Chukchi seas, from Sitka (Svetovidov, 1948) to at least as far north as Kotzebue on the Alaskan coast and from the Chukhotsk Peninsula south to Korea and the Yellow Sea on the Asian side. The saffron cod not infrequently enters rivers and may go considerable distances up-stream. It has also been found in freshwater lakes on Bering Island and the Kamschatka Peninsula (Jordan and Metz, 1913; Svetovidov, 1948; Andriyashev, 1954).

Throughout most of its range, the saffron cod is quite abundant, sufficiently so to be the object of commercial fisheries.

HABITS

Saffron cod spawn in the winter, December to February. The fish move from deeper (30-60 m) water to shallower, inshore water for this purpose. In Norton Sound, saffron cod have been reported spawning over pebbly bottoms (Turner, 1886). Water temperatures on the spawning grounds are -1.6 to -1.8°C. Fecundity is between 25,000 and 210,000 eggs per female. The eggs are said to be adhesive (Svetovidov, 1948). The young hatch in the spring, April to June, and for the first few months of their lives are planktonic. They are frequently encountered under the bells of large jellyfish (*Cyania ferruginea*) (Andriyashev, 1954).

Growth is rather slow. Three year old fish average about 300 mm long and weigh about 200 g (6 oz); at five years, 375 mm and 375 g; and at 7 years, 460 mm and 800-900 g. Sexual maturity is reached at 2 or 3 years, after which the fish spawn annually (Svetovidov, 1948; Andriyashev, 1954).

Saffron cod do not migrate long distances. They move inshore in fall and winter for spawning and offshore in spring and summer to feed in deeper water. They often enter rivers and may go considerable distances upstream. However, they usually stay within regions of tidal influence. They apparently are restricted to the less frigid parts of the arctic seas, being replaced by the Arctic cod in the colder regions (Popov, 1933; Svetovidov, 1938; Alverson and Wilimovsky, 1966).

Food of the saffron cod consists mainly of small crustaceans, such as shrimps, amphipods and mysids, as well as polychaete worms and small fishes.

IMPORTANCE TO MAN

Along the Alaskan coast the saffron cod is utilized almost exclusively in subsistence fisheries. The coastal eskimoes catch considerable numbers with hand lines through holes in the ice. Along the Siberian coast, commercial fisheries of some magnitude are directed at this species. Current statistics are not available, but landings in the post-war years were on the order of 18,000,000 kg annually. The flesh of the saffron cod is said to be very tasty in late fall and winter but not so during the warmer months (Andriyashev, 1954).

SECTION 13

STICKLEBACKS--FAMILY GASTEROSTEIDAE

The members of this family are to be found in marine and fresh waters of Europe, Asia, North America and the western Mediterranean coast of Africa. Characteristically, they have three or more free spines in front of the dorsal fin and one before the anal fin. The pelvic fin is reduced to a single, strong spine with 0-3 soft rays.

They are all small fishes and are often important in the food of larger fishes, birds, etc. In some situations, they are strong competitors for food with young salmon.

THREESPINE STICKLEBACK

Gasterosteus aculeatus Linnaeus

DISTINCTIVE CHARACTERS

The three (rarely 2 or 4) sharp, free spines before the dorsal fin, the pelvic fin reduced to a sharp spine and one small ray and the series of plates along the sides of the body identify the threespine stickleback.

DESCRIPTION

Body compressed, moderately robust, its depth about 25% of total length. (Deeper bodied individuals are usually either gravid females or are infected with a cestode, *Schistocephalus*, which may fill the body cavity). Head almost 25% of total length. Snout 27-31% of head length. Eye round, its diameter generally a little less than snout length. Mouth oblique, small, maxilla not reaching anterior margin of eye. Teeth small, fine, on both jaws. Gill rakers long and slender, 17-25 on first arch of strictly freshwater forms, one or two more in anadromous forms. Branchiostegals 3 or 4. Lateral line more or less parallel to dorsal outline, pores microscopic. Pyloric caeca 1 or 2, short.

Fins

D. II-IV (usually III), 10-14, the spines separate from each other and from the soft-rayed fin, each spine with a reduced membrane attached to its posterior side. A. I, 6-10, the spine free from the rest of the fin. P_1. 9-11, posterior margin nearly truncate. P_2. I,1. Caudal truncate to slightly indented.

Scales

No scales, but the sides with vertically enlarged bony plates. In freshwater populations, these usually number 5-9 on each side, with 7 the most common number. Marine and anadromous sticklebacks are completely armored with 22-37 plates. A few freshwater populations have 0-2 plates. The anadromous type has a keel along each side of the caudal peduncle.

Color

Freshwater forms usually mottled brown or greenish, anadromous fish silvery green to bluish black. A few isolated populations, in the Chehalis River system of Washington and in Mayer Lake, Queen Charlotte Islands, British Columbia, are black. Sides usually paler, belly yellow, white or silvery. Fins pale, pectoral rays often picked out with dark dots. (Greenbank and Nelson, 1959; McPhail, 1969; Moodie, 1972a, b).

Breeding males (except of the black forms) become brilliant bluish or green, with blue or green eyes, and the forward part of the body, especially the breast region, bright red to orange.

Size

Maximum size reported to about 100 mm (Jordan and Evermann, 1896), but the size of adults in different populations is highly variable.

RANGE AND ABUNDANCE

Along the Pacific coast of North America from Rio Rosario, Baja California, north to the Bristol Bay region of Alaska, and St. Lawrence Island. On the Asian coast, south to Korea. On the Atlantic side of North America, this stickleback is found from Chesapeake Bay north along the coast to the western shore of Hudson Bay, and to Baffin Island and Devon Island in the Canadian Arctic. It is also present in southern Greenland, Iceland and most of western Europe. Wherever present, the threespine stickleback is usually abundant.

HABITS

Description of the habits of the threespine stickleback is not made any easier by the great variation shown between populations. It is quite probable that several subspecies or even full species are involved in this group, but adequate analysis has not yet been possible and authorities are divided in their opinions. Some suggest that the variations represent the response of a single, plastic species to different environmental conditions. Others feel that various degrees of speciation have occurred, still others that the differences are due to several lines of evolution (Hagen, 1967; Miller and Hubbs, 1969; McPhail, 1969; Hagen and McPhail, 1970; Moodie, 1972b; Ross, 1973; Bell, 1976). The discussion below is an attempt to provide a generalized summary, based on many published accounts and personal observations.

Breeding occurs in the spring and summer, usually June and July in Alaska, with a few fish in breeding condition as late as August. Just prior to the breeding season, males become strongly territorial and take on the breeding colors. They defend their territories by ritual displays, a head-down position, and by chasing and biting invading males. The resident male builds a barrel-shaped nest, using sand-grains, bits of vegetation, etc, which he cements together with a glue secreted by a special portion of the kidney. When the nest is completed, with an entrance and an exit, the male courts females by means of a zig-zag dance toward the female, then turning and swimming toward the nest. The intensity of the zig-zag dance is extremly variable in different populations, ranging from short dashes each way to little more than head-wagging. Non-receptive females ignore the dance and may be driven from the territory, but a receptive female will follow the male to the nest. There he points out the entrance by posing above it with his head down. The female enters the nest and deposits a clutch of eggs. At this time, males may butt the side of the nest, which apparently stimulates the female to lay her eggs. Fecundity ranges from 80 to nearly 1,300 eggs, but only 50-200 are deposited at one time. Females may lay eggs in several nests on several days, or may be courted again by the same male. In between spawnings, which usually occur at intervals of 3-4 days, the female may eat her own weight of food. If adequate food supply is not available, egg production goes on at the expense of body tissues, or spawning stops (Wootton and Evans, 1976).

When the female has laid her eggs, she leaves the nest by the exit. Attempts to back out of the nest are resisted by the male. Following egg deposition, which takes several minutes, the male may immediately enter the nest and fertilize the eggs, or, less frequently, he may court another female before entering the nest himself. In any case, the female is driven away after the eggs have been deposited. Several females generally are induced to deposit eggs in each nest, and it is not uncommon for a male to have several sets of eggs, at different stages of development, in a single nest.

Following courting and fertilizing, the male guards the nest. He also takes a characteristic position in front of one of the entrances, maintaining his body at an angle of about 45° from horizontal with head toward the nest, and fanning with his pectoral fins.

The eggs are sticky and adhere to each other. Diameter of newly laid eggs is 1.1-1.6 mm, but they quickly swell to 1.5-1.9 mm. Hatching time may be as short as six days at 17°C in California to as long as 14 days at 9-16° C in Karluk Lake, Kodiak Island, Alaska. The young are about 4.2-4.5 mm long at hatching and have a large, spherical yolk-sac. About 8 days after hatching, the young, now about 7 mm long and with the yolk-sac absorbed, begin to emerge from the nest and the male is kept busy catching them in his mouth and spitting them back into the nest. When the young are fully developed and free-swimming, they school around the male for a few days, then disperse. The male may now build a new nest and repeat the cycle.

Growth rates are extremely variable. In Karluk Lake, young threespine sticklebacks are about 28 mm by early August, but only about 12 mm long in the Dixon River, Glacier Bay National Monument. It is not known whether this reflects slower growth or later spawning in the latter area. Karluk Lake sticklebacks at one year of age are about 47 mm long, 60 mm at two years. In Cowichan Lake, British Columbia, threespine sticklebacks reach 64 mm in only 10 months. Normal life span in this population is 2 1/4 years; elsewhere it ranges from 1 to 3 years.

Sexual maturity is first attained at one year, though most do not mature until the second year. It is not known whether the early-maturing fish survive to spawn a second time. In at least some populations, the fish are hermaphroditic. Males have apparently non-functional ovaries while females may have functional testes and perhaps are capable of self-fertilization. At any rate, Karluk Lake females have been found with eyed eggs in the ovaries.

Freshwater threespine sticklebacks generally inhabit shallow water in association with a modicum of aquatic vegetation. However, they have been found in large numbers at the surface over deep water in some Alaskan lakes and as deep as 24 m (80 ft) in Karluk Lake. (Kuntz and Radcliffe, 1917; Tinbergen and Van Iersel, 1947; Vrat, 1949; Jones and Hynes, 1950; Carl, 1953; Greenbank and Nelson, 1959; Narver, 1969).

The food of sticklebacks consists mostly of zooplankton and insects. Copepods, Cladocera and chironomids are the most important item, but the list is a long one, including rotifers, ostracods, oligochaetes, small molluscs, amphipods, beetle larvae, leeches, planarians, mites, and their own eggs and larvae (Markley, 1940; Hynes, 1950; Carl, 1953; Greenbank and Nelson, 1959).

Although the number of lateral plates on freshwater threespine sticklebacks varies between 0 and 9, the modal number in most populations is 7. This number of plates seems to be associated with behavioral traits which make those individuals less subject to predation by larger fishes such as trout and squawfish. The threespine stickleback relies mostly on camouflage and cryptic coloration for protection. Lying motionless in the water, as they often do, the fish resemble a floating stick or twig. Individuals with more or less than seven lateral plates apparently are more active and hence more likely to attract the attention of predators than are seven-plated fish. Why this is so in unknown (Greenbank and Nelson, 1959; Moodie, 1972a; Moodie et al, 1973; Hagen and Gibertson, 1973).

The anadromous threespine stickleback differs from the freshwater form in a number of respects. Morphologically, this difference appears in the lateral plates and gill rakers. The anadromous form is fully plated, with up to 37 plates on the sides and a rather pronounced keel on each side of the caudal peduncle. In addition, the number of gill rakers on the first arch tends to be slightly higher in the anadronomous form.

Life history also differs. Spawning behaviour is essentially like that of the freshwater form, but breeding may occur in either fresh or salt water in salinities at least as high as 28.5 o/oo (McPhail, 1969). Sexual maturity is more often reached at one year rather than two, and the spawning areas seem to be in thicker vegetation, such as eel-grass beds (Narver, 1969). The young leave the streams and estuaries where they were hatched and move out into salt water. At first they stay close to shore, sheltering in seaweeds and such, but enter the open sea in the fall. Some remain near shore through the winter, but others apparently move out for considerable distances. Large numbers have been taken at the surface 800 km from shore in the Gulf of Alaska and on Georges Bank in the Atlantic (Bigelow and Schroeder, 1953; Andriyashev, 1954; Clemens and Wilby, 1961; McPhail and Lindsey, 1970). Whether or not these little fish which go so far from shore ever find their way back is a moot question.

IMPORTANCE TO MAN

The three spine stickleback is of but little direct importance to man. It has occasionally been taken commercially in Scandinavia and rendered into meal and oil, the latter said to have a healing effect on wounds and burns (Bigelow and Welsh, 1925; Nikolskii, 1961). It is an important forage species for predaceous fish like Dolly Varden, lake trout and northern pike. Large populations in some lakes may have adverse effects on the growth of young sockeye salmon through competition for food, but its old reputation and name of "salmon killer" (Jordan and Evermann, 1896) seem to be completely unjustified. The threespine stickleback makes an interesting aquarium fish.

NINESPINE STICKLEBACK

Pungitius pungitius (Linnaeus)

DISTINCTIVE CHARACTERS

The ninespine stickleback is set off by the presence of 7-12 free spines before the dorsal fin, and a long caudal keel, usually reaching to beneath the dorsal fin.

DESCRIPTION

Body elongate, slender, its greatest depth 19-22% of total length; caudal peduncle notably long and slender. Head short, 20-23% of total length. Snout about equal to eye diameter, about 25% of head. Mouth oblique, small, reaching back about to anterior margin of eye. Small, fine teeth present on both jaws. Gill rakers rather slender, 10-15 on first arch. Branchiostegals 3 on each side. Lateral line nearly straight, the pores microscopic. No pyloric caeca.

Fins

D. VI-XII, 9-13, the spines separate and each with a rudementary membrane on its posterior side. A. I, 8-11, the spine stout and curved. P_1. 10-11, posterior edge of fin rounded. P_2. I,1, the ray closely appressed. The pelvic girdle is occasionally reduced or absent (Nelson, 1971). Caudal usually truncate, varies from slightly indented to slightly rounded.

Scales

No scales. 0-15 small, bony plates along anterior part of lateral line. Caudal peduncle with a noticeable keel which may reach forward to below anterior edge of dorsal fin.

Color

Dull olive to light brown above, sides mottled or blotched with darker patches of the same color. Belly yellowish to silvery white. Fins colorless. Breeding colors may be quite variable, depending on sex, population and stage of the breeding cycle. Colors of females are always less intense than those of males. Aggressive females become dark dorsally and paler below, then sometimes become paler with more conspicuous saddle marks as actual breeding approaches (McKenzie and Keenleyside, 1970). Aggressive males become totally black, except for the colorless fins and the membranes on the pelvic spines, which are white. At breeding, the males become paler dorsally and more intensely black ventrally, especially under the chin (Morris, 1958; McKenzie and Keenleyside, 1970). Breeding males on the east coast of North America have been reported as reddish under the head and greenish on the belly (Bigelow and Welsh, 1925).

Size

Up to 90 mm (3.5 in), but the average is about 65 mm (2.5 in) or less.

RANGE AND ABUNDANCE

The ninespine stickleback is circumpolar in its total distribution. In Asia, it ranges from the Yangtse River of China north to the Arctic Ocean, westward across northern Siberia to the Atlantic coast of Europe as far south as the Loire basin in France. Present on the southern tip of Greenland. In North America, the species ranges from Cook Inlet, Alaska, north along the coast to the Arctic Ocean, east to the Atlantic. The Arctic North American range includes Victoria and Baffin islands and most of the arctic archipelago. From the mouth of the MacKenzie River, the ninespine stickleback ranges southeastward across Canada to the Great Lakes (except Lake Erie) and south along the coast to New Jersey. Isolated populations are present in the upper Mississippi drainage (Nelson, 1968b, c,). There are two quite distinct forms in North America, a coastal, Bering form confined to Alaska and the coastal regions of Canada and eastern United States, and an inland, Mississippi form found in the rest of the range. The two groups are distinguished on the basis of lower average numbers of gill rakers and dorsal spines and higher numbers of lateral plates in the Bering form (McPhail, 1963). Wherever it is present, the ninespine stickleback is abundant.

HABITS

The ninespine stickleback is quite strictly a freshwater form. Although it can survive salinities up to 20 o/oo, fresh water is required for spawning (Nelson, 1968c). The coastal form, however, may winter in the sea, at least in Hudson Bay, and has been taken in Norton Sound at Nome (McPhail and Lindsey, 1970).

Spawning occurs in the spring and summer, generally May to July, but ripe females have been found as early as April and as late as August (Nelson, 1968b). The first indication of the onset of the breeding season is a breakdown of schooling and a beginning of aggressive behavior. Subsequently, individuals, both males and females, set up territories which are defended against intruders of either sex. At this time, males become black, females dark above and silvery below (see Color). Males construct nests of algae and bits of debris. The nests are generally located in aquatic vegetation and 10-15 cm above the bottom, but may be on the bottom or even slightly sunk into the bottom. In some areas, nests have been observed under or between rocks at depths as great as 2 m (McKenzie and Keenleyside, 1970). The material is stuck together with a glue secreted by the male's kidneys. Nests are more or less tubular or barrel shaped, with an opening at each end.

As the nest is completed, the males become paler dorsally but more intensely black below, especially on the throat and anterior part of the abdomen. They now begin to court the females, instead of attacking them. Courtship consists of a series of quick, head-down dancing movements toward the female. This may be accompanied by bending the body in an S shape in front of the female. If the female is receptive, she lowers her tail, displaying her swollen belly to the male. He then dances back towards his nest, the female following with her snout between the male's pelvic spines. If the female is not responsive to courting, she may be attacked and driven from the male's territory. At the nest, the male takes up a position just above it, with his snout pointing to the opening, and fans with his pectoral fins. The female enters the nest, but, as she is longer than the nest, her head and tail protrude. The male then contacts his throat against the side of the posterior part of the female's body, and quivers. This stimulates her to lay her eggs, after which she leaves the nest, while the male enters the nest and fetilizes the eggs. Total fecundity of a female is 350-960 eggs (Andriyashev, 1954), but only 50-80 are laid at a time. If the female is still near the nest when the male emerges, he attacks her and drives her out of his territory. The female soon begins feeding voraciously and in a day or so is ready to be courted again by the same or other males and lay another clutch of eggs. The male usually collects several clutches of eggs from the females on adjoining territories.

Egg laying and fertilization accomplished, the male again becomes black all over. He spends most of his time at one or the other entrances of the nest, in a nearly horizontal position, facing the nest and fanning with his pectoral fins. This keeps gentle currents of water moving over the eggs, bringing oxygen and removing metabolic wastes. He also moves the eggs around in the nest and removes and eats any dead eggs. Sometimes the nest begins to fall apart before the eggs have hatched. The male may then build a new nest nearby and transfer the eggs to it (Morris, 1958).

The eggs, which are sticky and 1-1.5 mm in diameter, hatch in about a week at 18°C. At hatching, the male often enters the nest and removes the broken remains of the egg membranes. The newly hatched larvae move to the top of the nest and settle on it. At this time, the male may construct a nursery, a loose mass of vegetation in the weeds a few centimeters above the nest. As the young develop and begin to move about, the male catches them in his mouth and spits them back into the nest or the nursery. As the young grow older, and become still more active, the male is less and less successful in this, and finally loses interest in them, except, perhaps, as food. The male may now build a new nest and start the reproductive cycle all over again, or the breeding season comes to an end (Morris, 1958).

Nothing is known of growth rates of ninespine sticklebacks in northwestern North America. However, judging by the size they attain, they must grow considerably faster than those in England, which averaged only 37 mm (1.5 in) long at three years old (Jones and Hynes, 1970). Sexual maturity is reached at one year by about half the males and most of the females. Nearly all are mature by the age of two. Maximum life span is less than 3 1/2 years (Jones and Hynes, 1970).

Nothing definite is known of the migrations of the ninespine stickleback. However, there would appear to be seasonal movements inshore to shallow water in the spring for spawning, and offshore to deep water, or even to the less saline parts of the sea, by the young and such adults as survive spawning, in the fall. Shortly after hatching, the young are common in and just below the zone of rooted vegetation in lakes. Adults are common down to about 20 m and also at greater depths, 90-110 m, in Lake Superior. They appear to be most numerous in water of temperatures between 6° and 12°C (Dryer, 1966; Nelson, 1968b).

Food of ninespine sticklebacks consists mostly of copepods and chironomids, but they also eat cladocera and other small crustaceans, ostracods and oligochaete worms, as well as their own eggs and larvae upon occasion (Hynes, 1950; Morris, 1958). In turn, they are fed upon by various predaceous fishes such as Arctic charr, Dolly Varden, lake trout, walleye, grayling, and fish-eating birds (Rawson, 1957; Dryer et al, 1965; McPhail and Lindsey, 1970).

IMPORTANCE TO MAN

The ninespine stickleback is of little direct value, as it is too small and of too uncertain occurrence. However, they may be so abundant at certain times of year the the natives of Siberia, the Yukon-Kuskokwim delta, and similar regions, catch them for dog and human food. They have also been used as a source of oil in some areas (Bigelow and Welsh, 1925; Nikolskii, 1961; McPhail and Lindsey, 1970).

Indirect importance is probably greater than the direct, for ninespine sticklebacks may form a significant part of the food for larger fish.

They also make excellent aquarium fishes.

SECTION 14

SURFPERCHES--FAMILY EMBIOTOCIDAE

The members of this family, numbering about 20 North American species, are almost all marine. One species lives in fresh water in California and another, the shiner perch, is mainly marine but often enters rivers.

The surf perches are live-bearers, bringing forth living young rather than laying eggs. In appearance, they are typically perch-like, with spiny and soft dorsal fins and three spines in the anal fin. However, the scales are cycloid rather than ctenoid. A remarkable feature of this group is the fact that, in at least some species, the males are sexually mature at birth.

Surf-perches are small fishes, rarely exceeding 150 mm (6 in) in length. They are utilized to some extent for human food or as bait for larger fishes.

SHINER PERCH

Cymatogaster aggregata Gibbons

DISTINCTIVE CHARACTERS

The rather deep, compressed body, large scales and three spines in the anal fin distinguish the shiner perch from other Alaskan freshwater fishes.

DESCRIPTION

Body compressed, deep, its depth 33-38% of fork length. Head compressed, moderate, its length 27-34% of fork length. Snout length usually slightly greater than eye diameter, 26-33% of head. Eye moderate, round or nearly so, diameter 24-30% of head. Nostrils double on each side. Mouth terminal, rather small, directed slightly upward, upper jaw reaching backward to below anterior margin of eye. Small conical teeth present on both jaws, but absent on vomer and palatines. Gill rakers short, slender, 28-33 on first arch. Branchiostegals 5 or 6. Lateral line slightly arched, complete, 36-43 pored scales.

Fins

C. VIII - XI, 19-22, usually IX, 20, the spiny portion higher than the soft-rayed part. A. III, 22-25, usually 24. P_1. 19 or 20. P_2. I, 5. Caudal forked.

Scales

Large cycloid. A scale sheath present along posterior three fourths of base of dorsal fin, separated from body scales by a furrow.

Color

Generally silvery, back dusky to greenish. Middle of sides anteriorly with groups of fine, black dots on each scale, forming about eight longitudinal stripes. The stripes often interrupted, especially in females, by three vertical, pale yellow bands. Paired fins colorless. Dorsal and caudal plain or dusky. Anal usually colorless, sometimes with a yellow blotch anteriorly. Breeding males may be almost solid black (Eigenmann and Ulrey, 1894).

Size

Reported up to 203 mm (8 in) (Evermann and Goldsborough, 1907), but the vast majority are between about 100 and 127 mm (4-5 in). Males are generally smaller than females.

RANGE AND ABUNDANCE

The shiner perch is found along the west coast of North America from San Quintin Bay, Baha California (Miler and Lea, 1972), north to Wrangell, Alaska (Bean, 1884). It appears to be rather scarce at the extreme ends of the range, but is an abundant species from about San Diego to Ketchikan. Occasionally found in brackish or fresh water (Bailey et al, 1970).

HABITS

The surf perch is viviparous, bearing fully developed young which develop in the ovarian cavity of the female. Mating is preceded by courtship. The male moves slowly toward the female, who retreats. Her flight stimulates pursuit by up to ten males. During the pursuit, males attempt to bring their anal regions in contact with that of the female. One male heads off the female, urging her away from the group of males and also driving them away. The female is conducted to the shelter of a rock or other object, where the courtship dance begins. In this dance, the male, with dorsal fin fully erect, swims by means of his pectoral fins in a figure eight pattern over the female, undulating in both the horizontal and vertical planes. The male then stops, faces the female head to head, quivers, moves his jaws and undulates his dorsal fin. He then moves beside the female, facing in the same direction, and repeats the movements. Finally, the male tilts on his side, the female tilts slightly away from him, and the anal regions are brought in contact with each other. Copulation lasts less than a second (Hubbs, 1917; Wiebe, 1968b).

Males are mature and ripe at birth. Juvenile females are mated soon after being born. Shortly before breeding, the males develop fleshy lobes on both sides of the anal fin. One lobe ends in a tubular intromittant organ which points more or less forward and downward. Mating takes place in June and early July in most areas, less commonly in May or August. Sperm is stored in the female's ovary until about December, when fertilization occurs. Gestation of the young requires 5 to 6 months and they are born in June or July, about a year after the parents have mated (Eigenmann, 1894; Turner, 1938).

The eggs are extremely small, only about 0.3 mm in diameter, and shrink still further during early development to about 0.2 mm (Eigenmann, 1894). Fertilization occurs while the eggs are still in the follicles, but development does not begin until after their release. Eggs which are not ripe at the time of fertilization degenerate and may contribute to the nourishment of the developing embryos. During the course of gestation, the epithelial cells of the ovary become filled with fluid and slough off. The embryos are nourished by these cells, as well as by the ovarian fluid itself, which enter the embryonic alimentary canal through the gill opening, later through the mouth as well. Respiration of later embryos is accomplished by the development of highly vascularized tissues along the margins of the dorsal and anal fins. These are in close contact with vascularized portions of the ovary and most probably function in the exchange of oxygen and carbon dioxide. In about half the embryos, one gill opening is invaded by a fold of tissue from the ovary wall, apparently another respiratory device (Turner, 1952). Brood size ranges from 3 to 36 young. Older and larger females produce more and larger young and generally give birth earlier in the season than do smaller, younger fish. The development of sex products and secondary sex characters of the male is enhanced by warm temperatures and increasing day-length. Development of egg cells of the female, by contrast, is encouraged by cool temperatures and decreasing light, although development of the embryos is promoted by warmth (Eigenmann, 1894; Evermann and Goldsborough, 1907; Wiebe, 1968a, b; Wilson and Millemann, 1969). Breeding apparently occurs annually during the life of the individual.

The young fish are 34-44 mm long at birth and are ready to mate at this time. Males are smaller than females, a relation which continues throughout life. At one year of age, females average about 93 mm long in Yaquina Bay, Oregon. At 2 years, they are about 111 mm; at 3, 118 mm; at 4, 130 mm; at 5, 133 mm; and at 6 years, about 135 mm (Eigenmann, 1894; Wilson and Millemann, 1969).

Except for seasonal onshore-offshore movements, the shiner perch apparently does not migrate. However, it does appear in shallow water inshore in the summer and has been taken in trawls as deep as 128 m in winter (Clemens and Wilby, 1946; Hart, 1973).

Food of the shiner perch varies with the size of the individual and the time of year. The young feed mainly on copepods, while the adults eat various small crustaceans, molluscs and algae. Adults often eat the appendages of barnacles on piers and rocks (Clemens and Wilby, 1946; Gordon, 1965).

IMPORTANCE TO MAN

The shiner perch is of little importance. Some are marketed in British Columbia, chiefly for the oriental trade in Vancouver (Clemens and Wilby, 1946) and also in California, especially at San Francisco and Los Angeles. However, the shiner perch is only a minor constituent of the California "perch" landings (Roedel, 1948). It is used to a slight extent as bait for larger fishes and provides considerable sport in the summer, when numbers are found close inshore, for juvenile anglers. It is said to be "a very fair pan fish" (Evermann and Goldsborough, 1907).

SECTION 15

SCULPINS--FAMILY COTTIDAE

Sculpins are bottom-dwelling fishes, mostly marine but some freshwater, with a few of the marine forms entering rivers, sometimes to considerable distances upstream. There are at least 300 species in the family. They have large heads, the gill covers usually armed with sharp spines; robust bodies tapering to a narrow caudal peduncle; both a spiny and a soft dorsal fin, a single spine in each pelvic fin but none in the anal; and ctenoid-type scales, but the scalation is usually much reduced and the scales are often highly modified.

The sculpins are primarily fishes of the northern temperate and arctic seas. One genus, *Cottus*, is circumpolar in fresh water in the northern hemisphere. Most are fairly small fishes, especially the freshwater forms, but a few of the marine species may reach lengths of 600 mm (2 ft) or more. Freshwater sculpins occasionally prey upon the young of various salmonids, but only rarely does this reach significant levels. In turn, they are eaten by larger fishes such as lake trout and burbot.

A number of old records of freshwater sculpins in Alaska were based on mis-identifications. Mr. Kevin M. Howe, Department of Fisheries and Wildlife, Oregon State University, has recently re-examined the specimens which formed the basis for Evermann and Goldsborough's (1907) record of the riffle sculpin, *Cottus gulosus*, from Loring and the Boca de Quadra. Mr. Howe finds these specimens to be a mixture of coastrange sculpins, *Cottus aleuticus*, and prickly sculpins, *Cottus asper*.

PACIFIC STAGHORN SCULPIN

Leptocottus armatus Girard

DISTINCTIVE CHARACTERS

The Pacific staghorn sculpin is set off by the large upper preopercular spine ending in 3 or 4 sharp, upturned, curved spinules; and the large, dark spot on the posterior part of the spiny dorsal fin.

DESCRIPTION

Body elongate, more or less cylindrical anteriorly, somewhat compressed posteriorly. Depth about 17-20% of total length. Head rather flat and broad, its length about 33% of total length. Snout about 25% of head length. Eye oval, horizontal diameter greater than vertical, length 13-18% of head. Mouth moderate, terminal, lower jaw slightly shorter than upper, upper jaw reaches back to below eye. Small, sharp teeth present in bands on both jaws, vomer and palatines. Gill rakers reduced to flat, bony plates, each bearing a cluster of small teeth, 8 or 9 on lower portion of first arch, none on upper portion. Branchiostegals 6. Lateral line nearly straight, with 37-42 pores, each associated with a small, sub-dermal, cartilaginous plate.

Fins

D_1. VI-VIII. D_2. 15-20, the spinous and soft parts separated by a short gap. A. 15-20. P_1. 19. P_2. I, 4. Caudal slightly rounded.

Scales

No scales. Skin smooth and naked except for the lateral line plates.

Color

Grayish olive to greenish, occasionally with some yellow, dorsally. Orange-yellow to white or silvery below lateral line. Spiny dorsal dusky, with a black spot near tips of last 3 spines, a white band below it. Soft dorsal dusky, with several oblique white to yellowish bands. Pectorals yellow with 5 or 6 dark greenish bars. Caudal dusky with one or two pale bands. Anal and pelvic fins pale.

Size

Reaches about 460 mm (18 in) total length.

RANGE AND ABUNDANCE

Found along the Pacific coast of North America from San Quintin Bay, Baha California (Roedel, 1948) to Izembek Lagoon in the southeastern Bering Sea (Tack, 1970; Paulson and Smith, 1974). Throughout most of its range, it is a common fish of the sub-tidal zone and tide pools. Even in the Bering Sea, at the northern limit of its range, it is not at all uncommon in favorable locations. Although a marine fish, the Pacific staghorn sculpin can tolerate freshwater and not infrequently penetrates rivers and even fairly fast small streams. It has been found in fresh water on Admiralty Island, Alaska, among other places (Gunter, 1942).

HABITS

The Pacific staghorn sculpin spawns from October to March, but the majority of reproductive activity takes place in January and February. Spawning areas are probably most common in bays and estuaries with relatively stable salinities, but must also exist in the ocean, for very young staghorn sculpins have been found in areas far from fresh water inputs. Eggs develop normally in salinities between 10.2 and 34.3 parts per thousand, with greatest survival in the range of 17.6-26.4 parts per thousand. The higher of these two figures is probably close to the optimum salinity (Jones, 1962).

Development to hatching under laboratory conditions requires 9-14 days at 15°C, with most of the eggs hatching in between 10 and 12 days. The newly hatched larvae are 3.9-4.8 mm long, with a large, globular yolk sac (Jones, 1962). Growth and longevity appear to vary tremendously in different localities. Fish from Walker Creek, Tomales Bay (north of Point Reyes, California) were reported to grow exceedingly fast, reaching an average total length of 127 mm at one year of age, 156 mm at 2 and 197 mm at 3. The maximum age observed in this population was three years (Jones, 1962). By contrast, fish from Puget Sound, near Friday Harbor, reached 10 years of age, with average calculated total lengths of I, 34 mm; II, 55 mm; III, 80 mm; IV, 101 mm; VII, 174 mm; X, 228 mm (Weiss, 1969). Females appear to reach greater size and age than do males.

Recently metamorphosed young move from the spawning areas in the estuarine regions into completely fresh water, where they remain for up to six weeks. Because of the extended spawning period, the fish farthest upstream are usually somewhat older and larger than those in the lower estuary. However, this migration into fresh water is not an essential part of the life history, for staghorn sculpins may spend their entire lives in highly saline water (MacGinitie, 1935). Adults apparently tend to remain in shallow water in the lower estuary, or farther offshore. The adult staghorn sculpin is often one of the dominant species of the sand flats and in some regions, at least, is common to as deep as 90 m (Jones, 1962; Tack, 1970; Isakson et al, 1971; Pearcy and Myers, 1974; Paulson and Smith, 1974). This broad distribution reflects the considerable degree to which this sculpin can tolerate different salinities. This tolerance range goes from essentially zero (fresh water) to a maximum of about 51-53 parts per thousand, considerably higher than ordinary sea water (Hubbs, 1947; Erkkila et al, 1950; Carpelan, 1961).

The Pacific staghorn sculpin is essentially a sedentary fish, resting on or moving slowly about just over the bottom. However, it is capable of rapid movement over short distances when occasion demands. When violently disturbed, it "rushes rapidly to a new place and buries itself, leaving only the eyes exposed" (MacGinitie, 1935). This mode of life is reflected in the food habits. Juveniles in the Walker Creek estuary subsisted almost entirely on amphipods of the genus Corophium, with nereid worms, gammarid amphipods, insect larvae and nymphs, and 18 other items of minor importance. Adults in San Francisco Bay had fed chiefly on four species of bottom-dwelling shrimps, smelt and crabs, with other fishes and invertebrates occurring in small amounts in the stomach contents (Jones, 1962).

IMPORTANCE TO MAN

The Pacific staghorn sculpin is of little direct importance to man. Although it is edible, the large head and slender body result in a small yield of meat per fish. It is sometimes a nuisance to anglers, greedily taking baited hooks intended for more desirable fishes. It probably competes strongly for food with other fishes, especially in confined regions such as bays and estuaries. It is an important food for herons, loons and cormorants (MacGinitie, 1935).

SLIMY SCULPIN

Cottus cognatus Richardson

DISTINCTIVE CHARACTERS

The two pores on the chin and the short lateral line ending under the second dorsal fin distinguish the slimy sculpin.

DESCRIPTION

Body tadpole-shaped, nearly round in cross-section anteriorly, strongly compressed posteriorly. Depth 17-21% of total length. Head broad, somewhat flattened, expanded posteriorly, its length 22-28% of total length. Snout rounded and broad as seen from above, its length 27-28% of head length. Nostrils in short tubes, one above middle of upper jaw on each side, the other near antero-dorsal margin of eye. Eyes more or less on top of head, diameter a little less than snout length. Mouth broad, terminal, upper jaw projecting, maxilla reaching anterior margin of eye or farther back. Fine teeth on jaws and vomer, none on palatines (teeth rarely present on palatines, according to McAllister, 1964). Gill rakers short and stubby, about six on first gill arch. Branchiostegals 6. Lateral line incomplete, ending under middle of soft dorsal fin, usually a few isolated pores behind this, the main portion with 12-26 pores.

Fins

D_1. VII-X. D_2. 14-19. A. 10-14. P_1. 12-16, fins large and fan-shaped, tips of lower rays exserted. P_2. I,3, sometimes I,4, but the fourth ray much reduced. Caudal rounded.

Scales

No scales, but small prickles sometimes present behind pectoral fins.

Color

Dark brownish or greenish to dark gray on back and sides, whitish below, with vague, dark mottlings or bars below soft dorsal. Belly sometimes with orange tints. Soft dorsal, pectoral and caudal fins usually barred, pelvics and anal usually immaculate but sometimes barred. Spiny dorsal dark basally, with a clear margin which may turn orange in breeding males. Breeding males usually dark, sometimes black, all over.

Size

Known to reach 121 mm total length (Van Vliet, 1964), but most do not exceed about 75 mm (3 in).

RANGE AND ABUNDANCE

The slimy sculpin is distributed all across northern North America, from eastern New Brunswick, Canada, to western Alaska, including Nunivak and St. Lawrence islands. On the east coast it is found as far south as Virginia and north to Ungava Bay, though it has not been recorded from the northernmost parts of Newfoundland and northwestern Labrador, nor the most northerly parts of Keewatin. It is present in all the Great Lakes, the upper Mississippi drainage, thence northwesterly across most of Saskatchewan to northern Alberta (absent from most of southern Alberta). Present in the upper Columbia drainage and the Fraser River, north through British Columbia east of the Continental Divide, reaching the west coast in southeastern Alaska. Present throughout the Northwest Territories (except northeastern Keewatin), Yukon Territory and mainland Alaska. Also known from the eastern part of the Chukhotsk Peninsula in Siberia.

Throughout its range it is an abundant species. It inhabits lakes to considerable depths being most common in Lake Superior at depths between 90 and 110 m. In Lake Michigan it has been found all the way from near shore to 128 M (Deason, 1939). It is common in streams, particularly those with fairly fast current and rocky bottoms, where it stays on the bottom, darting from place to place when disturbed. Its quiescent, bottom-dwelling habits and cryptic coloration make it difficult to observe until it moves.

HABITS

Spawning takes place in the spring, shortly after break-up, at water temperatures between 4.5 and 10°C. This may occur as early as late March in the southern part of the range to late May or even later in the far north. Before spawning, males select nest sites, usually under rocks, logs, boards, etc., in shallow water, from about 2 cm to more than 30 cm deep. The floor of the nest is often sandy and may be excavated to some extent by strong swimming or fanning movements on the part of the male. He may also remove gravel from the nest by picking up small particles in his mouth and moving them outside. The nest is usually 20-40 mm high, both height and width depending on the size of the fish. At this time, the male assumes a dark brown to black color and the orange margin of the first dorsal fin is bright (Koster, 1936; Van Vliet, 1964).

Nesting males are strongly territorial and aggressive towards other males. They defend the nest by "barking" (quickly opening and closing the mouth) at intruders, which may be followed by a quick dart with gill covers spread and head flattened, and by fighting. In contrast to most fishes, in which agonistic behavior is usually ritual, the loser of a fight between two male sculpins is often killed (Koster, 1936; Van Vliet, 1964).

Courtship begins when a ripe female approaches the nest. The male barks, undulates and twitches his body and fins, then rushes to the side of the female and drives her into the nest. Within the nest, there is more barking, as well as butting or biting the female's side near the vent. Both fish turn upside down and the female deposits her eggs on the roof of the nest. The male presses her against the roof, which may help in extruding the eggs, and releases milt (Koster, 1936). After spawning, the female leaves the nest and shows no further interest in the eggs.

Spawning apparently goes on at any time of the day or night. The female deposits all of her eggs in a single mass. Fecundity ranges from about 42 to 1420 eggs, the number tending to increase with the size of the female. The average size of a clutch is 150 to over 600 eggs. Males usually mate with two or three females in the same nest, but nests have been found with as many as 10 egg masses (Koster, 1936; Van Vliet, 1964; Craig and Wells, 1976).

The eggs are quite large for so small a fish, 2.5-3.0 mm in diameter, and are yellow to pink in color. Development to hatching requires about 30 days. During this time the male remains in or near the nest, guarding it against intruders, fanning the eggs with his pectoral fins and removing debris and dead eggs. The young are about 7.2 mm long at hatching, with a large, spherical yolk sac. They seek the bottom of the nest and remain there for about a week. By that time the yolk has been absorbed, the young are nearly 11 mm long and they leave the nest to take up the solitary life characteristic of this species.

Growth rates vary from locality to locality, with one-year-old fish as small as 36 mm total length in the Cree River, Saskatchewan, or as long as 93 mm at Otter Rapids on the Churchill River (Van Vliet, 1964). In general, however, growth seems to be rather slow. Most fish mature in their second year, although in the Chandalar River of Alaska, 4 years was the usual age at maturity. Maximum age recorded is seven years, in the Chandalar River fish (Craig and Wells, 1976).

Except for probable movement into shallow water for spawning, slimy sculpins apparently do not migrate. It is not known whether the sculpins found at considerable depths in the Great Lakes breed at those depths or whether they come in to shore in the spring. The slimy sculpin is quite sedentary, rarely moving more than a few meters, even when violently disturbed. However they have been seen to travel considerable distances through the semi-consolidated, jelly-like sediments on the bottoms of some deep lakes on the Canadian shield (Emery, 1973). In some areas, they are common in brackish water (Dunbar and Hildebrand, 1952). Presumably, these individuals must migrate to and from fresh water, at least for spawning.

The slimy sculpin is almost exclusively insectivorous in its food habits. In most areas, the major items are the larvae of Diptera, Ephemeroptera and Trichoptera, with Odonata and amphipods sometimes important for larger individuals. The smaller fish feed most heavily on Diptera, especially chironomids and simuliids, while larger fish tend to make more use of the larger items (Kendall and Goldsborough, 1908; Rimsky-Korsakoff, 1930; Sibley and Rimsky-Korsakoff, 1931; Pate, 1933; Koster, 1936, 1937; Van Vliet, 1964; Petrosky and Waters, 1975; Craig and Wells, 1976). Although the slimy sculpin has often been accused of devouring the eggs and young of trout and other salmonids, it seems that this happens but seldom. Fish are rarely eaten, and young sculpins, as well as sculpin eggs, are taken far more frequently than are other fishes. Sculpins do, on occasion, eat larval trout; however, salmonid eggs are too well protected by the redd to be vulnerable to sculpins large enough to eat them and the eggs are too large to be eaten by sculpins small enough to burrow into a redd (Koster, 1936, 1937; Kogl, 1965; Clary, 1972; Petrosky and Waters, 1975; Craig and Wells, 1976).

IMPORTANCE TO MAN

The slimy sculpin is of no direct importance to man. In some places it may be used as bait for larger fishes, but even this seems to be rare. Indirectly, however, it may be more significant. Although this sculpin is almost exclusively a bottom feeder and the salmonid fishes with which it frequently co-exists are mostly mid-depth and surface feeders, the two groups feed on much the same groups of organisms at different developmental stages. In a Minnesota stream, it has been found that slimy sculpins made up about 1/3 of the total annual fish production, with three trouts (Salvelinus fontinalis, Salmo gairdneri and Salmo trutta) contributing the remaining 2/3. In the Chatanika River, Alaska, sculpins and grayling share many of the same food items. It is conceivable that a large population of sculpins could compete strongly with the salmonids and limit the production of the latter, although this matter has not been proven (Schallock, 1966; Vascotto, 1970; Petrosky and Waters, 1975; Craig and Wells, 1976).

PRICKLY SCULPIN

Cottus asper Richardson

DISTINCTIVE CHARACTERS

The complete lateral line, a single pore at the tip of the chin, 15-19 anal rays, and well developed palatine teeth distinguish the prickly sculpin.

DESCRIPTION

Body elongate, broad and nearly cylindrical anteriorly, compressed posteriorly. Depth 16-18% of total length. Head large, its length 25-32% of total length. Snout 21-27% of head length. Eye round, its size variable, 18-33% of head length. Two nostrils on each side, each in a short tube, anterior nostril near edge of upper jaw, posterior close to anterior margin of eye. Mouth large, maxilla reaches middle of eye or further back in adults. Teeth small but well developed, present on both jaws, palatines and vomer. Gill rakers short, 5-6 on first arch. Branchiostegals 5-7 (usually 6) on each side. Lateral line complete, with 32-43 pores. Pyloric caeca short, 4-6.

Fins

D. VII to X - 18 to 23. A. 15-19. P_1. 15-18, large and fan-shaped. P_2. I, 4 (rarely 3 or 5). Caudal truncate or slightly rounded.

Scales

No true scales. Prickles on body, distribution ranging from covering most of the skin (except on abdomen) to a small patch behind base of pectoral fins.

Color

Dark brown, olive or gray above and on sides, whitish yellow to white below. Usually three dark, irregular blotches or bars below soft dorsal fin. Vague, irregular, dark marks on sides. Fins (except anal) with dark bars, first dorsal with a dark spot posteriorly. Both sexes show an orange band on the edge of the first dorsal at spawning time.

Size

The largest species of the genus *Cottus*, said to reach about 300 mm (1 ft) (Jordan and Evermann, 1896), but the majority generally not over 150 mm. However, the original specimen, on which the description was based, was 9 1/2 inches (241 mm) (Richardson, 1836) and Jordan and Gilbert (1882) listed 10 inches (245 mm) as the maximum length.

RANGE AND ABUNDANCE

Known from the Ventura River, California, in the south, then north in coastal streams of the Pacific coast to Seward, Alaska. Ranges well inland in the San Joaquin and Sacramento rivers of California, the northern part of the Columbia River drainage (but not the Snake River) as well as in the Fraser and other major Pacific coastal rivers of British Columbia (Krejsa, 1967a). Isolated populations are present in the Peace River drainage in British Columbia as far downstream as McLeod Lake (Lindsey, 1956). An abundant form wherever present. The record of C. gulosus from southeastern Alaska was based on a mixed sample of C. asper and C. aleuticus (Kevin Howe, Department of Fisheries and Wildlife, Oregon State University, pers. comm.).

HABITS

The prickly sculpin exhibits at least two genetically distinct forms. The inland form is generally more densely prickled over a larger portion of the body and does not migrate to estuaries to spawn, while the coastal form shows reduced prickles and spawns in brackish water (Krejsa, 1967b). Except for the difference in spawning localities, the life histories of the two are quite similar, as far as is known.

Spawning may occur as early as February in the south and as late as July in the north. Prior to breeding, the males move downstream and select nest sites under cobbles, large, flat rocks, etc. The females aggregate some distance upstream, then move down singly to the spawning area. They display to the male, who courts a female and brings her to his nest. Further courtship goes on in the nest. The orange eggs, somewhat less than 1 mm in diameter, are sticky and adhere to the roof of the nest. Fecundity ranges between 280 and 7,410 eggs per female (Patten, 1971). Since males may mate with as many as ten females, there may be 25,000-30,000 eggs in a single nest (Krejsa, 1967b; Ringstad, 1974). After spawning, the female goes back upstream to feed, while the male remains at the nest, fanning and guarding the eggs. He does not feed until the eggs have hatched. Spawning takes place in water temperatures of 8-13°C. Development to hatching requires 15-16 days at 12°C, but about 3 weeks at 8°C (Krejsa, 1967b).

Within a few hours of hatching, the larvae, about 5 mm long, swim up to the surface, where they remain in a planktonic existence for the next 30-35 days. They are positively rheotactic and swim actively, in short bursts, against currents greater than 1 cm/sec. They are probably swept up and down the estuary by tidal currents, but any carried out to sea doubtless perish, as none have been taken in the ocean. However, in late spring and early summer, they are numerous around and below the spawning grounds (Krejsa, 1967b; Pearcy and Myers, 1974; Mason and Machidori, 1976). Larvae hatched upstream in freshwater may be carried into a lake or estuary during this phase of existence (McLarney, 1968).

During the planktonic stage of life, the larvae of the freshwater, non-anadromous form in lakes show distinct diurnal vertical migrations. They are most abundant at the surface during the darkest hours of the night, between 2100 and 0400 hours (9PM-4AM). During the day and on bright moonlight nights, they apparently stay deep (Sinclair, 1968).

Metamorphosis has been completed by the end of the planktonic period and the little fish take up a demersal mode of life. The adults move back upstream during the late summer, followed by the young in the early fall, although the young may remain in the estuary for a full year. Upstream movement is usually no more than a few miles and may be blocked by relatively small obstructions such as falls of 30 cm (1 ft) height (Krejsa, 1967b; Ringstad, 1974; Mason and Machidori, 1976).

Yearling fish (and possibly older ones also) have been observed to form schools in shallow water in lakes (Northcote and Hartman, 1959). Whether this is related to feeding or represents a remnant of their pelagic life or has some other explanation is not known.

The prickly sculpin grows rather slowly and shows wide variations in growth rates within and between year-classes, as well as from place to place. Some approximate lengths at different ages for fish from Oregon and Vancouver Island, B. C., are, 1+ 45-46 mm; 2+, 52-65 mm; 3+, 71-89 mm; 4+, 85-98 mm. The establishment of typical lengths at different ages is difficult because of the fact that this sculpin appears to make about 50% of the entire year's growth in only two months, July and August. Hence, the time of collection makes a great difference in the observed average lengths (Bond, 1963; Ringstad, 1974; Mason and Machidori, 1976).

The oldest specimen reported was a 7 year old fish from Oregon (Bond, 1963). If the very large specimens (240-300 mm) reported in the literature grew at the rates shown here, they must have been at least 13-17 years old.

Food of the prickly sculpin consists mainly of invertebrate animals of various sorts; as would be expected, these are mostly bottom-dwelling organisms and the developmental stages of insects. The list is a long one, including cladocerans, copepods, ostracods, amphipods, molluscs, mites, at least seven orders of insects, and small fishes. Among the insects, the Trichoptera, Ephemeroptera and Diptera seem to be the most important. However, the relative ranking of food items varies with season and locality and depends largely on availability. In some areas, salmon eggs and fry, sockeye, pink and chum, and even year old sockeye are eaten in considerable numbers. Up to 111 sockeye fry have been found in the stomach of a single prickly sculpin. This sculpin also eats other fishes, and even its own kind. One was found which had swallowed another sculpin more than half as long as itself (Pritchard, 1936b; Ricker, 1941; Robertson, 1949; Northcote, 1954; Hunter, 1959).

IMPORTANCE TO MAN

The prickly sculpin is of no direct importance to man. It is too small to be used as food and too difficult to capture in large numbers to be used for anything else. Indirectly, however, this species may be of considerable importance as a predator on the young of more valuable species and as food for the adults. It is an important item in the food of several fish-eating birds such as mergansers.

COASTRANGE SCULPIN

Cottus aleuticus Gilbert

DISTINCTIVE CHARACTERS

The coastrange sculpin is distinguished by having only a single pore on the tip of the chin, no palatine teeth, and no pronounced gap between the first and second dorsal fins.

DESCRIPTION

Body elongate, rather round anteriorly, compressed posteriorly; depth about 18% of total length. Head moderate, 20-23% of total length. Snout 27-33% of head. Eye small, round, its diameter less than snout length. Nostrils two on each side, well separated, each in a short tube, posterior nostril at antero-medial margin of eye. Mouth moderate, broad, maxilla reaching almost to below anterior edge of eye. Teeth small but well developed on both jaws and on vomer, absent from palatines. Gill rakers short, 5-7 on first arch. Branchiostegals 6. Lateral line complete, 34-44 pores, generally with a marked flexion on caudal peduncle. Pyloric caeca 3-6.

Fins

D. VIII-X, 17-20. A. 12-15. P_1: 13-16, usually 14. P_2. I, 4. Caudal fin truncate.

Scales

No scales. Skin smooth except for a small patch of prickles behind each pectoral fin.

Color

Dark brown to greenish or grayish on back and sides, with darker blotches. Sides lighter, ventral areas white. Usually two or three dark, saddle-like blotches below soft dorsal fin. Dorsal, anal, pectoral and caudal fins with dark bars. Spiny dorsal of spawning males with orange edge.

Size

Up to 172 mm (6 3/4 in) in southern California according to Hubbs (1921), but generally not over about 115 mm (4 1/2 in) and most are between 50 and 100 mm (2-4 in).

RANGE AND ABUNDANCE

From Peidras Blancas Point, California, north in coastal streams to Bristol Bay, Alaska, westward in the Aleutians to Kiska Island. An isolated population is found in the Kobuk River, Alaska, some 800 km north of the nearest Bristol Bay fish. Apparently isolated populations also are present in Lake Washington, Washington, and Cultus Lake, British Columbia, perhaps also in other lakes of that general area (Ricker, 1960; Ikesumiju, 1975; Larson and Brown, 1975). The coastrange sculpin is one of the more abundant small fishes throughout its range.

HABITS

Spawning generally takes place in the lower reaches of the streams and in the estuaries, but may occur well up stream as well. The eggs are deposited in clumps and clusters in crevices between rocks or (more often) on the underside of logs, cutbanks, rocks, etc. (Ringstad, 1974; personal observation). The eggs are yellow to orange, sticky, about 1.24 to 1.91 mm in diameter, and are usually present in at least two distinct groups of different stages of development. Spawning behavior has not been observed, so it is not known whether the clumps represent several spawnings by a single female or single spawning by several females, but judging by the numbers of eggs per nest, it is almost certainly the latter. Over 7,000 eggs have been found in a single nest, whereas fecundity ranges from 100 to 1,764 eggs per female (McPhail and Lindsey, 1970; Patten, 1971). The male guards the nest until all eggs have hatched.

Spawning occurs in the spring, as early as mid-February to as late as August in various areas, but mostly in May and June, in water temperatures around 6-8°C (Ikesumiju, 1975). Time required for development to hatching is 19-20 days at 10-12°C under laboratory conditions (Mason and Machidori, 1976). Larvae are about 5 mm long at hatching and swim to the surface within a few hours. The young are planktonic, floating near the surface, and are carried downstream to the inter-tidal portions of estuaries or out into open waters of large lakes. Feeding begins 6-10 days after hatching, by which time the yolk is noticeably depleted and most of the larvae have drifted down to the lake or estuary (Mason and Machidori, 1976). Young coastrange sculpins may be 20-30 mm long in the intertidal zone by mid-August (Heard, 1965; McLarney, 1968). In Carnation Creek, British Columbia, they average 41.5 mm long at age 1 (in August), 57.0 mm at age 2, 70.0 mm at age 3 and 79.5 mm at age 4. Sexual maturity is achieved in the third year (Ricker, 1960; Patten, 1971). Maximum age recorded is 8 years, although in Oregon they apparently do not survive beyond 4 years (Bond, 1963; Mason and Machidori, 1976).

The coastrange sculpin undertakes regular seasonal migrations. The adults move downstream to estuaries or at least the lower reaches of rivers in the spring, moving mostly at night. This migration is associated with spawning, although in some streams spawning takes place in the normal winter habitat upstream (McLarney, 1968; Mason and Machidori, 1976). A reverse upstream migration of yearlings and adults occurs in late summer to early winter, August to December. The young fish apparently spend nearly a full year in the downstream habitat. The winter is spent in the upper parts of the streams (McLarney, 1968; Ringstad, 1974). Where coastrange sculpins co-exist with prickly sculpins, in the lower portions of streams, the latter occupy sheltered areas of low current velocities, while the former are found more often on the heads and tails of riffles in swifter water. In the absence of prickly sculpins, especially upstream, the coastrange sculpin occupies both swift and quiet water (Ringstad, 1974). The coastrange sculpin is generally solitary, but large aggregations have been seen. It is not uncommon to find two or three individuals in the general vicinity of a nest (Greenbank, 1957; personal observations).

Food of the coastrange sculpin consists mainly of benthic insect larvae and nymphs. However, depending on the season of the year and the time of day, feeding habits vary. Feeding is most intense at night. During daylight hours in summer, Trichoptera larvae dominate the food. In late evening and early morning, Plecoptera and Ephemeroptera nymphs and chironomid larvae are important. In some streams, this sculpin preys heavily on pink salmon fry. Other foods include ostracods, mysids, cladocerans, amphipods and isopods. They can survive without food for 94 days or more, but lose about 33% of their weight in such circumstances (Hunter, 1959; Sheridan and Meehan, 1962; Ringstad, 1974; Ikesumiju, 1975).

IMPORTANCE TO MAN

The coastrange sculpin is of no direct importance. However, it may be, in some situations, a significant predator on salmon fry of several species, and has been shown to compete for food, sometimes severely, with coho salmon fry (Ringstad, 1974). In turn, the planktonic larvae of this sculpin are eaten by juvenile sockeye salmon and the adults may be important food items for larger predatory fishes such as Dolly Varden.

FOURHORN SCULPIN

Myoxocephalus quadricornis (Linnaeus)

DISTINCTIVE CHARACTERS

The fourhorn sculpin is identified by the four bony protuberances on the top of the head (smaller in females and young and absent in the freshwater form); the chain-like lateral line; the sharp, straight spines on the preoperculum; and no palatine teeth.

DESCRIPTION

Body tadpole-shaped, tapering posteriorly. Depth about 25% of total length. Head moderately large, 27-30% of total length, broad and flattened, its width notably greater than its depth. Four bony or warty protuberances on top of head, two between the eyes and two on occiput. Four preopercular spines on each side; upper spine long, straight and sharp, longer in males than in females; the two lower spines short and pointing downward. Snout broad, long, 26-30% of head length. Eye small, 60-80% of snout length.

Mouth large, terminal, lower jaw included, maxilla reaching to below middle of eye or farther back. Jaws and vomer with bands of small teeth. Gill rakers reduced to rounded, spiny protuberances, 7-8 on first arch. Branchiostegals 6. Lateral line chain-like, with about 45 pores, each with a small embedded plate.

Fins

D. VII to IX - 13 to 16, the spiny and soft fins separated by a space about equal to eye diameter. Soft dorsal often much enlarged in adult males. A. 13-17. P_1. 15-18. P_2. I, 3-4. Caudal truncate to slightly rounded.

Scales

No true scales. Lateral line with embedded, bony plates. Sides above and below lateral line with several irregular rows of round, bony, prickly plates, these best developed and most numerous in adult males, poorly developed or absent in females and young.

Color

Young are gray above, with three or four dark saddles below dorsal fins and a dark spot on dorsal side of caudal peduncle. Adults are darker. Spiny dorsal dusted with black, soft dorsal, anal, pectorals and caudal with dark bars. Pelvics pale.

Size

Reported to reach a length of 365 mm (Andriyashev, 1954) but most adults do not exceed about 280 mm and a weight of about 260 grams.

There are two distinct forms of M. quadricornis, the marine, brackish water and riverine form described here, and the dwarf, strictly lacustrine form, which is often considered a separate subspecies, M. quadricornis thomsoni. In Canada, this lacustrine form is called Deepwater Sculpin. It differs from the marine type chiefly in lacking the bony protuberances on the head and the spiny plates on the sides and in its small size. The deepwater sculpin has not yet been found in Alaska, but may be present in some of the deep, unexplored lakes of the Arctic.

RANGE AND ABUNDANCE

Circumpolar in cold, brackish and moderately saline water. In Europe, from the Baltic eastward along the Siberian coast to the Chukchi and Bering seas, south in the Bering Sea to the Anadyr River. From north-western Greenland westward along the arctic coast of Canada and the Canadian Arctic Archipelago, the north coast of Alaska and south in the eastern Bering Sea to Norton Sound and St. Lawrence Island. Ascends rivers for considerable distances. It has been found in the Meade River, Alaska, as much as 144 km (90 mi) upstream, and 192 km (120 mi) up the MacKenzie River in Canada. It is an abundant species, as far as is known.

HABITS

Most of the knowledge of the biology of the fourhorn sculpin comes from studies made in the Baltic Sea. Presumably, the life history of the fish in Alaska is not very different.

Spawning takes place from mid-December through January at depths of 15-20 m and water temperatures of 1.5-2°C. With the approach of the spawning season, males become territorial and aggressive towards other males. When an intruding male appears on the territory, the resident male advances toward him in quick, short darts, stopping 3-5 cm from the intruder with his dorsal and pectoral fins spread. At the same time, the resident produces a low-pitched humming sound, with a frequency of 125 cycles per second. The intruder usually lowers his dorsal fin and turns away. If he does not, the resident male bites him.

Two or three days before spawning, the females become restless, swimming about with short periods of resting. When a female swims over a male, he undulates his body laterally and raises his spiny dorsal fin. If the female comes to rest near the male, he moves close to her in a series of short darts. Both sexes fan rhythmically with their pectoral fins, sometimes for hours, resulting in a hole 20-25 cm in diameter and 10-15 cm deep in the soft bottom. Finally the male and female lie side-by-side, with the male's caudal fin twisted under that of the female. The male makes rhythmic motions toward the female with his tail, which apparently stimulates her to release her eggs (Westin, 1969, 1970b).

The eggs are adhesive and are extruded in a single clump. They are quite large, 2.4-2.9 mm in diameter and the color varies from greenish to bluish to yellow. At one time, the different egg colors were thought to indicate genetic differences (Svärdson, 1958; 1961) but subsequent investigation has shown that the colors of the eggs are controlled by diet (Nyman and Westin, 1968, 1969; Westin, 1968a, c). As would be expected with such large eggs, fecundity is low, 792-6,150, but in some populations up to almost 18,000 eggs (Andriyashev, 1954; Westin, 1968a).

After spawning, the female leaves and shows no further interest in the eggs. The male, however, remains with the egg mass, guarding it and attacking any fish that comes within about 30 cm. He generally lies close to the eggs, fanning them with his pectoral fins, and occasionally picking them up in his mouth and spitting away the dead ones. This cleaning is essential to successful hatching, as without it the eggs soon become infested with fungi and die. The male guards and cares for the eggs until they hatch, and does not feed during this period. Hatching requires 97 days at 1.5°C, 74 days at 2°C or 55 days at 4.7°C. At 10.5°C, all eggs die before hatching (Westin, 1969).

Fry hatch in the spring and reach a length of 20-24 mm by August. Little is known of subsequent growth except that it is slow. Fish one year old are 40-55 mm long, two-year-olds are about 97 mm, at 5-6 years only

210-240 mm long, those of 7-8 years are 240-270 mm, and at 10 years the average length is about 300-310 mm. Sexual maturity is first reached at 4-5 years of age, most fish being mature at 6 years (Andriyashev, 1954; Lukyanichov and Tugarina, 1965).

The fourhorn sculpin is most active in the daytime during the winter (November-April) but is largely nocturnal the rest of the year (Westin, 1971). It is quite strictly a cold-water fish, although under proper conditions of acclimation it can stand temperatures up to 25.5°C. In its adaption to very cold temperatures, around 0°C, it develops an organic "antifreeze" in the blood. At low temperatures, about 4°C, it adapts more readily to slight rises of temperature than to equal falls (Westin, 1968b; Oikari and Kristoffersson, 1973).

The fourhorn sculpin lives permanently near the coast. Barring short onshore-offshore seasonal movements and mass movements of fry into shallow water in summer (Andriyashev, 1954; Westin, 1970a) there are no migrations of large numbers of fish. Movements into fresh water and long distances up rivers are apparently undertaken by relatively few individuals at a time. Food of the fourhorn sculpin consists primarily of invertebrates of various sorts. The list includes priapulids, mysids, isopods, amphipods, molluscs, small fishes and fish eggs, the last most commonly the eggs of its own species. In the Baltic, the most important individual items are the isopod, *Mesidotea entomon*, and the amphipod, *Pontoporeia affinis*. It is the latter which gives the characteristic greenish or bluish color to the eggs. Fish living on diets which do not include *Pontoporeia* have yellow eggs (Andriyashev, 1954; Westin, 1968c, 1970a). In other areas, mysids may compose as much as 90% of the food (Lukyanichov and Tagarina, 1965).

Almost nothing is known of the biology of the deep water, lake-dwelling form. It lives at such great depths that its presence is often known only from the examination of stomach contents of deep-feeding carnivores like burbot and lake trout. It is present in the Great Lakes and in a number of deep lakes in Canada. It is most abundant at depths below about 75 m in the Great Lakes, at 25-37 m in Great Slave Lake. Its diet includes mysids, copepods, amphipods and chironomid larvae and pupae. This is a dwarf form. The three largest on record are a specimen 199 mm long from Lake Ontario and two of 103 and 109 mm from Lake Michigan. Similar and perhaps identical sculpins are known from a number of lakes in Europe. The forms in lakes which were most recently cut off from the sea, such as those on Victoria Island, Canada, and Lake Ladoga in Russia, are morphologically intermediate between those in older lakes and those in the sea (Deason, 1939; Rawson, 1951; Martin and Chapman, 1965; Dryer, 1966; Delisle and Van Vliet, 1968; Mc Phail and Lindsey, 1970; McAllister and Ward, 1972; Dyatlov, 1974).

IMPORTANCE TO MAN

The fourhorn sculpin is of no direct importance. Although it is edible and is used for food in some regions of the arctic coast, its distribution far from centers of population and the small yield of meat per fish militate against any high degree of utilization. The deep water lacustrine form is, where available, one of the first fish foods eaten by young lake trout, and is a minor constituent of the diets of adult lake trout and burbot (Andriyashev, 1954; Rawson, 1961).

SHARPNOSE SCULPIN

Clinocottus acuticeps (Gilbert)

DISTINCTIVE CHARACTERS

The flattened, tri-partite anal papilla and the cirri on eyeballs, head, lateral line and at the tip of each dorsal spine will distinguish the sharpnose sculpin from its relatives which occur in fresh water.

DESCRIPTION

Body elongate, slender, slightly compressed. Depth 15-19% of total length. Head rather small, about 23% of total length. Snout sharp, short, its length about 25% of head length. Eye nearly round, diameter about equal to or a little less than snout length, a slender cirrus on upper part of eyeball. Mouth terminal, upper jaw reaching to a vertical through anterior edge of pupil. Small teeth in bands on both jaws. Gill rakers reduced to low, smooth mounds, about six on lower limb of first arch, none on upper limb. Branchiostegals 6. Lateral line high anteriorly, recurved downward to middle of sides, straight posteriorly, 33-36 pores on body, often one or two more on tail, each of the anterior 15 or so pores with a slender cirrus. Anus located well forward, about 1/3 the distance from pelvic base to anal origin, with a broad, flattened, tripartite anal papilla.

Fins

D. VII to IX - 14 to 16. A. 10-13, next to last ray longer than the rays before and behind it. P_1. 13, reaching to or just beyond front of anal. P_2. I, 3, short. Caudal rounded.

Scales

No scales. On each side, one unbranched cirrus at inner side of base of nasal spine, one on upper part of eyeball, one above eye, two or three behind this on head, one or two at angle of gill opening, one above each of the anterior pores of lateral line, one at tip of each dorsal spine.

Color

Varies with the environment. Sometimes nearly uniform bright green, more often green to light brown above with dark, wedge-shaped saddles, broader below, on upper sides, with lighter color between. Sometimes a dark, longitudinal stripe along or below lateral line, sometimes interrupted with light spots. Ventral region creamy to white. Three dark lines radiating from eye, one to snout, one downward to behind mouth, third posteriorly to base of preopercular spine. Spiny dorsal with a dark blotch between first and third spines. Pelvic fins plain, others usually dusky, mottled or indistinctly barred.

Size

A very small fish, maximum size about 63 mm (2 1/2 in).

RANGE AND ABUNDANCE

The sharpnose sculpin is known from the Big Sur River, California, north along the coast to Alaska and westward along the Aleutian chain to Attu Island. It has been recorded from the Bering Sea side of Unimak and Unalaska islands (Wilimovsky, 1964;; Miller and Lea, 1972). Within this range it is a common member of the inshore rock/algae community, especially in sheltered tide pools in the upper intertidal zone (Green, 1971). At Amchitka Island, it is most abundant from late spring to early fall (Isakson et al, 1971). It occasionally ventures into fresh water.

HABITS

Virtually nothing is known of the biology of the sharpnose sculpin. It spawns in the spring and summer, for breeding has been observed at the San Juan Islands on 4 July and a ripe female was taken on 28 April. The eggs are brown, about 1 mm in diameter (Hart, 1973).

At Amchitka Island in the Aleutian chain, the sharpnose sculpin is most abundant near shore in warm weather (Isakson et al, 1971). Presumably, it moves into deeper, more sheltered areas to escape the rigors of winter.

Judging by its size and habitat, the sharpnose sculpin probably feeds on small invertebrates so common among the sea weeds and tide pools. However, nothing is known on this subject.

IMPORTANCE TO MAN

The sharpnose sculpin is a small, zoological curiosity, but as far as is known it is otherwise of no importance.

SECTION 16

FLOUNDERS--FAMILY PLEURONECTIDAE

The flounders are a remarkable group of fishes in which both eyes are on the same side of the head. The young are symmetrical at hatching and swim in an upright position. During larval development, one eye, usually the left, moves over the top of the head and comes to rest beside the other eye. The fish settles to the bottom, blind side down, and takes up a demersal mode of life. The eyed side is colored, usually brownish or greenish brown, and the blind side is white. The dorsal and anal fins are long, extending almost the entire length of the body, and have no spines.

Flounders are all marine, but a few species enter fresh water. Several species are highly important food fishes and are the objects of commercial fisheries. The group is of world-wide distribution in the ocean, but the greatest numbers of species and individuals are to be found in the northern hemisphere.

ARCTIC FLOUNDER

Liopsetta glacialis (Pallas)

DISTINCTIVE CHARACTERS

Both eyes on the same side of the head, the body covered with typical scales and the generally plain coloration distinguish the Arctic flounder.

DESCRIPTION

Body strongly compressed, broad, its depth 38-46% of total length. Head short, 22-26% of total length. Snout short, its length 14-18% of head. Eye a little longer than wide, diameter about equal to snout length, right (lower) eye a little before left. Nostrils in short tubes. Mouth small, oblique, asymmetric, jaws of blind side a little longer than on eyed side, maxilla reaching about to anterior edge of lower eye. Teeth incisor-like, small; upper jaw with 3-6 teeth on eyed side, 12-21 on blind side; lower jaw with 4-16 and 15-22. Gill rakers 9-15 on first arch. Branchiostegals 5-6. Lateral line with a very low curve above pectoral fin, straight behind, and a short, accessory branch on head; 73-76 pores in main portion. In males, the lateral line is complete, but in females as large as about 200 mm it is an open groove on the posterior part of the body (Walters, 1955).

Fins

D. 50-62, most anterior ray above eye. A. 35-44, an embedded forward-pointing spine before first ray. P_1. 9-11 (rarely 12). P_2. 6. Caudal rounded.

Scales

Weakly ctenoid on both sides of the body in males, with cycloid scales on the abdominal region of the blind side. Females usually with cycloid scales over most of the body and narrow bands of ctenoid scales along the bases of the dorsal and anal fins. In some populations the females are scaled like the males (Norman, 1934; Andriyashev, 1954; Walters, 1955).

Color

Eyed side dark olive green to brown, sometimes with scattered black dots or indefinite dark blotches. Blind side white, rarely with brown lapping over from the eyed side. Fins pale brownish, sometimes with a yellowish tinge or traces of dark spots.

Size

One of the smaller flounders, only rarely reaching 350 mm (13 3/4 in). Most are much smaller than 350 mm (10 in).

RANGE AND ABUNDANCE

The arctic flounder is almost circumpolar in its distribution. It is found in the Arctic Ocean from Queen Maude Gulf in arctic Canada westward along the coasts of North America and Siberia to the White Sea and the Barents Sea. It is present in the Chukchi and Bering seas southward to Bristol Bay on the American side and to the northern part of the Sea of Okhotsk on the Siberian side. It is a fish of the coastal waters, not found far offshore. In some places it is very abundant, at least inshore in summer. It often enters rivers (Jordan, 1884; Bean, 1887c; Andriyashev, 1954; Walters, 1955; Nikolskii, 1961; Alverson and Wilmovsky, 1966).

HABITS

As with so many arctic fishes, little is known about the arctic flounder. Spawning usually takes place in coastal areas in January-March, but may be as late as May in some regions. Spawning goes on in shallow water at depths of 5-10 m in regions of pronounced tidal currents, temperatures below -1°C and salinities of about 27-28 o/oo. Fecundity is relatively low for flounders, only 31,000-230,000 eggs per female. The fish usually reach maturity at 4-5 years of age, although maturity as early as 2 years has been reported. Spawning is said to occur only every second year. Females grow more rapidly than males, but growth is slow in both sexes. In the Barents Sea, five year old fish average only 177 mm long for males, 199 mm for females, and nine year old females are about 249 mm long. Arctic flounders appear to move offshore in the fall and onshore in spring. They move close inshore in the evenings, especially on a rising tide. Their food is mainly small molluscs, crustaceans and fishes (Turner, 1886; Bean, 1887c; Probatov, 1940; Esipov, 1949; Andriyashev, 1954; Nikolskii, 1961).

IMPORTANCE TO MAN

The arctic flounder is of little importance. Small quantities are taken commercially in the eastern parts of the Barents and White seas. In Alaska, this species was formerly (and perhaps still is) utilized by coastal subsistence fisheries, especially eaten raw. Opinions of early workers vary as to its utility. Jordan (1884) wrote that "...its great abundance and fine flavor make it an important article of food." By contrast, Turner (1886) found it "not palatable" and noted that, in summer, the fish often developed repulsive tumors along the fins.

STARRY FLOUNDER

Platichthys stellatus (Pallas)

DISTINCTIVE CHARACTERS

The starry flounder is set off by both eyes on the same side of the head, the dorsal and anal fins marked with dark and light (white to orange) bars, and especially by the stellate, bony tubercles scattered over the body.

DESCRIPTION

Body strongly compressed, asymmetrical, color on one side only. Depth 40-48% of total length. Head moderate, 23-26% of total length. Snout rather pointed, 15-18% of head length. Nostrils in short tubes, one at antero-dorsal margin of lower eye, the other just anterior. Eye small, diameter about equal to snout length or a little longer. Both eyes on same side of head, either right or left. Mouth terminal, oblique, lower jaw protruding. Teeth incisor-like, about 10 on eyed side of upper jaw, 15 on blind side, 12 and 16 on lower jaw. Gill rakers 6-11 on first arch. Branchiostegels 4. Lateral line with a slight arch over pectoral fin, 63-78 pores. Pyloric caeca usually 2 in North American specimens, sometimes 3 or 4; usually 4 in Asian fish.

Fins

D. 52-66, origin over middle of upper eye. A. 38-47, with a sharp, forward-pointing spine (often buried in skin) before first ray. P_1. about 11, the fin bluntly pointed. P_2. 6. Caudal slightly rounded.

Scales

Stellate, tuberculate, with well developed spines, scattered over head and body and in a row along bases of dorsal and anal fins. Tubercles more numerous on eyed side than on blind side, and increasing in number with size and age. Embedded cycloid scales present between the stellate tubercles, but their distribution seems to be quite variable (Norman, 1934; Orcutt, 1950; Batts, 1964).

Color

Eyed side dark brown to nearly black, sometimes with indefinite blotchings. Alaskan specimens sometimes have a greenish tinge. Blind side white to creamy. Dorsal with 4-7, anal with 4-6 dark bars with white to orange spaces between. Caudal with 3 or 4 dark longitudinal bars on its posterior part. Rather rarely, the blind side may be partly or completely colored like the eyed side; or white may be present on the eyed side, creating a piebald effect (Gudger, 1941; Follett, 1954).

Size

One of the largest, if not the largest, of the true flounders. Reported to reach nearly 1 m in length and 9.1 kg weight.

RANGE AND ABUNDANCE

The starry flounder ranges along the coast of North America from around Santa Barbara, California, north to the Arctic Ocean, then east along the Arctic coast of Canada to Bathurst Inlet, possibly even as far east as Queen Maude Gulf (Walters, 1955). To the west, starry flounders are found along the Chukchi and Bering coasts of Siberia (but not the Arctic Ocean coast) and southward to Japan and Korea. In the central parts of its range it is abundant and from Northern California to the Bering Sea. It is perhaps the most abundant of the flounders in near-shore areas. It is common in brackish water and may ascend rivers for some distance, even into fresh water (Gunter, 1942; C. Hubbs, 1947). The starry flounder apparently does not venture far from shore or into water of high salinity (Alverson and Wilimovsky, 1966; personal observations in the Chukchi and Bering seas, August, 1974).

HABITS

Spawning occurs in the winter and spring, from November to February off California, February to April in Puget Sound and British Columbia and still later farther north, with the height of the spawning season apparently corresponding with water temperatures near 11°C (Orcutt, 1950; Andriyashev, 1954; Hart, 1973). The eggs are quite small, 0.89-0.94 mm in diameter, colorless to pale orange, with a thin, vermiculated membrane. They are slightly less dense than sea water, so tend to rise and float near the surface. A medium-sized female of 565 mm standard length (about 690 mm total length) contained an estimated 11,000,000 eggs. Hatching occurs about 68 hours (2.8 days) after fertilization when the eggs are kept at 12.5°C, but 110 hours (4.6 days) at 10.5°C. The newly hatched larvae are about 2 mm long, with a large yolk sac. For the first few hours, they are largely quiescent and tend to float with the yolk sac uppermost. By 24 hours, however, the larvae, now about 3 mm long, have become quite active. The yolk is completely absorbed in about 10 days. The time of metamorphosis is unknown, but this phenomenon takes place at a length between 3.4 and 10.5 mm, probably closer to the latter (Orcutt, 1950).

Scalation with minute cycloid scales is present at 25 mm and these scales soon begin to develop into the typical stellate plates. Specimens of 100 mm show these plates on the eyed side of the head and along the dorsal and anal fin bases on both sides of the body. At 200 mm, there are broad bands of rough scales above and below the lateral line on the eyed side, on the head and in double lines above and below the lateral line on the blind side. As the fish continue to grow, the tubercles become more numerous and cover more and more of the entire body (Orcutt, 1950).

During the first 18 months of life there is a noticeable seasonal difference in growth rate; growth is rapid through spring and early summer, then slows through the fall to accelerate again in mid-winter through the following spring. The same growth pattern exists in older fish, but is less obvious. Typical lengths (converted from standard to total length by multiplying by a factor of 1.22) for fish from southern California are 1+, 129 mm ♂, 133 mm ♀; 2+, 287 ♂, 294 ♀; 3+, 364 ♂, 384 ♀; 5+, 477 ♂, 519 ♀; 7+, 620 ♀. A fish of this last length will weight about 3,250 g (7.15 lb) (Orcutt, 1950). Large individuals in more northern waters grow about 25 mm per year (Manzer, 1952)

Sexual maturity is reached at two years for males, three years for females. Females grow faster, reach a larger size and live longer than do males.

The starry flounder makes inshore-offshore migrations with the seasons. During the summer, they are inshore, often in very shallow water and in estuaries; they tend to move into deeper water, up to 300 m, in the winter. They may occur in the deep water at all times of year, for commercial fishermen fishing for other species have taken them at these depths in May (Turner, 1886; Bean, 1887c; Orcutt, 1950; Andriyashev, 1954). Other than these seasonal movements, starry flounders do not migrate much. However, the young move up rivers, and the adults may also, for as much as 120 km. Few adults have been taken far up rivers, however. A few fish tagged at the mouth of the Columbia River and in British Columbia waters had moved 96-200 km, but most were recovered within 5 km of the tagging area (Manzer, 1952; Westrheim, 1955).

The pelagic young feed on minute plankton. After metamorphosis and the adoption of a bottom-dwelling life style, demersal copepods and amphipods are important. As the fish grow, larger and larger items are included in the diet. From a length of about 100 mm on, food includes clams, snails, starfish, amphipods, polychaete worms, crabs, mysids and nemerteans. Fish are eaten only by the larger flounders, mostly those over 450 mm long. Small starry flounders graze on the siphon tips of clams, which lie buried in the bottom with only the ends of the siphons exposed. In Puget Sound, the starry flounder feeds heavily from July to October, stops feeding in January and apparently does not eat again until June. It is not known whether this feeding cycle occurs in other areas (Orcutt, 1950; Andriyashev, 1954; Miller, 1967).

When the fish is at rest, the dorsal and anal fins are curled towards the blind side, holding the body slightly off the bottom. Movement is most often a sort of crawling, using the fin rays of the dorsal and anal after the manner of the legs of a caterpillar. In quick, short movements, the pectoral fins are used as paddles. When disturbed, the starry flounder flutters its dorsal, anal and caudal fins so as to wave a covering of sand or mud over the body. It may bury so deeply that even the eyes are covered, and may be so confident of its concealment that force must be used to move it.

Adaptive coloration is pronounced. Starry flounders can alter their color and color pattern to simulate the bottom on which they lie. Fish on mud bottoms are dark, those on sand tend to be brownish, while on extremely light colored bottoms they are gray (Orcutt, 1950).

A major point of interest concerning the starry flounder lies in the fact that, although it belongs to a group which normally has the color and both eyes on the right side, it may have eyes and color either on the right side (dextral) or the left side (sinistral). There is some evidence, albeit inconclusive, which suggests that sinistral individuals are less viable than dextral fish, at least in some areas (Hubbs and Hubbs, 1944). Marshalled against this is the fact that over most of the range, sinistral starry flounders out-number dextral ones. There appears to be a general trend, with irregularities, for sinistrality to increase to the north and west. Off California, sinistral individuals make up 55.2-59.5% of the population; off the outer coast of Oregon, 49.2%; at the mouth of the Columbia River, 60.4%; off Washington, 66.4%; southeast Alaska, 58.2%; Kodiak Island and the Alaska Peninsula, 68.0%; Japan, nearly 100%. Sinistrality and dextrality are not correlated with sex, both males and females showing the same degree of reversal in a given population (Townsend, 1937; Hubbs and Kuronuma, 1942; Orcutt, 1950; Andriyashev, 1954; Forrester, 1969a).

The starry flounder hybridizes with at least two other species, the Japanese Karesius bicoloratus and the North American Parophrys vetulus. Both hybrids were given scientific names before their hybrid status was realized. The North American hybrid, Inopsetta ischyra, is not uncommon and has been studied to some degree. The hybrids have been found from Drake's Bay, California, north to the Bering Sea. Reproductive level of the hybrid is low due to abnormal development of eggs and sperm (Schultz and Smith, 1936; Herald, 1941; Hubbs and Kuronuma, 1942; Aron, 1958; P. Reed, 1965; Ueno and Abe, 1969).

IMPORTANCE TO MAN

Although the starry flounder is abundant and wide-spread, it is of relatively small importance. It is taken commercially, but mostly as an incidental catch when fishing for other species. Starry flounder is marketed, along with several other flatfishes, as "sole", so it is difficult to determine how much is taken. In California, landings have been fairly steady for many years at between 136,000 and 227,000 kg per year. Total landings of unclassified flounders on the west coast in 1971 amounted to about 909,000 kg. Probably about 75% of this was starry flounder. Smaller fish are considered superior to large ones for eating purposes, as the flesh of the latter is said to be somewhat coarse. Opinions vary as to the quality of the flavor. In Kamschatka it was canned as a luxury item for export (Andriyashev, 1935; Ripley, 1949; Orcutt, 1950; Anonymous, 1974).

The starry flounder is reasonably popular as a sport fish, for it bites readily most of the time and may often make the difference between a "dry" day and a successful one.

SECTION 17

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16. ABSTRACT

A summary of knowledge of the freshwater fishes of Alaska is provided. Covered are 56 species in 34 genera and 15 families, including strictly freshwater species, anadromous forms and those which normally are marine but which occasionally or regularly enter fresh water. For each species, a brief description is given, followed by discussion of its range and abundance, its general biology and its importance to man, as far as presently known.

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