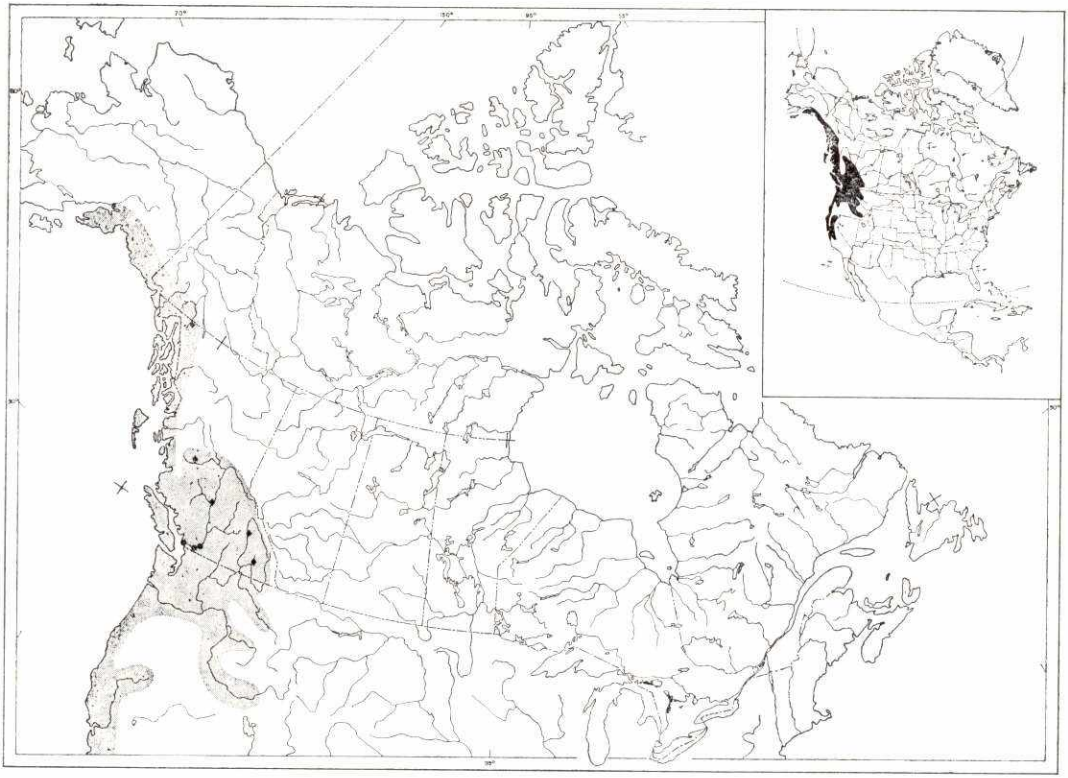

plates between dorsal and caudal or anal and caudal fins; 8 or 9 small plates, in pairs between anus and anal fulcrum; sometimes secondary rows of smaller plates between usual rows; no lateral line. Skeleton cartilagineous except for membrane bones of skull, jaw, and pectoral girdle, no vertebral centra, notochord persistent.

Colour Dorsal surface to upper edge of lateral plates and head to level of eyes dark to lighter grey, pale olive, or grey-brown, sometimes speckled with white; body below lateral plates, and head below eyes pale grey to white, ventral surface white; all plates light in colour; all fins dusky to opaque grey; viscera pale black and heavily pigmented. Young not distinctly different in colour from adults, simply lighter grey.

Distribution Restricted to the Pacific shores of North America from the Aleutian Islands of Alaska to Monterey, Calif. In Canada it is known to occur in the Fraser River system, including Harrison, Lower Pitt, and Stellako rivers, Fraser and Stuart lakes; Taku River; Kootenay Lake and River; the Columbia River above Revelstoke, B.C.; Duncan Lake, Vancouver Island, and possibly Okanagan Lake. Its coastwise distribution makes its presence in other British Columbia coastal drainages likely. Anadromous in most large rivers but landlocked in the upper Columbia River (mainly from Carl et al. 1967).

The first record of this species in Canada was that of J. K. Lord in 1866 (Clemens and Wilby 1961).

Biology Mature adults of this anadromous sturgeon move into large rivers in the early spring. The movements into and within fresh water are not clear and some adults may enter fresh water in the fall and winter. At times adults move great distances (as far as the Flathead River in Montana) on spawning migrations. The spawning period is usually May and June but could be later for distant migrants. Spawning probably takes place over rocky bottom in swift currents, near rapids or waterfalls, when water temperatures are between 48° and 62° F (8.9° and 16.7° C). Adults survive spawning and return to spawn more than once, but only after increasing intervals of years. In the younger females the interval is 4 years, and 9–11 years in older females. The adults probably migrate downstream in late summer and fall to return to the ocean. Egg number varies with size of female from about 699,000 eggs for a 35-pound female, 7 feet 10 inches (238.8 cm) total length to approximately 3–4 million in the largest spawners (Migdalski 1962). Ovary weight can be as high as 250 pounds. The eggs are brown and sticky and adhere to the bottom when laid. Nothing is apparently known of time to hatching or time to active feeding. Little is available on the growth of fish in the first year or two. Back calculation indicates one-year-old fish varied in length from 4.6 to 14.4 inches (11.7–36.6 cm) fork length (Semakula 1963). In general white sturgeon achieve a length of 20 inches (50.8 cm) total length by age 5, and grow about 2 inches (51 mm) per year to about age 25. Growth rate in length is slower after 35 years in age, and growth is mainly in weight. Growth pattern does not indicate a decrease in rate which might lead to a fixed upper maximum size.

Extensive data on age and growth rates for this species were given by Semakula (1963) and Semakula and Larkin (1968). The following age–weight, age–length data for Fraser River females to 35 years are based on the former publication.

Age	Mean FL		Mean wt of sample
(years)	*(inches)*	*(cm)*	*(lb)*
1	8.7	22.1	–
2	12.2	31.0	–
3	14.4	36.6	–
4	16.7	42.4	–
5	19.4	49.3	–
6	21.4	54.4	3.7
7	23.3	59.2	3.5
8	25.8	65.5	8.5
9	29.1	73.9	9.8
10	30.4	77.2	7.7
11	32.3	82.1	14.5
12	34.2	87.0	11.4
13	35.9	91.3	12.6
14	37.4	95.2	13.1
15	39.3	99.2	13.1
20	49.5	128.2	26.9
25	63.2	163.1	45.0
30	72.5	184.4	–
35	80.2	203.7	110.0

Semakula (1963) also stated that a 71-year-old female was 89 inches (226.1 cm) fork length and 173 pounds in weight. An individual 11.5 feet (348 cm) from the Columbia River was estimated to be 82 years old. It is highly possible that the largest specimens are over 100 years of age.

Age at attainment of sexual maturity is, like general growth, extremely variable and different for the sexes. First spawning in Fraser River white sturgeon, estimated from growth pattern, probably takes place between 11 and 22 years of age for males, and in females between 26 and 34 years of age. Spawning is preceded by 2–8 years of slower growth.

White sturgeon most often seen in British Columbia are those taken in the lower Fraser River incidental to salmon fishing. These vary in length from 7 to 89 inches (17.8–226.1 cm) and weigh a maximum of 218 pounds. They are known, however, to have grown much larger in the Fraser in the past and probably do today. The largest white sturgeon ever reported was purported to be over 1800 pounds, taken near Mission, B.C. There is an authentic record of one weighing 1387 pounds from the Fraser opposite New Westminster, reported in the *Daily Columbian*, New Westminster, August 14, 1897.

Apparently the angler record to date is a 394-pound fish taken below Swan Falls on the Snake River, Idaho.

This anadromous sturgeon spends most of its time in the sea. It is thought to stay close to shore in shallow water where it has been seen leaping, but is known to depths of 100 feet. It has been taken in water temperatures ranging from 32° to 74° F (0.0°–23.3° C) in salt, brackish, and fresh water. Movements in the sea are not well known, thought to be usually only local, but tagged fish have been known to move as much as 660 miles (Chadwick 1959). In fresh water there are unaccountable movements of small sturgeon upstream during the fall and early winter with a corresponding move downstream during late winter and early spring. Other vague seasonal movements, such as from deeper water in winter to shallower water in warm weather, and toward the ocean in summer months and fresh water in winter months, have been described (Migdalski 1962).

This species, like the other sturgeons, is mainly a bottom feeder, for which its ventral barbels, and ventral, protrusible, sucker mouth admirably adapt it.

The food of smaller sturgeon is predominantly chironomids, which occurred in 35.2% of the stomach of sturgeon of all sizes. Lesser amounts of mysids, *Daphnia*, *Chaoborus* larvae, molluscs, immature mayfly, caddisfly and stonefly, and a few copepods made up the rest of the food.

For individuals larger than 19 inches (483 mm) in length, fish become the principal food with crayfish *Pacifastacus* spp. second. Fish occurred in 48.6% of the stomachs that contained food but were more frequent in the larger sturgeon. Chironomids are also an important part of the diet of adults. In May, migrating eulachons were the most prevalent food items. Many of these, and lampreys, may have died after spawning and been sucked up off the bottom. However, other fishes such as: sculpins *Cottus* spp., threespine stickleback, and four sturgeons (*Acipenser transmontanus?*) found in a single stomach, must have been caught alive. The white sturgeon is apparently much more predacious or piscivorous than any other North American sturgeon (Semakula 1963; Semakula and Larkin 1968). Fishes as well as a wide variety of invertebrates probably make up the diet of this species when in the sea. White sturgeon either spend considerably more time in fresh water, or feeding does not stop until very shortly before spawning occurs.

There are no published accounts of predators of either young or adult sturgeon other than reports of attacks by the Pacific lamprey, *Entosphenus tridentatus*. Its size and protective plates may account for this. White sturgeon probably compete for food in fresh waters with the other Pacific sturgeons, the green sturgeon, *Acipenser medirostris*, as well as other bottom-feeding fishes.

The most serious limitation to this anadromous species may be the physical and ecological barriers created by dams and their impoundments.

Parasites listed for this species by Hoffman (1967) were as follows: Trematoda — *Nitzschia quadritestes*; Nematoda — *Cystoopsis acipenseri*.

Relation to man The flesh of this sturgeon is highly acceptable as food and the eggs, sometimes as many as 200 pounds in a single female, are readily prepared and marketed as caviar. The bulk of the Canadian commercial catch of this species comes from the Fraser River where it is taken in nets set for salmon (*Oncorhynchus* spp.). It has also been taken in otter trawls in the Strait of Georgia, purse seines on the west coast of Vancouver Island, and in salmon traps near Sooke (Clemens and Wilby 1961). Until 1928 it was legal to take it with set lines in the rivers. Over the years 1880–1963, the catch has been from 80,000 pounds to a low of 9800 pounds in 1942, to the greatest catch recorded, in 1897, of 1,137,696 pounds. Catches in recent years have fluctuated between 25,000 and 40,000 pounds. Prior to 1880 there was only a small subsistence fishery that yielded food to the Indians and isinglass from the swim bladder, which was sold to the Hudson's Bay Company. After the salmon fishery began, local markets for caviar and sturgeon flesh increased. By 1894 exports to eastern markets were being made. The peak catch of 1897 ensued and this was followed by a sharp decline (93.3% reduction in catch 1897–1905) to practically commercial extinction and reduction in licenses. Catch, size, and gear regulations were imposed, the catch recovered somewhat, but then declined in spite of the regulations. Since 1918 commercial catch has ranged from 10,000 to 50,000 pounds annually.

A diffuse sport fishery in the Fraser system might take an additional 20,000–30,000 pounds annually.

Nomenclature

Acipenser transmontanus	— Richardson 1836: 278 (type locality Fort Vancouver, Columbia River)
Acipenser aleutensis	— Heckel and Fitzinger 1836: no page number

Etymology *Acipenser* — old world name for sturgeon; *transmontanus* — beyond the mountains. Richardson who had come from the east was alluding to its Pacific coast distribution.

Common names White sturgeon, Pacific sturgeon, Oregon sturgeon, Columbia sturgeon, Sacramento sturgeon. French common name: *esturgeon blanc.*

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THE GARS — Order Lepisosteiformes

Gars are long, slender, cylindrical, predaceous fishes; with typical rayed fins; and a completely ossified skeleton. The head consists of many, heavy, small bones, but the opisthotic and supraoccipital are missing. The characteristic long, slender snout, which represents a lengthening of the ethmoid, is well armed with needle-like teeth. The lower jaw articulates with the skull in front of the eye. The body is completely covered in an armour of two-layered, ganoid scales most of which are joined by a peg and groove articulation. The pelvic fins are abdominal. The dorsal and anal fins are far back, opposite, and their rays bear a 1:1 relation with the supporting radials. All fins are without spine, but the anterior margins bear rows of fulcra. The tail is abbreviate heterocercal — heterocercal in internal structure, but externally superficially symmetrical. The vertebrae are ossified and of a unique opisthocoelous nature (anterior face convex, posterior face concave). The gars are physostomous, the swim bladder connected to the oesophagus, and the nasal openings connected to the pharynx. The swim bladder is cellular and highly vascularized. Gars are thus able to come to the surface and breathe atmospheric oxygen.

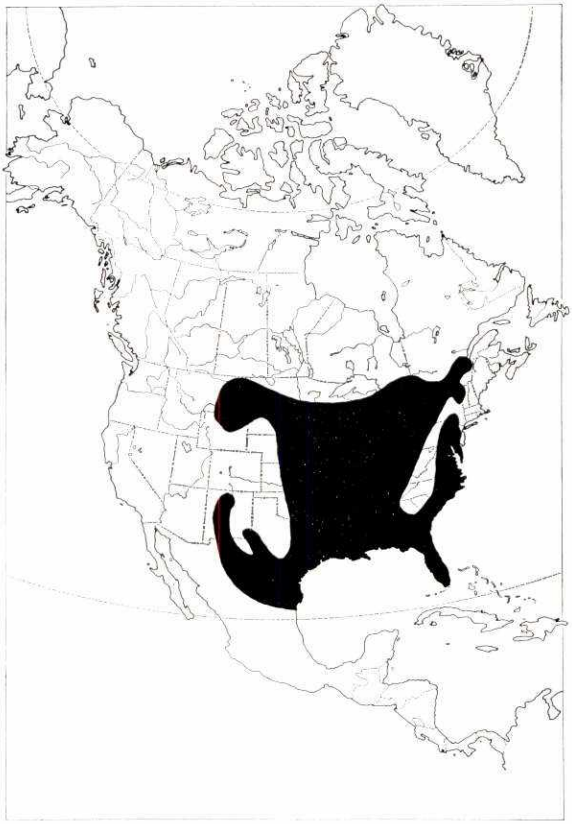
Once associated with Amiidae and Polypteridae they are now considered the sole living representative of a separate order known as fossils from the Jurassic.

GAR FAMILY — Lepisosteidae

The basic characters of this, the only family in the order, are as given for the order. They are long, cylindrical, predatory fishes with long, narrow, well-toothed snouts. The gars are primitive fishes with body covering made up of heavy, ganoid scales.

Primarily fishes of tropical and temperate fresh waters, some frequent brackish water, and to a lesser degree salt water. The single genus *Lepisosteus* contains 7 species sometimes organized in the subgenera *Lepisosteus* and *Atractosteus*. Gars are usually considered restricted to the New World but a species, *L. sinensis*, supposedly occurs in China. In the New World gars occur from Quebec, west to the Mississippi, and south to Costa Rica and Cuba.

Fossil evidence of this group dates from the Upper Cretaceous of Europe, the Eocene in India, and the Middle Eocene of North America.



World Distribution of the Gars

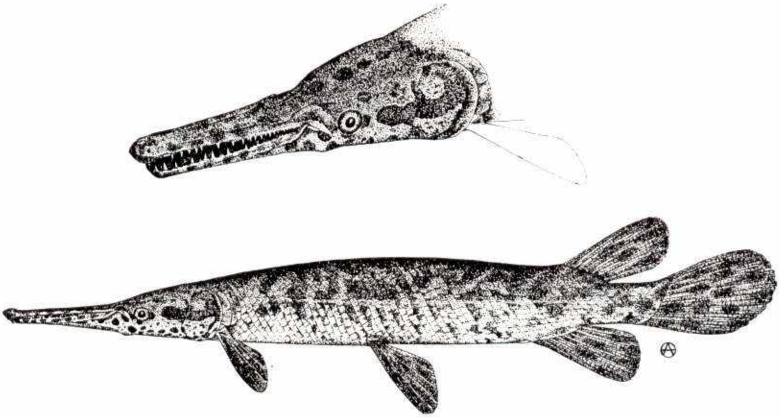
Key to Species

1 Snout long and narrow, least snout width into snout length 14–18 times; caudal peduncle shallow and long, least depth into length 2.3–3.4 times; lateral line scales 61–65; spots on body apparent only from pelvic fin to caudal peduncle, spots on dorsal, anal, and caudal fins. .... LONGNOSE GAR, *Lepisosteus osseus* (p. 105)

Snout shorter and broader, least snout width into snout length 6–8 times; caudal peduncle deeper and shorter, depth into length 2–2.3 times; lateral line scales 53–57; body, head, and all fins conspicuously spotted. .... SPOTTED GAR, *Lepisosteus oculatus* (p. 103)

SPOTTED GAR

Lepisosteus oculatus (Winchell)



Description Body long, oval in cross section, greatest body depth near anal fin, 7.9–10.9% of total length, usually 16–24 inches (406–610 mm) in total length; head long, 29.0–39.3% of total length, very bony, with pronounced depression in front of eyes; eyes in centre of head, moderately large, 8.2–11.0% of head length; interorbital distance, 11.8–20.9% of head length; snout long, 43.6–82.8% of head length, proportion variable with size, not so long as that of the much more common longnose gar, *L. osseus*, nostrils at tip; snout narrow (but broader than *L. osseus*), least width 9.9–16.0% of snout length, but wider than longnose gar; mouth with large number of sharp, needle-like teeth; teeth in row on palatines in fish longer than 12 inches (305 mm) small, but enlarged in smaller individuals; gill rakers 15–24 (mean = 19.3). Fins: dorsal and anal near caudal, opposite one another; base of dorsal shorter than that of anal, length 13.7–17.6% of total length, 7 or 8 rays; length of anal 12.0–18.7% of total length, rounded at tip, 8 or 9 rays; caudal peduncle shorter, deeper than longnose gar, depth 43.4–49.4% of length; caudal rounded but abbreviate heterocercal. There is in all gars a unique development sequence in the caudal fin at lengths less than 10 inches (254 mm). There is in this species and *L. osseus* a prominent, very motile, rayless, expanded filament on the dorsal and ventral surfaces of the notochord; the small, developing, rayed anal fin projects downward at 45°. Gradually the filament disappears and the anal assumes the shape and proportions of the adult. The pelvic fins are at the midpoint of body, wide, rounded at tip, 6 rays; pectorals very broad, distinctly rounded, 9–13 rays. Scales very heavy, rhomboid, articulated not overlapping, 53–57 in lateral series; lateral line apparent, complete; vertebrae characteristically convex in front, concave behind.

Colour Young brightly coloured; median, dorsal stripe broad and dark brown; dark, straight, lateral band with narrow reddish stripe above; ventral surface chocolate colour. At approximately 4–6 inches (102–152 mm) in length the spotted pattern characteristic of the adult begins to develop. Adults darker, less shiny than more common longnose gar, velvety brown; with darker brown spots, some as large as the eye, on snout, head, sides of the body, and fins.

Systematic notes The two short nosed gars in the north of North America were long confused and referred to as *L. platostomus*. When it was realized that two distinct forms were involved, Cope's 1865 name *productus* was applied to the spotted gar. Later, it was realized *L. oculatus* had priority. *Lepistosteus platostomus*, the shortnose gar, does not occur in Canada and apparently occurs in the Great Lakes drainage only in Wisconsin (Priegel 1963a).

Distribution The spotted gar occurs to only a limited extent in the Great Lakes basin but generally in the Mississippi River basin. It occurs from Lake Erie, Lake Huron (Saginaw Bay and south), Lake Michigan, the Ohio River possibly as high as Chautauqua Lake, N.Y., south to Alabama and western Florida, in the west from southern Minnesota, eastern Nebraska to eastern Texas as far as the Rio Grande River. More confined to fresh water than *L. osseus* but found in brackish water in the south (Suttkus 1963).

In Canada, it is limited to central and western Lake Erie, the Detroit River, and Lake St. Clair. It is not common and is rarely seen.

Biology The spotted gar is so rarely encountered in Canada that there are only eight specimens for study in the collection of the Royal Ontario Museum. There is no information on the biology of this species in the north and what little is known on populations in the south was summarized and published by Carlander (1969). It is stated in many publications that the biology of this species is very similar to that of *L. osseus*, but no detailed discussion seems to be available.

This gar spawns in the spring, in shallow, warm water where aquatic vegetation is abundant. Individuals 20.5–22.6 inches (522–575 mm) were said to be spawners (Suttkus 1963).

The food is almost exclusively fish, and Scott (1967) listed yellow perch, *Perca flavescens*, and minnows (Cyprinidae) as forming a large part of the diet. Feeding is most active in the morning (Carlander 1969).

Scott (1967) indicated 24 inches (610 mm) as the estimated average length in Ontario. Suttkus (1963) listed fish as large as a female of 29.8 inches (757 mm) from brackish Lake Pontchartrain, Louisiana. Migdalski (1962) recorded a spotted gar 44 inches (111.8 cm) long and 6 pounds in weight from Ohio. Maximum weight given by Carlander (1969) was 6 pounds, and growth rate of young was 1.4–2.1 mm and 0.7–1.3 grams per day in Oklahoma. Females are larger than males at the same age and probably live longer, as do females of *L. osseus*.

Relation to man The spotted gar is universally listed as an obnoxious fish because of its voracious and piscivorous feeding habits. Its true effect on fishes considered more valuable by man, and its possible benefit in management by controlling the numbers of smaller species, is largely unknown. The flesh is edible but not favoured. The eggs are probably poisonous as are those of the other gars.

Gars can be taken by hook and line, snare, or spear, but are so rare that none have been reported captured by anglers in Canada. They are not protected by commercial or sport fishery regulations.

Nomenclature

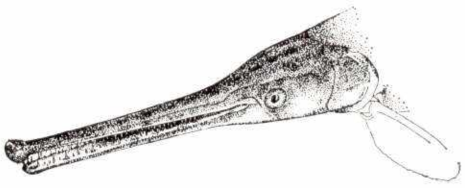
Lepidosteus (Cylindrosteus) oculatus	— Winchell 1864: 183 (type locality Huron River, Mich., type specimen UMMZ 55062)
Lepisosteus platostomus	— Nash 1908: 16
Lepidosteus platostomus Rafinesque	— Halkett 1913: 45
Lepisosteus productus	— Hubbs and Lagler 1941: 26

Etymology *Lepisosteus* — scale bone; *oculatus* — eyelike markings, referring to size, shape, and colour of spots.

Common names Spotted gar, shortnose gar, short-nosed gar, billfish. French common name: *lépisosté tacheté.*

LONGNOSE GAR

Lepisosteus osseus (Linnaeus)



Description Very long, cylindrical, slender, rodlike body; greatest body depth 5.5–7.4% of total length. They grow to 6 feet (183 cm) but those usually seen in Ontario are 2–3 feet (610–915 mm) in length. Head with characteristic, very long, narrow, bluntly pointed snout, with nostrils at tip, lower jaw conspicuously overhung by snout, head length 27.0–30.3% of total length, snout length 69.2–75.4% of head length, least snout width 5.8–6.2% of snout length; eye moderately large, interorbital width 10.5–13.7% of head length; gill rakers 24–28; teeth very abundant in whole of snout, villiform and sharp; caudal peduncle moderately long and narrow, least depth 29.1–36.5% of

length. Fins: single dorsal far back, nearly rectangular, high, with short base, above anal; dorsal base 83.5–97.6% of anal base, dorsal rays 7 or 8, anal rays 7–9; caudal rounded but abbreviate heterocercal, 11–14 heavy rays. Pelvic fins midabdominal, tip bluntly pointed, with 6 rays; pectoral fins low, only moderately wide, tip pointed, rays 10–13. Scales moderately large, thick, bony (ganoid scales), do not overlap but with peg and socket connection, 61–65 in lateral line series; thin, bony scutes on leading edges of unpaired fins and on both edges of caudal fin. Lateral line present and complete. The vertebrae of the gars are uniquely shaped, convex in front, concave behind.

Colour Adults usually soft olive-brown to dark green on the back and upper sides, lateral surfaces pale green or silver with white below. Median fins bright yellow to pale brown with large dark green, brown, or black spots; body with scattered spots of same size, mostly from pelvic fins back; paired fins dusky, usually without spots. Young are distinctively marked, velvety brown, rusty brown or velvety black contrasting sharply with cream to white. A broad, wavy, brown or black lateral band from snout to base of caudal fin, similar mid-dorsal stripe; ventral surface rich brown bordered by areas of cream to white. Spots on fins larger, more blotched, or in the form of bars (from Suttkus 1963). Good colour illustrations were included by Moore (1930).

Distribution The longnose gar is restricted to fresh and brackish waters of North America. It occurs from Quebec to Montana, south, in the east, through Lake Champlain to New Jersey, down the coastal plain to Florida, and in the west from Montana, northern Wyoming, central South Dakota, south to eastern Texas, northern Mexico and the Rio Grande River in New Mexico.

In Canada it occurs in Quebec as far down the St. Lawrence River as Ste. Anne de la Pocatière, 75 miles below Quebec City, in the eastern townships, and in Ontario south of a line from Lake Temiskaming to Sault Ste. Marie, including the lower Great Lakes. There is a single record north of this line, a specimen 26.8 inches (682 mm) in total length, from Nipigon Bay, Lake Superior, caught in June, 1961. This is the only record from Lake Superior in Canada. It is almost equally uncommon on the south shore of Lake Superior.

Although typically a freshwater fish it enters brackish water in its coastal distribution, particularly in the south. The salinity at the Ste. Anne de la Pocatière site was 13–20‰ on the surface to 25‰ on the bottom (Jean 1946).

Biology The longnose gar was said by Bensley (1915) to spawn in Georgian Bay, Lake Huron, in the middle of June. He said also it builds crude nests in 2 feet (610 mm) of water, on a bottom covered with short stems of aquatic plants. Beyond this, a few scattered notes on food and habits, comments on its destructive nature toward game and forage fish, and the numbers taken in control projects, constitute the Canadian literature on this species. Presumably, since it is of no economic importance it has never been deemed worthy of study in Canada.

Spawning takes place in the warm water of the shallows of lakes or large streams, over vegetation, in late spring or early summer depending on locality. There is evidence that some longnose gars make upstream spawning migrations. Netsch and Witt (1962) suggested gars move upstream to spawn coincident with the occurrence of spring freshets. Adults appear in large numbers over known weedy, spawning beds, and it is thought group spawning takes place; no nest is built, and the adhesive eggs, scattered randomly, become attached to vegetation. Eggs are large, 2.1–3.2 mm in diameter and dark green in colour. Number of eggs per female varied, in Missouri, from 4273 to 59,422 (Netsch and Witt 1962) with an average number of 27,830 for females 30.2–53.9 inches (76.7–137.0 cm) in length, or 3002 eggs/pound of body weight. Egg number as high as 77,156 has been recorded for a Florida longnose gar 56 inches (142.3 cm) long and 32 pounds in weight (Holloway 1954). In the warm, shallow waters of the spawning sites of this species eggs hatch quickly, 6–8 days in Wisconsin (Cahn 1927). *See* Fish (1932) for details and drawings of early development of young. *See also* Mansueti and Hardy (1967) for illustrations and description of larval stages in Chesapeake Bay region.

Young gar have an adhesive pad on the tip of the snout by which they adhere to vegetation above the bottom. They grow very rapidly, possibly 6 times as fast as the young of other North American freshwater fishes. In an experimental situation (mean water temperature 79.5° F or 26.4° C) they grew from 5.3 inches (135.7 mm) to 11.4 inches (289.6 mm) in 52 days with daily increments ranging from 2.7 to 3.9 mm. This species is characterized by unusual age and growth characteristics, large growth differential, and striking difference in longevity between sexes. Females grow faster, become larger, and live longer. Sex ratios in early life are as high as 262 males per 100 females but after age 10 these are as low as 8 males per 100 females.

Ages have been determined in longnose gar by means of otoliths, ceratohyal bones, and branchiostegal rays. Netsch and Witt (1962) used rings on the surface of cleaned branchiostegal rays and demonstrated annuli to corroborate this method. From this they also calculated a linear regression, $L = 131 + 3.8490\ R$ where L = total length in mm and R = length of branchiostegal in mm $\times$ 6.25, for back calculation of size at various ages.

At the end of the first year, females were 2.5 inches (64 mm) longer than males and this disparity increased to 7 inches (178 mm) at age 11, at which age males suffered almost complete mortality.

Mean age–length relation at time of capture is given in the following table for males and females in Missouri from 1 to 22 years of age (Netsch and Witt 1962).

Age	TL (male)		TL (female)	
	(inches)	*(cm)*	*(inches)*	*(cm)*
1	17.4	44.2	20.2	51.3
2	23.9	60.7	–	–
3	25.4	64.5	24.8	63.0
4	29.5	74.9	29.3	74.4
5	28.5	72.4	27.0	68.6
6	30.0	76.2	31.8	80.9
7	30.4	77.2	35.4	90.0
8	33.2	83.9	34.6	88.0
9	29.6	75.2	35.0	89.0
10	29.9	75.9	30.8	78.2
11	31.7	80.6	39.6	100.0
12	–	–	41.5	127.9
13	38.4	97.8	37.2	94.6
14	–	–	44.5	204.9
15	–	–	46.5	267.9
16	–	–	45.4	238.6
17	40.5	102.9	45.0	228.6
18	–	–	45.9	251.6
19	–	–	44.7	220.6
20	–	–	47.2	284.6
21	–	–	–	–
22	–	–	49.5	342.6

Netsch and Witt illustrated a curvilinear length–weight relation for specimens 3.7–53.9 inches (9.4–136.9 cm) in total length and 0.01–19.01 pounds in weight. This relation was log W = −7.0670 + 3.5075 log L, where W = weight in g and L = total length in mm. They also documented losses in weight, of up to 50%, in both sexes after spawning.

Maximum age of the Missouri specimens was 17 years in males and 22 years in females. Netsch and Witt (1962) recorded only two males beyond 11 years of age. Maximum size for this species is usually given as 5 feet (152.5 cm), but Walden (1964) gave the angler record as a gar 6 feet ¼ inch (183.4 cm) long, weighing 50 pounds taken in the Trinity River, Texas, July 30, 1954.

The usual habitat of this species is the quiet, weedy shallows of warm lakes or fairly large rivers where, in summer, the adults are often seen in groups, motionless at or near the surface. Apparently nothing is known of their habitat or activities in the north in ice-covered waters. They can withstand the warmest waters of the north and their ability to respire by gulping air at the surface enables them to live successfully in stagnant ponds, sloughs, and canals in the south. On the coasts they are often found in brackish water and, less often, in supposedly fully salt water. Short spawning migrations up streams have been described. Gars are apparently most active at night. The general conviction that the longnose gar is highly destructive of more valued fishes is doubtless the reason the bulk of the literature deals with food analysis.

This gar waits quietly in the cover of vegetation or debris, darts out at a nearby prey and, with a sideways thrust of its long beak, impales it crosswise in its needle sharp teeth. After a short time the food is moved back by successive movements and is eventually swallowed. The food of very small longnose gar consists of invertebrates, particularly larvae of aquatic insects. The fish quickly become piscivorous and numbers of minute minnows were found in a gar as small as 2 inches (51 mm) long. From that point on, fish form 59–88% of the diet. Several sunfishes and basses (Centrarchidae), suckers (Catostomidae), perches and darters (Percidae), catfishes (Ictaluridae), silversides *Labidesthes sicculus*, pikes (Esocidae), and various minnows (Cyprinidae) are most often represented in the list of fishes eaten in various places. Virtually all fishes that share its warmwater habitat are food for this voracious feeder. Other items include frogs, several species of crayfish (*Cambarus*), a short tailed shrew (*Blarina brevicauda*) in Indiana, and blue crab (*Callinectes sapidus*) in Louisiana. This species consumes large numbers of fishes and has a high food conversion efficiency. The rate of food intake with increase in length has been given as varying from 10.1% body weight/day, to 11.3% to 8%. Unlike many of the other gars, which eat dead as well as living material, the longnose gar is not considered a scavenger.

Its armour of ganoid scales and its secretive nature seem to protect it from predators, and records of its presence in the food of other fishes is limited to 1% of stomach contents (MacKay 1963). Although many other predatory, warmwater fishes, especially pikes, prey on the same species, the gars are able to succeed in waters where other predators cannot. Even in Canada this gar could, in summer, prey on fishes in hot shallows into which other predators may not be able to penetrate.

Parasites of the longnose gar (12) were listed in detail by Hoffman (1967) and included Trematoda (3), Cestoda (4), Nematoda (1), Acanthocephala (1), and Crustacea (3).

Relation to man Published comments on the longnose gar invariably utilize the words noxious, destructive, valueless, and nuisance. Large gars are destructive to fixed gear set for other fishes. Their flesh is not particularly attractive and, although used to a slight extent as food by man in the south, is scarcely used in the north. The eggs of gars are poisonous to man, other mammals, and birds. Consuming them causes severe illness in larger animals and, in some cases, death in smaller ones. Few animals will eat them, however. They are apparently not toxic to fishes since they have been recorded from the stomach contents of several fishes. Any gars marketed by Ontario fishermen were grouped as mixed scrap and animal food in the 1966 statistics of annual landings. This catch in 1966 (mostly alewife) was 1.5 million pounds, worth 11.6 million dollars. Up to 1967, landings of gar were reported as a unit with alewife, shad, and dogfish. In most areas they are killed and discarded. This species as well as the shortnose gar, *L. platostomus*, are, in the Mississippi, the host of the glochidea of the economically important shell mussel, the yellow sand-shell, *Lampsilis anodontoides*. Gars have been artificially infected and released in order to propagate this mussel.

The consequence of their feeding on species of fishes considered by man as more important has never been settled. In a study (Lagler and Hubbs 1940) that separated the fishes found in the stomachs of longnose gars into "game and pan fish" (basses, sunfishes, perch, and bullheads) and "other fishes" (mostly minnows, darters, and silversides), the relative percentages by volume were 59.9% and 36.5%. There is, however, no statement of the relative abundance of these species in the habitat. It would seem probable that the longnose gar is a voracious species, it may be a simple opportunist, and its effect on desirable species overemphasized. Its activity as means of advantageous control of numbers of small fishes, and the beneficial effects that might follow its removal, have never been demonstrated (Holloway 1954; Lagler et al. 1942).

Gars are sought by anglers with hook and line, snare, and spears in various areas and are not protected by any regulations.

Nomenclature

Esox osseus	— Linnaeus 1758: 313 (type locality Virginia)
Lepisosteus Huronensis	— Richardson 1836: 237
Lepisosteus rostratus, Nob.	— Cuvier *in* Richardson 1836: 238
Lepisosteus bison	— DeKay 1842: 271
Lepidosteus Huronensis	— Forelle 1857: 283
Lepisosteus longerostris Cuvier	— Fortin 1865: 67
Lepodosteus piquotianus	— Duméril 1870: 323
Lepisosteus osseus Gunther	— Jordan and Evermann 1896–1900: 110
Lepidosteus osseus Linnaeus	— Halkett 1913: 45
Lepisosteus osseus oxyurus Rafinesque	— Jean 1946: 100

Etymology *Lepisosteus* — scales of bone; *osseus* — bony.

Common names Longnose gar, northern longnose gar, garpike, common garpike, gar, billfish, northern mailed fish, needlenose. French common name: *lépisosté osseux*.

Suggested Reading – Lepisosteidae

AGASSIZ, L. 1850. Lake Superior. Its physical character, vegetation and animals compared with those of other and similar regions. Gould, Kendall and Lincoln. Boston, Mass. 428 p.

EYCLESHYMER, A. C. 1903. The early development of *Lepidosteus osseus* (with bibliography). Publ. Univ. Chicago 10: 259–275.

LAGLER, K. F., D. B. OBRECHT, and G. V. HARRY. 1942. The food and habits of gars (*Lepisosteus* Spp.) considered in relation to fish management. Invest. Ind. Lakes Streams, Ind. Dep. Conserv. 2: 118–135.

NETSCH, LT. NORVAL F., and A. WITT, JR. 1962. Contributions to the life history of the longnose gar, (*Lepisosteus osseus*) in Missouri. Trans. Amer. Fish. Soc. 91: 251–262.

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THE BOWFIN — Order Amiiformes

Stout bodied, oval, but somewhat laterally compressed, archaic, predatory fishes. A transitional group close to the gars but showing many characteristics leading to the higher teleost fishes. The head is rounded; the snout not produced. The toothed, lower jaw is a complex of many bones, and articulates with the ethmoid region of the skull. The ventral surface of the lower jaw has a large, characteristic, bony, gular plate. The fins are without spines. The rounded caudal fin is actually abbreviate heterocercal as in the earlier lepisosteans. Vertebral centra, when present, are double concave or amphicoelous (unlike the gars) and, in the tail region of some, diplospondylous (2 centra per vertebra). Fishes in this order have ganoid or cycloid, overlapping scales; fulcra are present, reduced, or absent.

Bowfins are known from the Upper Permian to the Recent of Asia, Europe, and North America. There is only one living family, Amiidae, which is restricted to North America.

Depending on the authority, there is a minimum of 6 and a maximum of 11 families in the order. Their transitional status, in relation to higher teleosts, and the changing concept of the relation of the amiids to other primitive groups, especially the gars, is demonstrated in the variety of ways in which they have been classified in the past. We utilize the concept (Berg) that 6 amiid families stand alone in the order Amiiformes adjacent to, but separate from, the gars.

Bowfin Family — Amiidae

This family constitutes the only living representatives of the order Amiiformes. *See* the description of the order for basic characteristics.

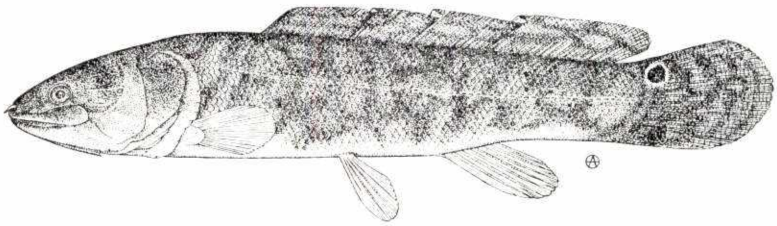
Bowfins are moderately large, oval, predatory fishes, with rounded, naked, bony heads, and bodies covered with cycloid scales. The mouths are well armed with pointed teeth. The possession of a bony, gular plate between the lower jaws is unique in Canadian freshwater fishes. The caudal fin is rounded and abbreviate heterocercal; the dorsal fin long. The swim bladder is physostomous, vascularized, and capable of assimilating atmospheric oxygen.

This primitive family is now represented by a single, living species, *Amia calva*, which is restricted to the fresh waters of eastern North America.

Fossil members of the family are known from the Tertiary of Europe and Tertiary to the Recent of North America.

BOWFIN

Amia calva Linnaeus



Description The bowfin has a moderately long, deep, robust body, greatest depth 14.2–19.7% of total length, body laterally compressed, cylindrical to oval in cross section near head. Those commonly seen are 18–24 inches (457–610 mm) in length and 2–3 pounds in weight. The head is massive, rounded, broad, naked, and bony, head length 21.9–24.1% of total length; eye small, diameter 30.5–38.5% of snout length; snout short, 5.9–7.3% of total length, bluntly rounded, with the nostrils well separated and the anterior pair opening through short, barbel-like tubes; interorbital width 25.9–29.8% of head length; mouth large, maxillary extending well past the eye; teeth varying from strong, pointed canines to shorter and peglike, present on premaxillary, maxillary, vomer, palatine, ectopterygoid, and on the dentosplenial coronoids and prearticular of the lower jaw. A unique character of this species, among Canadian freshwater fishes, is the heavy, oval, bony gular plate within the angle of the lower jaw. Branchiostegal rays 10–12, wide, bladelike; gill rakers mere knobs with denticles. The naked cheek, opercular bones, and the fleshy opercular flap are all wide. Fins: a single, very long, low dorsal with 46–50 soft rays, origin about 33% of total length and ending near caudal, base 42.7–47.5% of total length; virtually no caudal peduncle separating dorsal and caudal; caudal large, rounded, abbreviate heterocercal; caudal peduncle deep, greatest depth 11.0–13.2% of total length; anal with 9 or 10 rays, situated at midpoint of dorsal but base length only 14.3–20.2% of dorsal; pelvics small, rounded, and at midpoint of body; pectorals low, large, rounded, with 16–18 rays. Scales large, soft, and fleshy, "polygono cycloid," 64–68 in lateral line; lateral line complete; no pyloric caeca but gut with rudimentary spiral valve; physostomous, swim bladder bifid in front, cellular, and respiratory in function. Anterior vertebrae higher than wide, dense, amphicoelous, little sculpturing. One specimen from Lake Ontario had 80 vertebrae and one from Lake Erie had 87.

Colour Dark olive somewhat lustrous above, lighter on sides and below, the mingling of lighter yellow and darker olive giving a marbled or reticulated pattern, less so in females; belly cream to white; head yellow to brown with darker horizontal bars; dorsal fin dark olive with narrow darker bands crossing it, caudal light olive with irregular, broken, darker, vertical bars; at base of upper caudal rays a round to oval black spot twice the size of the eye, prominent in males and a yellow to orange halo, in females no halo and inconspicuous to absent; anal and paired fins bright green, often with orange at base and tip in males, and olive overall, without the orange in females; young individuals less than 8 inches (203 mm) in length are lighter in colour, light olive to apple-green, with dorsal and caudal tipped with narrow, black edge; snout, eye, cheek, and opercle crossed by a narrow dusky stripe (Forbes and Richardson 1920).

Distribution The bowfin occurs only in North America, from the St. Lawrence River–Lake Champlain drainage of Quebec and Vermont west across southern Ontario to the Mississippi drainage in Minnesota. In the east it extends southwest of the Appalachian Mountains to Florida, on the Atlantic coast from the Susquehanna River to Florida, but introduced in Connecticut. In the west it extends south through the eastern part of the states of South Dakota, Nebraska, Kansas (northeastern part only), and Missouri, to central Oklahoma and Texas.

In Canada it occurs in Quebec and Ontario in the upper St. Lawrence River (Lake St. Peter), Lake Champlain, Ottawa River, all the Great Lakes as far up as St. Joseph's Channel of lower Lake Superior, and in lakes Nipissing and Simcoe. Northward expansion of the range in Canada is possibly limited by temperature requirements, since distribution is south of 65° F (18.3° C) isotherm (Radforth 1944).

Biology The published information on this species in Canada is limited to some notes on its life history in Georgian Bay given by Bensley (1915), and growth data for Quebec published by Cartier and Magnin (1967). Otherwise we must turn to publications based on populations in Michigan and farther south.

The bowfin is a spring spawner. Bensley (1915) gave the spawning time in Georgian Bay as from May 24 to June 1, but they spawn as early as late April farther south. The males at this time move into shallow, vegetated water in lakes and rivers and prepare a nest. The nests, in 1–2 feet (305–610 mm) of water, are circular areas from which all leaves and stems are bitten off or torn out and removed, or are under logs, stumps, or bushes, and are 15–24 inches (381–610 mm) in diameter. The concave bottom contains the roots of the cut vegetation. Number and proximity of nests varies directly with the amount of suitable spawning territory. The male defends a small territory around the nest against other males, and torn fins suggest very aggressive defense. Optimum temperature for nest construction and spawning is 60.8°–66.2° F (16.0°–19.0° C) (Reighard 1904). A female is attracted into the nest and spawning takes place apparently during day or night. The female lies on the bottom of the nest, the male circles about her for 10 or 15 minutes, sometimes nipping her snout or sides. The male then takes up a position beside the female, there is a violent agitation of the fins of both fish, and eggs and milt are at this time released over a period of less than 1 minute. There are brief periods of circling and spawning, such that in 100 minutes four or five batches of eggs are laid. There are often three times as many males as females on the spawning grounds. More than one female may spawn with the same male in a single nest, and females may deposit eggs in more than one nest, so that a nest often contains eggs in different stages of development. The eggs are adhesive and stick to the bottom of the nest (Reighard 1900). A female bowfin 5 pounds in weight contained 23,600 eggs and a female 21 inches (533 mm) in length contained 64,000 eggs

(MacKay 1963). The eggs are creamy yellow when first laid but have been said to darken quickly and are then hard to see. The male guards the nest and maintains a current of water over the eggs by the motion of the pectoral fins. The young hatch in 8–10 days and are at this time 8 mm long. They have an adhesive organ on the tip of the snout by which they remain attached to vegetation for 7–9 days at which time they are 10–13 mm long. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region. Many authors, including Kelly (1924) and Doan (1938), have described the behaviour of males guarding a compact school of 30–40 (Doan 1938) to 1000 (Migdalski 1962) individuals for several weeks, up to the time they are 4 inches (102 mm) in length. The males at this time are pugnacious and, if forced to flee, drive the young down in a protecting cloud of silt created by their own departure. The young grow quickly and, in the United States, are 5–9 inches (127–229 mm) in length by October (Carlander 1969).

The age–length relation of the bowfin was for a long time unavailable as it was considered that age could not be determined from the scales. Cooper and Schafer in 1954 published age–length data for Michigan, and Cartier and Magnin in 1967 gave records for the Montreal region, using scales, gular plates, and otoliths. Cartier and Magnin also gave the following growth formula for all individuals: $\log L = 2.35137 + 0.59922 \log A$, where L = total length in mm and A = the age-group, and demonstrated the validity of back calculation of size at various ages. The age–observed length data are as follows:

Age	Observed length	
	(inches)	*(mm)*
1	8.7–9.3	221–236
2	14.9–15.6	378–397
3	16.2–19.0	412–482
4	16.2–23.8	412–605
5	20.1–25.2	511–640
6	21.3–24.2	541–615
7	24.6–28.3	624–718
8	26.1–27.3	662–693
9	25.2	640

They gave the weight–length expression as $\log W = -4.961 + 2.992 \log L$, where W = weight in g and L = length in mm, and the age–observed weight relation as follows:

Age	Observed weight	
	(lb) approx	*(grams)*
1	0.29–0.34	132–153
2	1.0–1.6	469–722
3	1.7–2.5	775–1150
4	1.5–4.7	675–2150
5	2.7–6.5	1255–2900
6	3.4–6.5	1539–2900
7	5.8–8.2	2605–3750
8	8.3–8.6	3760–3900
9	6.1	2750

Sexual maturity is thought to be reached at 3–5 years, at about 24 inches (610 mm) in females and 18 inches (457 mm) in males. Males are always smaller than females and probably do not live so long.

Maximum size in Quebec was given as 34.2 inches (870 mm) and approximately 15 pounds (6800 g), but this maximum weight appeared nowhere in the tabular or graphic presentation of weight data. The bowfin seen in Canada are usually 18–24 inches (457–610 mm) in length and 2–3 pounds in weight. Maximum age, it was suggested, was 12 years in Quebec but Carlander (1969) quoted ages of 20, 24, and 30 years for bowfin in captivity.

The habitat of the adults is swampy, vegetated bays of warm lakes and rivers. The capability of gulping air at the surface and withstanding high temperatures enables this species to succeed in stagnant areas in which other large predatory fish are unable to survive. The fact that the young are rarely seen after the schools break up suggests they move to deeper water or to dense vegetation. Neill in 1950 reported having unearthed an aestivating bowfin in a moist chamber 4 inches (102 mm) below the surface and 8 inches (203 mm) in diameter, $\frac{1}{4}$ mile from a river, the flood level of which had previously reached the location of the chamber.

Observations in aquaria suggest the bowfin is a slow, clumsy, stalking predator that uses scent as much as sight and captures food by means of a sudden intake of water.

The food of the bowfin is largely other fishes, crayfish, and frogs, although Breder (1928) reported individuals up to 17¾ inches (450 mm) in length in Mississippi had eaten mostly insects such as water boatmen, whirligig beetles, and dragonfly nymphs, the small shrimp *Palaemonetes exilipes*, and appreciable amounts of vegetation. Scott (1938) listed bluegills, *Lepomis macrochirus*; rock bass, *Ambloplites rupestris*; catfish, *Ictalurus*; pickerel (*Esox*); yellow perch, *Perca flavescens*; and bowfin, *Amia calva*. Lagler and Hubbs (1940) qualified stomach contents by volume as 59% game and pan fish (perch, catfishes, and sunfishes), 17.1% other fishes (mainly minnows), and 14.1% crayfish. They listed the following additional species of fish food: yellow bullhead, *Ictalurus natalis*; smallmouth bass, *Micropterus dolomieui*; large mouth bass, *Micropterus salmoides*; longear sunfish, *Lepomis megalotis*; pumpkinseed, *Lepomis gibbosus*; gizzard shad, *Dorosoma cepedianum*; carp, *Cyprinus carpio*; central mudminnows, *Umbra limi*; grass pickerel, *Esox americanus vermiculatus*, and Iowa darter, *Etheostoma exile*. They included 0.1% volume of carrion, so bowfin are obviously not significant scavengers. Insect forms listed were dragonfly, damselfly, caddisfly, soldierfly, and beetles. That it is an opportunist rather than a selective predator, as well as a voracious feeder, is exemplified by the fact that 84% of its food was gizzard shad in a Florida lake overpopulated by this species (Berry 1955). It takes (experimentally) approximately 32 hours for a young-of-the-year bowfin to digest a single fish at 69.8° F and 79.2° F (21.0° C and 26.2° C) the daily average ration of this size bowfin is 6.48% of body weight (Herting and Witt 1968). Aquarium observations of feeding show that adult bowfin often gorge on food when it is available in excess and, at this time, pass partly digested particles in the faeces, making insufficient use of food consumed.

There is apparently no information available on the predators of this species other than the fact that they appear in the food of the same species. They eat a range of fishes comparable to most other predatory fishes including several sport fishes. Their usual habitat is often unsuitable for sport fishes so that the true extent to which they compete with more valued species is not readily ascertained.

The parasites of *Amia calva* were listed in detail by Hoffman (1967) and these included 38 species as follows: Trematoda (16), Cestoda (8), Nematoda (6), Acanthocephala (4), leeches (1), Crustacea (2), and *Linguatula* (1).

Relation to man As with the gars, the bowfin, a voracious, piscivorous predator, is usually considered a pest since little commercial or recreational use is made of it, and since it consumes the same food as several more valued warmwater species. It may constitute a more serious direct predator on, and competitor of, sport fishes in Canada than it does in the south. Here the opportunity for it to utilize waters too hot and too deoxygenated for other forms is not so readily available and the bowfin and the sportfishes may more often be in the same areas of lakes or streams.

It is used as food to a limited extent in the south but not at all in Canada. The flesh, although edible, is very soft and jellylike and not considered of much value. Recent commercial catches in Canada are masked as they are grouped with several other species. MacKay (1963) listed the commercial catch in Ontario in 1956 as 77,000 pounds with a value of $2205, or an average of just over 2¢/pound. All of this was shipped to the United States. MacKay (1963) stated that the flesh can be made passably palatable by marination in spices and vinegar before cooking, by smoking, or by baking in highly seasoned dressing. Migdalski (1962) stated that the flesh is dry, has a mild flavour and when moulded into patties, dipped in egg and bread crumbs or corn meal, it makes passably good eating.

Although largely ignored as a sport fish it readily takes live bait and lures that are fished on the bottom. It provides considerable sport when taken on a light tackle. The bowfin is one of the few species that anglers and divers are permitted to spear as there are no regulations governing their capture.

The bowfin is usually considered detrimental to sport fish habitats. As a consequence of its appetite and diet, it may at times be a beneficial control on other species not favoured by man, as discussed by Berry (1955).

The small individuals make interesting and easily maintained aquarium subjects.

Nomenclature

Amia calva	— Linnaeus 1766: 500 (type locality Charleston, South Carolina)
Amia ocellicauda (Richardson)	— Richardson 1836: 236
Amia occidentalis	— DeKay 1842: 269
Amia canina	— Cuvier and Valenciennes 1846 (1828–1849): 424
Amia ocellicaudata Richardson	— Fortin 1866: 76
Amia thompsoni	— Duméril 1870: 419
Amia ocellicaudata	— Desrocher 1904: 38

Etymology *Amia* — an ancient name of a fish, possibly the bonito *Sarda sarda*; *calva* — smooth.

Common names Bowfin, dogfish, freshwater dogfish, mudfish, western mudfish, cottonfish, blackfish, John A. Grindle, grindle, grinnel, speckled cat, beaverfish, lawyer, scaled ling, choupiquel, poisson de marais. French common name: *poisson-castor*.

Suggested Reading – Amiidae

CARTIER, D., and E. MAGNIN. 1967. La croissance en longueur et en poids des *Amia calva* L. de la région de Montréal. Can. J. Zool. 45: 797–804.

FORBES, S. A., and R. E. RICHARDSON. 1920. The fishes of Illinois. Natur. Hist. Survey Div., State Ill. 357 p.

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THE HERRING-LIKE FISHES — Order Clupeiformes (Isospondyli)

The Clupeiformes are terete-bodied, elongate fishes, only moderately, laterally compressed; the body shapes of the Atlantic herring and salmons typify the appearance of the whole group; the head is well developed, covered with thin, membrane bones that are not well fused together; jaws may be weak, with minute or small, weak teeth, or may be well developed with strong teeth, the upper jaw usually bordered by premaxillary and the maxillary. Branchiostegal rays 1–36 and variously arranged. All fins without spines, always 1 rayed dorsal fin but, in addition, there may be an adipose dorsal fin located over, or slightly in advance of, the caudal peduncle; caudal fin extremely homocercal, internally the posterior 2 or 3 vertebrae may be upturned; 1 anal fin; pelvic fins abdominal and with many rays, pelvic girdle not attached to cleithra; pectoral fins located ventrally behind the head, the bases nearly or quite horizontal, and many rays. Scales small to large and cycloid or absent. Physostomes. Vertebrae numerous and not graduated in size, the earlier ordinal name, Isospondyli, is of Greek origin and means "equal vertebrae."

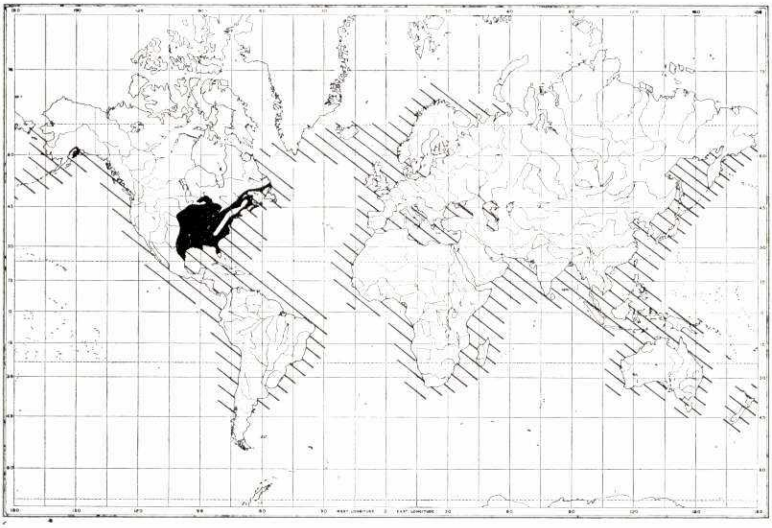
The clupeiform fishes are widely distributed through the world seas and in the fresh waters of the northern hemisphere. The order may be classified into as many as 9 suborders, 33 families, and over 900 species. Economically, this is the most important order of fishes occurring in Canadian fresh waters, and in terms of dollars and cents, is probably the most valuable group of fishes in the world.

Herring Family — Clupeidae

The herrings are of small to medium size, body usually slender, distinctly laterally compressed in most species; eyes with conspicuous adipose eyelids; mouth small to moderate, not large, jaws usually terminal, teeth small or absent. Gill rakers long, slender, and numerous. Scales confined to body, deciduous, cycloid, and with circuli arched across scale rather than in concentric rings; midline of belly, anterior to pelvic fins, often reduced to knife-edge thinness and armed with scutelike scales forming a saw-toothed edge. Lateral line absent. Adipose fin absent. Swim bladder thin walled. Pyloric caeca numerous. Vertebrae, total for Canadian species number about 39–59.

The herrings are silvery, pelagic fishes, primarily marine, but many species are anadromous and a few species live permanently in fresh water. They occur throughout the world's seas, except in antarctic waters.

The Clupeidae is a large family, containing approximately 190 species. Four species in 2 genera occur in Canadian fresh waters.



World Distribution of the Herrings

KEY TO SPECIES

1 Last ray of dorsal fin protracted into a long filament; snout rounded; mouth slightly subterminal; anal rays more than 25. .... GIZZARD SHAD, *Dorosoma cepedianum* (p. 133)

Last ray of the dorsal fin the shortest ray; snout more or less pointed; mouth terminal; anal rays fewer than 25 2

2 Lower jaw, when closed, nearly equal to upper, and fits into notch in upper jaw; maxillary extends at least to posterior margin of eye; gill rakers more than 55; usually 4–6 black spots in horizontal row behind operculum. .... AMERICAN SHAD, *Alosa sapidissima* (p. 128)

Lower jaw, when closed, extending beyond upper jaw; maxillary extends only to midpoint of eye; gill rakers fewer than 55; 1 prominent black spot near upper rear edge of operculum 3

3 Eye diameter usually greater than snout length; peritoneum silvery (otolith distinctive, *see* p. 121) .... ALEWIFE, *Alosa pseudoharengus* (p. 120)

Eye diameter usually smaller than snout length; peritoneum darkly pigmented (otolith distinctive, *see* p. 121) .... BLUEBACK HERRING, *Alosa aestivalis* (p. 119)

BLUEBACK HERRING

Alosa aestivalis (Mitchill)

Description The blueback herring is similar in shape and general appearance to the alewife, *Alosa pseudoharengus*, and is difficult to distinguish from it. The body is elongate, average length 8 inches (203 mm), compressed laterally and deep, its depth 22.1–25.2% of total length. Head broadly triangular, 18.5–20.6% of total length; eye moderate, adipose eyelid well developed, diameter of eye 22.0–26.4% of head length; snout length 23.4–30.0% of head length; interorbital 21.1–26.4% of head length; anterior end of lower jaw thick and rather heavy, extending beyond upper jaw when mouth closed and not fitting into groove in upper jaw; maxillary extending to below middle of eye; teeth small, weak, and few in number. Branchiostegal rays 7,7. Gill rakers 41–52. Fins: dorsal 1, height moderate, base short, 10.3–13.8% of total length, rays 16–18 (Hildebrand 1963, p. 325, said 15–20); caudal distinctly forked; anal 1, height relatively short, base long, 10.6–12.6% of total length, rays 15–17 (Hildebrand said 16–21); pelvic fins abdominal, rather small, length 8.4–10.0% of total length, rays 10 or 11; pectorals low on sides, length 13.0–15.0% of total length, rays 17 or 18 (Hildebrand said 14–16). Scales large, silvery, deciduous; lateral line not developed, scale rows 41–46. Ventral scutes well developed, pre-pelvic scutes 18–20, post-pelvic scutes 12–16. Pyloric caeca numerous. The colour of the peritoneum in the blueback herring is sooty to black as opposed to the pearly-grey peritoneum of the alewife. This is the most reliable character for distinguishing the two species except for otoliths, *see* p. 121. Vertebrae 49–51.

Colour The overall colouration is silvery but the back is greyish, blue-green, or dark blue, from whence the name blueback is derived. The sides and belly exhibit a silvery colour; peritoneum (lining of belly) sooty or blackish.

Distribution The blueback herring reaches its northern limit in Canadian waters and occurs along the eastern North American coast southward from Cape Breton, Nova Scotia, and the Fundy watershed of New Brunswick, to an area of relative abundance along the New England coast; thence as far south as northern Florida.

In Canada the species is not common. Specimens are known from the Bras d'Or Lakes on Cape Breton Island, in the Shubenacadie and Stewiacke rivers in Nova Scotia, and specimens were collected in the Kennebecasis River, King's County, N.B., in June 1967, and in the summer of 1968. The species occurs in other rivers such as the Saint John, but is not readily distinguished from the alewife.

Biology The blueback herring is an anadromous species, spending most of its life in salt water and returning to fresh water to spawn sometime in spring. It usually spawns in warmer water than the alewife and its spawning migration is correspondingly later. Various authors consider that this species does not go above brackish water for spawning purposes; others have indicated that it spawns in fresh water. As it does not ascend the freshwater streams as far as does the alewife, its spawning occurs nearer to the sea.

The large number of eggs, each about 1 mm in diameter, sinks to the bottom and adheres to sticks, stones, gravel, or other objects with which they come in contact, as is also true for the alewife. The spent fish return to sea on completion of spawning. Incubation is rapid, requiring about 2–3 days at a temperature of 72°–75° F (22.2°–23.9° C).

The young fish grow quickly and when they are about a month old they are 30–50 mm long, at which size they seem to move quickly into the sea. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region. Although known to be schooling fishes, little is known of the habits or growth of bluebacks at sea. They are caught along with alewives but generally not distinguished from them. There is some evidence that they may winter near the bottom. They grow to a size of 15 inches (380 mm) and a weight of about 13 ounces.

Food consists of plankton, copepods, pelagic shrimp, and small fish fry, as well as fish eggs and larvae.

Sumner et al. (1913) listed the acanthocephalan *Echinorhynchus acus* as a parasitic form infesting the blueback, and Gudger (1937) reported a specimen from Beaufort, N.C., with a large colonial hydroid, *Obelia commensuralis*, attached to its back.

Relation to man In Canada the blueback is caught commercially along with the alewife and generally processed or utilized in the same manner as that species. No special fishery or processing has been developed.

Nomenclature

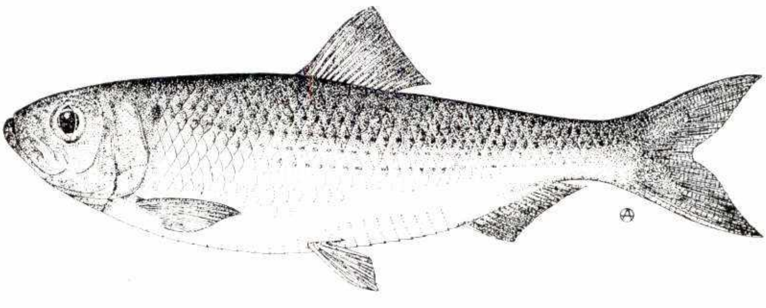
Clupea aestivalis	— Mitchill 1815a: 456 (type locality New York)
Alosa cyanonoton Storer	— Storer 1857: 266
Pomolobus aestivalis (Mitchill)	— Jordan and Evermann 1896–1900: 427
Pomolobus cyanonoton Storer	— Bean 1903a: 403
Alosa aestivalis (Mitchill)	— Bailey et al. 1970: 15

Etymology *Alosa* — Saxon "allis," old name of the European shad *Alosa alosa; aestivalis* — of the summer.

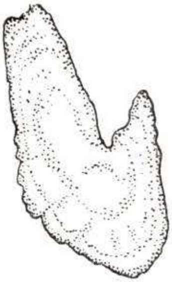
Common names Blueback herring, mulhaden, glut herring, blueback, summer herring, blackbelly, kyack. French common name: *alose d'été.*

ALEWIFE

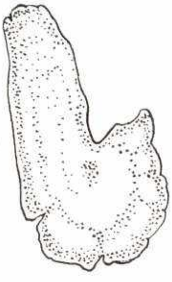
Alosa pseudoharengus (Wilson)



Description Body small, average length 6 inches (152 mm), strongly compressed laterally, and rather deep, its depth 17.8–21.7% of total length. Head broadly triangular, 20.3–23.7% of total length; gill membranes free; eye large, its diameter 26.1–32.0% of head length, adipose eyelid well developed; snout moderate, its length 26.9–35.7% of head length; interorbital width 15.7–21.6% of head length; anterior end of lower jaw thick and rather heavy, extending beyond upper jaw when mouth closed and not fitting into groove in upper jaw; maxillary extending to below middle of eye; teeth small and weak and few in number on premaxillary and mandible. Gill rakers on lower limb 38–43. Branchiostegal rays 7,7 (rarely 7,6 or 6,7). Fins: dorsal 1, height moderate, base short, 13.6–17.7% of total length, rays 12–16, usually 13 or 14; caudal distinctly forked; anal 1, height comparatively short, base long, 10.3–12.0% of total length, rays 15–19, usually 17 or 18; pelvics abdominal, rather small, length 8.2–11.6% of total length, rays 10; pectorals low on sides, length 13.0–16.6% of total length, rays 14–16, usually 16. Scales large, silvery, deciduous; lateral line not developed but scale rows about 42–50 along side; ventral scutes well developed, pre-pelvic scutes 17–21, usually 19 or 20, post-pelvic scutes 13–16, usually 14 or 15 — enumeration of scutes according to method described by Miller (1950a). Pyloric caeca numerous. Vertebrae 47–50 (Great Lakes 47–49, Atlantic coast 48–50). The shape of otoliths of *A. pseudoharengus* and *A. aestivalis* can be useful in identification. *See* outlines below.



A. aestivalis

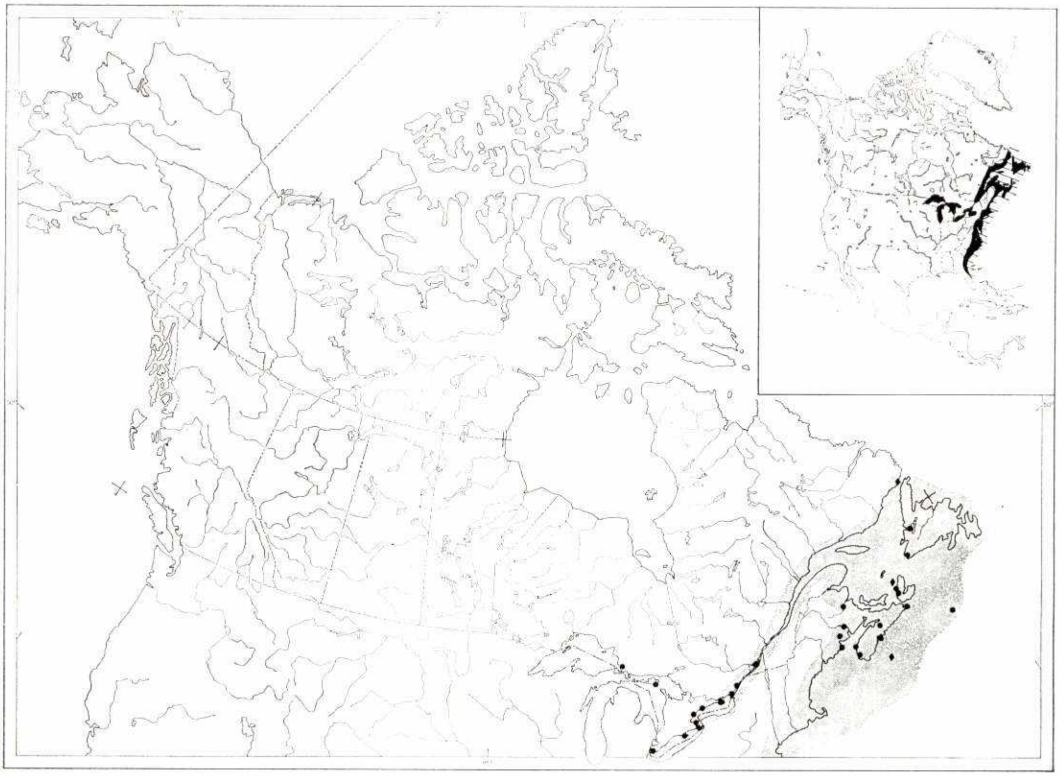


A. pseudoharengus

Colour The overall colouration of the alewife is silvery, the back greyish green and the sides and belly silvery, and iridescent when freshly caught. Adults sometimes have dark, longitudinal lines along the scale rows above the midline of the sides. Small specimens have a violet sheen on the silvery sides. Sea-run individuals have a golden cast on the head and upper parts but this is lost when in fresh water. A single black spot is present at eye level, immediately behind the head. The lining of the body cavity is pale to dusky.

Distribution The alewife is an anadromous species of eastern North America, a marine fish that uses freshwater streams for spawning and, hence, is indigenous to the lakes and streams of the Atlantic coastal drainage from Newfoundland to North Carolina. It is now landlocked in many inland lakes; in Ontario such lakes as Otter and Red Horse in Leeds County, the Rideau waters above Kingston Mills (Toner 1934), and throughout the western Rideau waters. Toner recorded the species from Gananoque Lake, Gananoque River, South Lake, Charleston Lake, Wiltsie Creek, from lower Beverly Lake (Toner 1937, 1938), in Kingston harbour, and in the St. Lawrence River below Kingston in 1941. In New York State it is also landlocked in Onondaga, Cayuga, and Seneca lakes, the Oswego River system, Ballston and Round lakes, and others. The greatest number of landlocked populations, however, occurs in the Great Lakes themselves. Presumably originating from Lake Ontario populations, the alewife now occurs in all of the Great Lakes, reaching extreme abundance in some years.

Much has been written regarding its abundance in fresh water, especially in the Great Lakes where the annual die-offs present serious disposal problems. First reported in Lake Ontario in 1873 (Bean 1884a), it became abundant in the late 1800's (Wright 1892). How the alewife became established in Lake Ontario is uncertain but it has been suggested that this resulted from its accidental inclusion with a planting of American shad, *Alosa sapidissima*, about 1870 (Bean 1884a). Smith (1892), in his report on the investigations of Lake Ontario fisheries, dismissed this theory since alewives were already present in Seneca and Cayuga lakes in New York State before shad planting began,



and could have migrated to Lake Ontario through certain lakes and water routes in that State, or even by ascending the St. Lawrence River. Radforth (1944) theorized that ". . . because the invasion of the Champlain Sea is held responsible for the occurrence of other marine species such as the smelt and shad in certain eastern waters, it is not improbable that the presence [of the alewife] in Lake Ontario may also be attributed to the marine invasions," or the alewife may be a native species, established when Lake Ontario was much higher and covered the entire Rideau lakes area, where they now occur in some lakes.

S. H. Smith in his study of the invasion and ecologic impact of the alewife in the Great Lakes (personal communication 1970) discussed in detail the theories of the alewife's entrance into Lake Ontario, and discounted the theory of accidental planting. He summarized as follows: ". . . there is convincing evidence that the major influx of alewives that contributed to the sharp population increase in Lake Ontario during the 1870's originated from downstream movement of alewives that were increasing sharply in the waters of the Erie Canal system in the 1860's. There is no reason to believe, however, that there was not at least some natural entrance from populations that long had access to the lake, or that some alewives had been accidentally introduced with plants of Atlantic shad fry. All evidence indicates, however, that alewives from these sources would have been too few, or too late to account for the population explosion in the 1870's."

Movement from Lake Ontario to the upper Great Lakes appears to have been exceedingly slow and was not detected until the first specimen was caught in 1931 and reported by J. R. Dymond in 1932. Niagara Falls presents an insurmountable barrier to all fish species attempting to move from Lake Ontario into the upper lakes, but the Welland Canal was completed in 1824, and the Erie Barge Canal, connecting the Hudson and Mohawk River systems with Lake Erie, in

Spread of the alewife in the upper Great Lakes, (modified from Miller 1957)

Date	Locality	Remarks[a]
Sept. 23, 1931	L. Erie, at E end off Nanticoke, Ont.	Adult, 7¾ inches long (Dymond 1932a)
Mar. 28, 1933	L. Huron, 12 miles E of Outer Duck Is., Ont.	Adult, from about 70 fath; others reported (MacKay 1934)
Apr. 15, 1935	L. Huron, 40 miles from Rogers City, Mich.	Adult, 188 mm SL, from 70 fath; UMMZ 109109 (Van Oosten 1935)
Dec. 26–31, 1940	L. Erie, off South Bass Is., Ohio	Adult, 9 inches TL, taken in gillnet by K. H. Doan (Trautman 1957)
May 5, 1949	L. Michigan, W of S Manitou Is., Mich.	Adult, 176 mm SL, from 60 fath, C. Anderson; UMMZ 157215
Mar. 20, 1951[b]	L. Michigan, off Whitehall, 14 miles SW of Montague, Mich.	Adult, 197 mm SL, from 60 fath, J. Grover; UMMZ 160969 (*see The Fisherman*, Vol. 19, No. 5, 1951, p. 6)
Mar. 12, 1952	L. Michigan, 10 miles ENE of Milwaukee, Wisc.	Adult, 177 mm SL, F. Miller; UMMZ 162861
July 14, 1953	L. Erie, South Bass Is., Ohio	Young-of-the-year (Langlois 1954, p. 207)
Dec. 22, 1953[c]	L. Michigan, 12 miles WNW of South Haven, Mich.	Adults, 180 and 188 mm SL, from 32 fath, C. Jensen; UMMZ 166514
Sept. 25, 1954	L. Superior, off Pendill's Cr., Chippewa Co., Mich.	Adult, 168 mm SL, R. Gordon; UMMZ 167872
Nov. 1954	L. Superior, Chequamegon Bay, off Long Is., Wisc.	Adult, 164 mm SL, obtained by R. Daly; UMMZ 167945
June 1 & 14, 1955	L. Superior, Whitefish Bay, about 1 mile N of mouth of Tahquamenon R., Mich.	Adults, 162 and 175 mm SL, from poundnet, E. L. Pomeroy
June 3, 1955	L. Huron drainage: Ocqueoc R. Weir near Rogers City, Mich.	Adults, 179 and 182 mm SL, A. E. Hall, Jr.; UMMZ 169062
June 11, 1955	L. Michigan, East Bay of Grand Traverse Bay, Mich.	19 juveniles, 55–76 mm SL, bait dealer for S. Lievense; UMMZ 170945
Sept. 14, 1955	L. Huron, along shore in the Les Cheneaux Channels, Mackinac Co., Mich.	Fingerlings, about 2 inches TL, bait dealer; identified by L. R. Anderson
Oct. 17 & Nov. 12, 1955	L. Superior, Gros Cap area near Sault Ste. Marie, Ont.	Adult male, 210 mm TL, and adult female, 273 mm TL, identified by K. H. Loftus and W. B. Scott; ROM 18157 (male)
Feb. 13, 1956	L. Superior, off Two Harbors, Minn.	Adult from herring net, Adolph Ojard; identified by J. G. Hale and S. Eddy
Mar. 1956	L. Superior, off Knife R., Minn.	Adult taken by I. Pederson; identified by J. G. Hale
June 6, 1956	L. Superior, at mouth of Blind Sucker R., Luce Co., Mich.	Adult, 9½ inches long, caught by G. McGary; 2 other adults also taken. Identified by L. R. Anderson
July 31, 1956	L. Superior, Split Rock R. area, Minn.	Adult, 161 mm SL, from herring net, Ragnivald Sve
Aug. 31, 1956	L. Superior, off Shaganance Is., (near entrance to Black Bay), Ont.	Adult male, 166 mm SL, taken by M. Gerow; identified by R. A. Ryder
Sept. 10, 1956[b]	L. Michigan, East Bay of Grand Traverse Bay at O-at-ka Beach, Mich.	341 postlarvae to young, 19–40 mm SL, taken in minnow seine for S. Lievense; UMMZ 171308
Nov. 5, 1956	L. Superior, Keweenaw Bay, 1 mile off town of Keweenaw, Mich.	Adult, 181 mm SL, from surface gillnet over 17 fath, taken by U. Weideman

[a]Abbreviations SL, standard length; TL, total length; UMMZ University of Michigan Museum of Zoology; ROM, Royal Ontario Museum.
[b]Approximate date.
[c]On Apr. 24, May 10, and Oct. 20, 1954, three more adults were taken in 32–50 fath by Mr. Jensen from the same general area; UMMZ 167702.

1825. Although it seems most probable that the alewife entered Lake Erie via the Welland Canal, it is also possible that entry was gained via the Erie Barge Canal.

The spread of the alewife through Lake Erie and upper Great Lakes has been the subject of much study since it provided a rare opportunity to observe the rapidity with which a species could invade and occupy a new environment. Dr R. R. Miller in 1957 provided a comprehensive review of the dispersal of the alewife and the following summary, modified from his data, traces the spread of this species in the upper Great Lakes. Some of the specimens listed are preserved in the University of Michigan Museum of Zoology (UMMZ) and one is in the Royal Ontario Museum (ROM).

By 1942 it was common in Lake Erie but did not become a dominant species, possibly because of the lack of deep water where it could overwinter to avoid the cold, and also because of the presence of large populations of predator species.

It appeared in Lake Huron in 1933 (MacKay 1934), where it became abundant. A measure of the rapidity of increase in Lake Huron can be seen from the following quotation from Scott (1963): "An appreciation of the rate of increase of the numbers of this species in Lake Huron may be gained from the following production figures for the experimental fishery operated on South Bay, Manitoulin Island, by the Ontario Department of Lands and Forests. The fluctuations in total catch from 1957 onward probably reflect variation in gear and fishing effort rather than fluctuations in population.

1951 — 1 specimen (4 oz)
1952 — 5 specimens
1953 — 53 specimens (6 lbs)
1954 — 2316 pounds
1955 — 16,302 pounds
1956 — 22,428 pounds
1957 — 19,045 pounds
1958 — 41,655 pounds
1959 — 28,540 pounds
1960 — 19,154 pounds
1961 — 40,563 pounds
1962 — 32,974 pounds
1963 — 24,666 pounds"

First reported in Lake Michigan May 5, 1949, the alewife is now the dominant species in the lake. The depletion by the sea lamprey of large predator fishes such as lake trout and burbot was probably an influential factor in the rapid increase in numbers of the small but prolific alewife. The Lake Michigan commercial fishery yielded 29 million pounds in 1966 and reached 40 million pounds in 1967. Many measures have been suggested to control the numbers of alewives, particularly because of the spring and summer die-offs. The recent introduction of the coho salmon, *Oncorhynchus kisutch*, into Lake Michigan waters is expected to have a marked effect on alewife numbers since coho feed heavily on alewives.

In 1945 the alewife appeared in Lake Superior but it is not particularly abundant there, possibly because it avoids water as cold as that of Lake Superior, and possibly because of predation by the lake trout and other large predator species.

Biology The marine populations of alewives spend most of their adult lives in the sea, entering fresh water to spawn in lakes and quiet stretches of rivers above the influence of the tide. Although they do not jump over obstructions, they can negotiate rapids and fishways and go farther upstream than their close relative the American shad, *Alosa sapidissima*. In the Miramichi River system in New Brunswick, spawning must take place largely in the river since there are few connecting lakes; in the Shubenacadie system in Nova Scotia they enter Grand or Shubenacadie lake, some spawning there, others moving on to Fletcher Run and Rawdon rivers.

Spawning migration from the sea is related to the water temperature of the river and hence takes place earlier in the southern part of the range. Leim and Scott (1966) stated that the migration begins in April and may last for 2 months in rivers tributary to the Bay of Fundy. Maturing alewives are caught in Saint John Harbour from late January but do not move up the river until early in April. The run is a little later in the rivers tributary to the Gulf of St. Lawrence. In the Margaree River, N.S., alewives appear first from May 4 to 27 and the run lasts from 1 month to 6 weeks. In the Maritime Provinces, where several commercial alewife fisheries are supported, spawning commenced in May and continued until late in June (Gillespie 1967).

The landlocked alewife inhabits the open lake waters during most of the year and moves onto the shallow beaches and into ponds to spawn. In Lake Ontario, Graham (1956) observed that the inshore movement of adult alewives from deep water began sometime in April, the precise time varying with the area. The greatest number arrived inshore about the middle of June in the Port Credit area of Lake Ontario where migration began in April and lasted until mid-July. In the Bay of Quinte region they were most abundant on the spawning grounds in late June and migration lasted until late July, again depending upon water temperatures.

Alewives move inshore at night and offshore during the daylight hours. Graham (1957) described the milling and "roller-coaster" movements of the schools when inshore. Females usually appeared on the spawning grounds first, with the males arriving soon afterwards. Spawning took place at night in groups of three or in pairs, over a sandy or gravelly bottom. The eggs were variously estimated from 10,000 to 12,000 from a freshwater female (Odell 1934). A sea-run female may produce on the average 60,000–100,000 eggs, the average size of the unfertilized egg being 0.9 mm in diameter (Mansueti and Hardy 1967). Eggs are broadcast at random, are demersal, and may be somewhat adhesive immediately after extrusion, but are essentially nonadhesive (Mansueti 1956). Hatching takes place in 6 days at a mean water temperature of 60° F (15.6° C) or in 3 days at 72° F (22.2° C). Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

Graham (1956) observed that the adults left inshore waters immediately after spawning, most migrating to deep water sometime in late August. About mid-September they appeared in water 150–300 feet deep, reaching abundance by December and remained to overwinter in the deep water until March.

Juvenile alewives migrate inshore in spring, like the adults. They are found in shallow water at dark, and during the daylight hours are located on the bottom in 6–10 feet of water. It is probable that time of migration of juvenile alewives to deep water and duration spent there are similar to that of adult alewives.

The young remain on the spawning grounds until at least the late larval stage and then move slowly into protected areas on their way to deep water. By fall the young have attained a length of 2–3 inches (51–75 mm) (Smith 1907). Little is known of the life history of the alewife in the sea but size attained is usually about 10–12 inches (254–305 mm), occasionally 14 inches (356 mm).

Graham (1956) gave detailed information on the relative growth in different areas of Lake Ontario, and also a comparison with Atlantic specimens. The alewife in Lake Ontario displays rapid early growth, decreasing with the onset of maturity which occurs at age 2 for males and age 3 for females. Average length of the adult alewife in fresh water is about 6 inches.

Female alewives attain greater size than males and may live longer. Females also exhibit faster growth rate than males (Pritchard 1929). Rounsefell and Stringer (1943) reported Atlantic female alewives average 6–9 mm longer than males in Nemasket River in Massachusetts and in Demariscotta and Orland rivers in Maine. Males appeared to become sexually mature 1 year earlier than the females.

Atlantic alewives of both sexes mature one year later than the landlocked Lake Ontario alewives. Graham has also shown that the Atlantic alewife had a more rapid rate of growth throughout most of its life than the Lake Ontario alewife. It is suggested that freshwater environment hastens sexual maturity with the attendant inhibition of growth.

Alewives are basically zooplankton feeders, both as adults and young. In fresh water, the principal food organisms seem to be copepods, cladocerans, mysids, and ostracods. Insect larvae may be significant components in the diet of inshore adults. Algae, diatoms, and pieces of plant material have also been found in stomachs but Norden (1968) suggested that these may be ingested accidentally. In a detailed study of the food of larval alewives (5.9–6.1 mm total length) in Lake Michigan, Norden demonstrated that cladocerans (mainly *Bosmina*) and copepods (mainly *Cyclops* and *Limnocalanus*) constituted 75% or more of the organisms eaten and that a high degree of food selectivity was apparently exercised by the alewives. Morsell and Norden (1968) noted that landlocked adult alewives tended to eat zooplankton until about 4.7 inches (119 mm) long, but larger fish ate increasing numbers of the more benthic amphipod *Pontoporeia*.

Specimens from Minas Basin (upper Bay of Fundy) contained amphipods, mysids, and copepods, as well as small fishes and fish eggs.

Freshwater populations of alewives are preyed upon by the larger piscivorous fishes such as freshwater burbot and lake trout. Indeed the alewife was the main food supply of the Lake Ontario lake trout. As noted in the section entitled *Relation to man,* coho salmon, *Oncorhynchus kisutch,* introduced into Lake Michigan, are known to eat large quantities of alewives. Eels have also been reported to prey on alewives in Lake Ontario. Alewives have been reported in the stomachs of the following fishes caught in Finger Lakes of New York State: lake trout, rainbow trout, cisco, northern pike, smallmouth bass, yellow walleye, and perch. Small alewives, 53–69 mm long, were found in the stomachs of lake whitefish caught in a small lake emptying into the North Channel of Lake Huron (C. A. Lewis, personal communication).

Studies of the parasites of landlocked alewives appear to be rare. Sumner et al. (1913) listed the following parasites of alewives captured in the vicinity of Woods Hole, Massachusetts: Acanthocephala (*Echinorhynchus acus*); cestodes (*Rhynchobothrium imparispine*); trematodes (*Distomum appendiculatum, D. bothryophoron, D. vitellosum,* and *Monostomum* sp.); and copepods (*Argulus alosae, Caligus rapax,* and *Lepeophtheirus edwardsi*).

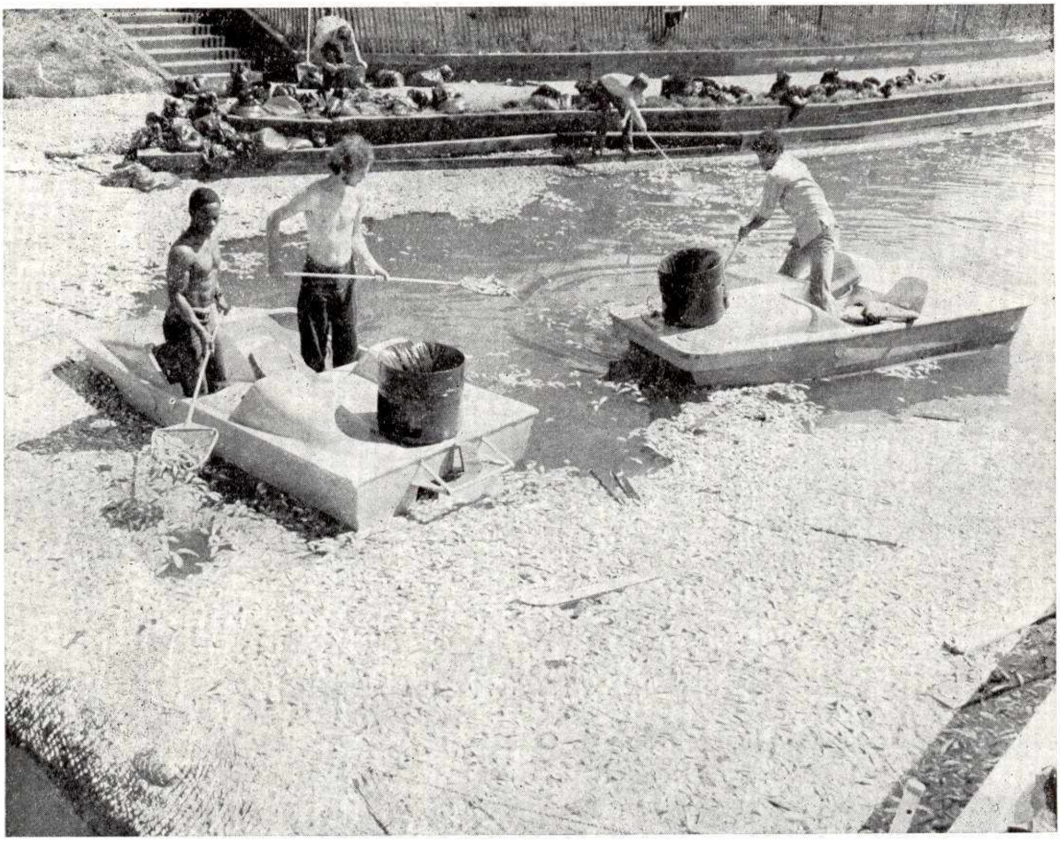
Rothschild (1966), discussing the probable reasons for mass mortality of alewives, stated that observations of alewives at Interlaken Beach, Cayuga Lake, disclosed a heavy infestation with a fungus that he presumed to be *Saprolegnia*.

Hoffman (1967) listed larval forms of trematodes *Diplostomulum flexicaudum* and *Neascus* sp.; the immature adult form of the nematode *Contracaecum* sp. and of the acanthocephalan *Leptorhynchoides thecatus*; molluscan Glochidia, and the crustacean *Argulus alosae*, from the alewife in North American waters.

Relation to man In the Great Lakes the alewife has long been considered a nuisance. In some instances live alewives are so abundant inshore that they may clog industrial and municipal intake pipes as in Chicago in 1967. They are particularly obnoxious, however, during the periods of mass die-offs. When in shallow water during the spring and summer months, alewives often die in large numbers, and dead and dying fish may drift in or be washed up on shore, littering beaches and harbours, a common occurrence in Lake Ontario's Toronto-Hamilton region (*see* accompanying photograph). Such mortalities can be severe enough to constitute a very real health hazard to adjacent communities.

Many theories have been advanced to account for these die-offs or mortalities. Graham's studies were the most comprehensive and pertinent and his conclusions concerning mortalities in Lake Ontario were as follows: "Briefly, the annual mortality of the alewife appears due to the alewife's inability to acclimate rapidly to rising or fluctuating temperatures. Early incidences of the mortality follow when the alewife invades the warm spring shoal waters while acclimated to the cold temperatures of the lake bottom. Later and more extensive incidences, although not fully explained here, are also probably associated with lethal temperatures." An exhausted thyroid was suggested by Hoar (1952) as the trigger mechanism of the summer mortalities.

The Great Lakes populations of alewives have not been seriously exploited by commer-



cial fisheries, largely because these landlocked fish are small, thin, and bony. However, in recent years they have been used increasingly in the preparation of pet food and also for fish meal.

The rapid growth of coho salmon, *Oncorhynchus kisutch*, planted in Lake Michigan waters in 1966 has been attributed, in part, to the abundant supply of alewives upon which they feed; but alewives have been shown to accumulate, in their tissues, particularly in their body fat, the chlorinated hydrocarbon dichloro-diphenyl-trichloroethane, commonly known as DDT, which they pick up from eating planktonic organisms. Because of the large quantities of alewives eaten by each individual coho, and because a relatively high proportion of DDT is retained by the ingesting organism, DDT levels in the tissues of cohos became alarmingly high, exceeding the tolerance levels permitted by health authorities.

The introduction of the alewife to freshwater lakes to serve as a forage fish was described and discussed by Vincent (1960) but experience suggests that considerable advance study be given to proposed introductions.

In its native environment along the Atlantic coast, the alewife is large and meaty and considered desirable as food for human consumption, as well as a forage fish for large predators.

In the Maritime Provinces commercial fisheries are conducted in the Saint John and Miramichi rivers in New Brunswick, and the Margaree, Mersey, Tusket, Gaspereau, and Shubenacadie rivers in Nova Scotia. In 1970, approximately 7.2 million pounds of alewives were landed, with a landed value of $156,000. Most were used in the pet food industry, a small quantity were used fresh and smoked (Gillespie 1967). The flesh is sweet but bony.

Nomenclature

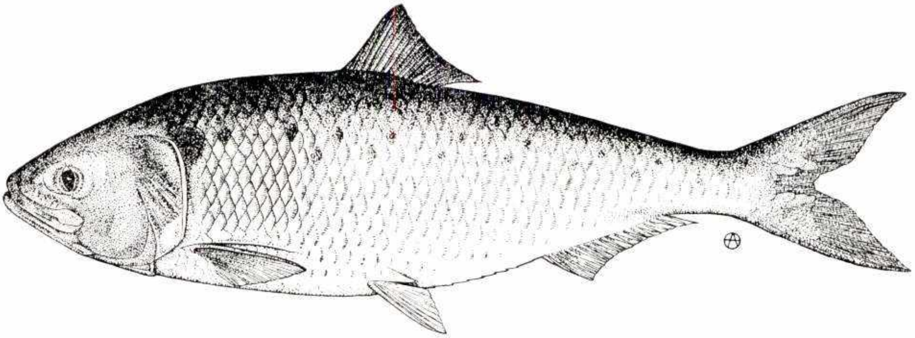
Clupea pseudo harengus Wilson	— *In* Rees' New Cyclopedia, 9 (no page), ca. 1811 (type locality probably Philadelphia)
Alosa vernalis Mitch.	— Richardson 1836: 229
Alosa tyrannus	— Perley 1852: 209
Clupea vernalis Mitchill	— Cox 1896b: 66
Pomolobus pseudo-harengus Wilson	— Hubbs 1926: 10
Pomolobus pseudoharengus (Wilson)	— Jordan, Evermann, and Clark 1930: 42
Alosa pseudoharengus (Wilson)	— Bailey et al. 1970: 15

Etymology *Alosa* — Saxon "allis," old name of the European shad *Alosa alosa; pseudoharengus* — false; herring.

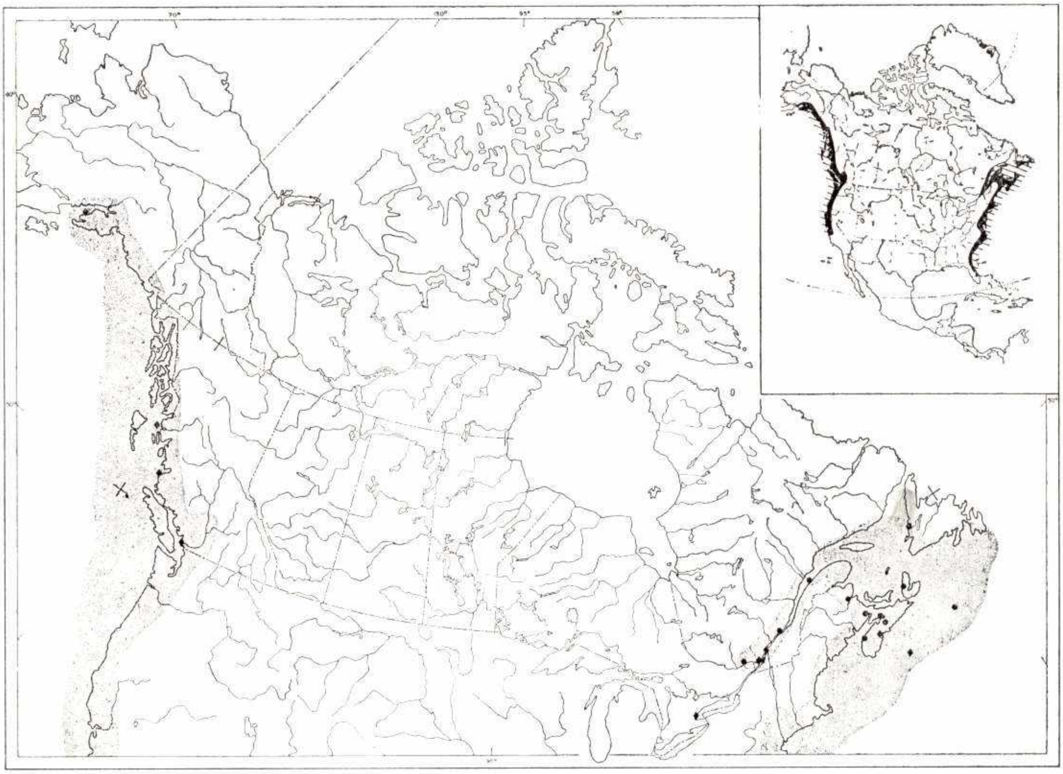
Common names Alewife, mulhaden, gray herring, blear-eyed herring, spring herring, golden shad, seth, green shad, skipjack, bang, racer, kyak or kiack, gaspereau, ellwife, branch herring, sawbelly, wall-eyed herring, big-eyed herring, glut herring, grayback. French common name: *gaspareau.*

AMERICAN SHAD

Alosa sapidissima (Wilson)



Description Body rather elongate, average length 15 inches (381 mm), strongly compressed laterally, and rather deep, its depth 17.2–19.4% of total length. Head broadly triangular, 22.7–24.0% of total length; gill membranes entirely free from isthmus; eye moderate, adipose eyelid well developed, diameter of eye 27.3–32.0% of head length; snout moderate, its length 26.9–32.0% of head length; interorbital width 18.6–21.6% of head length; anterior end of lower jaw not excessively thick or heavy, somewhat pointed, and fitting easily into a deep notch in upper jaw so that jaws about equal when mouth closed; maxillary extending to posterior margin of eye; teeth small, weak, and few in number on premaxillary and mandible. Gill rakers on lower limb only



59–73. Branchiostegal rays 7,7 (rarely 7,6). Fins: dorsal 1, its height moderate, base short, 11.3–12.9% of total length, total rays 15–19, usually 17 or 18; caudal distinctly forked; anal 1, base length greater than dorsal base, 12.8–14.2% of total length and height shorter than dorsal, rays 18–24, usually 20–22; pelvics abdominal, small, length 9.2–10.2% of total length, rays 9; pectorals low on sides, length 13.8–14.6% of total length, rays 14–18, most often 16. Scales large, crenulate on posterior margin, deciduous. Lateral line not developed but scales in about 50–55 rows, midlaterally; ventral scutes well developed, pre-pelvic scutes 19–23, usually 20–22, post-pelvic scutes 12–19, usually 15–17. Pyloric caeca numerous and usually clustered on right side. Vertebrae 53–59, usually 55–58. (Meristic data from Leim 1924.)

Colour The overall colour of the American shad is silvery, with a blue or blue-green metallic luster on the back. The sides are bright silvery. There is a large black spot on the shoulder close behind the rear edge of the gill cover, followed by several (4–27) smaller dark spots. Sometimes a second row of spots is present below the first, varying from 1 to 16 spots and, rarely, a third row of 2–9 spots may occur below the second row.

Distribution The American shad is an anadromous species, inhabiting the waters on the Atlantic coast from Newfoundland southward to Florida. It is most abundant from Connecticut to North Carolina. On the Pacific coast, where the shad was introduced into the Sacramento and Columbia rivers in 1871, it has become established from southern California to Cook Inlet, Alaska, and the Kamchatka Peninsula on the Asiatic side. It was first taken in British Columbia waters in 1876 near Vancouver Island and is now caught in the Fraser River in increasing numbers (Clemens and Wilby 1961).

In Canada the shad was reported in June 1932 from Bay Bulls, Nfld.; however, the first fully documented record was of a female 18.9 inches (480 mm) long, caught in a salmon net in Wild Cove, Bay of Islands, Nfld., in 1963. This appears to be the northernmost limit of range (Scott and Crossman 1964). In 1966 Hodder reported the capture of two specimens, one from St. John's and one from St. Phillips on the east coast of Newfoundland. Halkett (1913) indicated that the American shad occurred in Labrador but we have been unable to verify the information, and Backus (1957) did not record its occurrence there.

It is found in the Gulf of St. Lawrence and, in spring, ascends freshwater streams of the Maritime Provinces and Quebec. Leim (1924) reviewed the distribution of shad in Canadian Atlantic waters in considerable detail. He noted they were found mainly near the mouths of four rivers tributary to the Bay of Fundy — the Saint John, Petitcodiac, Shubenacadie, and Annapolis rivers. It is to be expected that deteriorating environmental conditions, particularly pollution, would render these rivers, especially the Saint John, much less suitable for spawning shad than in former years. Leim noted that runs in streams on the outer coast of Nova Scotia and Prince Edward Island, and in Northumberland Strait, were irregular and unimportant, but those in the Miramichi were regular and valuable. Runs also occurred in rivers tributary to the St. Lawrence, including the Ottawa River. There was an annual migration up the Ottawa River, at least to Point Fortune on the southwest shore at the Ontario–Quebec border. Presumably the fish were unable to ascend above this point after the erection of the dam in 1882. In a paper dealing with the fishes of the Ottawa River written in 1939, J. R. Dymond documented 19th century and later accounts of the movements of shad in the Ottawa River. It is of special interest to note that shad were once abundant at Chute à Blondeau, four miles above Point Fortune, but H. B. Small (1883), writing about shad, noted ". . . the beds of sawdust which extend everywhere above Carillon would hardly invite these delicate fish to pursue their wanderings any farther." Carillon is opposite Point Fortune on the Ottawa River. This region is probably even less attractive in 1973.

Introductions of American shad have generally proved unsuccessful, with the exception of those made in Pacific coastal rivers noted above. Attempts to introduce the species into Lake Ontario waters failed, as did efforts in the Mississippi River drainage, peninsular Florida, Colorado, and Great Salt Lake.

Biology The anadromous American shad ascends freshwater rivers and streams in the spring to spawn, the precise time depending upon the water temperature. Normally the American shad does not ascend the rivers as far as the alewife, but tagging has revealed that some do travel great distances; for example, from Virginia to New Brunswick's Miramichi estuary in the same year. The erection of dams and other obstructions in streams undoubtedly prevents or seriously impedes migration in many areas. Observations indicate that, unlike the alewife, spawning takes place rarely, if ever, in lakes. In Canadian waters spawning occurs in May, June, or even as late as July.

A detailed account of the life history of the shad was prepared by Leim (1924), the source for much of the following information. The males arrive on the spawning grounds first, soon followed by the females. Spawning does not commence until the water temperature reaches 53.6° F (12° C) and will continue as long as temperature does not drop significantly below this point. Peak of spawning run occurs at temperatures of about 65° F (18.3° C). During the spawning act, the female is accompanied by several males; the spawning fish swim vigorously close to the surface, leaving a visible wake. Leim noted that spawning took place in the evening after sundown and continued until midnight and even later. The eggs are released in the open water where they are fertilized by the males. It is often stated that female shad may produce from 20,000 to 150,000 eggs, depending upon her size, but the largest females do not necessarily produce the most eggs. In a study of shad fecundity in the St. Lawrence River near Ile Verte, Que., Roy (1969) reported a range of 58,534–390,633 eggs per female, with an average of 125,166 for 48 fish. The female with the largest number of eggs (390,633) measured 21.5 inches (546 mm) and weighed 6.25 pounds, another measuring 21.3 inches (541 mm) contained only 73,095 eggs. Davis (1957) estimated the ova production from five shad in each of six Atlantic coast rivers, from the Hudson River in New York to the St. Johns River in Florida, and results ranged from a low of 209,000 eggs from a 19.5-inch (495-mm) Hudson River shad, to a maximum of 616,000 from a 16.6-inch (421-mm) St. Johns River shad. Fertilized eggs are 2.5–3.5 mm in diameter and are transparent, pale pink, or amber. Only slightly heavier than the water and non-adhesive, they settle singly and are carried along by the current. Hatching takes place in 8–12 days at temperatures of 51.8°–59.0° F (11°–15° C). Leim (1924) provided evidence indicating that eggs hatch more successfully in slightly brackish water (7.5 ppm at 53.6° F (12° C) to 15 ppm at 62.6° F (17° C)).

Important work on shad biology is being done by W. C. Leggett, McGill University.

After spawning the spent fish begin to drop back to salt water and vanish until the next spawning season. Little is known of their life in the sea but, like the alewife, they are schooling fishes.

Cheek (1968) stated that shad that spawn in coastal streams of the South Atlantic states die after spawning. The reason for the mortality is unknown but he noted that the number of shad that survived after their first spawning, increased northward. Indications are that shad spawn more than once, and have been known to spawn as many as five times.

The larvae, about 9–10 mm long when hatched and very slender, spend their first summer in the river. They drift down to brackish water and by autumn, when 2–3 inches (51–76 mm) long, all have left fresh water and entered the sea. They remain in the sea until they are mature. Leim (1924) noted that Bay of Fundy shad may attain lengths of 3–6 inches (75–175 mm) at the end of the first growing season. Two-year-old fish average about 9.2 inches (230 mm), 3-year-olds about 11.8 inches (300 mm), and 4-year-olds about 16.9 inches (430 mm). For precise details *see* Leim (1924). Although a few spawn at age 4, most are 5 years old and 18–19 inches long when they commence spawning activity. The oldest shad in the Bay of Fundy are 8 or 9 years old; the largest shad in the Gulf of St. Lawrence are somewhat older. Cating (1953) reported shad 11 years old and 23 inches (584 mm) long from United States waters. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

American shad are plankton feeders. Larvae and young American shad eat copepods and related crustaceans and insect larvae (chironomids) while they are in fresh water. When in the sea, the diet consists principally of copepods and mysids, supplemented by small quantities of other planktonic crustaceans and some small fishes. Migrating fish eat little, if anything, prior to spawning, but commence feeding during downstream post-spawning migration.

American shad are preyed upon by seals but adults seem to have few enemies, except man. Young shad may fall prey to a variety of predators in fresh waters but Leim (1924) could not demonstrate predation by either eels or striped bass in the Shubenacadie River, N.S.

Shad do not appear to be severely infested by parasites. Leim (1924) noted that of 40 specimens examined in 1922, only two contained parasites. Adult shad at Scotsman Bay, N.S., were found to contain three kinds of parasites — distomes, nematodes, and Acanthocephala. Sumner et al. (1913) summarized the findings of Linton and Wilson, working with shad in the Woods Hole, Mass., vicinity, as follows: Acanthocephala (Linton), *Echinorhynchus acus.*; nematodes (Linton) — *Ascaris adunca*, *Ascaris* sp. (immature); copepods (C. B. Wilson) — *Caligus rapax*. *Lernallnicus radiatus* was also added to the list.

Hoffman (1967) listed only two parasites from the shad in North American waters: the larval form of the trematode *Clinostomum marginatum*, and the crustacean, *Argulus canadensis*.

Relation to man American shad are caught commercially in weirs, traps, and gill-nets while on their spawning migrations in rivers and estuaries in Nova Scotia, New Brunswick, Quebec, and the coastal United States. A few small sea fisheries exist. The maximum Canadian catch in 1875 was $3\frac{1}{3}$ million pounds, and the United States took 50 million pounds in 1896. Although catches have declined since 1900, the Canadian catch increased in the 1950's approximating the 1875 level, but has since declined again. Accurate landing records for American shad in recent years are unavailable, since the catch for the species is grouped under the category "shads" in the statistics.

Shad is esteemed as a game fish in many parts of the eastern United States where it is caught by fly-fishing and trolling, but it is seldom regarded as a game fish in Canadian waters.

American shad is marketed fresh and salted. The flesh is white and flaky and, when properly prepared, the caviar made from the roe is highly esteemed. Shad liver oil contains from 500 to 800 U.S.P. of Vitamin A, and from 50 to 100 I.U. of Vitamin D per gram, and thus is less rich in vitamins than oil from cod or haddock livers.

Nomenclature

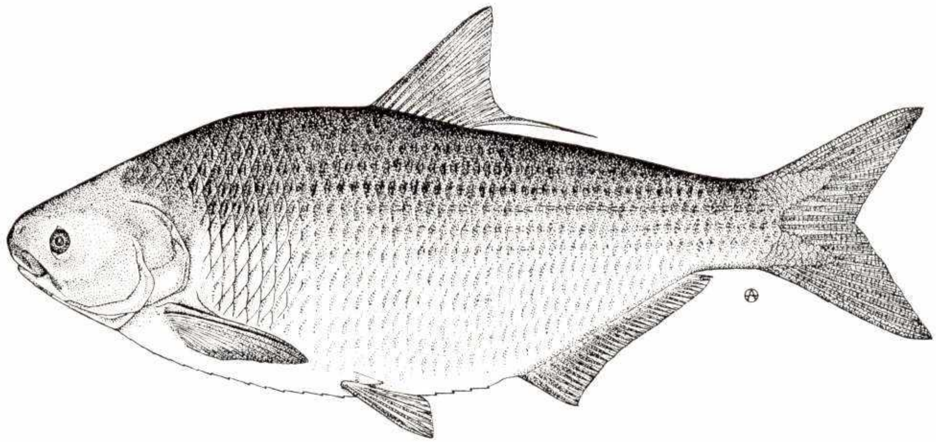
Clupea sapidissima Wilson	— *In* Rees' New Cyclopedia 9 (no page), ca. 1811 (type locality probably Philadelphia)
Alosa sapidissima Wilson	— Perley 1852: 206
Alosa sapidissima (Wilson)	— Bailey et al. 1970: 15

Etymology *Alosa* — Saxon "allis," old name of the European shad *Alosa alosa; sapidissima* — most delicious.

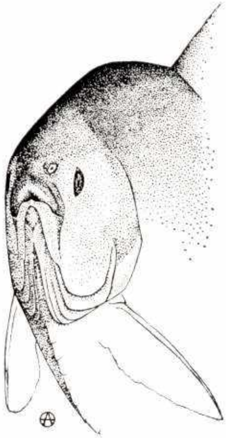
Common names American shad, shad, alose, common shad, Atlantic shad, North River shad, Potomac shad, Connecticut River shad, Delaware shad, Susquehanna shad, white shad. French common name: *alose savoureuse*.

GIZZARD SHAD

Dorosoma cepedianum (Lesueur)



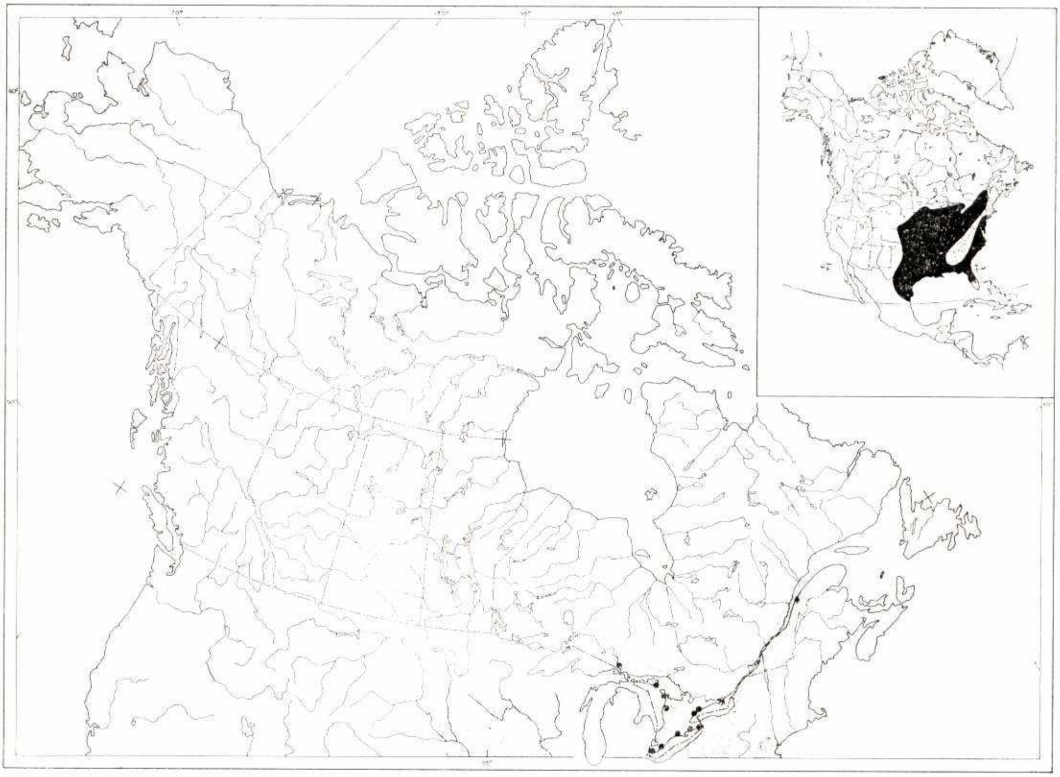
Description Body strongly compressed laterally and deep, 23.5–29.3% of total length, average length 10 inches (254 mm).



Head bluntly rounded anteriorly, its length 22.1–26.4% of total length; eye moderate in size, its diameter 20.2–26.4% of head length; adipose eyelid usually well developed and obvious; snout rounded, 16.9–24.2% of head length, and overhanging inferior mouth; interorbital width 21.2–26.8% of head length; maxillary terminating about anterior margin of eye; a few minute teeth on young but these are soon lost. Gill rakers numerous, long and slender, number increases with size, varying from 100 to about 400. Branchiostegal rays 6,6. Fins: dorsal 1, base short, height of anterior rays 15.3–17.2% of total length, last ray greatly prolonged on young adults, short or nonexistent on young, shorter on old adults, total rays 10–13, usually 10–12; caudal distinctly forked; anal 1, rays short, base long, 20.0–22.7% of total length, rays 27–34; pelvics abdominal, length 9.5–10.9% of total length, rays 8–10; pectorals longer than pelvics, length 15.0–16.8% of total length, rays 16 or 17. Scales large, silvery, 52–70 scales in a lateral series; lateral line not developed; ventral scutes well developed, pre-pelvic scutes 18 or 19 and post-pelvic scutes 12 or 13. Pyloric caeca numerous, and a thick-walled stomach ("gizzard"). Vertebra 47–49.

Colour The body of the gizzard shad is silvery blue on the back and upper sides, shading to silvery on the lower sides and milky white below. The scales often reflect a golden or brassy tinge. There is a large, round, dark spot on the "shoulder" (behind the opercle and above the pectoral fin base) prominent on fish up to 6–8 inches (152–203 mm) long.

Systematic notes Three subspecies have been described, *D. c. cepedianum*, *D. c.*



heterurum, and *D. c. exile*. Miller (1960) suggested that the accepted bases for these are not valid. He presented comprehensive morphometric and meristic values for the species throughout its North American range, indicating in many instances a wider range of values for many characters than are given above for Canadian populations.

Distribution An inhabitant of eastern North America, the gizzard shad occurs in the waters of the Atlantic slope from about 40°N (lower New York Harbour), south to the Gulf coast of the United States, and to the basin of the Rio Pánuco in eastern Mexico (Miller 1960). Inland, the species ranges from southeastern South Dakota and central Minnesota, the Great Lakes drainage, the most southern part of New York, and throughout the Mississippi valley.

The occurrence of the gizzard shad in many areas is believed to be due to its migration through canals and waterways. The Erie Canal is perhaps responsible for its presence in the northern region of Cayuga Lake, N.Y., and its first appearance in Lake Michigan in 1953 (Miller 1957) is attributed to entrance through the Chicago River Canal.

In Canada the species was reported erroneously from New Brunswick, but a correction was made by Scott and Crossman (1959). Its occurrence in the St. Lawrence River is rare. Vladykov (1945) reported six specimens taken in the St. Lawrence River near Quebec City in 1945. It is also rare in Lake Ontario but is a common species in Lake Erie. There is considerable speculation as to its origin in Lake Erie. Some authors believe it found its way through various canal connections from the Mississippi drainage (Kirtland 1850). Gerking (1945) suggested it might have migrated into the glacial Great Lakes from the Mississippi drainage during the Lake Maumee outlet stage, and Trautman (1957) thought this species was present in the lake before the canals were constructed. Miller (1957), discussing the origin of the gizzard shad in Lake Erie, stated that the question of whether the shad is native to Lake Erie cannot be solved conclusively. It also occurs in lakes St. Clair and Huron and in Georgian Bay. Previously unrecorded from Lake Superior, its range has recently been extended into this lake when a 1½-pound specimen was caught in a commercial gillnet in Batchawana Bay in 1961.

It is absent from the waters of western North America.

Biology There are no published observations on spawning of gizzard shad in Canadian waters, which is perhaps not surprising since the species is on the northern limit of its range in the Great Lakes and St. Lawrence River. In general, spawning occurs in fresh water, in the spring or early summer, on a rising temperature in our area, but elsewhere Miller (1960) noted that spawning may occur from mid-March to mid-August in sloughs, ponds, lakes, and large rivers. The same author observed, "A group of males and females swimming near the surface begin to roll and tumble about each other in a mass, the eggs and sperm being ejected during this activity. The sticky eggs slowly sink to the bottom or drift with the current, readily becoming attached to any object they may contact." Direct observation in Ohio waters suggests that spawning occurs during the daytime but Bodola (1966) was unable to confirm this during a detailed study of the species in western Lake Erie. He found only one spawning site, a sand, gravel, and boulder bar in 2–4 feet of water where spawning apparently occurred in 1955 between early June and early July at temperatures of 63°–73° F (17.2°–22.8° C). Temperature is an important factor in the initiation and continuation of spawning. Fish return to deeper water after spawning.

On extrusion, gizzard shad eggs are small, about 0.75 mm in diameter, adhesive, each containing one large, clear, oil globule and one or two smaller ones. There is apparently considerable variation in the number of eggs per individual. Data presented by Bodola, although based on small samples, indicated maximum egg production by age 2 fish, counts ranging from about 211,380 to 543,910 eggs, and averaging about 379,000. Egg production declined in age 3 and older fish and was significantly lower in precocious age 1 females.

The embryology of gizzard shad was studied by Warner (1941) but reported only in abstract. Material and figures from Warner's work were presented by Miller (1960) who noted that eggs hatch in 95 hours at 62° F (16.7° C) or in about 36 hours at 80° F (26.7° C). Young fish reared by Bodola, who gave hatching time as 36 hours to 1 week, depending on temperature, were 5.2 mm long in 4 days.

According to data from Bodola (1966), the average standard length in mm of five age-groups for Lake Erie males and females was:

Age	Avg SL (*mm*)	
	Male	Female
1	141	140
2	273	285
3	313	335
4	343	366
5	349	390

Notice that after the first year, females are consistently longer than males of the same age.

The oldest shad caught in Lake Erie during the same study were 3 age 6 fish (2 males, 1 female), although fish to age 10 have been reported from more southern waters. Mansueti and Hardy (1967) illustrated and described larval stages in the Chesapeake Bay region.

When the gizzard shad commences to feed, about the fifth day after hatching, it is slender in shape, with a straight, tubelike, alimentary tract or gut. At this time it feeds on minute animal plankton, especially protozoans and entomostracans. Young, up to 22 mm long, have been found to contain, almost entirely, water fleas (*Bosmina*), copepods, and a few ostracods. As the gizzard shad grows, its shape begins to change to the adult form (after the 20-mm stage), gill rakers increase and lengthen, the pyloric caeca begin to develop (at about 27.5 mm), the gizzard develops, the gut becomes convoluted and long, and the food changes from animal plankton to minute algae. The anatomy and biology of the digestive system have been described in detail by Wier and Churchill (1946).

Fully developed gizzard shad are herbivorous, feeding on the bottom on microscopic plants or phytoplankton and algae, which they are able to digest and assimilate because of their specialized alimentary canal. Although not unique in this respect (*see* Cyprinidae) they are one of the few species among our native fishes that can exist almost solely on vegetative material, thus forming a significant link with the economically important predators. Stomachs of adults often contain large quantities of mud, but this is believed to be ingested accidentally. Bodola (1966) observed that the species appeared to eat little in winter and early spring. Feeding habits of gizzard shad in Ohio waters have been described in detail by Tiffany (1921).

Young gizzard shad have many enemies and, indeed, form an important source of forage for most game and commercial species present. However, only large predators, such as northern pike, muskellunge, channel catfish, and large walleye could eat adult gizzard shad and there are few records of such predation in Ontario waters.

Miller (1960) noted that this species was generally free from parasites. The young may often be infested with a myxosporidian resulting in large white cysts in the body cavity. Smith (1949) found the copepod parasite *Ergasilus lanceolatus* in gizzard shad in Cumberland River, Ky. Hunter (1930) reported the cestode *Glaridacris confusus* in the intestine of this species in Oneida Lake, N.Y. (*see* Van Cleave and Mueller 1934, p. 262).

Bangham and Hunter (1939) examined five specimens of gizzard shad in Lake Erie during their study. All were taken from the western end of the lake. Only one, a young fish, contained a parasite — a nematode, *Agamonema* sp. Hoffman (1967) listed Protozoa (1), Trematoda (8), Cestoda (2), Acanthocephala (3), and Crustacea (3) from the species in the fresh waters of North America.

Relation to man The young gizzard shad is an important forage fish for game and predaceous fishes before its rapid growth makes it a less utilizable food item. Kutkuhan (1958) stated that studies in the midwestern United States showed that "... the species often passes out of range of effective utilization by the middle of its second year of life." Since the gizzard shad is not eaten by many predators after it has attained a large size, breeding stocks are perpetuated and can, when in sufficient numbers, compete with the predators. However, the gizzard shad is a highly efficient species in terms of energy exchange and, although not widely utilized in Canada as a pond culture forage species, its potential should be explored, especially since heated effluents from various types of power stations will produce the kind of habitat suitable for this species. Its role as a forage species was reviewed in detail by Miller (1960).

In some areas where the species is abundant, the gizzard shad creates a problem, and fish management programs have been instituted (Bodola 1966). In Lake Erie their value as a forage fish is outweighed by the nuisance created when heavy mortality occurs and by the inconvenience caused to fishermen in whose nets they become entangled. They may be particularly abundant in the shallow inshore waters of harbours and river mouths of Lake Erie's north shore in the fall of the year.

The gizzard shad is used for fertilizer and as food for cattle and hogs. Miller (1960) reported that a factory for the making of guano from the species existed in Florida in 1874.

It is not an entirely satisfactory bait fish since the young are fragile and die quickly. The flesh is soft and generally considered to be unappetizing and bony, making it an undesirable item for human consumption.

Nomenclature

Megalops Cepediana	— LeSueur 1818a: 361 (type locality Delaware and Chesapeake bays)
Dorosoma cepedianum	— Nash 1908: 52
Dorosoma cepedianum (LeSueur)	— Hubbs and Lagler 1941: 27

Etymology *Dorosoma* — lance; body (in allusion to form of body in the young); *cepedianum* — named for Comte de La Cépède (1756–1825), now spelled Lacépède, the author of Histoire Naturelle des Poissons.

Common names Gizzard shad, hickory shad, mud shad, lake shad, shad, sawbelly, eastern gizzard shad. French common name: *alose à gésier*.

Suggested Reading – Clupeidae

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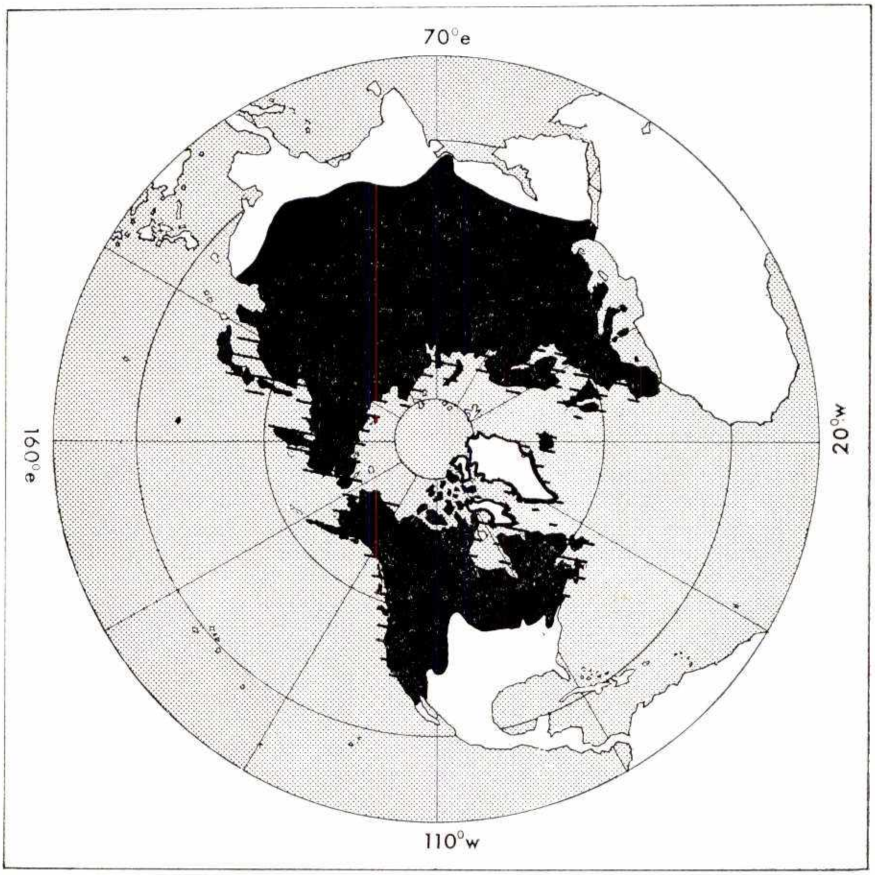
The salmonids are medium- to large-sized terete-bodied fishes, variable in shape and appearance, but, in general, less laterally compressed than the herrings. The mouth may be large and well toothed or small and almost toothless. Scales cycloid, confined to body, not on head, circuli formed in more or less concentric rings, lateral line present; pelvic, and sometimes pectoral, axillary scales present. Pyloric caeca well developed and numerous. Vertebrae, 3 upturned in caudal complex.

The family Salmonidae is composed of freshwater or anadromous fishes, ranging widely in the waters of the northern hemisphere. It is the dominant family in the northern waters of North America, Europe, and Asia. Some species, notably the arctic char, extend into the high arctic. There are 32 species belonging to this family in Canadian waters.

The family is composed of three subfamilies: Salmoninae (p. 144), Coregoninae (p. 230), and Thymallinae (p. 300).



World Distribution of the Salmonids

Key to Species

When in the sea, or in large lakes, body pigmentation is usually masked by heavy, silvery colouration. The characters enumerated in the key will be evident if the specimen is examined carefully.

1 Scales small, those in lateral line 115–200; teeth well developed on jaws and vomer; caudal fin usually truncate, occasionally forked; young (6 inches or less) with dark, vertical blotches (parr marks, *see* figures p. 145) on sides (except *O. gorbuscha*). .... SALMONS, TROUTS, CHARS (Salmoninae) 2

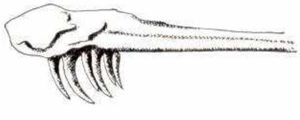
Scales large, those in lateral line 100 or less; teeth weakly developed or absent; caudal fin distinctly forked; parr marks usually absent (except *Prosopium* and *Thymallus*); colour generally silvery, silvery green, or silvery blue. .... WHITEFISHES (Coregoninae) and GRAYLING (Thymallinae) 14

2 Anal rays 13–19 (usually 14–16); body and caudal fin of adults with black spots. .... PACIFIC SALMONS, *Oncorhynchus* spp. 10

Anal rays 7–12 (usually 9–11); body and caudal fin with or without black spots 3

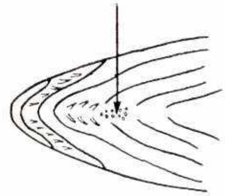
3 Black spots present on head and body (young *S. salar* have red spots between parr marks); scales conspicuous, fewer than 165 in lateral line; pelvic and anal fins without white leading edges; vomer flat with teeth extended backward in 2 rows on shaft 4

Light spots on body, pink, red, or cream in colour; scales not conspicuous; lower fins with snow-white leading edges; vomer boat-shaped, teeth on the anterior part (head) only, not on shaft 7



4 Caudal fin distinctly marked with radiating rows of black spots; body never with red spots; adipose fin often with black margin; scale rows 120–180 5

Caudal fin usually unspotted, but never with regular rows of black spots; reddish spots sometimes on body; scale rows usually 110–130 6



5 Red or orange-red dash on lower jaw, along inner border of mandible; minute teeth usually present at base of tongue (basibranchial teeth). ...... CUTTHROAT TROUT, *Salmo clarki* (p. 177)

No red colouration present on lower jaw; minute teeth at base of tongue absent. ...... RAINBOW TROUT, KAMLOOPS TROUT, STEELHEAD TROUT, ~~*Salmo gairdneri*~~ (p. 184)

Oncorhynchus mykiss

6 Maxillary to below centre of eye in 6-inch fish, seldom far behind eye (except in large males); gill cover with 2 or 3 large spots only; branchiostegals usually 12; dorsal fin rays usually 11; vomerine teeth usually not well developed; small fish have red spots between parr marks; no red on adipose fin. ...... ATLANTIC SALMON, *Salmo salar* (p. 192)

Maxillary to below last half of eye on 5-inch fish, and extending well beyond eye in larger fish; gill cover usually with many spots; branchiostegals usually 10; dorsal fin rays usually 9; vomerine teeth well developed; rust-red spots sometimes on adults and often on margin of adipose fin. ...... BROWN TROUT, *Salmo trutta* (p. 197)

7 Caudal fin deeply forked; dorsal and caudal fins, body and head covered with small, often bean-shaped, light spots; body never brightly coloured with orange or red; parr marks quite irregular and narrow; pyloric caeca over 90. ...... LAKE TROUT, *Salvelinus namaycush* (p. 220)

Caudal fin square (truncate) or slightly forked; body with light-coloured spots of cream, pink, or red; dorsal and caudal fins with dark, wavy lines and marks, or without light spots; pyloric caeca fewer than 75 8

8 Caudal fin square or nearly so; dorsal and caudal fins with distinct, dark, wavy lines or blotches; lower fins with pure white leading edges usually followed by black; back usually with wavy lines (vermiculations); sides with pink or red spots, many of which have blue borders; young with 8–10 regularly arranged parr marks on sides. .... BROOK TROUT, *Salvelinus fontinalis* (p. 208)

Caudal fin nearly square or slightly forked (may be deeply forked in freshwater populations in eastern Canada) without dark, wavy lines on dorsal and caudal fins; lower fins with pure white leading edges, but not usually followed by black; sides with creamy, pink, or reddish spots, not extending onto fins; parr marks vague or irregular, not well defined 9

9 Spots usually large and less numerous; gill rakers on upper limb of first gill arch 7–13, on lower limb 12–19; pyloric caeca 20–74. .... ARCTIC CHAR, *Salvelinus alpinus* (p. 201)

Spots round, small, and numerous; gill rakers on upper limb of first gill arch 3–9, on lower limb 8–14; pyloric caeca 13–47. .... DOLLY VARDEN, *Salvelinus malma* (p. 214)

10 Distinct black spots on back and on caudal fin 11

No distinct black spots on back or caudal fin, but fine black speckling may be present 13

11 Large black spots on back and caudal fin, the largest as large as eye; scales small, 169–229 in first row above lateral line; gill rakers 26–34. .... PINK SALMON, *Oncorhynchus gorbuscha* (p. 148)

Spots on back and caudal fin small, largest as large as pupil of eye; scales moderate, fewer than 154 in first row above lateral line; gill rakers 19–28 12

12 Small black spots on both lobes of caudal fin; flesh at base of teeth of lower jaw black; pyloric caeca 140–185; gill rakers 20–28. .... CHINOOK SALMON, *Oncorhynchus tshawytscha* (p. 172)

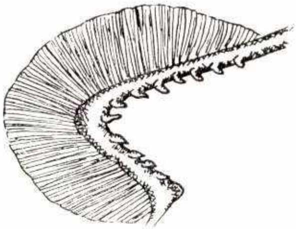
Small black spots, when present on caudal fin, on upper lobe only; flesh at base of teeth of lower jaw pale; pyloric caeca 45–80; gill rakers 19–25. .... COHO SALMON, *Oncorhynchus kisutch* (p. 158)

13 Gill rakers on first arch 30–40, long, slender, and crowded; pyloric caeca 60–115. .... KOKANEE, SOCKEYE SALMON, *Oncorhynchus nerka* (p. 165)

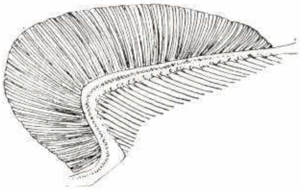
Gill rakers on first arch 19–26, short, stout, and widely spaced; pyloric caeca 140–186. .... CHUM SALMON, *Oncorhynchus keta* (p. 153)

14 Dorsal fin base equal to or longer than head, dorsal fin usually with more than 17 rays, fin larger and sail-like on fishes 8 inches or larger; colour of back bluish or purple; dorsal and pelvic fins sometimes with green or reddish spots. .... ARCTIC GRAYLING, *Thymallus arcticus* (p. 300)

Dorsal fin base shorter than head, dorsal fin rays fewer than 17; dorsal fin not expanded; colour usually silvery, back sometimes black, blue, or green. .... WHITEFISHES (Coregoninae) 15



15 A single small flap of skin between nostrils; snout pinched, rather pointed; mouth inferior; gill rakers stout, short, usually 13–20 but up to 26 in Alberta and British Columbia. .... ROUND WHITEFISHES, *Prosopium* spp. 16



Two small flaps of skin between nostrils; snout not pinched but usually somewhat broad; mouth inferior, overhung by snout, or mouth terminal, lower jaw may be projecting beyond upper; gill rakers generally long and slender, more than 22 (except in *Stenodus*) 18

16 Gill rakers 20–25 (rarely 26); scales around caudal peduncle in 20–23 rows. .... MOUNTAIN WHITEFISH, *Prosopium williamsoni* (p. 291)

Gill rakers 13–20 17

17 Lateral line scales 85–100; scales around caudal peduncle 22–24; pyloric caeca 50–117. .... ROUND WHITEFISH, *Prosopium cylindraceum* (p. 286)

Lateral line scales 55–70; scales around caudal peduncle 18–20; pyloric caeca 15–23. .... PYGMY WHITEFISH, *Prosopium coulteri* (p. 282)

18 Mouth inferior, overhung by snout; premaxillaries retrorse; gill rakers usually fewer than 32 19

Upper and lower jaws nearly equal, or lower jaw projecting; premaxillaries antrorse; gill rakers usually more than 32 (except in *Stenodus*) 21

19 Gill rakers 19–25, short; maxillary short and broad, its length less than twice its width; lower fins thick, opaque, often with bluish cast in life. .... BROAD WHITEFISH, *Coregonus nasus* (p. 278)

Gill rakers 23–33, long; maxillary longer, its length twice or more the width; lower fins not especially thick, translucent, often sprinkled with dark speckles 20

20 Scales in lateral line less than 90 (70–85); mouth inferior, obviously overhung by snout; minute teeth on premaxillaries, palatines and vomer of juveniles only (under 100 mm long). .... LAKE WHITEFISH, *Coregonus clupeaformis* (p. 269)

Scales in lateral line more than 90 (91–100); mouth terminal or nearly so; teeth on premaxillaries, palatines, and vomer, small but present even on adults. .... ATLANTIC WHITEFISH, *Coregonus canadensis* (p. 281)

21 Body shape pikelike; lower jaw distinctly projecting; gill rakers 19–24; scales small, 97–110 in lateral line. .... INCONNU, *Stenodus leucichthys* (p. 295)

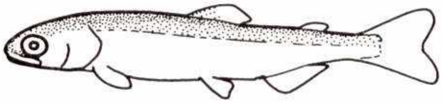
Body shape herring-like; upper and lower jaws equal or nearly so (lower jaw may project slightly); gill rakers more than 32 (commonly 40 or more); scales larger, usually 65–85 (*Coregonus autumnalis*, 86–111). (Numerous keys to the species of the subgenus *Leucichthys* have been attempted. All of them are unsatisfactory because of the excessive phenotypic plasticity of the ciscoes, hence no attempt to separate them is made here. The most variable and wide ranging species is *C. artedii*.) .... Subgenus *Leucichthys*, 11 species (p. 230)

SUBFAMILY SALMONINAE The salmon, trouts, and chars, with orbitosphenoid and suprapreopercular bones, a basibranchial plate; large teeth on maxilla and premaxilla; dermosphenotic bone absent, usually no hypethmoid or epipleurals; and parietals separated at midline by supraoccipital; scales small, rounded; 16 or fewer dorsal fin rays; usually eggs large, no postlarval stage, young usually with parr marks.

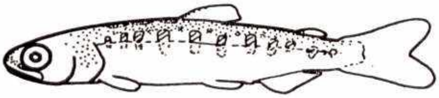
Summary of some meristic characters of Canadian Salmonids

		Principal anal rays	Principal dorsal rays	Branchio-stegal rays	Lateral line scales	Pyloric caeca	Total gill rakers	Vertebrae
Oncorhynchus gorbuscha		13–19	10–15	9–15	147–205	95–224	24–35	63–72
O. keta		13–17	10–14	12–16	124–153	140–249	16–26	59–71
O. kisutch	Gt. Lakes	12–15	10–12	–	112–139	68–79	21–23	–
	anadromous	12–17	9–12	11–15	121–148	45–114	18–25	61–69
O. nerka	kokanee	11–16	11–13	13–14	121–140	50–87	31–44	62–67
	sockeye	13–18	11–16	11–16	120–150	45–115	29–43	56–67
O. tshawytscha		14–19	10–14	13–19	130–165	9–240	16–26	67–75
Salmo clarki		8–12	8–11	10–12	116–230	27–57	14–22	60–64
S. gairdneri		8–12	10–12	9–13	100–150	27–80	16–22	60–64
S. salar		8–11	10–12	11–12	109–121	40–74	15–20	58–61
S. trutta		10–12	12–14	10	120–130	30–60	14–17	56–61
Salvelinus alpinus		8–11	10–12	10–13	123–152	20–74	19–32	60–71
S. fontinalis		9–13	10–14	9–13	110–130	23–55	14–22	58–62
S. malma		9–11	10–12	10–15	105–142	13–47	11–26	57–70
S. namaycush		8–10	8–10	10–14	116–138	93–208	16–26	61–69

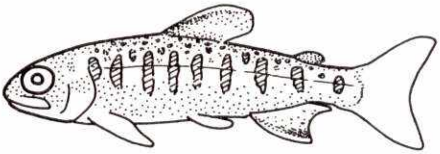
Young Trouts, Chars, and Salmons
(2–5 inches long)



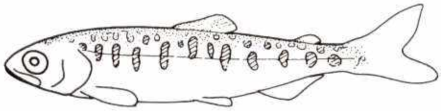
Oncorhynchus gorbuscha



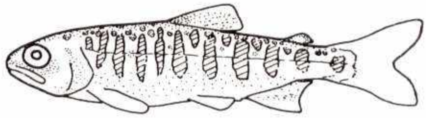
Oncorhynchus keta



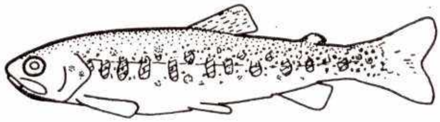
Oncorhynchus kisutch



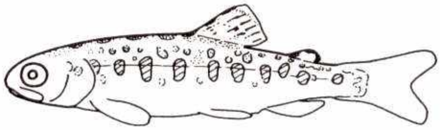
Oncorhynchus nerka



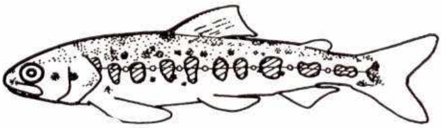
Oncorhynchus tshawytscha



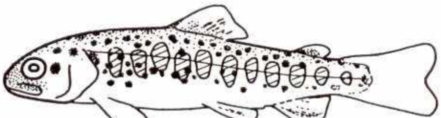
Salmo clarki



~~*Salmo gairdneri*~~ Oncorhynchus mykiss

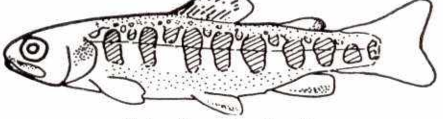


Salmo salar

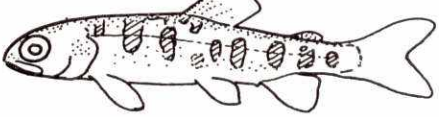


Salmo trutta

Salvelinus alpinus
Salvelinus malma



Salvelinus fontinalis



Salvelinus namaycush

Few fishes, except possibly the Atlantic cod and the Atlantic herring, have had as large an impact on man, and of man on them, as have the five Pacific salmons — pink, chum, coho, sockeye, and chinook (two further species, the *biwa* and *masou* are found only in Japan or Russia). In the past, these fishes were often referred to as quinnat in order to distinguish them from the older salmon of the Atlantic. The fact that these rather large marine fishes must return, at differing intervals, to fresh water to spawn has regularly brought millions of fishes to the rivers of the west coast of North America and the east coasts of Japan and the USSR. Before the advent of the white man in North America, this yearly abundance of food facilitated the establishment of permanent settlements of sedentary and highly sophisticated peoples whose food literally came to them.

The written scientific record of these species began with the publications of Steller and Walbaum in the late 1700's. Since that time, the exploitation and value of, and the interest in, these fishes has led to a profusion of literature. As early as 1894 Tarleton Bean published, as Bulletin 12 (1894b) of the United States Fish Commission, a bibliography of such writings. In the late 1800's, primary work on the basic biology of these fishes in the Columbia River was published by Evermann and his co-workers. The obvious value of such fishes was recognized early by people in areas beyond their natural distribution. As early as 1872, the United States Fish Commission had established an egg-taking station on the Sacramento River in California, for the sole purpose of distributing eggs of the various species for introduction elsewhere. By 1930, eggs had been sent to 17 states from Louisiana east, to Canada, to several countries in Europe and South America, to New Zealand, Australia, and Hawaii. In 1966 the Japanese masou (*Oncorhynchus masou* Brevoort) was introduced into Ontario. This is apparently the only known introduction of a species other than those which are native to North America. Only some of these introductions were temporarily or permanently successful.

Commercial exploitation of these species dates at least to 1864 in North America, and Kasahara (1963) attempted to summarize the recorded commercial and sport catches for all species on both sides of the Pacific Ocean. Commercial catch (964.5 million pounds in 1961) has been carried out over the years by means of weirs and huge, anchored, floating traps, gillnets, purse seines, long lines, and trolling with natural and artificial baits. The sports fishery for various species has developed at different times and is of differing intensity.

The ever-increasing exploitation through the 1900's, the extremely high value of the fish as a food resource and as a complex industry employing vast numbers of people, has led to competition between Pacific nations for these fishes and to the eventual establishment of international commissions for the regulation of the fishery. All these pressures required that the various state and federal governments of four competing nations — Canada, the United States, the USSR, and Japan, acquire greater knowledge of these fishes. This included large-scaled examination of salmon caught on the high seas and very sophisticated analyses of characteristics ranging from parasites to bones, meristics, and serum, in order to designate the continent of origin or "ownership" of the various stocks. In addition to such practical requirements, there were biological interests in the bodily functions of an animal that, twice in its life, must adjust to a change from salt or fresh water and is able, by visual and olfactory cues, to navigate from the open ocean to the very tributary, often hundreds of miles inland, where its life began.

These various interests have led to a volume of information which cannot be properly summarized for this discussion of all the freshwater fishes of Canada. These species are part of the freshwater fauna only as spawning adults and for a varying period as young. Their external characteristics and details of biology vary from river to river.

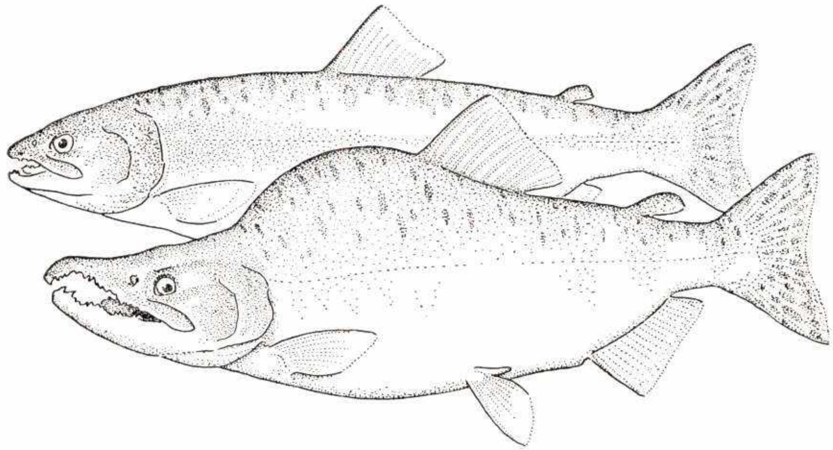
The discussion of each species will deal largely with their freshwater existence and the accounts may seem brief, in view of the importance of these fish, and lacking in detail compared with those of less known but totally freshwater species. We have relied heavily on Clemens and Wilby (1961) and McPhail and Lindsey (1970) for parts of these outlines. The reader interested in greater detail on all or any of these salmon in North America is advised to see the publications of the Department of Fisheries and the Fisheries Research Board of Canada (now the Department of the Environment), the United States Bureau of Commercial Fisheries (now the United States National Marine Fisheries Service), the provincial and state governments of Pacific coast areas, the International Pacific Salmon Fisheries Commission, and the International North Pacific Fisheries Commission. Some specific publications of general interest are as follows: McMurrich (1909) — life history; Dymond and Vladykov (1934) — distribution and relationship; Davidson and Hutchinson (1938) — distribution and environment; Clemens (1953), Foerster (1955) — biology; Wilimovsky and Freihofer (1957) — literature; Rounsefell (1957) — fecundity; Rounsefell (1958) — anadromy; Neave (1958) — origin and speciation; Rounsefell (1962) — morphometrics and relationship; Vladykov (1962) — osteology; Kasahara (1963) — world catch; Bilton et al. (1964) — scale key to species; Margolis et al. (1965) — parasites; Maxfield (1967) — literature 1909–1959; Hart (1973) — general. Hoar and Brett and their students or co-authors have published extensively on the physiology of all species.

The following table shows the comparison of biology and meristics of the Canadian species of Pacific salmon.

	Avg FL (*inches*)	Avg wt (*lb*)	Length of life cycle (*years*)	Gill rakers	Branchiostegal rays	Dorsal fin rays	Anal fin rays	Pelvic fin rays	Pectoral fin rays	Lateral line scales	Pyloric caeca	Vertebrae
Pink	17–19	4	2	24–35	9–15	10–15	13–19	9–11	14–17	147–205	95–224	63–72
Chum	25	11–12.8	3 or 4	16–26	12–16	10–14	13–17	10–11	14–16	124–153	140–249	59–71
Coho												
(anadromous)	18–24	8–12	3 to 5	18–25	11–15	9–12	12–17	9–11	13–16	121–148	45–114	61–69
(freshwater, Ontario)	25	5	3 or 4	21–23	–	10–12	12–15	9–11	12–15	112–139	68–79	–
Sockeye	24–28	5	4	29–43	11–16	11–16	13–18	9–11	11–21	120–150	45–115	56–67
Kokanee	6.3–11	0.65–0.70	2 to 4	31–44	13–14	11–13	11–16	–	–	121–140	50–87	62–67
Chinook	33–36	30–40	4 or 5	16–26	13–19	10–14	14–19	10–11	14–17	130–165	980–240	67–75

PINK SALMON

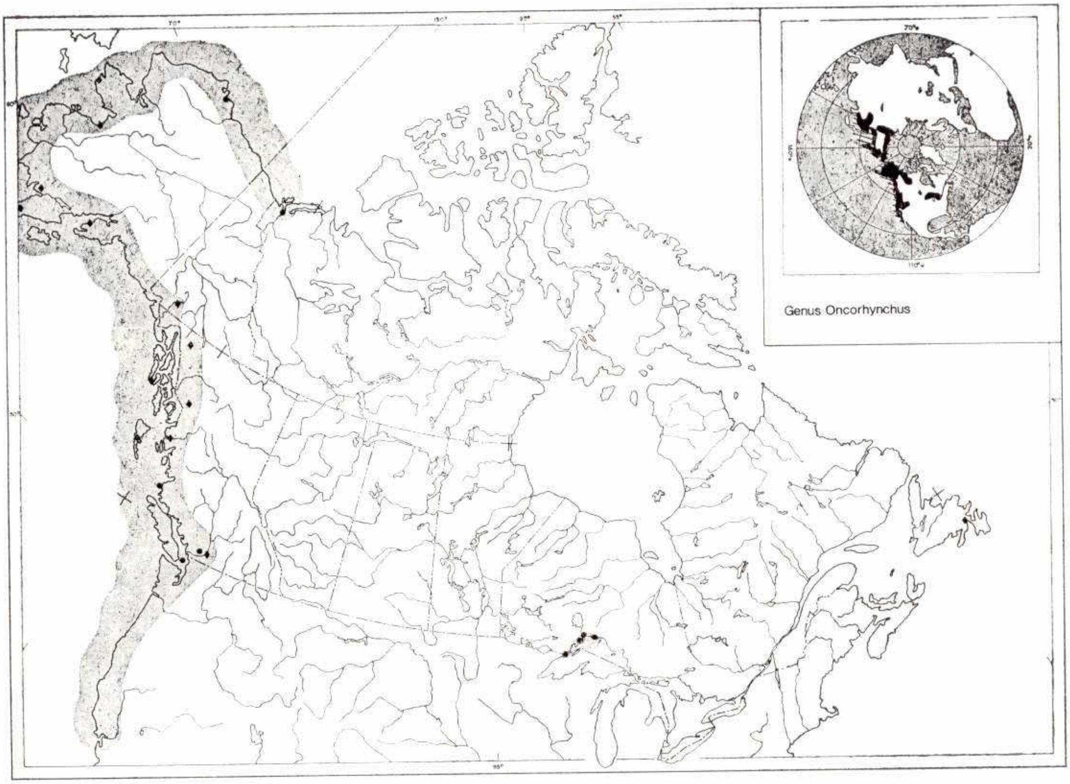
Oncorhynchus gorbuscha (Walbaum)



Description Body fusiform, streamlined, somewhat laterally compressed, usually about 24 inches (610 mm) long as marine adults, but usually not over 18 inches (457 mm) in fresh water in eastern Canada; body depth moderate, deeper in breeding males. Head approximately 20% of total length (longer in breeding males), conical; eye not large, position variable with sex and condition; snout greatly extended, narrow, and turned down at tip in breeding males; mouth terminal, normally very little oblique but greatly deformed in breeding males, with lower jaw enlarged, turned up at tip, mouth unable to close; premaxillaries not protractile; maxillary extending beyond eye; well-developed, sharp teeth on both jaws, head and shaft of vomer, palatines, and tongue, none on basibranchial (= hyoid) bones. Gill rakers of moderate length, 24–35, with 16–21 on lower limb, 8–14 on upper limb. Branchiostegal rays 9–15. Fins: rather large fleshy adipose present; dorsal 1, at centre of body, soft rayed, neither high nor long, square to slightly emarginate, usually 10–15 principal rays; caudal broad, shallowly forked, tips rather pointed; anal with long base, not particularly high, edge square, 13–19 principal rays; pelvics abdominal, not long, axillary process obvious, fin squared to slightly rounded, 9–11 rays; pectorals low, moderately long, tip a rounded point, 14–17 rays. Scales small, cycloid, deeply embedded in spawning fish; lateral line complete, almost straight, 147–205 lateral line scales. Pyloric caeca 95–224. Vertebrae 63–72.

No nuptial tubercles but breeding males with more compressed body and head, prolonged, hooked snout, gaping mouth, enlarged teeth, large hump before dorsal fin, embedded scales and colour change; female changes little except in colour; males permanently in fresh water (Lake Superior) with less spectacular degree of change.

Colour Marine colour: steel blue to blue-green on dorsal surface, sides silver, ventral surface white; back and extreme upper sides with large black spots, adipose fin and both lobes of caudal fin with black spots, those on caudal fin oval, and some as large as the eye. Colour and pattern similar but less brilliant in permanent freshwater populations. Breeding males with head and back darker, sides pale red with brown to olive-green blotches. The young are blue-green on the back, with silvery sides lacking parr marks, and the fins have no black spots.



Distribution As marine adults this salmon occurs in the Pacific and Arctic oceans, the Bering and Okhotsk seas, and the Sea of Japan. Young and spawning adults are found in most tributary rivers of northeast Asia from Peter the Great Bay, north to the Lena River, and in North America from the Sacramento River, Calif., north around Alaska, including the Aleutian Islands, to the delta of the Mackenzie River. They are most abundant in the central part of this range.

In the late 1800's this species was introduced from Maine to Maryland without permanent success. In 1956 pinks collected in the fall of 1955 from the Skeena River, B.C., were introduced in Goose Creek, an Ontario tributary of Hudson Bay. This introduction failed but some of the same brood were released into Lake Superior and have maintained a small population there since that time. In 1958 eggs from Indian, Glendale, and Lakelse rivers of British Columbia were planted in the North Harbour River, St. Mary's Bay, Nfld. By 1967, strays of this stock had spread to Nova Scotia and Labrador, and had penetrated the Gulf of St. Lawrence as far as the Great Watchichou River, Que.

Pink salmon have been introduced in Kola Peninsula of northern Europe and in the Caspian and Black seas. Individuals have been taken as far away as Scotland and Iceland. One stock of pink salmon was maintaining itself in northern Europe in 1968.

Biology Details are from numerous sources and from short summaries by Neave (1966) and Aro and Shepard (1967). Adults migrate from the sea into freshwater rivers from June to September depending on location. They usually move only about 40 miles upstream but may move as much as 300 miles in larger rivers, or may spawn in the lower tidal areas in other rivers. Spawning takes place from mid-July to late October in rivers and tributary streams. Spawning occurs at temperatures as high as 60.8°F (16° C) but spawning of later runs peak at 50° F (10° C). The males are territorial and are aggressive to other males (females are to females also, but to a lesser extent). In this group of fishes it is the female that prepares the nest or redd. This is an excavation in medium-sized gravel and may be as long as 3 feet (915 mm) and as deep as $1\frac{1}{2}$ feet (457 mm), in about 1–2 feet (305–610 mm) of water. The female lies on her side and beats vigorously with her tail to remove silt and light gravel down to a firm gravel bed. The result is a rather deep trough with a raised rim of gravel at the downstream edge. Several males may spawn with a single female in one nest, individual females may build more than one nest, and a single male may spawn with more than one female. The spawning fish settle near the centre of the nest, their mouths gape widely, and sexual products are released during vigorous vibration. Because of the current, eggs may be deposited over the whole length of the excavation. Eggs are covered after spawning by more digging at the upstream edge of the nest which causes gravel to partly fill the nest.

The number of eggs carried by fish entering the spawning area varies with size of the female, the area, and the year. The average has been estimated as 1500–1900 with lows and highs of just over 800 and a little more than 2000. The eggs are large, about 6 mm in diameter, and orange-red in colour. Details of early development were given by Ievleva (1951).

The female usually guards the nest as long as she is able but the spawning adults die in a few days or weeks. Depending on water temperature, hatching occurs from late December to late February. The alevins (young with large yolk) remain in the gravel until the yolk is absorbed in April or early May (rarely late February) when they struggle up out of the nest and become free swimming. They are about 1.3–1.5 inches (33–38 mm) long at this time. Almost immediately after emerging, the fry, which are about 1.25–1.7 inches (30–45 mm) fork length, move downstream at night, often covering 10 miles to the sea in a single night. Those emerging from the higher spawning grounds hide in the gravel by day, become active at night, and are displaced downstream by the current. Other reports suggest they are active, school, and move downstream actively during the day also, particularly when a migration of several days is required. They generally form large schools and are active in the daytime when they reach estuarial water. Young pink salmon may stay in inshore waters for several months before moving to the open sea.

When they first reach the sea they are usually 1.0–1.6 inches (25–40 mm) in length and weigh 0.4 grams. Skud (1955) gave details of length and weight of fry over the migration period in Alaska. In Alaska fingerlings as large as 3.5 inches (89 mm) in length have been taken. It is not known whether they overwinter in fresh water. These large fingerlings may however be chum salmon or chum × pink hybrids.

Pink salmon on the whole live 2 years, although individuals of 3 years of age have been reported. Two-year-old adults, after spending about 18 months in the sea, return to the spawning streams in predictable and highly segregated even-numbered-year and odd-numbered-year runs. Both types of runs or races may use the same stream or one or the other may predominate in a particular river. The Fraser River has an odd-year run and the Queen Charlotte Islands an even-year run. Some streams with a dominant run of one type have a very much smaller off-year run of the other race, which often utilizes different tributaries as spawning grounds. There may be a significant difference in the date of return and in the length and weight of individuals of the two races or of the same race in different spawning rivers. Most of the adults return (home) to the river, and usually to the tributary in which they hatched. There is, however, a degree of wandering, that is, using another stream for spawning. Adults have been taken in spawning streams as much as 400 miles from their original stream. Tagged adults have been captured as much as 1700 miles from the site of tagging. Over the whole area, size of returning adults varies from 2 to 14 pounds. Individuals over 11 pounds are rare, most are 2–7 pounds, and 4 pounds is the overall average. Returning fish are usually 17–19 inches (432–483 mm) in length. When they appear at the river mouths, they are still silvery and the secondary sexual characteristics mentioned in the description develop in the estuary or during the upstream journey.

Pink salmon as young or adults do not remain in fresh water long enough to be said to have a habitat there. The spawning streams are usually small ones with not very coarse gravel, but the main channels of such large rivers as the Fraser and the Yukon are also utilized. Upper lethal temperature and preferred temperature of the young, determined experimentally (Brett 1952) were 75.02° F (23.9° C) and 53.6°–57.2° F (12°–14° C). The extreme low temperature of Hudson Bay may have been responsible for the failure of the pink salmon introduced there. Pink salmon utilize spawning rivers over a wider area than does the sockeye salmon but a very few rivers account for a major part of the British Columbia production. About 78 rivers or 8% of the total number of streams utilized by pink salmon in British Columbia, support 75% of the spawners.

Pink salmon remain in fresh water for such a short time as young that many do not feed at all. Those on longer migrations do take some nymphal and larval insects. Juvenile pinks taken close to shore have fed on copepods, euphausiids, amphipods, ostracods, larvae of decapods, cirripeds, tunicates, and dipterous insects. A detailed study of food of downstream migrants was given by Levanidov and Levanidova (1957). The diet at sea consists of a wide variety of organisms, the most important of which are euphausiids, amphipods, a variety of fishes, squid, copepods, and pteropods. On the Pacific coast, adults do not normally feed after they begin the ascent of the spawning rivers. However, in the Lake Superior population, specimens showing early stages of spawning transformation have been caught in the rivers by anglers using live bait.

The young pink salmon are preyed upon by a variety of stream fishes including cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, squawfish, and various sculpins. Hunter (1959) estimated that in a single stream coho smolts, prickly sculpin, and coastrange sculpin consumed approximately 500,000 pink and chum fry per year. Kingfishers, mergansers, other predaceous birds, and mammals probably account for a small number of fry. Even larvae of stoneflies may prey on eggs and alevins. However, temperature, floods, drought, other water level fluctuation, and too many or too few spawners also control numbers. For details *see* Wickett (1958). Adults at sea are preyed upon by man and marine mammals, and, to a lesser extent, by large fishes. Up to 20% of the pink salmon returning to the Fraser River in 1967 had been attacked by the Pacific lamprey. The Arctic lamprey also parasitizes this species (William and Gilhousen 1968).

Details of the parasites of this species (mainly of marine adults) including the newly described trematode *Genolinea oncorhynchi* (Margolis and Adams 1956), will be found in the many papers of Arai, Boyce, and Margolis (and co-authors) in the Journal of the Fisheries Research Board and the Canadian Journal of Zoology. Hoffman (1967) listed the following parasites of pink salmon in the fresh waters of North America: the protozoan *Cryptobia salmositica*; and trematodes *Genolinea oncorhynchi*, *Hemiurus levinseni* and *Lampritrema nipponicum*, the leech *Piscicola salmostica*, and the crustacean *Lepeophtheirus salmonis*.

The pink salmon is known to hybridize in nature with the chum salmon if not with others. *See* Foerster (1935) and Simon and Noble (1968) for results of artificial hybridization.

Relation to man The pink salmon was apparently less important as a staple food of native people anywhere other species of Pacific salmon were available. Hoar (1951) summarized the fishery from 1917 to 1947. It was also late entering the commercial catch. It and the chum salmon, referred to as "autumn salmon," were considered less desirable, "cheaper species" on the market. Prior to 1911 very few were taken, but the catch jumped drastically because of wartime food requirements and the temporary decrease of the Fraser River catch of other salmon as a result of the Hell's Gate slide. Since that time it has formed an increasing part of the total annual catch in Canada, the U.S., the USSR and Japan. North American catches are lower than those in Asia. The fish are taken mainly by purse seine and gillnets, but a smaller number are taken by troll fishermen. Over the years 1951–1963, the average Canadian catch was 10.1 million fish weighing 48.85 million pounds. In 1968 the catch was 54.83 million pounds with a landed value of nearly 7 million dollars. The bulk of the catch is canned. Only 5% of the catch is prepared as fresh or frozen salmon. The flesh is pink (hence the name) in contrast to the deeper red of the sockeye, and most people today do not look upon it as being so much less desirable than the fancier and more expensive sockeye.

Not until about 1957 was it generally known that the pink salmon in the ocean would take a trolled artificial bait. Since that time it has increased in popularity as a sport fish. Between 1957 and 1961 the estimated annual catch in British Columbia varied from 1000 to 37,000 fish. The 1964 angler catch in British Columbia was analyzed by Tuomi (1964).

The pink salmon has been transplanted to a far less extent than some of the others. The 1956 introduction of about 21,000 fingerlings (1955 year-class) into Lake Superior has never resulted in populations large enough for serious commercial exploitation. The first knowledge of the survival of offspring of that stock was based on captures by anglers in Minnesota in 1959. The first adult pink salmon taken in Ontario was caught in Black Bay, Lake Superior, by a commercial fisherman. Since that time small but increasing numbers have been taken by commercial fishermen and anglers almost every spawning year. The run in 1969 seemed greatly increased. In an Ontario sample of 114 pink salmon taken September 5–27 from seven areas of Lake Superior and its tributaries, the fish varied in length from 13.5 to 18.4 inches (343–467 mm) and were mostly 14–16 inches (356–406 mm). In weight they varied from a spent female 13.9 inches (353 mm) long, that weighed only 8 ounces, to a male 18.4 inches (467 mm) long, that weighed 2 pounds 1 ounce. Most specimens seen have been emaciated and little more than 2 inches (51 mm) thick (side to side).

The introduction into Newfoundland, begun in 1958, has developed a small run in the original river, sporadic reports of the species over the whole east coast of the Island, and a few in Labrador, Nova Scotia, and Quebec. Eggs were last introduced in 1966 and there were spawning runs in 1969 and 1970 of adults that had developed from natural egg deposition. Newfoundland commercial fishermen took 800 pink salmon in 1969. These are apparently marketed as Atlantic salmon at the price charged for that species. Only a few pink salmon are taken each year by Newfoundland anglers.

Nomenclature

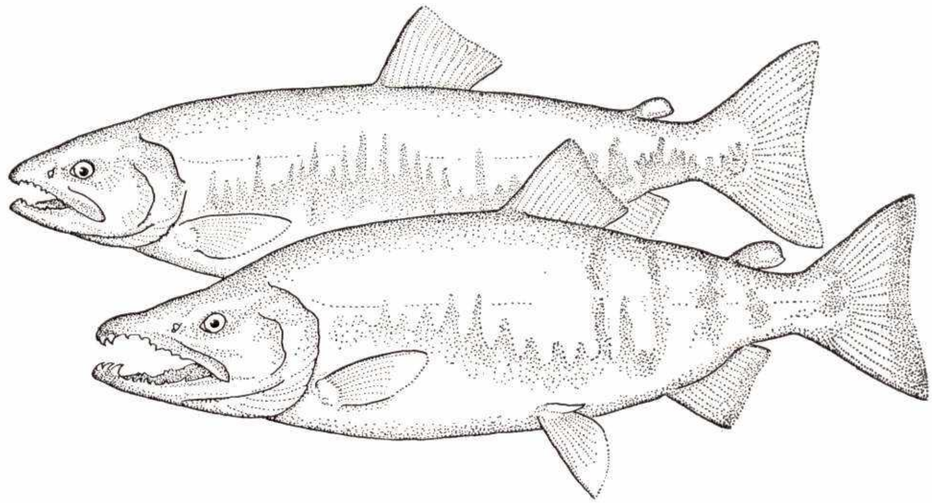
Salmo gorbuscha	— Walbaum 1792: 69 (type locality Kamchatka, USSR)
Salmo Scouleri (Richardson)	— Richardson 1836: 158
Oncorhynchus Scouleri	— Suckley 1862b: 313
Oncorhynchus gorbuscha	— Jordan and Gilbert 1883a: 305
Oncorhynchus gorbuscha (Walbaum)	— Jordan and Evermann 1896–1900: 478

Etymology *Oncorhynchus* — hooked snout; *gorbuscha* — Russian name for this fish in Alaska.

Common names Pink salmon, pink, humpback salmon, humpback. French common name: *saumon rose.*

CHUM SALMON

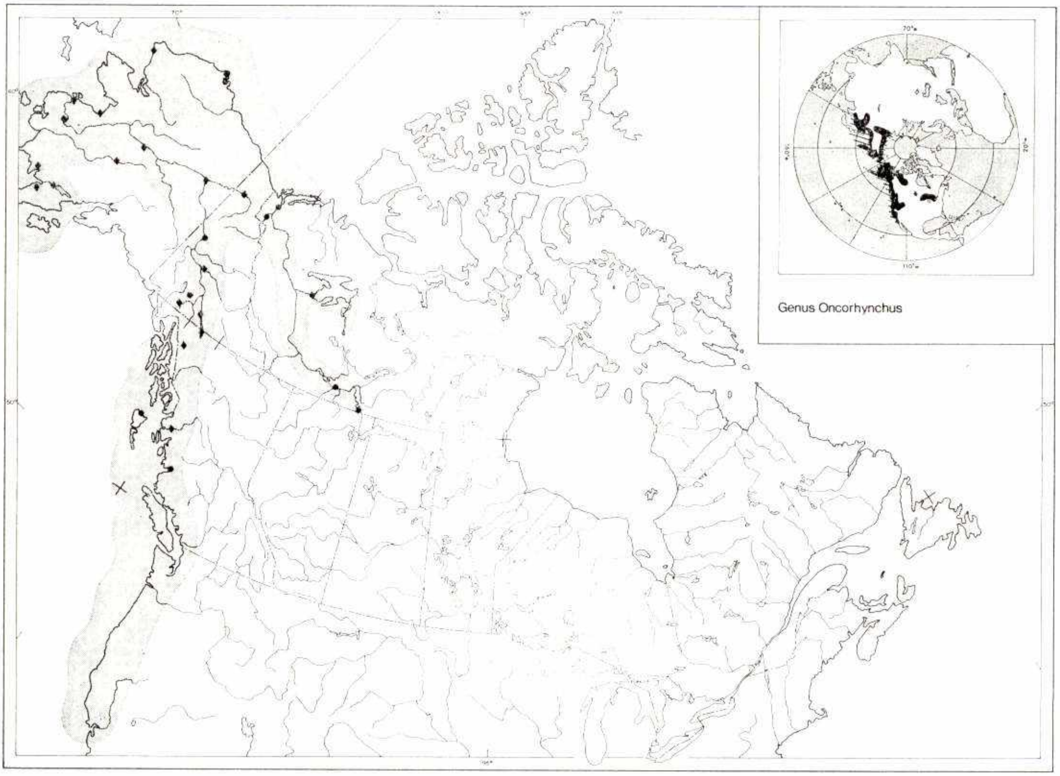
Oncorhynchus keta (Walbaum)



Description Body fusiform, streamlined, laterally compressed, usually about 25 inches (635 mm) in length and 10 pounds in weight as mature adults; body depth somewhat greater than other species, greater in breeding males. Head approximately 22% of total length (much longer in breeding males), conical; eye not large, apparent position variable with sex and condition; snout normally moderate and bluntly pointed but greatly extended, compressed and turned down at tip in breeding males; mouth terminal, normally very little oblique but greatly deformed, unable to close, lower jaw enlarged and turned up at tip in breeding males; premaxillaries not protractile; maxillary extends beyond eye; teeth well developed, sharp, on jaws, head and shaft of vomer, palatines and tongue, no teeth on basibranchials. Gill rakers smooth, short, stout, widely spaced, 11–17 on lower limb, 5–9 on upper limb. Branchiostegal rays 12–16. Fins: large, fleshy dorsal adipose present; dorsal 1, near centre of body, soft rayed, neither high nor long, edge square to slightly emarginate, usually 10–14 principal rays; caudal rather broad, shallowly forked, tips pointed; anal with long base, not high, edge square, 13–17 principal rays; pelvics abdominal, not long, axillary process obvious, fin rounded, 10 or 11 rays; pectorals low, moderately long, tip a rounded point, 14–16 rays. Scales small, cycloid, deeply embedded in spawning individuals; lateral line complete, almost straight, 124–153 lateral line scales. Pyloric caeca 140–249. Vertebrae 59–71.

No nuptial tubercles but breeding males with more compressed body and head, prolonged, hooked snout; gaping mouth; large, bared teeth (hence alternate common name dog salmon); slight hump before dorsal fin, embedded scales, and a distinct colour change; females change less.

Colour Larger individuals in the sea are steel-blue on back and upper sides, the sides are silver and the ventral surface silvery to white, no distinct black spots on back, sides, or fins but upper sides and back may be finely speckled with black. There are tinges of black on the tips of the caudal, anal, and pectoral fins of males. Spawning males are dark olive to almost black above, grey-red



on the sides, with dirty green, vertical bars or blotchings, resembling paint that has run. The ventral surface and fins are often dark grey, the tips of the anal and pelvic fins are often white. Spawning females are similarly but less distinctly marked. The young are bright, mottled green on the back, silvery, iridescent green on the sides and ventral surface, the sides are marked by 6–14 narrow, short parr marks, most of which do not cross the lateral line, or cross it very little, space between adjacent parr marks wider than a parr mark. The fins are white.

Distribution As marine adults this species is found in the Pacific and Arctic oceans, the Sea of Japan, Okhotsk and Bering seas from the Sacramento River in California to Pusan, Korea. In the Arctic Ocean, it extends west to the Lena River, and east at least to the Peel and Mackenzie rivers and possibly the Anderson River. This species ascends the Mackenzie River to the rapids below Fort Smith on the Slave River, and to the mouth of the Hay River; it also enters Great Bear Lake.

The chum salmon has been the least used for introduction beyond its natural range. In January, 1955, eyed-eggs from Puget Sound, Wash., were planted in the Winisk River, a river tributary to Hudson Bay. In June, 1955, fingerlings (eggs presumably from same source), hatched and reared at a Thunder Bay hatchery, were liberated in the Attawapiskat River, which flows into James Bay. This attempt to establish chum salmon in the Ontario section of Hudson and James bays failed.

Biology Various details were derived from a number of published studies and from a summary by Neave (1966). The time that mature fish migrate to the spawning rivers differs with location. In northern British Columbia they arrive on the spawning grounds as early as July. In the south they begin to arrive at the mouth of some streams in September, and arrival on the spawning grounds varies from September to early January. There are distinct autumn and summer runs. In general, they are looked upon as the latest salmon to arrive on the spawning grounds in British Columbia.

Chum salmon arrive at the mouths in an advanced state of sexual development, frequently spawn in tidal areas, show less ability than other species to surmount obstacles, and rarely penetrate rivers more than 100 miles. They do, however, move farther up in such rivers as the Babine, Yukon, Kuskokwim, and Mackenzie. In the Yukon, the main run ascends over 1200 miles, arriving on the spawning grounds above Dawson in late September. However, others spawn in July not far from the mouth. As a result of this wide spread of time and area there is no known correlation between water temperature and spawning.

The males are aggressive on the spawning grounds. The female prepares the redd by facing upstream, lying on one side and vigorously lashing the tail up and down to displace sand and silt. The average size of redds in Washington was 2.7 square yards (2.26 m^2), consisting of an elongate trough up to 16 inches (406 mm) deep with a downstream ridge of gravel. However, spawning takes place over substrates ranging from medium gravel to bedrock strewn with boulders. In the latter case, eggs are released and simply fall into the crevices. A single female is often attended by more than one male, and may build and spawn in more than one nest. A single male may spawn with more than one female. The male and female settle in the nest, their mouths gape, and eggs and milt are released during rapid vibration of the two fish. After the eggs are laid the female partly fills the nest by digging again at the upstream end. Egg number per female is variable with size, area, and year, and may reach 4000 but usually varies from 2400 to 3100. The eggs are large, usually 5.1–5.9 mm in diameter in the ovary, but said to be 6–7 mm in diameter (McPhail and Lindsey 1970) or 8.0–9.5 mm when fertilized (Mahon and Hoar 1956). Eggs are demersal and orange in colour. Details of embryonic development were given by Disler (1953), and by Mahon and Hoar (1956). The female guards the nest as long as she is able but the adults die in a few days without returning to the sea. Chum salmon may be in an advanced stage of sexual maturity when they reach fresh water, spawn almost immediately and total adult life in fresh water may not exceed one week. Some Russian workers suggest the female stays over the nest for 2–10 days protecting it from other females.

Depending on water temperature, hatching occurs from late December to late February. The newly hatched alevins, about 20.5 mm long when hatched, remain in the gravel until conditions for seaward migration develop. During the waiting period they live on the yolk. In late April or early May when they are about 1.3 inches (33.2 mm) long, they struggle up through the gravel, and leave the nest. Sparrow (1968) gave range of fry length in fresh water in various British Columbia localities from March to June as 1.2–2.6 inches (32–67 mm), and weight as 0.3–2.5 grams. Where the spawning grounds are close to the sea, the fry move down the first night after emergence, often covering the distance in one night. Where the migration is longer they hide in the gravel during the day and move by night. In certain long migrations or cases of high water, they travel by day as well and form schools earlier than other stocks. Very often chum and pink salmon fry migrate together from nearby spawning grounds. In some areas they spend several weeks in fresh water. At times the fry school before they reach the sea but they always form schools in estuarial water. They can be as large as 2.7 inches (70 mm) at this time. They often remain near shore for several months before they disperse into the sea and are usually gone from the shore by late July or early August. Individuals, 4.7–9.8 inches (120–250 mm) in length, have been taken in the Strait of Georgia and Dixon Entrance as late as early September and, rarely, to November.

The following table shows age-length relation for chum salmon from several localities.

	FL	Age 2+	3+	4+	5+
Fraser R., B.C. (Chatwin 1953)	*inches*	–	26.8	28.8	32.5
	mm	–	681	732	826
Johnstone Strait, B.C. (Chatwin 1953)	*inches*	–	25.5	28.5	31.1
	mm	–	648	724	790
Yukon R., Alaska (Gilbert 1922)	*inches*	23.5	25.5	27.4	–
	mm	597	648	696	–
	Wt(*lb*)	6.1	7.5	9.6	–

Most chum salmon in British Columbia mature in their third or fourth year of life. However, Pritchard (1943) reported that ages 2–7 were present in the commercial catches but that 2-year-olds were rare and the 7-year determinations required confirmation. Fish in their fifth year occur regularly but form only a very small part of the returning stock in many streams. At Hooknose Creek, King Island, fish of ages 3, 4, and 5 represented the following percentages of the total number returning: 19.7, 71.8, and 8.5; whereas at Nile Creek, Vancouver Island, they represented 24, 76, and 0. Third and fourth year fish usually constitute 90–99% of the upwardbound run, but one or the other year may predominate in different years or in different streams. Average age seems to increase with distance from the mainland and toward the north. Details of age determination by scales for this species were given by LaLanne and Safsten (1969). Chum salmon are considered to exhibit a strong tendency to home to the natal stream but the degree to which they wander is not well known. A tagged adult was captured, 6 months later, 3000 miles from the site of tagging. There are so-called summer and fall runs in different places.

The average individual returning to spawn in British Columbia 1952–1960, weighed 11.0–12.8 pounds, but weights to 45 pounds are known. Males grow faster and larger than females. Specimens captured in Great Slave Lake were 23.6–24.6 inches (600–625 mm) in length, and one was so emaciated it was only 15 mm thick. Others taken near Aklavik in 1937 and 1938 were as large as 27½ inches (698 mm) and as heavy as 8¼ pounds. Chum salmon in the fishery infrequently run as large as 36 inches (915 mm) but the average length is 25 inches (635 mm). When the adults appear at the river mouths secondary sexual characteristics have begun to develop.

The spawning territory varies considerably but is rarely far upstream except in Alaska and the Arctic, and adults rarely attempt to negotiate barriers of any consequence. This species utilizes almost all the suitable rivers along the Pacific coasts (880 streams in British Columbia) and there is not the concentration in a smaller number of streams evident in the case of the pink salmon. The upper lethal temperature has been experimentally determined as 74.8° F (23.8° C). Greatest preference was for temperatures between 53.6° and 57.2° F (12°–14° C) and temperatures above 59° F (15° C) were generally avoided (Brett 1952).

The fry spend so little time in fresh water it was long assumed there was little or no feeding there. Sparrow (1968) contrasted this with several Russian records of feeding, and reported extensive feeding in the Cowichan River. A variety of insects, mature and immature, were included, as well as copepods and nematodes. Chironomid larvae predominated. Growth of these fry was accelerated over that in other areas where no food was taken.

In the early stages of marine life, food varies with season and area, includes a wide variety of organisms such as diatoms, chaetognaths, ostracods, cirripeds, mysids, cumaceans, isopods, amphipods, decapods, dipterous insects, and fish larvae. Copepods, tunicates, and euphausiids dominate the diet of the young and of the older fish at sea. Other items eaten at sea are fishes, copepods, pteropods, and squid. Adults in fresh water do not take food.

Young chum salmon on the spawning grounds and during downstream migration are preyed on by cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, squawfish, and sculpins. Hunter (1959) estimated that in a single stream coho smolts, prickly sculpin, and coastrange sculpin consumed approximately 500,000 pink and chum fry per year. Kingfisher, merganser, other predaceous birds, and mammals are also responsible for a small loss. Even stonefly larvae and possibly other predaceous insects may prey on eggs and alevins. Water temperature, floods, droughts, other fluctuations in water level, spawning competition, and poor returns of adults, control number of young to a far greater extent. For details of factors controlling populations *see* Wickett (1958). Where adults migrate long distances from the sea, bears, some other mammals, and birds such as osprey and eagles, prey on them or remove the dead and dying spent spawners. Adults at sea are preyed on by man, marine mammals, lampreys, and, in the early sea life, possibly by large fishes.

Hoffman (1967) listed the following parasites of this species in North American fresh waters: the protozoan *Myxosoma squamalis*; the trematode *Nanophyetus salmincola*; cestodes *Pelichnibothrium speciosum*, *Phyllobothrium ketae*, *Proteocephalus exiguus*, and *Triaenophorus crassus*.

United States and Japanese scientists found that chum salmon at sea are parasitized by more than 30 species of protozoan and metazoan parasites. The frequency and intensity of infection by the larval nematode *Anisakis* sp. and by the acanthocephalans *Echinorhynchus gadi* and *Bolbosoma* sp. was greater off Asian than North American coasts.

The chum salmon is known to hybridize in nature with the pink salmon if not with others. Simon and Noble (1968) described the artificial cross of these two species and mentioned a report of a cross between the chum salmon and the Pacific cod. Foerster (1935) dealt with various artificial salmon hybrids.

Relation to man The chum salmon has always been of importance to native people, particularly in the north, as food for themselves and their dogs. They still capture large quantities, in nets and fishwheels, which they smoke and dry. Hoar (1951) summarized the Canadian commercial fishery from 1917 to 1947. The chum and pink salmons referred to as "autumn salmon" were long considered less desirable, cheaper species and were of a lesser concern to the fishery. The contribution of chum salmon to the catch has steadily increased. Between 1951 and 1963 it was the fourth most abundant in British Columbia with an average yearly Canadian catch of 2.8 million fish weighing 32.82 million pounds. There were also drastic declines over that period and the average catch between 1955 and 1963 was 2.01 million fish. The catch in 1968 was approximately 36.5 million pounds with a landed value of 1.6 million dollars.

They are taken mainly by purse seines and gillnets, in inside passages and inlets, from mid-June to the end of November, with largest catches from August to October. Some chums are taken by troll fishermen. Large quantities are sold fresh, some are frozen or dry salted, or smoked, but the bulk of the catch is canned. The flesh is white with a creamy tinge and is the lowest of all the salmons in fat content.

Chum salmon are not considered a sport fish and are not regularly sought after by anglers.

Nomenclature

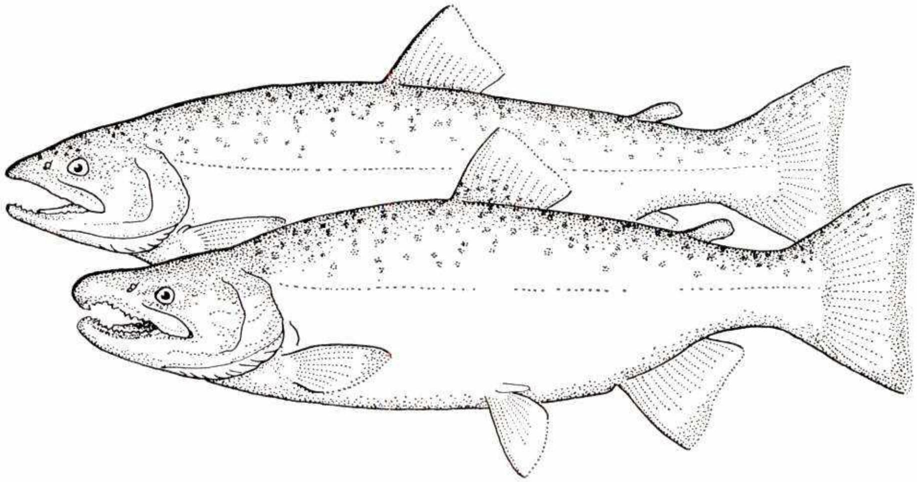
Salmo keta vel kayko	— Walbaum 1792: 72 (type locality rivers of Kamchatka, USSR)
Salmo dermatinus	— Richardson 1854: 167
Salmo consuetus	— Richardson 1854: 168
Salmo canis	— Suckley 1862b: 312
Oncorhynchus canis	— Suckley 1862b: 313
Oncorhynchus dermatinus	— Suckley 1862b: 313
Oncorhynchus consuetus	— Suckley 1862b: 313
Oncorhynchus lagocephalus	— Günther 1866: 161
Oncorhynchus keta	— Jordan and Gilbert 1883a: 305

Etymology *Oncorhynchus* — hooked snout; *keta* — Russian name for this salmon.

Common names Chum salmon, chum, dog salmon, keta. French common name: *saumon keta.*

COHO SALMON

Oncorhynchus kisutch (Walbaum)



Description Body fusiform, streamlined, laterally compressed, usually 18–24 inches (457–610 mm) in length and 8–12 pounds in weight as marine adults and 10.8–25.8 inches (279–656 mm) fork length in Great Lakes freshwater populations; body depth moderate, greater in breeding males. Head approximately 22% of total length, longer in breeding males, conical; eye not large, position variable with sex and condition; snout normally bluntly pointed but greatly extended, thickened and turned down at tip in breeding males; mouth terminal, slightly oblique, deformed in breeding males with lower jaw enlarged, turned up at tip, mouth unable to close; premaxillaries not protractile; maxillary extending well beyond eye; well-developed, sharp teeth on both jaws, head and shaft of vomer, palatines, and tongue, no teeth on basibranchials (= hyoids). Gill rakers rough, widely spaced, 18–25 with 12–16 on lower limb and 6–9 on upper limb. Branchiostegal rays 11–15. Fins: rather long, thin dorsal adipose present, dorsal 1, at centre of body, soft rayed, neither high nor long, edge square to slightly emarginate (often rounded in young), usually 9–12 principal rays; caudal broad, usually only emarginate, tips pointed; anal not particularly high, edge square or with a small rounded lobe anteriorly (large and with protracted first rays in young), usually 12–17 principal rays; pelvics abdominal, not long, axillary process obvious, fin rounded, tip somewhat pointed, 9–11 rays; pectorals low, rather long, somewhat pointed, 13–16 rays. Scales small, cycloid; lateral line complete, almost straight, 121–148 lateral line scales. Pyloric caeca 45–114. Vertebrae 61–69. *See* section entitled *Systematic notes* for meristics of Great Lakes populations.

No nuptial tubercles, but breeding males with more compressed head and body, snout thick and hooked but less deformed than in other species, teeth enlarged, more exposed, hump little or not developed, scales embedded, some colour change; females change little and changes in males of permanent freshwater populations less spectacular.

Colour Adults in ocean or Great Lakes are steel-blue to slightly green on dorsal surface, sides brilliant silver, ventral surface white, small black spots on back, sides above lateral line, base of dorsal fin, and upper lobe of caudal fin. In breeding males the back and head are darker, dirty blue-green, the sides are dull with a brilliant red stripe, ventral surface grey to black. The lower gums are usually pale not black in marine populations. In the Great Lakes most do have grey to black gums. Colour is less spectacular in Great Lakes males and change much less pronounced in females generally.

The young are blue-green on the back, with silvery sides and 8–12 narrow parr marks. The lateral line runs through the centre of most of them, and the pale area between parr marks is greater than the width of a parr mark. The adipose fin is uniform, dusky; the caudal fin and most of the anal fin red-orange. The anal fin is large, the first rays elongate and white with black behind. However colour varies greatly from river to river.

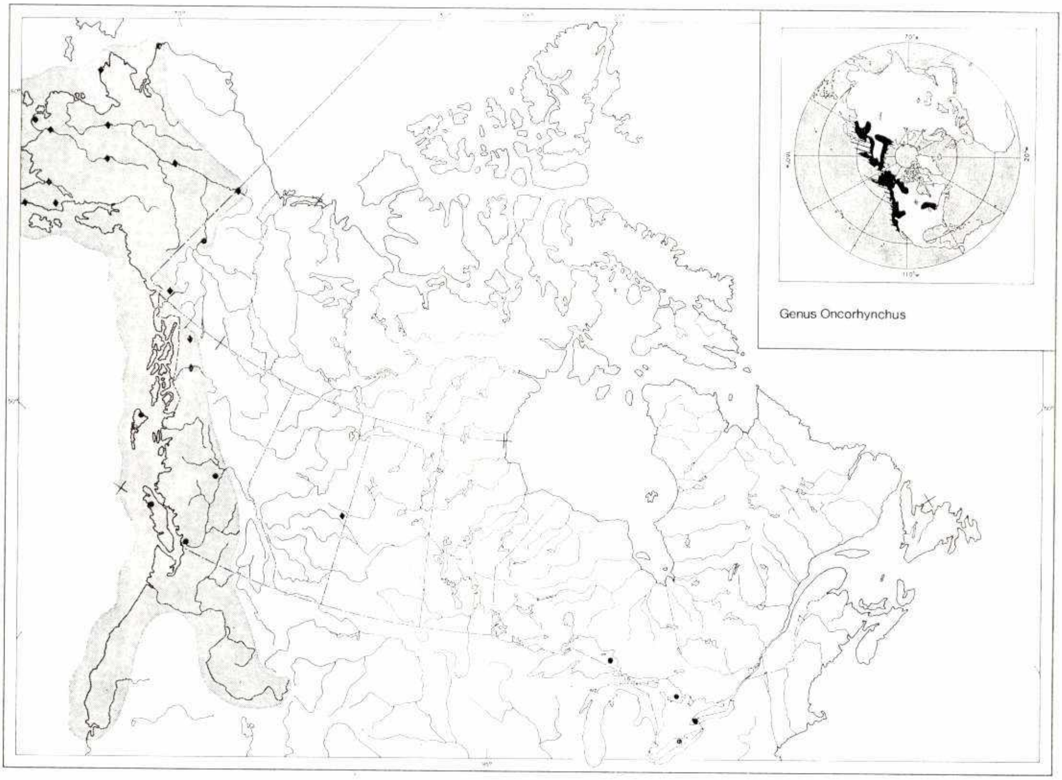
Systematic notes The range of values for various meristic characters is broad but fairly uniform over the distribution in the Pacific. It is interesting to note effect on meristics of moving a species with rather plastic characters, from different areas of its natural range, subjecting them to different embryonic development in different eastern hatcheries and liberating them into the same exotic habitat, as well as into the wide range of conditions from Lake Superior to Lake Ontario. The following table (W. J. Christie and ROM records) compares meristics of coho salmon planted in Lake Ontario by New York State (origin Washington via Michigan?) in 1968 and in 1969, and by Ontario in 1969 (origin Michigan) with the general figures given in the description.

Character	Ontario 1969	New York 1968	New York 1969	Pacific
Gill rakers	21–23	–	–	18–25
Dorsal rays	10–12	10–12	10–11	9–12
Anal rays	12–14	13–15	13–14	12–17
Pelvic rays	9–10	9–11	10	9–11
Pectoral rays	12–15	13–15	14	13–16
Lateral line scales	112–133	127–139	114–124	121–148
Pyloric caeca	76	68–79	–	45–114

The Lake Ontario sample is small and values may eventually spread to fill the range of anadromous populations. Presently, however, number of anal rays, lateral line scales, and pyloric caeca tend to be lower in Lake Ontario. Early attempts to identify salmon from the Great Lakes and to provide characters to separate exotic salmon from rainbow trout, led to confusion as a result of depending, for the salmon, on published figures of meristics of Pacific populations. It would be useful to expand this comparison now that coho salmon are available in all the Great Lakes, from at least three liberations (Michigan, New York, Ontario) and possibly from several different original sources.

Distribution This species occurs naturally only in the Pacific Ocean and its tributary drainage. It is known in fresh water in North America from Monterey Bay, Calif., (in the sea infrequently to Baja California) to Point Hope, Alaska. In Asia, it occurs from the Anadyr River, USSR, south to Hokkaido, Japan.

The states of Alaska, Washington, Oregon, and California have long maintained, by fish culture, stocks in freshwater lakes for angling. Montana had limited success with a 1948 introduction. In the early 1900's attempts were made to introduce the coho



into the Atlantic from Maine to Maryland, and in Argentina and Chile. Chile was the only country reporting at least early success. Coho are apparently present in New Hampshire fresh waters.

The history of the attempts to establish this species in the Great Lakes goes back to 1873. Between 1873 and 1878 thousands of fry were liberated in Lake Erie and its tributary rivers by Ontario, Ohio, and Michigan. There was no success. In 1933, Ohio again attempted to establish them in Lake Erie. From 1933 to 1935, cohos of 3–5 pounds were taken, but the stocks did not succeed. The greatest excitement generated by liberations were those commenced in the Great Lakes in 1966 by Michigan and followed later by Ohio, New York (1968), and Ontario (1969). These stocks are presently being maintained by fish culture rather than by dependence on doubtful natural reproduction, but there have been indications of natural reproduction in Michigan.

Alberta planted coho salmon in Cold Lake in May 1971, and there have been reports of fish from this source captured downstream in Pierce Lake, Sask. They now occur in Canada in all the Great Lakes, and in Alberta, as well as in their native range.

Biology Details derived mainly from Shapovalov and Taft (1954), Godfrey (1965), and Tody and Tanner (1966). The adults migrate from the sea or lake late in the season (later than sockeye and pink salmon) and over a prolonged period. They school at the mouths of rivers and often move in when fall rains increase river flow. The spawning run in the Great Lakes is from early September to early October. Adults move upstream during the day. They sometimes utilize the whole length of smaller rivers, penetrating beyond sockeye, pink, and chum salmon, but more often do not travel more than 150 miles from the sea in large rivers. Segregation into summer and autumn, or autumn and winter runs is more apparent in Asia than in North America. Spawning takes place in swifter water of shallow, gravelly areas of river tributaries, from October to March, but usually October to November, or November to January in North America. On the spawning grounds males and females are aggressive. The nest is built by the female, which, by lying on her side and beating the tail vigorously up and down, excavates a long oval to round trough in medium to small gravel. Several males may be in attendance but one (larger) is dominant. The dominant male swims into the nest with the female, their mouths gape, the two vibrate, and eggs and sperm are released. The other attendant males (smaller jacks or grilse?) may dart in at this time and release sperm. The female may spawn in as many as four different nests, probably with different males. After the eggs are laid they are covered by digging and displacing gravel from the upstream edge of the nest. Egg number is variable with size of female, area, and year, and has been reported in Washington to be 1440–5700 for females 17.3–28.3 inches (440–720 mm) in length. Average number in British Columbia ranges from 2100 to 2789. The eggs are large, those of west coast populations usually have a diameter of 4.5–6.0 mm, but are smaller than in some other salmon. Eggs taken from females from Lake Ontario were 6.6–7.1 mm in diameter after preservation, outside the range given for the western anadromous populations. They are orange-red in colour and demersal. After covering the nest the female guards it as long as she is able. Soon after spawning is completed the adults die. Details on early development were given by Ievleva (1951). Hatching usually takes place in early spring, in 35–50 days, 38 days at 51.3° F (10.7° C) to 48 days at 48° F (8.9° C) in California, possibly 42–56 days farther north and as much as 115 days in Asia. The alevins remain 2–3 weeks in the gravel, at least until the yolk is absorbed, and then emerge as free-swimming, actively feeding fry. Because of the spread in spawning time, fry emergence occurs from early March to late July.

Apparently some fry migrate almost immediately to the sea or lake but most remain at least 1 year in freshwater or lake tributaries (1 year in British Columbia and 2 years in the Yukon River). Those remaining in the spawning stream take up residence in nearby shallow, gravel areas near the stream bank, feed voraciously, and grow quickly. They congregate in schools at first but later disperse and become aggressive and territorial. In the late summer to fall they move into deeper pools. Usually in late March or April (February to June) of the year (or second year) following their emergence, most of the fish begin to migrate to the ocean or lake. At this time the one-year-olds are about 4 inches (100 mm) long, are referred to as smolts, turn silvery, and, on the Pacific coast, go through physiological changes in preparation for life in salt water. They usually migrate in small schools, mainly at night, and generally arrive at the river mouth in late May (April to August). Not all progeny of anadromous coho migrate, and in various lakes and streams there are cohos older than 2 years (residuals) which never migrate to sea. They do mature but never spawn and consequently all residuals are the progeny of successive runs of anadromous parents. In Cultus Lake, B.C., these residuals grow to 18.3–23.4 inches (465–594 mm) (Foerster and Ricker 1953). Cohos that migrate to the sea (and probably in Great Lakes also) remain close to shore for the first few months and then move to the open ocean (or lake). They do not usually migrate far, but tagged individuals have been caught up to 1200 miles from the tagging site. Most coho spend about 18 months (two summer seasons) in the sea or lake and return to spawn in the fall, usually at age 3 or age 4. The number of 4- and 5-year-old fish in the run of anadromous coho increases northward. In some southern areas of British Columbia the spawning run can consist of 2-year-old precocious males (jacks) and, rarely, females (= first fall following downstream migration), and the more usual 3-year-old fish. In Cultus Lake, B.C., the older fish are usually 21–30 inches (533–762 mm) in length and the jacks are 10.5–13.5 inches (267–343 mm). About 85% of the spawners home to their natal stream. Straying or wandering of adults is apparently greater in the Great Lakes than in the marine populations (*see* the history of the Great Lakes introductions in section called *Relation to man*).

The only freshwater habitat of the marine adults is the spawning stream which is usually a small, coastal, gravelly stream, or a similar tributary of a larger river. The young that remain in spawning streams have, at first, a habitat near shore in gravelly shallows; later they move into deeper pools below riffles, often around large boulders or log jams. They are active in summer and feed voraciously. Activity and feeding decreases considerably in winter. Coho residuals utilize the shallow waters of the whole of smaller lakes or are residents of larger streams. Great detail on the life of young coho in fresh water and their interaction with trout was given by Hartman (1965). Upper lethal temperature for coho fry was determined experimentally (Brett 1952) to be 77.2° F (25.1° C), and preferred temperature 53.6°–57.2° F (12°–14° C).

Young coho in fresh water in Alaska feed mainly on insects including dipterous larvae, Tricoptera, Plecoptera, and Coleoptera. Small quantities of oligochaetes and spiders are also eaten. Sockeye salmon fry are often next to dipterans in importance (Roos 1960). Large numbers of chum and pink salmon are consumed by young coho. When they enter the sea, the smolts (over 100 mm in length) are predaceous and feed on pink and chum fry, herring, sand lance, other fishes, squid, and Crustacea. Probably larger young in the Great Lakes prey on young fishes. The food of the marine adults is more pelagic and more varied than that of many Pacific salmon. It consists of fish (80%), invertebrates (20%), and includes the following: pilchard, herring, anchovy, coho salmon, capelin, lanternfish, Pacific saury, hake, whiting, rockfishes, black cod, sculpins, sand lance, squid, barnacles, isopods, amphipods, euphausiids, crab larvae, and jellyfish. Herring and sand lance make up 75% of the volume (Pritchard and Tester 1944). Food varies from place to place and with time, and a detailed analysis of food of ocean dwelling coho was given by Prakash (1962). It is obvious from this list why it was hoped coho in the Great Lakes would utilize the very abundant rainbow smelt and alewife. This they have done as these two species make up the bulk of the food of larger cohos taken.

Coho salmon have been attacked by river lamprey in the Skeena River, B.C. Coho fry (and smolts), especially when aggregated and abundant, are preyed on by a variety of fishes. In the west these include coho smolts, cutthroat and rainbow trout, Dolly Varden, squawfish, and sculpins. Mergansers, loons, kingfishers, other birds, and some small mammals, may also take numbers of young. All these predators sometimes gorge themselves on young migrating salmon. In the Great Lakes some warmwater predators will probably be added to this list. The adults in the west are taken during their spawning run by bears, other mammals, and large birds. In the ocean, man, lampreys, and aquatic mammals such as seals and killer whales are the chief predators. Individuals in recent spawning runs to tributary rivers of Lake Ontario have shown multiple scars of the sea lamprey.

As young, the fry and smolts will compete with all other bottom feeders. As adults in the ocean or Great Lakes, the adults will be competitors of other predaceous fishes such as the rainbow and lake trouts. However, coho probably feed at depths much shallower than those used by lake trout and are dominated in a competitive situation by rainbow trout; thus they may not adversely affect either of those species, or other highly valued predatory species in the Great Lakes.

Bangham and Adams (1954) examined 132 specimens from seven freshwater locations in British Columbia, and found 88 infected. Parasites identified were trematodes *Crepidostomum farionis*, *Diplostomulum* sp., Gyrodactyloidea; nematodes *Hepaticola bakeri*, *Metabronema salvelini*, *Philonema oncorhynchi*, *Rhabdochona cascadilla*; cestodes *Diphyllobothrium* sp., *Proteocephalus* sp., and acanthocephalans *Neoechinorhynchus rutili* and *Pomphorhynchus bulbocolli*.

Boyd and Tomlinson (1965) reported on the presence of spores of the myxosporidian parasite *Henneguya salminicola* in the body musculature of cohos. This parasite causes a "milky" condition in the flesh of the fish it infests.

Hoffman (1967) listed fungi (1), protozoans (10), trematodes (8), cestodes (8), nematodes (7), acanthocephalans (3), and crustaceans (1), from this species in the fresh waters of North America and Russia.

Natural hybrids of this species and the chinook salmon are known. Anglers in Ontario turned in a specimen which was tentatively identified by the Ontario Department of Lands and Forests (now Ministry of Natural Resources) as a coho × rainbow trout hybrid. *See* Foerster (1935) for results of artificial hybridization of salmons.

Relation to man The coho has long been of considerable importance as a commercial fish and as a sport fish in British Columbia. From 1951 to 1963 the annual commercial catch there was 3.04 million fish weighing 21.54 million pounds. The catch of 29.99 million pounds in 1968 had a landed value of 10.45 million dollars. The usual size of fish in the catch is 8 pounds, ranging from 5 to 12, with 20 pound fish not uncommon. Some immature fish or grilse (up to 3 pounds) are taken by the commercial fishermen in the Strait of Georgia. The best catches are made from July to September, with a peak in August.

Cohos are taken by gillnets and purse seines from the inlets in August, but the most important catches are those of the trollers which begin in June but are most successful from mid-July to mid-August. They troll large plugs, spoons or feathered jigs. The coho is canned, mild cured, smoked, or, if troll-caught, sold fresh, or fresh frozen, as choice and fancy quality. The wholesale price in November 1970 in the east was $1.15/pound for fresh-frozen coho. The fishery was summarized by Milne (1964).

Cohos are taken by marine anglers from July to October and the larger fish taken are those in their last year of sea life. The presently listed angler record is a coho weighing 31 pounds that was caught in Cowichan Bay, B.C., in 1947. However, a coho taken recently in the Manistee River, Mich., weighed 33 pounds. They are also caught late in their first ocean year and called grilse or blueback (silvers in the United States, as blueback is used for smaller sockeye). At this time they are 4–8 pounds. Plugs, spoons, and jigs, like those used by the commercial trollers but smaller, are the standard tackle for coho salmon. Fly fishermen using large bucktail flies take coho when they are concentrated at stream mouths, and they are pursued by anglers as far upstream as they remain silvery and take food. Frozen or pickled herring are also used, and a small industry developed to prepare this bait. British Columbia anglers catch, on the average, 85,000 older and 110,000 grilse per year.

The dramatic results of the introduction of coho into the Great Lakes has resulted in a phenomenal explosion of interest in this species. The introduction, first by the State of Michigan in lakes Michigan, Huron, and Superior, began in May 1966, with 4–6 inch (102–152 mm) smolts. In September 1966, Michigan commercial fishermen took many 17-inch (432-mm) jack coho up to $2\frac{1}{2}$ pounds weight, and an angler caught one $23\frac{1}{2}$ inches (597 mm) long, weighing 7 pounds. This set off a wild fishing fever, and a near catastrophe, in which thousands of anglers, in boats as small as canoes, were up to 2 miles offshore on these large lakes during the stormy time of year. Michigan anglers caught about 2000 coho averaging 2 pounds weight. In the spring and summer of 1967 the stock spread widely and Canadian anglers started catching coho in Georgian Bay and Lake Erie. In September 1967 large runs of mature 4-year-old fish returned to the Michigan streams. About 31,000 were taken with an average weight of $11\frac{1}{2}$ pounds and some as heavy as 20 pounds. In the first 9 months of 1970 United States anglers took 700,000 pounds of coho from the Great Lakes.

New York introduced coho in Lake Ontario, starting in 1968. Most of the early recoveries were made in Ontario and were fish as large as 24.2 inches (615 mm) in length and up to 8 pounds in weight. In the spring of 1969, Ontario introduced coho into rivers flowing into western Lake Ontario, and Nipigon Bay, Lake Superior.

Eggs from Michigan, reared in Ontario, were the source of the smolts used. In April 1969, Ontario anglers were still catching strays of the Michigan stock and Ontario commercial fishermen were catching and marketing up to 9000 pounds of fish of Michigan origin, which Michigan commercial fishermen were prohibited from catching. Some of these fish taken by anglers in October–November 1969, in Georgian Bay were up to 27 inches (686 mm) long and $17\frac{1}{2}$ pounds weight. A 32-inch (814-mm) fish of 11.1 pounds was caught at Port Bruce in Lake Erie. Since that time, some of the smolts introduced into the Ontario side of Lake Ontario returned in 1970 to spawn, as 3-year-olds, with a mean length of 25 inches (635 mm) and weight of 5 pounds. The cohos are definitely utilizing the alewife and smelts, and, more rarely, even lampreys, to achieve this extremely fast growth.

Several factors are involved in the future success of this most recent attempt to establish Pacific salmon in the Great Lakes, and in the possibility that this introduction will have longer-lasting results than did the former ones. These are: the ability of the coho to reproduce naturally or the decision that the stock is economically worthy of maintenance by means of constant fish-cultural activity; maintenance of habitat conditions which will ensure survival of the coho stocks and stocks of food fishes; and the ability of these exotic fishes to live through what appears to be a high rate, at least in Lake Ontario, of sea lamprey attack.

Nomenclature

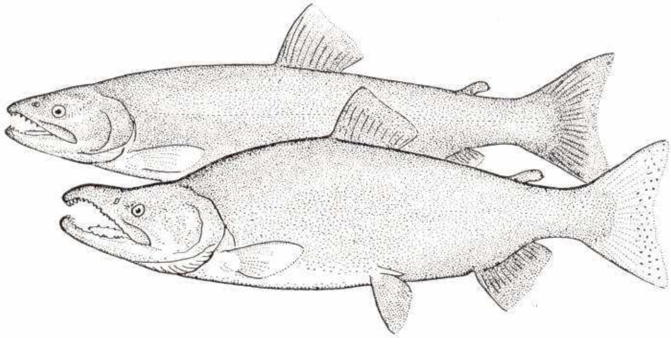
Salmo kisutch	— Walbaum 1792: 70 (type locality rivers and lakes of Kamchatka, USSR)
Salmo tsuppitch	— Richardson 1836: 224
Oncorhynchus kisutch (Walbaum)	— Jordan and Evermann 1896–1900: 480

Etymology *Oncorhynchus* — hooked snout; *kisutch* — vernacular name for this species in Kamchatka.

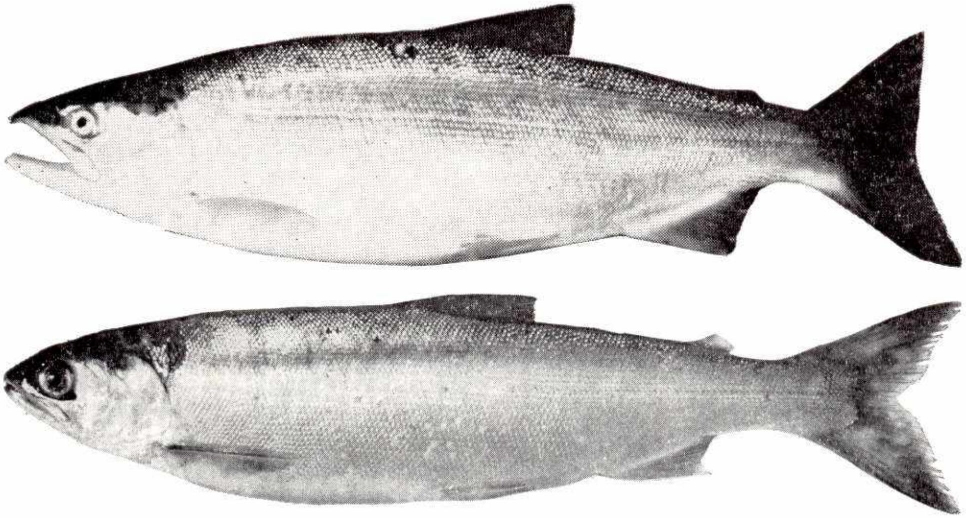
Common names Coho salmon, coho, silver salmon, sea trout, blueback. French common name: *saumon coho.*

KOKANEE AND SOCKEYE SALMON

Oncorhynchus nerka (Walbaum)



Since there are well-known populations of a truly freshwater form of this species, and since there is great interest in its introduction in North America distant from its natural habitat, the kokanee will be emphasized here. Information is provided on the anadromous sockeye salmon in fresh water but anyone interested in that form should see Foerster's (1968) masterful compilation and analysis of available information.



Upper photo, *kokanee from Kootenay Lake, B.C.*; lower photo, *introduced kokanee from Boulter Lake, Ont. (Kootenay Lake stock)*.

Description Body fusiform, streamlined, laterally compressed, usually 8–9 inches (203–229 mm) when mature (sockeye usually 24 inches or 610 mm when returning to fresh water), body depth only moderate, little more in breeding males. Head bluntly pointed, conical, eye rather small, position variable with sex and condition; snout rather pointed; mouth terminal, slightly oblique; premaxillaries not protractile; maxillary extends at least to posterior margin of eye and often beyond; well-developed but rather small teeth on jaws, head and shaft of vomer, palatines, and tongue, no teeth on basibranchials. Gill rakers long, slender, serrated, closely spaced, 31–44 in British Columbia (in sockeye usually 29–43 with 19–27 on lower limb and 10–16 on upper limb). Branchiostegal rays 13 or 14 (11–16 in sockeye). Fins: a rather small dorsal adipose present, dorsal 1, at centre of body, soft rayed, neither high nor long, edge square to slightly emarginate, usually 11–13 principal rays (11–16 in sockeye); caudal broad, moderately forked, tips pointed; anal with long base, low, square, 11–16 (usually 13 or 14) principal rays (13–18 in sockeye); pelvics abdominal, not long, axillary process present, tip of fin a rounded point, 9–11 rays in sockeye; pectorals moderately long, tip a rounded point, 11–21 rays in sockeye. Scales small, cycloid; lateral line complete, straight, 121–140 lateral line scales (120–150 in sockeye). Pyloric caeca 50–87 (45–115 in sockeye). Vertebrae 62–67 (56–67 in sockeye).

No nuptial tubercles but breeding males with more compressed head and body, prolonged, hooked, turned up snout, gaping mouth, very small hump before dorsal fin, embedded scales, and striking colour change. Colour change in females almost equal to males but other changes much less. Spawning sockeye show less deformity of head, snout, mouth, and teeth than do most other Pacific salmons.

Colour Dorsal surface of head and body brilliant steel-blue to green-blue, with no distinct black spots, sides overall bright silver, no markings, ventral surface white to silver, dorsal fin sometimes with a few dark marks, other fins clear to dusky on membranes.

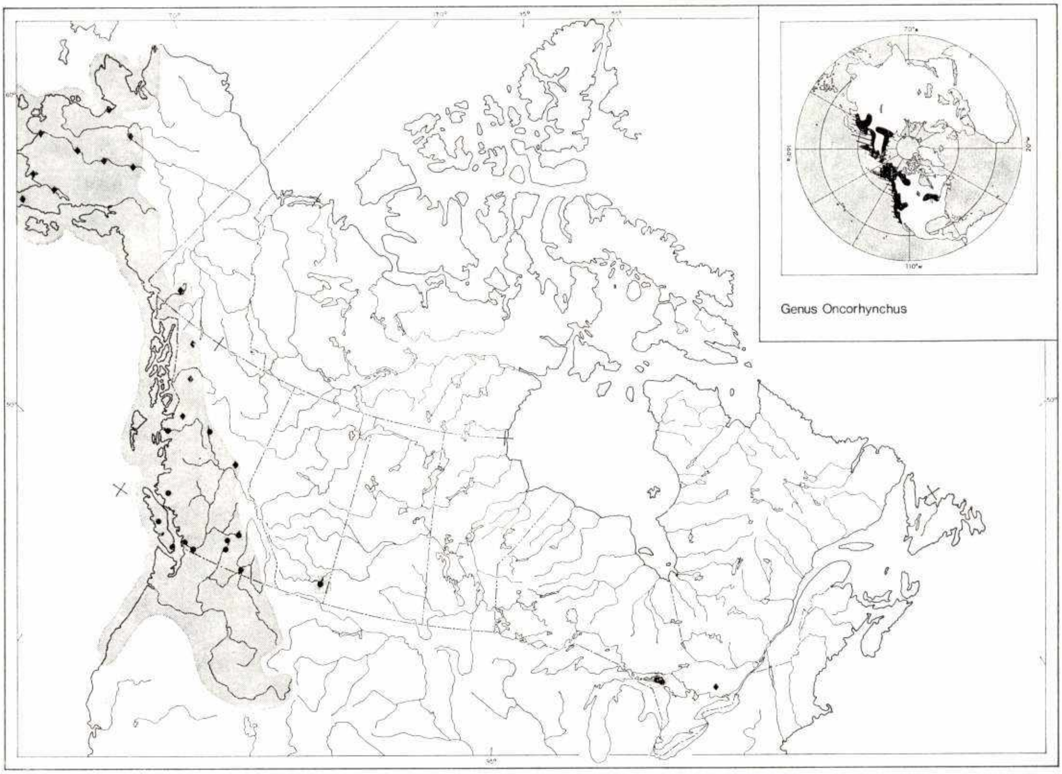
In breeding males back and sides bright red to dirty red-grey, dirty red to grey on ventral surface, head to lower jaw bright green to olive with black on maxillary and snout, lower jaw white to grey; dorsal, adipose and anal fins red, pectoral, pelvic, and caudal fins green to almost black. Female similar but the body is a darker grey-red colour. In some freshwater populations, and in rare anadromous populations, the spawners are dull green to yellow without prominent red colouring. Little difference between kokanee and sockeye salmon.

Systematic notes The permanent freshwater form of this species, the kokanee, was originally described as a separate species, *Salmo kennerlyi* Suckley. Later it was realized that it and the anadromous form were the same species but they were given subspecific status, the sockeye salmon *Oncorhynchus nerka nerka* Walbaum, and the kokanee *O. n. kennerlyi* Suckley. Various studies showing differences in races in the same lake (Vernon 1957), in gill raker count from population to population (Nelson 1968e) and in transplant progeny vs. original stock (McCart and Anderson 1967), the existence in different lakes of so called "residual" sockeye (an intermediate condition), and the fact that kokanee can and will migrate and return with anadromous sockeye under certain circumstances (Foerster 1947), all indicate the futility of separating the two forms.

The kokanee is generally very similar to the anadromous sockeye except in ultimate length and weight, and its meristic characters fall within the range of the sockeye but usually have much smaller extremes.

As mentioned above, there exists, in fresh water, a confusing intermediate form referred to by Ricker (1938b) as "residual sockeye." These sockeye do not migrate, become mature in fresh water at a smaller size, but do not reproduce. They do not occur where there are no anadromous stocks from which they can be derived. *See* Ricker (1940, 1959) for concept of the origin of kokanee. The meristics of Great Lakes populations may deviate from those of the western populations from which they were derived as have the coho salmon in the Great Lakes.

Distribution The kokanee is probably present over most of the range of the sockeye salmon, which extends in North America from the Klamath River, Calif., to Point Hope, Alaska (with stragglers to Bathurst Inlet in the Arctic Ocean), and in Asia from northern Hokkaido, Japan, to the Anadyr



River, USSR. The kokanee occurs naturally in Japan, USSR, Alaska, Yukon Territory (Alsek River), British Columbia, Washington, Idaho, and Oregon (Nelson 1968d). It occurs naturally in many lakes to which anadromous salmon no longer have access, but must have had at one time. The extent of the distribution of true kokanee populations may be clouded by the presence in various freshwater localities of "residual" populations of sockeye that do not reproduce. They occur most widely and abundantly in British Columbia.

Kokanee have been introduced widely in North America including Maine, California, Montana, Colorado, Connecticut, New York, Pennsylvania, Vermont, North Dakota, Nevada, Utah, Wyoming (Buss 1957), farther inland in states where they occur naturally, and in Canada in Alberta, Saskatchewan, Manitoba, and Ontario. They have been introduced into lakes Huron, Michigan, and Superior by Michigan and into lakes Huron (successful) and Ontario (failed) by Ontario.

Biology The biology of the kokanee will be treated here but it will be contrasted with that of the sockeye by providing only brief parallel information on the freshwater life of the anadromous form (mainly from short summaries by Ricker 1966, and Margolis et al. 1966). The most comprehensive summary of the biology of the anadromous form is available in Bulletin 162 of the Fisheries Research Board, entitled *The Sockeye Salmon* (Foerster 1968).

Kokanee spawn in the fall, generally during September and October in Kootenay Lake and elsewhere in British Columbia, and in November and December in Boulter Lake, Ont. Spawning in different areas may be from August to February, over temperatures from 51°–41° F (10.5°—5.0° C) and in 1–30 feet (0.3–9.2 m) of water. Spawning takes place while ice is forming on the lake in Ontario.

The colourful mature adults usually enter inlet streams of the lake in which they are living or they may spawn on gravel beds along its shore. *See* Lorz and Northcote (1965) for details of factors governing spawning run in Nicola Lake, B.C. On the spawning grounds the male (and sometimes the female) is aggressive to other spawning males. The female prepares a nest in streams, in pea-sized gravel, by lying on her side and beating the tail violently up and down. This results in a depression longer than the female and 2–4 inches (51–102 mm) deep, with a rim of gravel at the downstream end. It has been noted that fish spawning in lakes where there is no current, often utilize a vertical, side to side action of the tail characteristic of other lake-spawning fishes. The male and female swim into the nest, their mouths gape, they vibrate, and the eggs and sperm are deposited. The nest is covered by the female, digging at the head end of the nest and displacing gravel into it. The female may dig and spawn in more than one nest, with different males, and a single male may spawn with more than one female. A good description of spawning behaviour was given by Schultz (1935). The adults of both sexes usually die a few days to several weeks later, but in Ontario some may live most of the winter. Egg number is extremely variable over the range. It varies with size of female, and has been reported to be from 368–1764, with a mean number of approximately 450. Sockeye eggs are 4.5–5.0 mm in diameter and orange-red in colour. Time to 100% hatching, determined experimentally by Fallis (1970), varied from about 140 days at 39.2° F (4° C) to 48 days at 59° F (15° C), and 70–82 days at descending habitat temperatures of 55.4°–41.2° F (13.0°–5.1° C) according to Lindsey (1958). In British Columbia streams with constant winter temperatures just above freezing, spawning is early, hatching occurs in December–January and emergence may not occur until March–May. At that time the young struggle out of the nest and become free-swimming, feeding fry.

Growth is rapid, particularly in the first year. In Boulter Lake, Ont., they achieved a length of 5.5 inches (140 mm) in the first year. It is extremely variable in different habitats. In northern British Columbia they are usually 8–9 inches (203–229 mm) in length at maturity whereas in southern British Columbia they are 12–15 inches (305–381 mm). The following table compares growth from several localities.

Generally, kokanee mature, spawn, and die at 4 years of age, but fish age 2–4 may be in the spawning run and fish as old as 8 years have been seen. Kokanee in British Columbia spawning runs summarized by Nelson (1968b) were as large as 13.4 inches (340 mm) fork length and those in Kootenay Lake, B.C., were 6.3–11.0 inches (160–279 mm) and 295–320 grams in weight. The spawning runs in the Blue Jay and Manitou rivers of Manitoulin Island, Lake Huron, appear to be mostly fish 2 years of age. Kokanee as large as 21 inches (533 mm) in length and weights to 4 pounds are not uncommon. Kokanee as heavy as 8 pounds have been reported.

Kokanee, which in spring and fall may inhabit all depths, usually inhabit the upper middle layers of the open lake during the summer in some areas. They move into deep-

		Age (*years*)			
		1	2	3	4
Moore Creek, Nicola L., B.C. (Lorz and Northcote 1965)	FL *inches*	–	6.1–7.3	8.0–10.6	8.4–10.8
	mm	–	155–185	205–270	215–275
Pend Oreille L., Idaho (Buss 1957)	FL *inches*	2–3	7–8	8–9	10–12
	mm	51–76	178–203	203–229	254–305
Boulter L., Ont. (Fallis 1970)	Avg FL *inches*	–	7.5	9.4	9.8
	mm	–	190	240	250
	Wt (*g*)	–	90	160	179

er water with increased summer temperature and in the winter. In summer, they have extensive daily vertical and onshore–offshore movements, possibly associated with temperature and food. Temperature preference is 50°–59° F (10°–15° C). For young sockeye salmon upper lethal temperature is 75.9° F (24.4° C) and preferred temperature is 53.6°–57.2° F (12°–14° C).

The kokanee is mainly a pelagic, plankton feeder but it may derive a significant portion of its food from bottom organisms. Crustacean plankton forms the bulk of the food of adults in summer and autumn in Nicola Lake, B.C., and diaptomids were dominant in the spring. Chironomid pupae were important (up to 70% volume) throughout the summer but larvae contributed in only a minor way and mostly in the daytime. In addition there were miscellaneous zooplankters, terrestrial insects, and water mites (Northcote and Lorz 1966). *Daphnia*, *Cyclops*, *Diaptomus*, *Epischura*, *Chaoborus*, mayflies, and adult dipterans taken at the surface have been mentioned elsewhere as important. Average volume of food in the stomachs appears to be highest in June and October. Volume of food decreases as maturity approaches. The kokanee and young anadromous sockeye salmon eat identical food.

Kokanee, as a result of their plankton diet and open water habitat, may compete little even with other plankton feeding fishes. They are not known to prey on other fishes but small sockeye salmon have been reported eating cottids while the cottids were so small as to be still inhabiting the surface water.

In British Columbia the young are consumed by a wide variety of predaceous fishes including rainbow and cutthroat trout, Dolly Varden, coho salmon, and squawfish. Their role as a food item of predaceous fishes in areas where they have been introduced in the east is presently poorly known. In the Fraser River, they have been found in the stomachs of smallmouth bass and, in the Great Lakes, will no doubt be eaten by larger rainbow trout, lake trout, and coho salmon.

Maturing anadromous sockeye salmon returning to spawn appear in coastal waters from May to October, the time of arrival at river mouth depending on the time of spawning and the length of freshwater migration to the spawning grounds. They usually have a dominant year run and a subdominant year. Elsewhere populations exhibit a striking extreme, 4–5 year, cyclical abundance. They can be at this time 3–8 years of age (usually 4 in southern and 5 in northern parts of the range) and about 24–28 inches (610–711 mm) in length (known to 33 inches or 840 mm) and 5 pounds in weight (known to 15 pounds). Some enter fresh water in May and remain there until fall. The runs to various upriver spawning grounds (= different stocks or races) can be detected at the river mouth by such techniques as scale characteristics (Henry 1961). After reaching a home lake they go to the natal river (usually an inlet) to spawn, but some spend 3–4 months before spawning. Spawning in different areas takes place sometime between July and December, takes place at 37.4°–44.6° F (3°–7° C) and mainly in streams, but in some areas along lake shores.

Egg number and egg size vary with size of female and between stocks. Eggs hatch during the winter or early spring, remain in the gravel until some weeks or months after the yolk is absorbed, and emerge in April to June. Some fry move downstream to the sea shortly after emerging (probably do not survive), most move down (or up) out of the spawning stream to the "nursery" lake and disperse throughout the lake. The fry feed in the open water on plankton crustaceans, chironomid pupae, and at times terrestrial insects. The large number of young resulting from the spawners of a dominant year often deplete the plankton of the nursery lake. In the Fraser River and other southern systems most spend only 1 year in the lake and grow to 2.3–4.1 inches (59–106 mm), but certain stocks spend 2 years and reach 4.0–5.1 inches (101–131 mm) and some, more rarely, spend 3 or 4 years. While in the lakes they are very subject to predation by trouts, Dolly Varden, coho salmon smolts, squawfish, and diving birds. Toward the end of the period of lake residence, characteristic of that stock, the smolts turn silvery and begin physiological changes preparatory to life in the sea.

Seaward migration of smolts occurs in the spring months of their second to fifth year of life. In the ocean sockeye are pelagic, feed on zooplankton, squid, and, infrequently, on small fishes.

After a growth period in the sea of over 1 year (jacks), or more usually 2 or over 3 years, they home to their natal stream to spawn. Some remain in the sea for 4 years. The adults returning to spawn are usually 4 years of age with 2 years of freshwater life and 2 of ocean life, but they can be from 3 to 8 years old with a complex combination of freshwater and ocean years.

Hoffman (1967) listed the following as parasites of the kokanee: protozoans (1), trematodes (3), cestodes (6), nematodes (3), acanthocephalans (2), molluscs (1), crustaceans (3). Bangham and Adams (1954) reported Myxosporidia and 6 species of cestodes, 4 of nematodes, 3 of trematodes, 2 of crustaceans, and 1 species of acanthocephalan from sockeye salmon and kokanee examined from 9 localities in British Columbia. Most of the fish examined were parasitized.

The parasites of the sockeye salmon are much better known and those of the marine adults were discussed in detail by Margolis and co-authors (1963, 1965, 1966). As far as the anadromous sockeye (in freshwater?), the flagellate *Cryptobia salmositica* was recorded from the sockeye (Katz et al. 1966), *Triaenophorus crassus* from smolts in Alaska (Margolis 1963, 1967a) and smolt infection by the cestode *Eubothrium salvelini* and the nematode *Philonema oncorhynchi* (Dombroski 1955). Hoffman listed the following parasites from *O. nerka*: fungi (1), protozoans (5), trematodes (8), cestodes (12), nematodes (6), acanthocephalans (4), molluscs (1), crustaceans (8). From *O. nerka kennerlyi* he listed the following parasites: protozoans (1), trematodes (3), cestodes (6), nematodes (3), acanthocephalans (2), crustaceans (3).

Apparently no natural hybrids are known, but Foerster (1935) gave results of artificial hybridization. Crossman and Buss (1966) reported the artificial hybrid of this species and the brook trout.

Relation to man Kokanee have long been sport fish of interest, at least at certain times of the year, in their natural range. They gained even more prominence when moved to areas where anglers did not have an abundance of other salmonids. They are often looked upon as difficult to catch when the angler learns they are plankton feeders. They are, however, rather readily taken fishing rather shallow with a flashy metal troll (willow leaf troll) of various patterns, with a small baited hook attached. Salmon eggs, maggots, and pieces of worm are the baits usually used. In certain areas they are at the surface in cool weather taking adult insects and can then be caught flyfishing. For their size, they provide good sport. The flesh is often blood-red, oily, and is delicious cooked in a variety of ways, or brined and hot-smoked.

They have apparently been commercially fished (200 per day by hook and line only) in Lake Pend Oreille, Idaho, since 1941. The average annual harvest there, by sport and commercial anglers, in 1951–1957 was estimated at over 1 million fish (Buss 1957). The fact that they can develop extremely large populations (14 tons were seined from Christina Lake, B.C., in a single night in 1898–1899) makes them both useful and potentially dangerous in exotic situations. Their introduction by the province of Ontario into lakes Huron and Ontario, starting in 1964, was successful in establishing a self-supporting population in Lake Huron but not in Lake Ontario. It was hoped that this plankton-eating species might utilize food resources now little used, provide a new sport fish and possibly a future commercial fish in these depleted lakes. An experimental introduction into Boulter Lake, Ont., has been successful and is providing a limited amount of very enjoyable angling. The original stock of these Ontario introductions were eggs taken from Kootenay Lake stream spawners at the Meadow Creek, B.C., egg station, eggs from Idaho, and eggs of shore-spawning stocks from Colorado, Montana, and Washington. The distribution is now being extended by eggs taken from large Lake Huron spawning runs in the Blue Jay and Manitou rivers, Manitoulin Island, now in their third spawning year. Adults are homing to the streams into which they were introduced, but there is a moderate amount of wandering. A 15-inch (381-mm) maturing kokanee was caught off Port Dover, Lake Erie. Those maturing in Lake Huron and Georgian Bay are averaging 15–17 inches (381–432 mm) in length and up to $2\frac{1}{2}$ pounds in weight.

The sockeye salmon was long the mainstay of the Pacific salmon fishery. Its deep red flesh colour, rich flavour, high oil and protein content, uniform size and ease of mechanical handling in canneries all made it highly acceptable to the trade and on the market. It has always enjoyed the top price. It is caught largely by gillnetters working at the mouths of rivers, and purse seines at the south end of Vancouver Island. A small number are caught by trollers. Virtually all the catch is canned. It has long been the most important salmon in Alaska where it is called red salmon. The Fraser River in British Columbia, with all its nursery lakes, supports one of the chief groups of stocks of this species and these are exploited in inshore waters by Canada and the United States. The Adams River run of Fraser River sockeye is of tremendous value, has been extensively studied, and is probably known by fisheries biologists around the world. This exploitation has long required international agreement to govern the fishery, divide the catch, and provide for the passage upstream to various spawning grounds of adequate spawners to maintain the different stocks.

The British Columbia (= Canadian) catch of sockeye from 1951 to 1961 varied from a high of 12.04 million fish in 1958 (approximately half the total Canadian catch of all Pacific salmons in that year), to a low of 2.84 million fish in 1955. It runs on the average of 2–6 million fish per year (Kasahara 1963). In 1968 the British Columbia catch was a little over 41.2 million pounds, with a landed value just over 15.6 million dollars.

The sockeye is not an important sport fish but anglers have taken them in the Bristol Bay area of Alaska for many years. Sport and commercial fishermen have now developed lures which are effective for sockeye in the ocean, and are beginning to take them off the mouth of the Fraser River. In recent years British Columbia commercial trollers have taken very substantial catches with this new gear.

Nomenclature

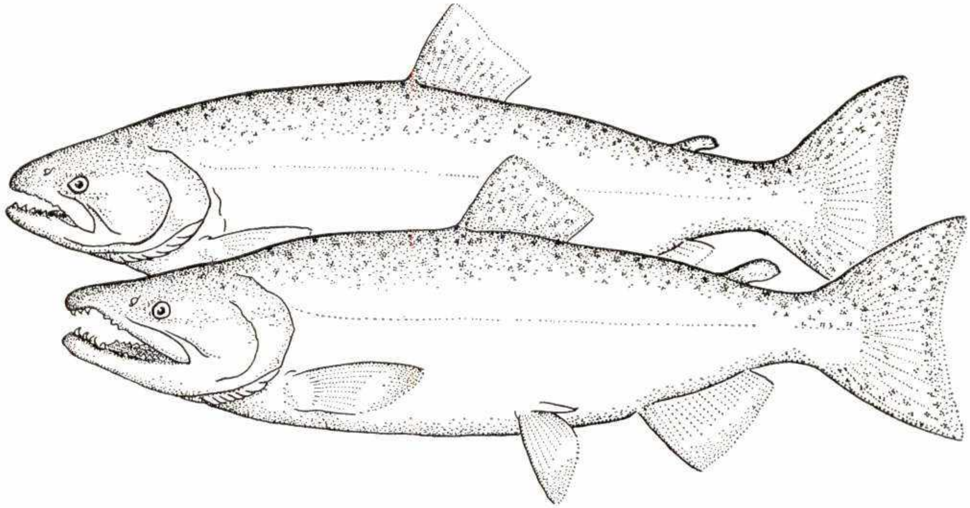
Salmo nerka	— Walbaum 1792: 71 (type locality rivers and seas of Kamchatka, USSR)
Salmo paucidens (Richardson)	— Richardson 1836: 222
Salmo Kennerlyi Suckley	— Suckley 1862b: 307
Hypsifario kennerlyi	— Gill 1863: 330
Oncorhynchus nerka kennerlyi	— Bean 1891: 42
Oncorhynchus nerka (Walbaum)	— Jordan and Evermann 1896–1900: 481

Etymology *Oncorhynchus* — hooked snout; *nerka* — Russian name for the anadromous form.

Common names Kokanee, kickininee, little redfish, land-locked sockeye, Kennerly's salmon, silver trout, yank. French common name: *kokani*; anadromous form — sockeye salmon, sockeye, red salmon, blueback salmon, blueback. French common name: *saumon nerka.*

CHINOOK SALMON

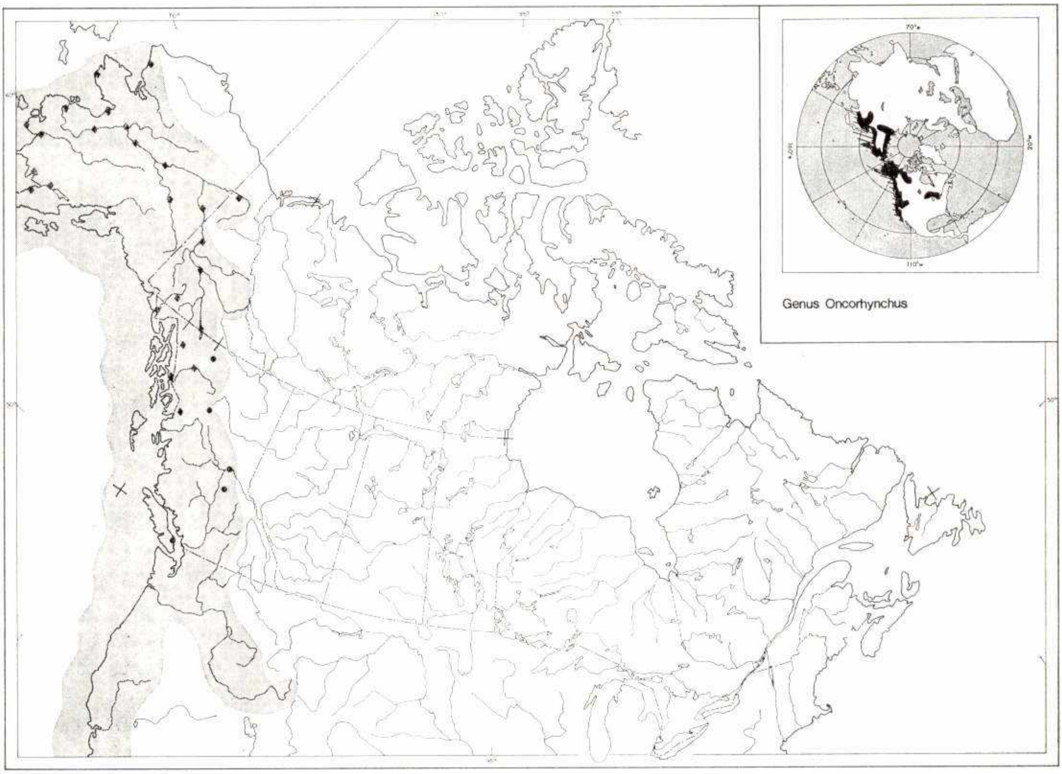
Oncorhynchus tshawytscha (Walbaum)



Description Body fusiform, streamlined, noticeably laterally compressed in large adults, the largest Pacific salmon, adult length variable but usually 33–36 inches (839–915 mm) in marine populations, and as much as 34¾ inches (882 mm) and, in the past, at least 30 pounds in the Great Lakes; body somewhat deeper than other species. Head approximately 20% of total length (longer in breeding males), conical; eye not large, position variable with sex and condition; snout rather blunt, greatly extended, narrowed, and turned down at tip in breeding males; mouth terminal, normally very little oblique, but greatly deformed in breeding males with lower jaw enlarged, turned up at tip, mouth unable to close; premaxillaries not protractile; maxillary extending well beyond eye, at least in adults; well-developed, moderately large, sharp teeth on both jaws, head and shaft of vomer, palatines, and tongue, none on basibranchials (= hyoids). Gill rakers rough, widely spaced, usually 16–26 with 10–16 on lower limb, 6–10 on upper limb. Branchiostegal rays 13–19. Fins: rather long, narrow, dorsal adipose present; dorsal 1, at centre of body, soft rayed, neither high nor long, edge square, usually 10–14 principal rays; caudal broad, emarginate to very shallowly forked, tips pointed; anal with long base, not particularly high, edge square, usually 14–19 principal rays; pelvics abdominal, not long, axillary process obvious, fin rounded, 10 or 11 rays; pectorals low, rather long, tip somewhat pointed, 14–17 rays. Scales small, cycloid, deeply embedded in breeding fish; lateral line complete, almost straight, 130–165 lateral line scales. Pyloric caeca 90–240. Vertebrae 67–75.

No nuptial tubercles but breeding males with more compressed body and head, prolonged, hooked snout, gaping mouth, enlarged more obvious teeth, embedded scales and colour change, female changes little. Freshwater stocks do not change as drastically as anadromous ones.

Colour As marine adults, back, top of head, and upper sides iridescent green to blue-green with gold flecking or sheen, sides below lateral line silvery, ventral surface silvery to white; back, top of head, upper sides, and all fins with at least a few black spots, both lobes of caudal fin spotted but more on dorsal lobe; lower gums black. Breeding fish are an overall olive-brown to



purple colour, males darker than females. Young have 6–12 parr marks, each longer and wider than other Pacific salmon, the lateral line passes through centre of most, dark area of parr marks equal to, or greater than, intervening light area. The adipose fin is pigmented at edge, clear in centre-front. There are no spots on dorsal fin. The first ray of the anal fin is elongate (less so than in coho salmon), white, but usually no black behind as in coho salmon.

Systematic notes Meristic characters have a broad range over the whole area of distribution, but are fairly uniform within stocks or races. Care should be taken in applying Pacific coast meristic values to the newly established Great Lakes populations. (*See* section entitled *Systematic notes*, coho salmon). Meristics of chinooks caught in Lake Ontario in 1970 are compared in the following table with those given for Pacific populations in the *Description* section.

	Lake Ontario	Pacific
Dorsal rays	11–12	10–14
Anal rays	14–16	14–19
Pelvic rays	10–11	10–11
Pectoral rays	14–15	14–17
Lateral line scales	130–137	130–165
Pyloric caeca	138–172	90–240

Distribution As marine adults this salmon occurs in the Pacific Ocean and, rarely, Arctic Ocean and in the Bering and Okhotsk seas and Sea of Japan. Young and spawning adults are found in most of the rivers flowing into these water bodies, from the Ventura River of southern California, north mainly to Point Hope, Alaska; and, as stragglers, east to Coppermine River (personal communication, J. G. Hunter), and in northeast Asia from northern Hokkaido to the Anadyr River. They ascend the Yukon River to its headwaters.

This species was the first Pacific salmon to be introduced elsewhere, and has probably been used more extensively in the past than any of the others. From 1872 to 1930 many attempts were made to establish California stock in the United States from Maine to South Carolina, as well as in Georgia, Louisiana, and Mississippi. It was also introduced in Mexico, Argentina, Chile, Nicaragua, England, Ireland, Holland, France, Germany, Italy, Hawaii, Australia, Tasmania, and New Zealand (Davidson and Hutchinson 1938). The only self-supporting anadromous populations that developed were on South Island, N.Z. Great Lakes populations in the past seemed to thrive initially but failed to maintain spawning populations.

A brief history of their introduction (California stock, at least prior to 1933) into the Great Lakes and elsewhere in Canada, and subsequent captures, is as follows:

Introductions 1873–1878 into Lake Erie by Michigan and Ohio; 1874–1881 into Lake Ontario from Newcastle, Ont., hatchery; 1881–1882 into Saint John River, N.B.; 1919–1925 into Lake Ontario (and Lake Huron?) by Ontario (and Michigan?); 1933 into Lake Erie, by Ohio; 1966 into Great Lakes by Michigan; 1969 into Lake Ontario by New York; 1971 into Great Lakes by Ontario.

Captures and Results 1876, 13–15-inch (330–381-mm) individuals, lakes Ontario and Erie; 1876–1881, to $32\frac{3}{4}$ inches (833 mm) and $14\frac{1}{2}$ pounds, Lake Ontario, Ont.; 1921–1927, to 30 pounds in Lake Ontario, from Credit River to Napanee River, spawning runs of thousands in at least Credit River and Twelve Mile Creek, Halton County, Ont., one caught as far away as Georgian Bay near Killarney, Ont. (from Michigan?); 1935, commercial fishermen in Ohio catching 3–5 pound fish daily in Lake Erie, but probably both chinook and coho salmon, a chinook $19\frac{1}{4}$ inches (489 mm) caught near Kingsville, Ont.; 1939, $8\frac{1}{2}$ miles off Saint John River, N.B. (from Maine?); 1940, $12\frac{1}{2}$ pounds, Saint John River, N.B.; 1935 onward many reports from Great Lakes, probably all large rainbow trout, possibly including one said to have been caught in Georgian Bay, mounted, and now hanging in Georgian Hotel, Midland, Ont.; 1969, Nottawasaga River, Georgian Bay; 1970, small numbers, Bay of Quinte, Lake Ontario (from New York), 16.0–20.8 inches (406–530 mm). In September 1971, adults migrated up the Saugeen River from Lake Huron.

Biology (Details on anadromous stocks partly from Mason 1965; and Aro and Shepard 1967, those on a New Hampshire freshwater population from Hoover 1936.) Maturing chinook salmon move inshore into spawning rivers over most of the year. Many rivers have more than one run (spring to winter chinooks) each made up of fish bound for different spawning grounds (= stocks or races). The general trend is for runs to be earlier farther north, but they appear at the mouth of the Fraser River as early as January, reach maximum numbers in August and September, and are present to December in some years. Generally, the fish that appear at the river mouth earliest migrate farthest. There is the added complication of two varieties, known by flesh colour as red chinook and white chinook.

The adults proceed up river as short a distance as the point just above tidal influence, or as much as 600 miles in the Fraser River and over 1200 miles in the Yukon River. Spawning time varies with time of arrival, area, and length of river migration. In the Fraser River it is July to November, July and August in the Yukon River, August to September elsewhere on mainland British Columbia and October on Vancouver Island. In a freshwater population in New Hampshire, spawning took place from late September to early October. Chinook salmon generally spawn in larger rivers or larger tributaries, near riffles. They tend to spawn in deeper water and on larger gravel than the other Pacific salmon. The males and females are aggressive on the spawning grounds. The female digs the redd by lying on her side and thrashing the tail up and down. Freshwater populations may spawn in rivers flowing into the lake, or on gravel shoals in the lake. The redd or nest can be as much as 12 feet (3.66 m) long and 1 foot (305 mm) deep. Each female is attended by a larger, dominant male and often several smaller males. At spawning the female and the dominant male swim into the nest, the two fish approximate, their mouths gape, they vibrate, and eggs and sperm are released. The smaller males may dart into the nest and release sperm also. After spawning the female digs at the head of the nest and covers the eggs with gravel displaced in this way. The female may dig more than one redd and spawn with more than one male. Egg number varies with stock and size of female, but in Alaska, for females 28.7–39.8 inches (75.5–100.5 cm), it was from 4242 to 13,619, with an average of 8517. In the New Hampshire freshwater population, average egg number was 2500. The eggs are large, 6–7 mm in diameter, demersal, and orange-red in colour. The female guards the nest as long as she is able but the adults die, usually within a few days to 2 weeks. Precocious males have been known to live 5 months after spawning. Adults in New Hampshire, after spawning in a lake, migrated up tributaries and lived as long as a month, but the eggs failed to hatch.

Incubation of the eggs of anadromous stocks takes place with both ascending and descending temperatures, but eggs hatch in the following spring. The alevins spend 2–3 weeks in the nest while the yolk is absorbed, before struggling up through the gravel to become free-swimming, feeding fry. Some fry proceed almost directly to the sea but in many British Columbia stocks they remain in fresh water for a year, and those in the Yukon River, for 2 years. The fry in fresh water school at first but later become territorial and aggressive. At the end of their stay in fresh water they become smolts, their colour becomes silvery and in coastal populations they undergo preparations for the move to salt water. Migration to the sea takes place at different times. The smolts spend some time close to shore before moving to the open ocean or lake.

In Canada, most chinooks spend 2 or 3 years in the sea but adults migrating to the spawning rivers can be 2–9 years of age (Pritchard 1940), with only 1 year (jacks) or as many as 5 years at sea. Females are usually 4 or 5 years old. More northern populations spend a longer time at sea. Those in the New Hampshire lake matured at 3–5 years (mostly 4). Chinooks grow larger than the other Pacific salmons. Those usually seen are a maximum of 38 inches (968 mm) in length, and 30–40 pounds in weight. There is a record of an Alaskan chinook of 58 inches (147 cm) in length, and 126 pounds in weight. Another large chinook salmon caught in Alaska weighed 120 pounds, was 53½ inches (135.9 cm) long and 36½ inches (92.8 cm) in girth. The present angling record is 58½ inches (149 cm) in length, 36 inches (91.5 cm) girth, and 92 pounds in weight, caught in the Skeena River, B.C., in 1959. In reservoirs in California, chinooks were 3–5 pounds after 1 year, and 15–18 pounds after 3 years.

The only freshwater "habitat" of the anadromous stocks is the gravelly spawning stream or river. This species utilizes about 260 streams in British Columbia, fewer than do other species. About 50% of the production results from 14 streams or 5.5% of the streams used by this species for spawning. Upper lethal temperature (Brett 1952) for fry is 77.2° F (25.1° C) and preferred temperature 53.6°–57.2° F (12°–14° C).

The young in fresh water feed on terrestrial insects, Crustacea, chironomid larvae, pupae, and adults, corixids, caddisflies, mites, spiders, aphids, *Corethra* larvae, and ants. Obviously, food is taken at or above the water surface, in the water mass, and off the bottom. Even those spending a year or two in fresh water do not seem to utilize fish as food as do coho smolts in fresh water. Young in the sea close to shore feed on chironomid larvae and pupae. Fishes make up the bulk (to 97%) of the food of marine adults, and invertebrates such as squids, amphipods, shrimps, euphausiids, crab larvae, and other crustaceans make up the remainder (3%). Pritchard and Tester (1944) listed the following fishes as part of the food of marine adults: pilchard, herring, anchovy, capelin, surf smelt, eulachon, threespine stickleback, whiting, tomcod, grey cod, yellow shiner, sandfish, rockfish, wolf-eel. Herring and sand lance were the most frequently eaten fishes. Shad and smelt have been given as important foods of different landlocked populations, and growth is said to be poor in freshwater lakes lacking a pelagic forage fish.

Like the young of the other Pacific salmons, young chinook salmon in fresh water are preyed on by rainbow and cutthroat trouts, Dolly Varden, coho salmon smolts, squawfish, sculpins, mergansers, kingfishers, and other diving birds. Fry or smolts in the sea are probably taken by fishes, and birds when congregated at the river mouths. Adults at sea probably fall prey only to man, large mammals, and possibly the Pacific lamprey. Spawning adults are eaten by bears, other mammals, and the larger flesh-eating birds.

The young compete with other salmons and trouts for food, the marine adults with other fish-eating fishes, especially coho salmon, for food, and with most other salmonids for spawning grounds. Factors other than predation and competition associated with successful spawning, hatching, and migration to the sea, govern numbers of chinooks far more.

The parasites of the chinook salmon appear to be poorly known. Hoffman (1967) listed the following parasites: fungi (2), protozoans (9), trematodes (2), cestodes (5), nematodes (6), leeches (1), crustaceans (4), and molluscs (1). The presence of spores of the myxosporidian parasite *Henneguya salminicola* from this species as well as from the coho and pink salmons, was reported by Boyd and Tomlinson (1965).

Apparently a natural hybrid between the chinook and coho salmons is known. *See* Foerster (1935) for results of artificial hybridization.

Relation to man The chinook salmon has long been very important in the native food fishery and in the commercial and sport fisheries of the west coast. Its geographic importance may increase if recent introductions into the Great Lakes succeed. Capture and canning of chinook salmon, possibly the first full scale Pacific salmon fisheries, was underway in California in 1864.

The largest Canadian commercial catches of chinook salmon take place in southern British Columbia. Most of the catch (75%) is taken by trollers, but purse seines and gillnets are used also, and longlines and fish wheels are used elsewhere. The best troll catches are May to September. Between 1951 and 1961 catches in British Columbia ranged from a high of 1.06 million fish in 1958 to a low of 685,300 in 1961. An all-time high catch of 1.74 million fish took place in 1934 (Kasahara 1963). The British Columbia catch in 1968 was 13.6 million pounds, worth over 6.8 million dollars. Much of the troll catch is sold fresh, fresh-frozen or canned, the net catches are canned. Alone among Pacific salmon, the flesh of this species is regularly either red or white and the red commands the higher price. Some white coho has been reported but it is rare.

Chinook salmon are often called "tyee" by anglers and there is a fishing club by that name in Campbell River, B.C., members of which come from far and wide to fish for this species. On the whole, chinook caught by anglers are smaller than those caught by commercial fishermen but individuals of 50–70 pounds are not rare. Most of the angling was between Vancouver and Victoria, Nanaimo, Cowichan Bay, and Campbell River, but now most of the Strait of Georgia is used by Canadian and United States anglers. Anglers catch, per year, about 59,000 chinook over 2 years of age, and about 35,000 grilse (= coho and chinook). The adult catch has been as high as 93,000 in one year. Chinook are taken to a lesser extent in fresh water also. Plugs, spoons, and live or dead herring are trolled rather deep for this species, and live, salted, or fresh-cut herring are used as bait for still fishing in moderately deep water. The potential size is the main attraction, but the flesh is highly prized also. The commercial and sport fisheries for this species were summarized by Kasahara (1963), Milne (1964), and Tuomi (1964).

Establishing this voracious, fish-eating but non-reproducing species in the fresh waters of New Hampshire led to the interesting suggestion of using it in fresh water for control of coarse fish. The chinooks exterminated smelt from a lake in 3 years and then died out themselves, leaving the lake ready for the re-introduction of native trout.

Nomenclature

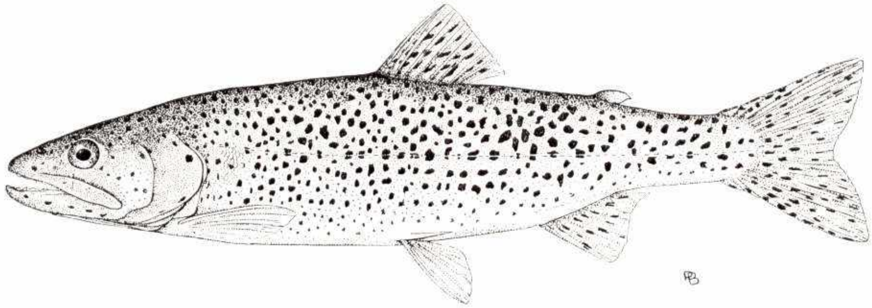
Salmo tschawytscha	— Walbaum 1792: 71 (type locality rivers of Kamchatka, USSR)
Salmo quinnat	— Richardson 1836: 219
Salmo warreni Suckley	— Suckley 1862b: 308
Salmo richardii Suckley	— Suckley 1862b: 311
Salmo cooperi Suckley	— Suckley 1862b: 312
Oncorhynchus Cooperi	— Suckley 1862b: 313
Oncorhynchus chouicha	— Bean 1894a: 26
Oncorhynchus tschawytscha (Walbaum)	— Jordan and Evermann 1896–1900: 479
Oncorhynchus tshawytscha (Walbaum)	— Clemens and Wilby 1946: 85

Etymology *Oncorhynchus* — hooked snout; *tshawytscha* — vernacular name of this species in Kamchatka.

Common names Chinook salmon, spring salmon, king salmon, tyee, spring, chinook, king, quinnat. French common name: *saumon chinook*.

CUTTHROAT TROUT

Salmo clarki Richardson



Two forms of this species are regularly recognized in Canada, the coastal cutthroat trout and the Yellowstone cutthroat trout. There is great variability of all characters including those usually used to separate the two forms. It is difficult to separate them other than on the basis of their location. Non-anadromous populations occur even in the area of the anadromous coastal form. Therefore, the two forms are treated here together.

Description Body typically troutlike, elongate, average length 12–15 inches (305–381 mm), body rather rounded to moderately compressed, greatest depth at dorsal fin usually only moderate, about equal to head length, body rather deep in large adults of some populations. Head short, conical, length equal to body depth; eye moderate, about 22% of head length; snout somewhat pointed to rounded, slightly greater than eye diameter, more so in spawning males; mouth terminal, little oblique, rather large; maxillary long, at least to posterior margin of eye, often far beyond; teeth well developed on upper and lower jaws (premaxillary, maxillary to near tip, dentary), head and shaft of vomer, palatines (narrow space between anterior vomerine and palatine teeth), 2 rows on tongue, 2–20 teeth on basibranchials or hyoids, often difficult to see or obsolete. Gill rakers 14–22, usually 7 on upper limb, 11 or 12 on lower limb. Branchiostegal rays usually 10–12. Fins: dorsal adipose present, dorsal 1, soft rayed, 8–11 principal rays (10–13 total rays); caudal shallowly forked; anal with 8–12 principal rays (11–13 total rays), tip pointed to rounded, edge square to emarginate; pelvic rays 9 or 10; a distinct pelvic axillary process present; pectoral rays 12–15. Scales cycloid, small to medium in size (*see* Vernon and McMynn 1957, for scale characteristics and comparison with rainbow trout), 116–230 scales in lateral line (usually 120–180 slightly larger ones in anadromous populations); lateral line complete, decurved at front and then straight. Pyloric caeca 27–57. Vertebrae usually 60–64. (*See also* Miller 1950b; Qadri 1959; Clemens and Wilby 1961; Carl et al. 1967 for characters to separate coastal and inland stocks.)

No nuptial tubercles, but, in breeding males, kype slightly developed in anadromous populations and lower jaw appears extremely long.

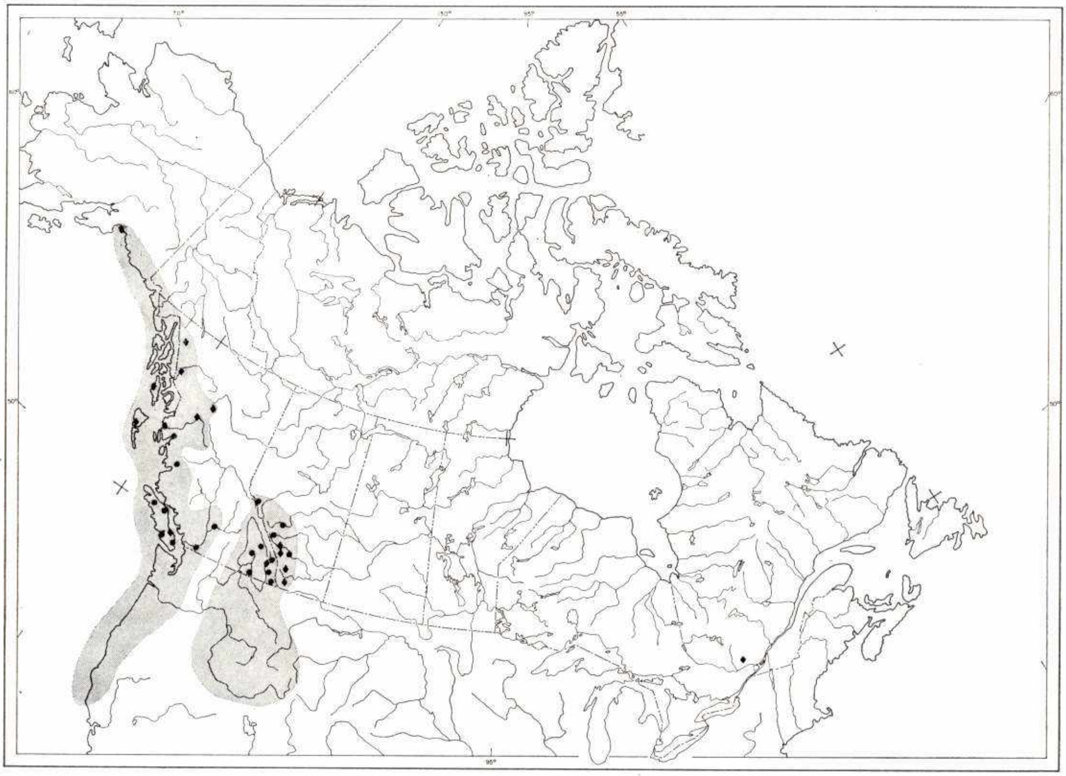
Colour This species shows a bewildering array of colours and pigment patterns, different from watershed to watershed and between the anadromous and inland stocks. This has been further complicated by cross transplantation of the two main stocks in British Columbia and elsewhere on the Pacific coast. One of the main colour characters usually used to distinguish this species from other blackspotted trout are two yellow or orange to red lines in the skin folds of each side of the lower jaw, from which the common name is derived. These are variable in size and intensity, faint in young, and faint to absent in individuals in the sea or recently migrated from the sea.

Coastal form Body dark green above, olive-green on sides, silvery below, pink sheen on gill covers, black spots on back and side numerous, usually extending well below the lateral line, those below the lateral line about equal in number on front and back halves of body; rounded spots on dorsal, caudal, usually on anal and bases of paired fins; several on adipose fin, edge of adipose fin usually not a complete black border; fins usually uniform in colour, without coloured borders. Fish in sea, or newly migrated from sea, more blue, sides silvery, spots less conspicuous.

Interior form (= Yellowstone cutthroat) Body yellow-green with red on sides of head, front of body, and on belly at all times or in spawning fish; spotting variable but spots below lateral line are closer and more numerous on the posterior half of the body than on the anterior half; spots on dorsal, adipose, and caudal fins, anal and paired fins without spots; at times a narrow pink streak, not a broad pink band, along sides. Colours intensify in spawning males. *See* colour illustrations of various stocks or forms in Dymond (1932c) and Paetz and Nelson (1970). Qadri (1959) included photographs of specimens of both stocks or subspecies with both types of supposedly characteristic spotting.

Young of both forms with about 10 oval parr marks on lateral line, overlaid except in smallest, with fine black spots; at times up to five dark ovals on back, dorsal fin often with dark leading edge, sometimes small patches of white on dorsal and anal fins, a few black spots on adipose fin, red to yellow hyoid marks visible on individuals over 3 inches (76 mm) in length.

Systematic notes The coastal form alone was originally described as *Salmo clarki*, the interior form was described later as *Salmo lewisi*, and the two forms were later reduced to the subspecies recognized today. *See* Qadri (1959) for details of subspecies distinction, and Hartman (1956) for taxonomy of the coastal form. As a result of the bewildering tendency to develop different colour and spotting patterns in different



southern rivers, populations in many rivers were, at one time, known by separate subspecies names. Many of these semidistinct forms are still known by common names involving watershed or regional designations. Miller (1950b) listed 11 such combinations. The cutthroat was long known as *Salmo mykiss* and thought to be part of a form by that name which occurs on Kamchatka. It may be closely related. Several early descriptions of the cutthroat by that name are confusing combinations of cutthroat and rainbow trouts. In 1931, Dymond described from isolated, alpine situations in British Columbia, a form he called *S. c. alpestris*. The few characteristics by which this form differed are now thought to be the result only of its unique isolated habitat, as is the case with most of the more southern forms. The general situation has been still further confused by natural hybridization with rainbow trout planted in the range of the interior form, by the introduction of cultured hybrids of the rainbow and cutthroat trouts (called "Cranbrook trout"), by the transfer of the coastal and interior forms into each other's region and the resulting intergradation of the two forms in both areas. Simon and Dollar (1963) treated cytological concepts of speciation and systematics.

The cutthroat trout is known to hybridize with the rainbow trout and with the golden trout. The two subspecific forms intergrade readily. All of these are apparently fertile combinations.

Distribution The cutthroat trout occurs in fresh, brackish or salt water, in North America mostly west of the Rocky Mountains. Its distribution extends from the Eel River in northern California to Seward, southeastern Alaska, on the coast, and penetrates as far inland as central Colorado and northwestern New Mexico.

In Canada the coastal and Yellowstone varieties are separated by a central area in which the rainbow trout occurs. The inland form occurs in western Alberta in the headwaters of river systems from the Milk to the Athabasca (native and introduced), west as far as the Arrow Lakes (Columbia River), and Shuswap Lake (Fraser River), B.C. It is absent from the Okanagan River system. The coastal form occurs as far inland in the south as a line from Hope, B.C., to the Thompson River near Ashcroft, B.C., and to Babine Lake in the north.

It has been extensively introduced within this natural range. About 1942, it was introduced in Laurentian lakes in Quebec. It succeeded but began to appear in the fishermen's catches only in 1966.

In Alberta there are four blackspotted trouts of the genus *Salmo*. In addition to the two native species, the cutthroat and rainbow trouts, there is the introduced brown trout and the exotic golden trout, *Salmo aguabonita* Jordan. This species, whose native distribution is basically in lakes above 10,000 feet altitude in the Kern River drainage of the Sierra Nevada Mountains of California, was introduced into high altitude lakes (South Fork, Three Isle, Gap, and Galatea) in southwestern Alberta in 1959. At least one fish, of 4 pounds 7 ounces, has been taken from South Fork Lake (Paetz and Nelson 1970).

Biology Adult anadromous cutthroat return to freshwater spawning streams in late autumn and early winter. Ripe individuals are found in the Cowichan River, Vancouver Island, as early as November but spawning apparently takes place there in February and March. Elsewhere it is February to May. The Yellowstone cutthroat spawns in spring and early summer about 3–5 weeks after ice breakup, when the water temperature is near 50° F (10° C). In both forms spawning apparently takes place only in small, gravelly streams. On the spawning grounds the males court the females (nudging and quivering) and are aggressive toward other males. Males or females will drive off a female that attempts to dig too close to a redd being dug or spawned in. The female prepares a redd by lying on her side and thrashing the tail up and down so as to create a depression in clean gravel. This is usually at least 1 foot (305 mm) in diameter and 4–5 inches (102–127 mm) deep. When digging is completed, the female settles into the nest, head and tail curved upward, the male swims to her side, the fish gape, become rigid, vibrate, and sperm and eggs are released. The eggs fall into the spaces between the gravel in the bottom of the redd. Other males may take part in the spawning act also. After spawning the female digs at the upstream edge of the nest covering the eggs with as much as 6–8 inches (152–203 mm) of displaced gravel. Females often dig more than one redd and may spawn with more than one male. Males often spawn with more than one female. Spawning takes place during the day or night. Smith (1941) gave a detailed description (and photographs) of spawning from which these details have been taken. Over the whole distribution, reported egg number per female ranges from 226 to 4420 for females 7.9–17.1 inches (202–434 mm) total length. It is often higher in fish of equal size spawning for the first time as compared to the second time, and is not necessarily higher in one subspecies than in the other (Carlander 1969). Average egg number per female, disregarding size and location, would be 1100–1700. Eggs are usually 4.3–5.1 mm in diameter, orange-red in colour, demersal and adhesive at least at first.

There is a high mortality of adults in the spawning runs of many populations and a high egg mortality in the redds. The eggs usually hatch in 6–7 weeks and the alevins remain in the redd for another 1 or 2 weeks. With the different spawning times, fry emergence can be from April in coastal populations to August in Yellowstone populations. In some areas fry move directly out of the small streams into the larger river or into a lake. Even in the coastal area, some fish remain in fresh water at all times whereas others may go to sea very soon, or go to sea for the first time at about 5 inches (127 mm) length in the second or third year. The migration to the river, lake, or sea is usually in the spring, and may coincide with that of Pacific salmons, leading to heavy predation on the salmon. Some may spend as much as 4 years in creeks before migrating to a lake. Those of the coastal form which move down river to the sea usually remain within the influence of the river or go only a very short distance to sea. They stay in the estuaries, often moving into the streams in spring to feed when young salmon are migrating. Individuals may remain in the sea for one or more years and each year some move into their spawning stream in fall and winter in preparation for spawning.

Growth and potential maximum size of this species varies from stock to stock, and between the sea-run coastal form and the inland form in Canada. Carlander (1969) gave an extensive summary of age–length relation indicating area, altitude, and habitat. He also discussed factors governing growth. Accurate age determination of cutthroat trout from high, cold habitats is often made difficult by the fact that some fish pass the first winter without scales and have no annulus at the end of the first growing season. Cooper (1970) gave details on scale development and growth of cutthroat on Vancouver Island. The following table gives the age–length relation (and age–weight in British Columbia) for a Vancouver Island coastal population and for the type locality of the Yellowstone subspecies.

The coastal subspecies apparently has non-anadromous stocks which grow to 30 inches (762 mm) and 17 pounds in British Columbia. The sea-going fish range from 1½ to 4 pounds. The interior type is usually about 12 inches (305 mm) long and about one pound weight but grow to be as heavy as 10 pounds. Carlander (1969) listed this species to lengths of 39.1 inches (991 mm) and weight of 41 pounds, which is probably the fish listed as the angler record. It was caught in Pyramid Lake, Nev., in 1925. Sexual maturity is reached by males as early as 2 years of age and by females as late as 5 or 6. The average age at first spawning is 2–4 years. Many cutthroat live only a few years, will not spawn more than once, and there may be 2 years between spawning. Ten years would appear to be maximum life expectancy but 4–7 is more common.

The habitat of the cutthroat trout consists of gravelly, lowland, coastal streams and lakes, inland alpine lakes and small rivers, and estuaries or the sea near shore. They occur in lakes and streams over 8000 feet altitude. The young, whether of the anadromous or inland stock, spend their early life in the gravelly spawning streams. Not all populations within the range of the coastal subspecies go to sea, some spend their whole life in fresh water. Hartman and Gill (1968) studied habitat relation of cutthroat trout and steelhead in British Columbia. They found that cutthroat were usually in smaller tributaries and headwaters, and in streams of smaller drainage areas which ran through sloughs rather than dropped directly to the sea. In some areas individuals of stream-resident populations have a home territory, usually a gravelly pool, limited to as little as 20 yards (18.3 m) in which they spend the whole of their life (Miller 1957).

Food of this species consists mainly of insects, both aquatic and terrestrial, but small fishes form an important part, at least at times. Other food items include various plankton crustaceans, crayfish, salmon eggs, and dead salmon. Midges, other dipterous flies, mayflies, caddisflies, and beetles enter the diet. The young start feeding 14–23 days after hatching and the food is at first all small invertebrates. Fry and older fish in rivers and lakes feed mostly on fishes, at times almost exclusively migrating salmons. Examination

		Age (*years*)						
		1+	2+	3+	4+	5+	6+	7+
	FL							
Buttle L., Vancouver Is., B.C.	*inches*	8.7	12.9	14.3	15.6	16.1	–	–
(McMynn and Larkin 1953)	*mm*	221	328	363	396	409	–	–
	Wt (*oz*)	3.9	12.5	16.9	20.5	21.2	–	–
	TL (calculated)							
Yellowstone L., Wyo.	*inches*	1.8	5.1	8.9	12.3	15.5	17.5	19.1
(Bulkley 1961)	*mm*	46	129	225	312	393	444	485

of stomachs at other times showed that 78.3% of the cutthroat had eaten fishes such as salmon, trout, sculpin, and stickleback. Of the fishes eaten then, coarse fishes made up over 55% and possibly 62%. In general, the sticklebacks were most often eaten (Idyll 1942). Cutthroat trout consume large quantities of fry and yearling sockeye salmon in Cultus Lake, B.C. (and other salmons elsewhere), and have been looked upon as its main predator there. Detailed analysis of the food of this species elsewhere was given by Hazzard and Madsen (1933) and Dimick and Mote (1934).

Very little is known of the predators of this species. Coho salmon smolts, other cutthroat trout, rainbow trout, and squawfish probably prey on the young. In certain southern, inland areas, the white pelican is a serious predator, so other aquatic and predaceous birds may be also. In various areas food habits lead to competition between cutthroat trout and such species as brook trout, other trouts and salmon, longnose sucker, redside shiner, and speckled dace. Hatchery-reared cutthroat trout compete poorly for space and food with wild cutthroat trout and did not do well when released in Alberta streams containing wild fish (Miller 1954).

Bangham and Adams (1954) examined 179 specimens of *S. clarki* from 11 locations in British Columbia and reported all specimens with one exception were infected with parasites. They stated that 64% of the trout carried the trematode *Crepidostomum farionis*, 57% the nematode *Metabronema salvelini*, 35% the acanthocephalan *Neoechinorhynchus rutili*, and 32% the cestode *Proteocephalus salmonidicola*, these being the principal parasites. Black-spot was also reported by the authors. In all, 18 species of parasites were identified.

See Cope (1964) for a list of publications on the parasites of this species in Yellowstone Lake, Wyo., and Davis (1953) for diseases of the cutthroat trout.

Hoffman (1967) listed the following parasites for the cutthroat trout over all of its North American range: protozoans (5), trematodes (14), cestodes (10), nematodes (16), acanthocephalans (3), leeches (2), molluscs (1), crustaceans (4).

Relation to man The cutthroat trout is an important sportfish where it occurs in Canada. Most anglers, however, consider it inferior in sporting quality to the steelhead and Kamloops varieties of the rainbow trout. It is a hard fighter, can be large, but does not leap and thrash as much as a rainbow does. This species will strike a wide selection of lures including flies (wet flies best), small spoons, spinners, and plugs, and live bait (where permitted). Cutthroat provide good river fishing in areas where other trout may be in the lakes. Best angling success in lakes is usually during the mayfly hatches of July to September. Often best catches are in the rivers earlier than this. The sport fishery for cutthroat trout in Lakelse Lake, B.C., was discussed by Bilton and Shepard (1955). Angler success there has in the past, varied from 0.6–1.4 fish/man-hour in the river and 0.9–1.9 in the lake. Several reports on angling for the Yellowstone variety in the United States were listed by Cope (1964).

Cutthroat trout are raised commercially in southwestern United States but probably mainly for introduction into private ponds rather than use as food as is the case in many rainbow trout farms.

The flesh is orange-red, rich, and of excellent flavour smoked, fried, or, in the case of large individuals, baked.

Nomenclature

Salmo Clarkii (Richardson)	— Richardson 1836: 225 (type locality Cathlapooth River, Wash.)
Fario stellatus	— Girard 1857b: 219
Fario clarkii	— Girard 1857b: 219
Salmo purpuratus	— Günther 1866: 116

Salmo brevicauda Suckley	— Suckley 1862b: 308
Salmo lewisi	— Suckley 1874: 139
Salmo mykiss Walbaum	— Eigenmann 1895: 115
Salmo clarkii alpestris	— Dymond 1931b: 394
Salmo clarkii Richardson	— Dymond 1932c: 27
Salmo clarkii clarkii Richardson	— Dymond 1932c: 28
Salmo clarkii lewisi (Girard)	— Dymond 1932c: 30
Salmo clarki clarki Richardson	— Scott 1958: 6
Salmo clarki lewisi (Girard)	— Scott 1958: 6

No real attempt has been made to trace the many changes of single *i* and double *i* endings nor in the use of species and subspecies.

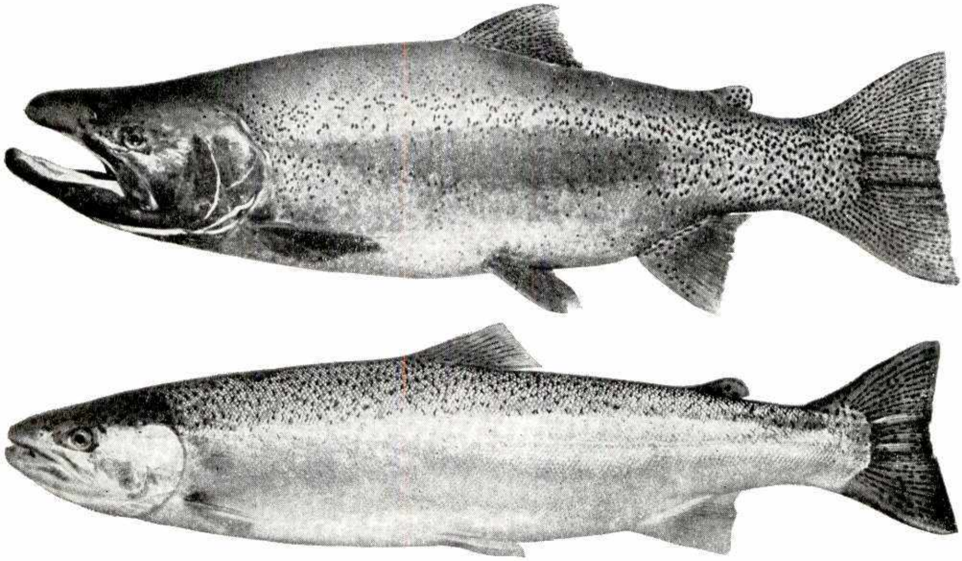
Etymology *Salmo* — Latin name for the salmon of the Atlantic; *clarki* and *lewisi* — Captains William Clark and Meriwether Lewis, leaders of the Lewis and Clark expedition.

Common names Cutthroat trout, coastal cutthroat, Yellowstone cutthroat, coastal cut-throat trout, red-throated trout, Clark's trout, lake trout, sea trout, short-tailed trout. French common name: *truite fardée.*

Oncorhynchus mykiss

RAINBOW TROUT, KAMLOOPS TROUT, STEELHEAD TROUT

Salmo gairdneri Richardson



Upper photo, *rainbow trout*; lower photo, *steelhead trout.*

Description Body troutlike, elongate, average length of rainbows and Kamloops 12–18 inches (305–457 mm), steelhead 20–30 inches (508–762 mm), body somewhat compressed especially in larger fish and all steelhead; body depth variable with area and size. Head length about 20% of total length, but variable with sexual maturity in males, especially steelhead; eye moderate, usually about 20% of head length; snout rounded, length only slightly greater than eye diameter except in breeding males when it is extended and lower jaw is turned up; mouth terminal, only slightly oblique, rather large; premaxillaries not protractile; maxillary long, usually passing eye; well-developed teeth on both jaws (premaxillary, maxillary, dentary), on head and shaft of vomer, palatines, tongue, no teeth on basibranchials (= hyoids). Gill rakers moderate, 16–22, usually 6–9 on upper limb, 11–13 on lower limb. Branchiostegal rays 9–13, often different number on each side. Fins: dorsal adipose present; dorsal 1, at midpoint of body, neither high nor long, soft rayed, 10–12 principal rays, edge square; caudal broad but not long, moderately forked, rather square in large individuals; anal neither long nor high, edge square, 8–12 principal rays; pelvics abdominal, rather small, square to rounded, 9 or 10 rays, small axillary process present; pectorals not long, rounded to rather pointed, 11–17 rays. Scales cycloid, rather small but variable with different stocks (*see* Vernon and McMynn 1957); lateral line complete, slightly curved anteriorly, 100–150 pored lateral line scales. Pyloric caeca 27–80 (*see* Northcote and Paterson 1960, for relation of caeca number to fish size). Vertebrae 60–66 (*see* Garside 1966, for effect of rate of development on number).

No nuptial tubercles but minor changes to head, mouth, and colour especially in spawning males.

For bewildering variability in body proportions with size, and in number of parts, over the whole range of the species, between stocks, and with changing environmental conditions, *see* Mottley (1936b), Needham and Gard (1959), Bidgood and Berst (1967), MacCrimmon and Kwain (1969).

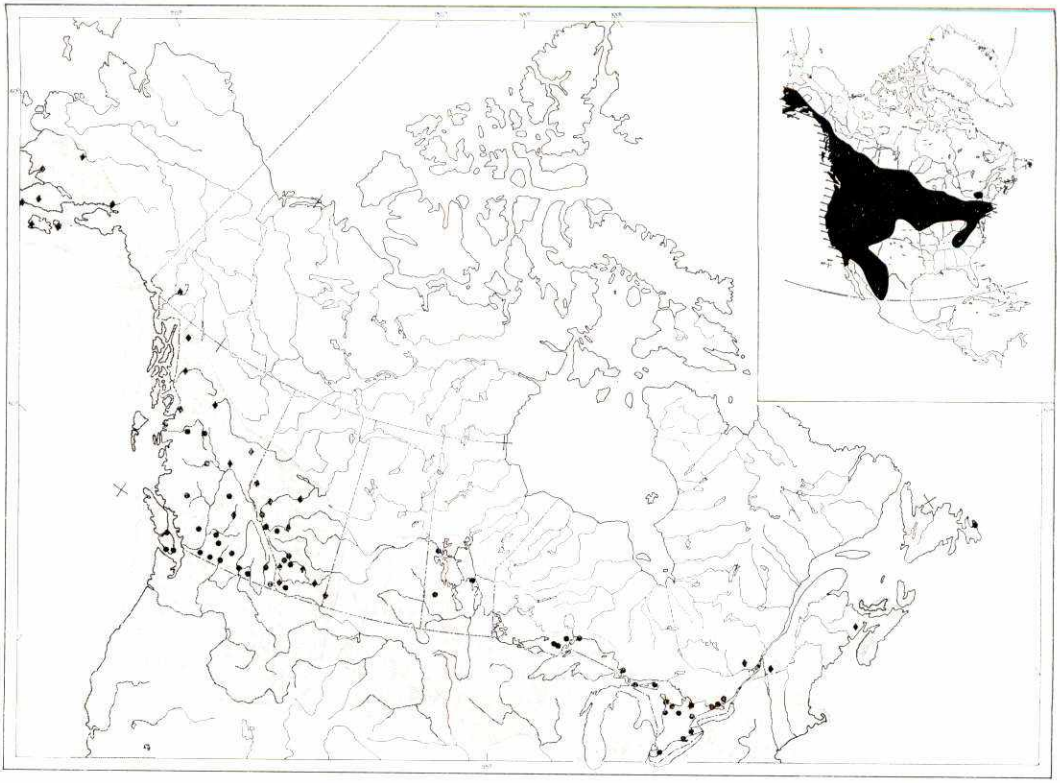
Colour Variable with habitat, size, and sexual condition. Stream residents and spawners darker, colours more intense, lake residents lighter, brighter, more silvery. Different colour types often called by different names by anglers — darker stream fish often called rainbows; brighter, silvery fish in small lakes often called Kamloops trout; large silvery specimens returning from the sea and in Great Lakes or tributaries called steelhead. Back, top of head, and upper sides steel-blue, blue-green, yellow-green to almost brown; sides silvery, white, or pale yellow-green to grey; underparts silvery, white, or grey to yellowish. Cheeks and opercula are pink, the body sides marked with a vague, pink blush to wide rose to red band and a large number of rather small black spots, mostly restricted above the lateral line or scattered over whole side. Dorsal and caudal fins with regular or radiating rows of black spots, adipose fin with black border and a few spots, other fins with a few spots, dusky, or immaculate. Skin folds of undersurface of lower jaw in certain areas with faint, red lines causing confusion with cutthroat trout. Spawners and spawned-out fish recently returned to the lakes (often called kelts) are very dark, often referred to as dirty, and the lateral band is very red. Stream residents often retain parr marks into adult stage and appear quite different from lake residents of comparable age and size.

The young are blue to green on the dorsal surface, silver to white on the sides, and white below. There are 5–10 dark marks on the back between the head and dorsal fin. There are 5–10 short, dark, oval parr marks widely spaced on the sides, straddling the lateral line, the space between adjacent parr marks wider than a parr mark; some small dark spots above but not below lateral line. The dorsal fin has a white to orange tip and a dark leading edge, or a series of bars or spots; the adipose fin is edged with black, the anal fin has an orange to white tip, and there are few or no black spots on the caudal fin (McPhail and Lindsey 1970).

Systematic notes Like the cutthroat trout, this is a very plastic species that differs considerably over the whole of its range. Populations in different watersheds were long called by different scientific names and still by different regional common names in the south. The various forms in Canada have, from time to time, been referred to as separate species, as distinct subspecies, and as only races, stocks, or variants of a single species. There is still argument as to the relation of this species and such black-spotted forms as *Salmo gilae*, the gila trout, *Salmo aguabonita*, the golden trout of California, and *Salmo mykiss* of Asia, which are still recognized as separate species. The golden trout has been introduced in Alberta and may lead to confusion there.

Richardson's original description of *Salmo gairdneri* in 1836 was a steelhead, that of Jordan in 1892, as *Oncorhynchus Kamloops*, was an inland lake form. Dymond in 1931 described an alpine form as *S. kamloops whitehousei*. It was later considered another of the habitat variables that are not really distinct. Other common synonyms in use in Canada as species or subspecies (*see Nomenclature* section) were *irideus*, *rivularis*, *purpuratus*, *stellatus*, and *argentatus*. Since this species is so variable, Needham and Gard (1959) suggested there was no utility in subspecies names. There is, however, some utility in use, at least by anglers, of the separate common names rainbow trout, Kamloops trout, and steelhead or steelhead trout. Confusion does arise here, however, as steelhead is a term usually restricted to large, west coast, sea-run fish. The stock originally introduced into the Great Lakes was steelhead and the purely freshwater stocks retain a life history pattern which utilizes these large lakes as they originally did the sea.

See also Mottley (1934, 1936a), Miller (1950b), Hartman (1956), Behnke (1966), and Northcote et al. (1970).



The rainbow trout is known to hybridize in nature with the cutthroat trout, and various interesting and colourful, artificial hybrids with other species were described by Buss and Wright (1956).

Distribution The native range of the rainbow trout (including all varieties) was the eastern Pacific Ocean and the fresh water, mainly west of the Rocky Mountains, from northwest Mexico (including extreme northern Baja California), to the Kuskokwim River, Alaska. It is probably native in the drainages of the Peace and Athabasca rivers east of the Rocky Mountains. This species, under all its names, has been so widely introduced in North America outside its natural range as to suggest it occurs throughout the United States in all suitable localities. A New York State introduction of 1874 is possibly the earliest. It has also been introduced into New Zealand, Australia and Tasmania, South America, Africa, Japan, southern Asia, Europe, and Hawaii. *See* MacCrimmon (1971) for details of world distribution and introductions.

In Canada, it occurs outside British Columbia from the Avalon Peninsula of Newfoundland, across the southern portions of the provinces from Nova Scotia to Ontario, north to central Manitoba (and central Saskatchewan?), to northern Alberta, and in the Yukon Territory (McPhail and Lindsey 1970). This species apparently occurs naturally in the Alsek River, Yuk., and was also introduced near Whitehorse, Dawson, and Mayo. The distribution map shows a wavy line in Saskatchewan and in the United States which is intended to indicate that occurrence west and south is of a scattered and indefinite nature and usually supported only by constant hatchery introductions.

Some dates of first introduction in Canada are: Newfoundland 1887; New Brunswick and Nova Scotia 1899; Prince Edward Island 1925; Great Lakes 1895; Ontario at least by

1904 and possibly as early as 1883; Manitoba 1938; Saskatchewan 1924; Alberta 1958; Yukon Territory 1943.

Biology Various life history factors of this species are extremely variable depending on location, type, and habitat. A river system in British Columbia could contain river-resident rainbow trout, early migrating (winter-run) steelhead spending 3–4 months there, late migrating (summer-run) steelhead spending 9–12 months there, and lake resident Kamloops trout. Each of these populations could have different life history characteristics. Even though anadromous steelhead spend a considerable part of their time in fresh water and are usually a sport fish only there, they will be treated here only superficially. For extensive life history information on anadromous steelhead *see* Shapovalov and Taft (1954), Maher and Larkin (1955), Withler (1966).

The situation is not made simpler by excluding anadromous steelhead, as the stocks of this species introduced into the Great Lakes were, in the main, steelheads. They utilize these large lakes as seas, their biology is somewhat different and they are often referred to as steelhead in the literature and by anglers. We will not make this distinction here.

Rainbow trout are basically spring spawners. They spawn in smaller tributaries of their rivers, or inlet or outlet streams of their lakes, from March to August but mainly from mid-April to late June (Lindsey et al. 1959; Hartman et al. 1962). Spawners in some areas move toward the spawning stream while ice is on the lake. The usual site chosen is a bed of fine gravel in a riffle above a pool. Unlike the chars, there is little evidence that rainbow trout can be successful spawning on beaches of lakes that do not have rivers flowing into them. Great Lakes populations enter some spawning streams from late October to early May and spawn from late December to late April (Dodge and MacCrimmon 1970). Some rainbow trout in California may spawn twice a year (Hume 1955).

Spawning temperature is usually between 50° and 60° F (10.0°–15.5° C). Males are aggressive on the spawning grounds and drive other males away from a nest occupied by a female. The male courts the digging female by sliding along and crossing over her body, rubbing his snout against her caudal peduncle, by body vibrations, and body pressing. Each digging female is usually attended by more than one male but a larger one is dominant and more active in courtship. The female digs a redd in the gravel by turning on her side and beating her tail up and down. In this way she cleans the gravel and excavates a pit that is longer and deeper than her body. Nest building takes place day and night. When ready to spawn, the female rests near the bottom of the centre of the nest, the dominant male quickly moves in to a position parallel to her, the bodies are pressed close together, both fish gape, arch the body, vibrate, and the eggs and milt are released over a few seconds. Often two males participate with a single female in one spawning. The eggs fall into spaces between the gravel. Immediately the female begins digging at the upstream edge of the nest and the eggs are covered by the displaced gravel.

Females dig and spawn in several nests with the same male or other males, depositing as many as 800–1000 eggs in each redd. Egg number per female in interior British Columbia has been given as 1366–2670, and as averages of 4083 and 4422. Egg number may be as low as 200, and as high as 12,749 in certain selected broodstocks elsewhere. Starved fish have considerably fewer mature, viable eggs (Scott 1962). The eggs are 3–5 mm in diameter, demersal, and pink to orange in colour.

Eggs usually hatch in approximately 4–7 weeks and alevins take an additional 3–7 days to absorb the yolk before becoming free swimming. However, time of hatching varies greatly with region, habitat, and type, as a result of vastly different spawning times and temperature history after egg laying. Early development of eggs and alevins was given in detail by Wales (1941) and Knight (1963). The fry commence feeding about 15 days after hatching. Fry are usually seen emerging from the nests from mid-June to mid-August when spawning is in April or May. The fry of lake-resident spawners move up or down the spawning river to the lake almost immediately or by autumn, or they may spend as much as 1–3 years in the streams. Those of stream-resident spawners remain in the streams and those of steelhead migrate to the sea, usually after 2 years (1–4) in fresh water.

Growth can only be described as bewilderingly variable with area, habitat, life history type, and quantity and type of food. Ages can be determined from the scales and the scale diameter × body length relation is close enough to direct proportionality for back calculations (Smith 1955). The following tables give age–length and age–weight relations for several populations across Canada and compare an anadromous steelhead population with a population of rainbow trout from the Great Lakes.

See also Larkin et al. (1957), for a summary of average size at various ages for many different types of lakes in British Columbia.

As with all other factors, the growth history differs from one population to another. Length of time spent as young in the spawning stream, length of time spent at sea or in a lake, and number of years before first spawning, can vary with different individuals in the same population and influence potential size (*see* bottom part of table below). Individuals returning to spawn in a Lake Huron stream were mostly 5 years of age but ages 3–7 were represented. The males

		Age						
		1	2	3	4	5	6	7
L. Simcoe, Ont.	TL							
(McCrimmon 1956)	*inches*	4.0	7.5	16.5	22.0	26.0	28.5	31.5
	mm	102	190	419	559	660	724	800
Pyramid L., Alta.	FL							
(Rawson and	*inches*	2.4	5.3	7.5	9.3	11.6	14.8	17.9
Elsey 1950)	*mm*	61	135	190	236	295	376	455
	Wt (*oz*)	0.8	1.5	3.0	5.6	11.3	21.6	38.0
Kootenay L., B.C.	FL							
(Cartwright 1961)	*inches*	2.4	4.9	11.4	17.5	23.6	30.8	–
	mm	62	125	289	445	598	785	–
L. Okanagan, B.C.	TL							
(Clemens et al. 1939)	*inches*	2.6	4.7	11.4	17.1	20.3	23.2	28.0
	mm	65	120	290	435	515	590	710
	Wt (*lb*)	0.1	0.3	1.0	3.0	4.5	8.0	12.0
Buttle L.,	FL							
Vancouver Is., B.C.	*inches*	–	10.0	10.5	11.5	12.4	–	–
(McMynn and Larkin	*mm*	–	254	267	292	315	–	–
1953)	Wt (*oz*)	–	5.6	7.3	8.6	9.8	–	–

Years in ocean (or lake)		1				2			3				4	
Years in fresh water (or stream)		1	2	3	4	1	2	3	1	2	3	4	2	3
	FL													
Nottawasaga R.,	*inches*	–	18.1	16.5	24.5	–	21.5	23.2	–	23.1	24.4	–	23.3	–
Ont.	*mm*	–	460	419	622	–	546	589	–	587	620	–	592	–
(Wainio 1962)	Avg *inches*	17.3				22.4			23.7				23.3	
	FL													
Chilliwack R., B.C.	*inches*	19.0	18.7	18.0	–	27.9	27.5	27.6	31.9	31.9	32.2	32.7	38.0	33.5
(Maher and	*mm*	483	475	457	–	709	698	701	810	810	818	830	965	851
Larkin 1955)	Avg *inches*	18.6				27.6			32.0				34.6	

were 12.2–13.4 inches (310–800 mm) in length, and the females 8.2–35.4 inches (210–900 mm). Individual spawners represented 14 different combinations of the factors mentioned above (*see* age–length table).

Sexual maturity is first achieved as early as 1 year by males (rarely) to as late as 6 years by females. In general, the usual age would be 3–5 in all types, with males often maturing a year younger than females. Size at maturity is extremely variable, from 6–10 inches (152–254 mm) in some small lakes or streams, to 16 inches (406 mm) in steelhead and Great Lakes rainbows. A spawning run from Georgian Bay consisted of fish from 16–27 inches (406–686 mm) length, and 3–6 years of age. Individual rainbow trout have been known to spawn in as many as five successive years. If food and other factors are suitable, most mature individuals spawn each year. However, survival is often low and the number spawning more than once can be less than 10%. Generally there is a high degree of homing by spawning adults. It was as high as 94% at Loon Lake, B.C., where fish that mixed in the lake separated to spawn in the inlet or the outlet stream. There is much more wandering in Great Lakes introduced populations.

Maximum size also varies with area, type, and habitat. Steelhead grow to 48 inches (122 cm) and 36 pounds, but 8–9 pounds is the average in the angler's catch. Great Lakes rainbow trout grow to about 36 inches (915 mm) but weight rarely exceeds 20 pounds. The Kamloops type usually do not exceed 6–8 pounds but one taken many years ago in Jewel Lake, B.C., weighed 52 pounds. Rainbow trout grow at least as large as 7½ pounds in Newfoundland, and 17 pounds in Alberta. The present angler record (all types combined) is apparently one caught in Lake Pend Oreille, Idaho, in 1947, which was 40½ inches (103 cm) long, 28 inches (711 mm) in girth, and 37 pounds in weight. Rainbow trout 10–18 pounds win annual anglers contests in Ontario.

Life expectancy can be as low as 3 or 4 years in many stream and lake populations, but that of steelhead and Great Lakes populations would appear to be 6–8 years.

The habitat of stream-dwelling rainbows is usually small to moderately large, but shallow rivers with moderate flow and gravel bottoms, of the pool-riffle type. When in fresh water, steelhead are usually caught in the lower reaches of larger, swift, bouldery rivers of which their spawning stream is a higher tributary. The lake-resident Kamloops type are usually found in moderately deep to deep, cool lakes with adequate shallows and vegetation for good food production. For a lake population to be self-sustaining there must be a gravelly river to which the adults can migrate to spawn. Black (1953) determined the upper lethal temperature of Kamloops trout fingerlings to be 75.2° F (24° C) when they had been acclimated at 51.8° F (11° C). Final preferred temperature calculated by Garside and Tait (1958) was 55.4° F (13° C). Rainbow trout are most successful in habitats with temperatures of 70° F (21° C) or slightly lower, but, so long as there is cooler, well-oxygenated water into which they can retreat they can thrive in lakes which warm at the surface to well over 70° F (21° C) for long periods in the summer. In colder alpine lakes growth rate is slower and maximum size is less.

Generally, the territory utilized by lake-resident rainbow trout is not great. The introduction of the anadromous steelhead into the Great Lakes has resulted in some prodigious journeys. One fish, taken in the Bay of Quinte, Lake Ontario, in January, 1958, had been part of a tagged group released in Great Lakes rivers in Michigan. From release to capture, a period of 8 months, it had travelled about 600 miles, survived a descent of Niagara Falls (unless it negotiated the Welland Ship Canal), and grew 10 inches (254 mm) in length.

In general, rainbow trout feed on various invertebrates including plankton, larger crustaceans, insects, snails, and leeches. Depending on size and location, other fishes (rarely other rainbow trout) and fish eggs (usually salmon) can be important. The bottom organisms it consumes consist mainly of larger crustaceans such as *Gammarus*, and the larvae of virtually all aquatic insects that occur in its habitats. There is usually a shift with increase in size from plankton to insects and crustaceans and then to fishes, if they are available. These trout feed on the bottom most often, but the habit of rising to feed at the surface on emerging or egg-laying insects is well known to most fly fishermen. There have been many detailed analyses of food by size and season of the Kamloops type trout (*see* Neave and Bajkov 1929; Larkin et al. 1950; Crossman and Larkin 1959). The availability of other fishes as food is often considered necessary for the attainment of large size by rainbow trout. Where such fishes are present in large western lakes and in the Great Lakes, rainbows do grow to great size. However, in smaller lakes, rainbow fare well on invertebrates alone. Kamloops type trout introduced into some barren lakes which contained vast numbers of *Gammarus* or other large crustaceans grew to 14 pounds in as few as 3 years. Often this growth rate decreased drastically as trout population increased and food decreased. Other lakes are able to maintain populations of fish to 4 or 5 pounds on invertebrates alone.

Rainbow trout are subject to predation in western streams by other trouts, chars, and coho salmon smolts — in the Great Lakes most of the larger, native predatory fishes are not found in the streams used by young rainbows. Diving birds and a variety of mammals also take a small number. Young rainbow trout potentially compete with all other salmonids for food. Where they are lake resident in the east they compete also with a vast complex of other bottom-feeding fishes. The large adults compete for food with other bottom-feeders and with other predaceous fishes.

An interesting and long-documented history of a single population of angler-exploited Kamloops type rainbow trout is that of Paul Lake, B.C. It exemplifies the typical pattern of invertebrate food and adequate growth before introduction of the redside shiner — a food competitor, the decrease in trout growth through competition, and the changing competitor–predator–prey interaction of the two fishes with time (*see* Larkin et al. 1950; Larkin and Smith 1954; Crossman 1959a, b; Crossman and Larkin 1959; Johannes and Larkin 1961).

Over its range in Canada, the rainbow trout is subject to a wide variety of parasites too extensive to list. Bangham and Adams (1954) gave details of 51 populations of the Kamloops type in British Columbia. Bangham (1955) identified parasites of rainbow trout in Lake Huron, and Sandeman and Pippy (1967) listed parasites of this species in Newfoundland. Hoffman (1967) summarized much of the North American information as follows: fungi (1), protozoans (19), trematodes (20), cestodes (12), nematodes (20), acanthocephalans (9), leeches (2), molluscs (4), gordiaceans (1), crustaceans (6).

The Pacific lamprey parasitizes the steelhead in the Pacific Ocean to a minor extent and the sea lamprey causes multiple, serious wounds which probably bring about direct and indirect mortality of larger rainbows in the Great Lakes.

Relation to man It may simply be said that this species is one of the top five sport fishes in North America and the most important, west of the Rocky Mountains. It is the fly fisherman's delight as it takes a fly without indecision, fights hard at the surface, and leaps often. It is also taken by trolling flies, by trolling or casting other small artificial lures, by still fishing with artificial lures activated by stream current, or with natural baits such as clusters of salmon eggs. The rainbow in all its forms is important not only from the enjoyment it gives anglers across Canada but from the incomes generated by the businesses and industries this pursuit supports. The difficulties of landing a hooked steelhead in a swift, rocky river in winter are legendary and the subject of many books. The more comfortable lake or stream fishing in summer is different but no less enjoyable. The rainbow has been one of the more successful, more appreciated, and less potentially dangerous of the many attempts to introduce a fish to areas beyond its natural range. The flesh is usually bright red and rich in smaller individuals in lakes where the food is invertebrates, or pink to white in larger lakes where they feed on fishes. It is highly acceptable cooked in any way, or when hot-smoked after a brine and sugar cure.

A few thousand cases of canned steelhead are processed annually from those taken by commercial fishermen of Pacific salmons. Small rainbow trout presently for sale in Canada as frozen whole fish are pond-reared in Europe and Japan. Under intensive investigation at present is the possibility of utilizing small prairie potholes for annual commercial crops of rainbow trout. Fish cannot survive over winter in these ponds but invertebrates highly suitable as natural food can, and are very abundant in the summer. Ponds tested to date in Manitoba (21–68 surface acres, 10–25 feet or 3.0–7.6 m deep) have been stocked with 2½-inch (64-mm) trout in April and have produced by October or November trout 10–14 inches (254–356 mm) long, with a yield of 10–105 pounds per acre (Johnson et al. 1970).

Nomenclature

Salmo Gairdnerii (Richardson)	— Richardson 1836: 221 (type locality Columbia River at Fort Vancouver, Vancouver, Wash.)
Salmo iridea Gibbons	— Gibbons 1855: 36
Salmo irideus	— Bean 1894a: 36
Fario gairdneri	— Girard 1859: 313
Salmo masoni	— Suckley 1860: 345
Salmo truncatus	— Suckley 1862a: 3
Salmo purpuratus	— Günther 1866: 116
Salmo stellatus	— Günther 1866: 117
Salmo gairdneri	— Suckley 1874: 114
Oncorhynchus Kamloops	— Jordan 1892: 405 (type locality Kamloops Lake, B.C.)
Salmo Kamloops Jordan	— Jordan and Evermann 1896–1900: 47
Salmo rivularis Ayres	— Halkett 1913: 52
Salmo rivularis kamloops Jordan	— Halkett 1913: 52
Salmo irideus argentatus	— Bajkov 1927: 377
Salmo kamloops whitehousei	— Dymond 1931b: 393

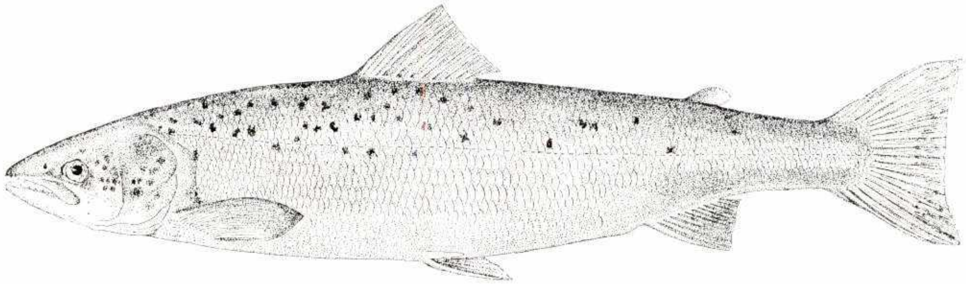
No attempt has been made to list the changing combinations of the names *irideus, gairdneri* and *kamloops* as species or subspecies for the various forms of this trout, nor the changing attitude towards *i* or *ii* endings.

Etymology *Salmo* — Latin name for the salmon of the Atlantic; *gairdneri* — after Dr Meredith Gairdner, a naturalist in the employ of the Hudson's Bay Company.

Common names Rainbow trout, Kamloops trout, steelhead trout, steelhead, coast rainbow trout, silver trout. French common name: *truite arc-en-ciel.*

ATLANTIC SALMON

Salmo salar Linnaeus

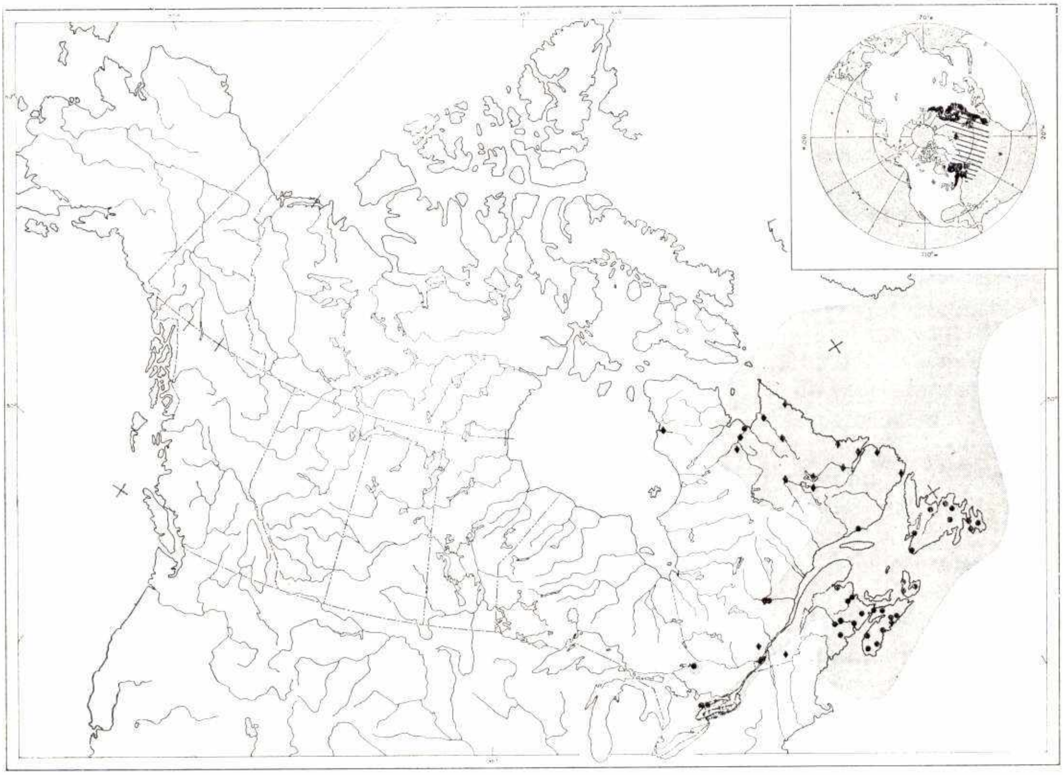


Description Body typically troutlike, elongate, average length about 18 inches (457 mm), somewhat compressed laterally, greatest body depth usually at dorsal fin origin or slightly posterior to it, 18–22% of total length. Head length about equal to or slightly greater than body depth, 20–23% of total length, but most variable during modifications to head during spawning; eye moderate, 14–19% of head length (variable depending on growth rate); snout rounded, its length greater than eye diameter on fish over 12 inches (305 mm) long; mouth terminal, large, maxillary extending posteriorly to posterior margin of pupil when 6 inches (152 mm) long, and seldom to posterior margin of eye except on mature males, which develop a pronounced hook or kype on lower jaw (for information on prespawning transformation of skull, *see* Tchernavin 1943); teeth developed on upper and lower jaws (premaxillary, maxillary, dentary), usually a few teeth in single row on shaft of vomer (none on head), on palatines, on tongue in 2 rows, no hyoid teeth. Gill rakers, total count 15–20. Branchiostegal rays usually 11 or 12 (rarely 10 or 13); in Ungava 11(4), 12(15), 13(2) (Power 1969). Fins: dorsal adipose present; major dorsal rays 10–12; caudal with shallow fork; major anal rays 8–11; pelvic rays 9 or 10, a distinct pelvic axillary process present; pectoral rays 14 or 15. Scales cycloid, 109–121 in lateral line, 10–13 scales from posterior edge of adipose base to lateral line; lateral line decurved anteriorly, then straight. Pyloric caeca 40–74 (Belding 1939). Vertebrae 58(1), 59(6), 60(11), 61(3) (Power 1969).

(*See also* Belding 1939; Wilder 1947; Power 1969.)

Colour In the sea, salmon are silvery on sides and silvery white below, the back may be brown, green, or blue. On entering fresh water the adults lose the silvery appearance and become darker; as they approach spawning they take on a bronze and dark brown colouration, sometimes with reddish spots on head and body. The pectoral and caudal fins may become dark. When spawned-out, both male and female become dark in colour and may be called black salmon. The slender young have 8–11 narrow pigmented parr marks on each side with a single red spot between each parr mark along the lateral line. When they become smolts and go to sea, the parr marks are lost and the fish become silvery.

Systematic notes For many years freshwater populations were thought to be taxonomically distinct from normal anadromous populations. Some, such as the salmon of Sebago Lake, Maine, were considered to be distinct species, *Salmo sebago* (Girard 1854; Kendall 1935). Most taxonomists of the time were prone to regard these various



populations as only subspecifically distinct, thus:

Salmo salar salar	– sea-run salmon
Salmo salar sebago	– Sebago Lake salmon
Salmo salar ouananiche	– Lake St. John salmon

In a systematic study of a number of populations, Wilder (1947) was unable to demonstrate consistent differences between the different populations and concluded that subspecific designations were unwarranted. This view has been accepted by most subsequent workers.

Distribution The Atlantic salmon is native to the basin of the North Atlantic Ocean, from the Arctic Circle to Portugal in the eastern Atlantic, from Iceland and southern Greenland, and from the Ungava region of northern Quebec south to the Connecticut River.

In Canada, the Atlantic salmon is found throughout Newfoundland and Labrador, the Maritime Provinces and eastern Quebec and the Ungava region of northern Quebec. A number of populations of landlocked salmon occur throughout the region, especially in Newfoundland, Labrador, and Quebec. A specimen was reported from the mouth of the Kogaluk River on the east shore of northern Hudson Bay (Le Jeune and Legendre 1968) the westernmost limit of the northern range. The salmon formerly occurred in Lake Ontario but was extirpated from that basin before 1900. Innumerable attempts have been made to introduce Atlantic salmon into a number of North American lakes but few have been successful (*see* McCrimmon 1948, 1956; MacKay 1963). In Trout Lake, near North Bay, Ont., a self sustaining population now exists following introductions which commenced in 1935.

Biology The biology of the Atlantic salmon, at least the salient features, has been known to man for centuries, and a wealth of literature has accumulated on many aspects of its life story.

The Atlantic salmon is the classic anadromous fish, that is, it spawns in freshwater streams, the adults return to sea, the young remain in fresh water for 2 or 3 years, then descend to the sea to spend one or more years feeding and growing before returning to fresh water to spawn.

In Canada, Atlantic salmon spawn in October and November. The actual date depends on the region. In the Ungava area of Quebec, Power (1969) observed that spawning was unlikely before the end of September, but farther south it may take place as late as November. Marine salmon move into estuaries and, thence, to fresh water in spring, summer, or early autumn, the approximate time being characteristic for each river. The ability of salmon to surmount falls and other obstacles in the river in order to reach the spawning grounds has been a source of wonder for centuries. Landlocked or permanently freshwater salmon simply move from the lake into the tributary stream to be used for spawning.

As the adults prepare for spawning, the head of the male undergoes transformation. The head elongates and the lower jaw becomes enlarged and hooked at the tip, forming a kype. The actual nesting site is chosen by the remale, usually a gravel-bottom riffle area above or below a pool. While the male drives off males and other intruders, the female, while on her side, uses her caudal fin like a paddle and excavates a nesting depression (the redd). During the spawning, several such depressions may be excavated. When it is prepared to her satisfaction, she settles into the nest, the male aligns himself beside her, and the eggs and sperm are released, after which the female covers them with gravel. This operation is repeated many times until spawning is completed. The eggs are large, about 5–7 mm in diameter after extrusion, and somewhat adhesive for a short time. The number of eggs deposited varies from population to population and does not necessarily vary directly with the size of the female. On the average, a female deposits about 700 eggs/pound of body weight. After spawning, the parent fish, now called a kelt, may drop downriver to a pool and rest for a few weeks, or the female may leave and the male remain in the pool. In some cases the males may overwinter in the river. Atlantic salmon often do not die after spawning and may spawn more than once.

The eggs incubate in the gravel during the winter, the rate of development depending upon temperature. Hatching usually occurs in about 110 days at 39° F (3.9° C), usually in April, but the young remain buried in the gravel, absorbing the yolk sac and finally emerging from the gravel in May or June. The young remain in the rapid water until about 2.5 inches (65 mm) long. Growth of parr in the streams is usually rather slow. In the Maritime Provinces parr go to sea, as smolts, when 5–6 inches (127–152 mm) long and 2 or 3 years old. In the Ungava region, however, they do not go to sea until at least 7.1 inches (180 mm) long and at ages of 4–8 years (Power 1969).

Growth in the sea (or lake) is relatively rapid, and some salmon, often males, may return from sea in a year, as grilse, weighing 3–6 pounds. Others may remain at sea for 2 years and return weighing 6–15 pounds. In eastern Canada, few salmon live beyond 9 years, but in Ungava ages to 11 years have been reported by Power (1969). *See* the following table for growth rates of some Canadian freshwater populations.

The size attained by Atlantic salmon varies greatly depending on whether the populations are anadromous (sea-run) or entirely freshwater. Anadromous salmon may weigh as much as 79 pounds 2 ounces (35.8 kg) (Norway) although Yarrell (1836) mentioned the largest fish known to him was a female weighing 83 pounds. A 55-pound (24.9-kg) fish, caught in Grand Cascapedia River, Que., may be a Canadian record. Sea-run salmon range about 5–20 pounds (2.3–9.1 kg); commercially caught fish average about 10 pounds (4.5 kg). "Landlocked" or freshwater salmon, also called "ouananiche," usually average smaller than sea-run, but one

		Age								
		1	2	3	4	5	6	7	8	9
Terra Nova R. System, Nfld.	FL									
(Andrews 1966)	*inches*	3.9	4.4	6.9	8.5	9.9	11.1	12.6	15.2	–
(freshwater)	*mm*	99	113	176	217	250	281	320	385	–
Gambo Pond, Nfld. (Leggett and Power	*inches*	8.0	15.7	20.5	32.2	36.7	34.9	42.1	43.7	53.2
1969)	*mm*	203	399	521	818	932	886	1069	1110	1351
Astray L., Ungava	*inches*	2.5	4.5	6.9	9.8	12.9	16.2	20.0	–	–
(Power 1958)	*mm*	63	114	174	248	328	412	508	–	–
Trout L., Ont.	TL									
(MacKay 1963)	*inches*	–	–	21.2	23.0	29.3	–	–	–	–
	mm	–	–	538	584	744	–	–	–	–
	Wt (*oz*)	–	–	–	55	184	–	–	–	–

weighing 35.5 pounds (16.1 kg) was caught in Sebago Lake, Maine, many years ago (Kendall 1935), and salmon weighing up to 44.7 pounds (20.4 kg) were reported for Lake Ontario (Fox 1930). The average weight of landlocked salmon is probably about 2–4 pounds (907–1814 g), but Lake St. John (Quebec) fish reached a maximum weight of about 7 pounds.

Like most migratory fishes, salmon have a different habitat at each stage of their life history. Thus, the young remain in gravelly streams for 2 or 3 years, then descend the river as smolts, and enter the sea-dwelling phase. When at sea, they may remain within the influence of the estuary or move as far as Greenland, a journey of at least 1500 miles. The life at sea is not well known. Salmon living throughout their lives in freshwater lakes usually spawn in tributary streams, then return to the lake. They remain in shallow upper layers of the lake following breakup, gradually retreating to the cooler deep water as summer advances. With falling temperatures in the autumn, salmon again move into shallower water, ascend the streams to spawn, and repeat the cycle.

When at sea, Atlantic salmon eat a variety of marine organisms including crustaceans such as euphausiids, amphipods, and decapods, and such fishes as sand lance, smelt, alewives, herring, capelin, small mackerel, and small cod. On entering fresh water preparatory to spawning, salmon do not feed, despite their apparent willingness to take an angler's fly. Young salmon in streams feed mainly upon aquatic insect larvae but terrestrial insects may be particularly important, especially in late summer or early autumn. The most important aquatic insect groups used as food are larvae and nymphs of chironomids, mayflies, caddisflies, blackflies, and stoneflies.

Atlantic salmon are preyed upon by many other animals, particularly when they are young. American mergansers and kingfishers have been known to eat large numbers of salmon in Nova Scotia and New Brunswick streams (White 1957). Eels may also eat large numbers of young salmon, *see* White (1933) who noted the remains of 429 salmon fry from the stomach of one 20-inch eel. McCrimmon (1954) observed that northern pike and brook trout fed upon introduced salmon in Duffin's Creek, Lake Ontario.

At sea, salmon have been found in the stomachs of sharks, pollock, tuna, and swordfish. When caught in traps, salmon are often eaten by marauding seals but it is not known if seals feed on free-swimming salmon.

The number of species of parasites known to infect Atlantic salmon is numerous and includes nematodes, cestodes, trematodes, acanthocephalans, parasitic copepods (some of which are called "gill maggots"), and the fish louse, *Argulus*. Recent reviews of the parasites infecting salmon in two eastern Canadian localities have been provided by Sandeman and Pippy (1967) and Threlfall and Hanek (1970) (Newfoundland), and

Power (1969) (Ungava). A most comprehesive account of parasites known to infect landlocked salmon in Maine was provided by Havey and Warner (1970). For additional information on parasites *see also* Jones (1959). Hoffman (1967) listed parasites in *S. salar* in fresh waters of North America and northern Europe.

Perhaps the most serious disease of salmon is the so-called salmon disease or Ulcerative Dermal Necrosis or simply UDN, which attacks European fish. Salmon disease, believed to be caused by a virus, is highly infectious. It manifests itself as serious skin lesions, resembling ulcers, which enlarge and coalesce. The breaks in the skin permit the entry of secondary infections. The disease is usually fatal.

Relation to man Few animals, whether fish, bird, or beast, have attracted as much attention through the ages as has the Atlantic salmon. Prized by the Gauls, then by the Romans, an abundant commercial fish in the British Isles, mentioned in the Magna Charta, revered by the sportsman and esteemed by gourmets, its relation with man has been truly unique. After centuries of exploitation, Yarrell (1836) told us that the last salmon was caught in the Thames in 1833. After less than a century of exploitation the last salmon was removed from Lake Ontario about 1890. (For information on Lake Ontario salmon *see* Richardson 1908; Fox 1930; Huntsman 1944; McCrimmon 1954.)

The Atlantic salmon was one of the first Canadian fishes in the Great Lakes region to disappear as a result of man's careless use of natural resources. It was to be the first of many. In Lake Ontario the erection of mill dams on streams denied it access to spawning grounds. It was also the first to suffer from DDT sprays (in New Brunswick), hydro-electric dam construction, domestic pollution, and a thousand and one other indignities thrust upon the environment by man.

One of the most serious threats to continued survival of anadromous stocks is the commercial fishery off Greenland which threatens all populations, for it is to Greenland waters, apparently, that anadromous salmon from both sides of the Atlantic go to feed. The catch of salmon in Greenland waters, which was 127 metric tons in 1961, reached 1588 metric tons in 1967 and dropped to 1200 in 1968. This is both an inshore and a high seas fishery, and although only Greenlanders can fish inshore, any nation can fish the high seas. It is the latter aspect of the fishery that poses the greatest threat.

Atlantic salmon is world renowned, both as a game fish par excellence, and as a commercial species. Canada possesses the finest salmon waters left on earth but the future of the species is uncertain at the rate at which the environment is being despoiled. For a review of the Atlantic salmon on the world scene, *see The Atlantic Salmon, a vanishing species?* by Anthony Netboy (1968). For details of North American fisheries, *see* Huntsman (1931), Dymond (1963) with extensive reference lists, Power (1969), and Havey and Warner (1970).

Nomenclature

Salmo salar	— Linnaeus 1758: 308 (type locality seas of Europe)
Salmo omisco maycus	— Walbaum 1792: 65
Salmo salar (Auctorum)	— Richardson 1836: 145
Salmo Gloverii Girard	— Adams 1873: 306
Salmo sebago	— Girard 1854b: 380
Salmo salar ouananiche McCarthy	— Jordan and Evermann 1896–1900: 487
Salmo ouananiche McCarthy	— Jordan, Evermann, and Clark 1930: 56

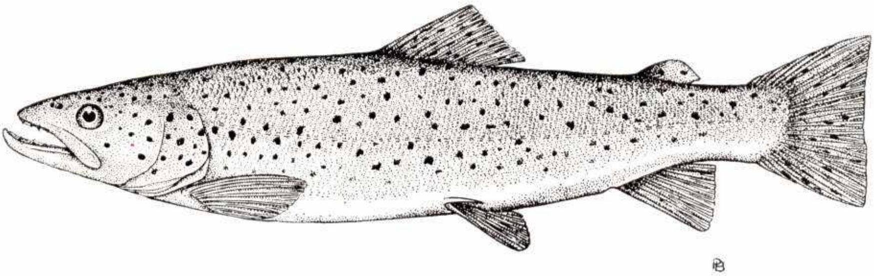
(For detailed synonyms and references *see* Dymond 1963)

Etymology *Salmo* — Latin name for the salmon of the Atlantic; ***salar* — old name** from "salio," to leap.

Common names Atlantic salmon, lake Atlantic salmon, ouananiche, common Atlantic salmon, Kennebec salmon, landlocked salmon, sebago, sebago salmon, salmon, black salmon, grilse, kelt, grayling (in N.S.), slink (spent fish), grilt, fiddler, smolt (young running to sea), parr (before running), saumon, bratan. French common names: *saumon atlantique, saumon d'eau douce, ouananiche.*

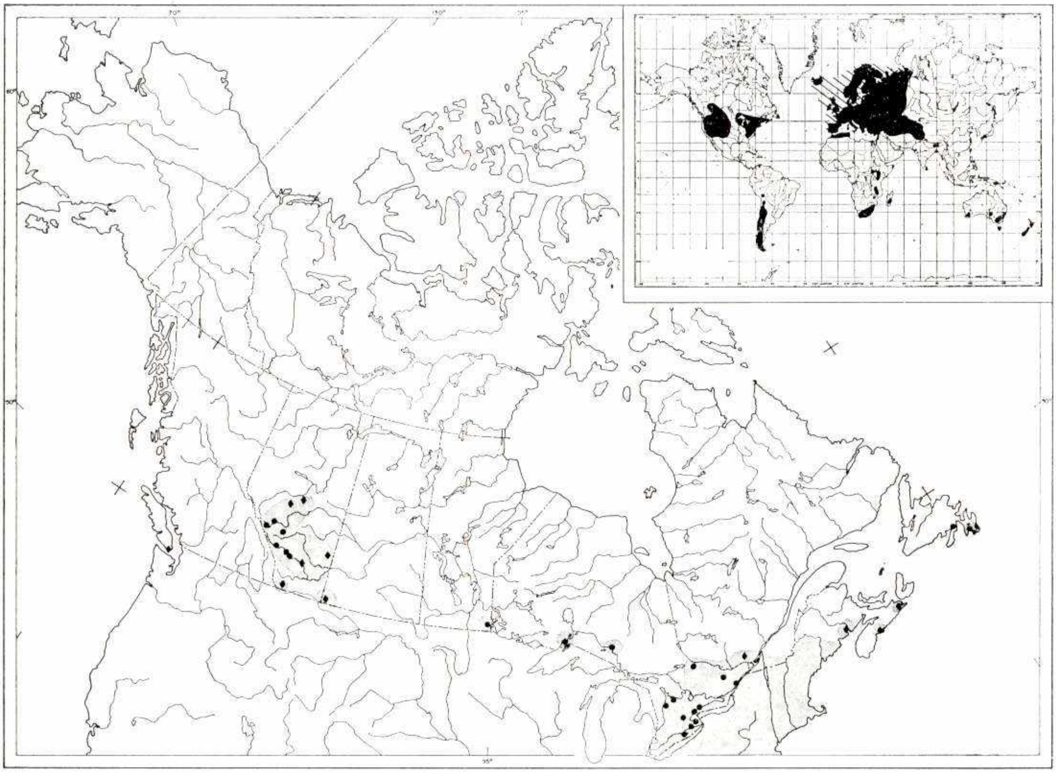
BROWN TROUT

Salmo trutta Linnaeus



Description Body typically troutlike, elongate, average length about 16 inches (406 mm), compressed laterally, greatest body depth at dorsal fin origin, 20–24% of total length. Caudal peduncle deep, its depth 12.5% of total length or greater. Head long, about 23% of total length of adults; eye moderate, 16–18% of head length in adults; snout rounded, its length greater than eye diameter on adults; mouth terminal, large, maxillary extending posteriorly to posterior margin of eye even at lengths of 6 inches, (152 mm) and past posterior margin of eye at large sizes; mature males develop pronounced hook or kype on lower jaw; teeth developed on upper and lower jaws (premaxillary, maxillary, dentary), usually many teeth on head and shaft of vomer, on palatines, on tongue in 2 rows, no hyoid teeth. Gill rakers, total count 14–17. Branchiostegal rays usually 10. Fins: dorsal adipose present; major dorsal rays about 12–14; caudal square or truncate, a shallow fork in young; major anal rays about 10–12, fin rounded on males, falcate on females (Gruchy and Vladykov 1968); pelvic rays 9 or 10, a distinct pelvic axillary process present; pectoral rays 13 or 14. Scales cycloid, small, 120–130 in lateral line, 13–16 scales from posterior edge of adipose base to lateral line; lateral line decurved anteriorly, then straight. Pyloric caeca 30–60. Vertebrae 56–61.

Colour In streams, a light brown or tawny overall colouration, brown on the back, becoming silvery on the sides, with pronounced black spots on back, sides of body, and head, the spots tending to spread below the lateral line anteriorly, but less so posteriorly. Spots often surrounded with a lighter ring or halo. Rusty red, irregularly shaped spots also on sides. Dorsal and adipose fins with dark spotting, but caudal never with more than occasional vague spots, these not arranged in a series of radiating lines of spots distinctly visible even to tip of fin (as in rainbow trout). The adipose fin with an orange or orange-red colouration. The fins of adults have a smoky, opaque,



sometimes yellowish colouration, and on large males in autumn the lower fins may become slate coloured.

In large lakes or in the sea, overall colouration silvery, masking most of the spotting on body; spots on head small and numerous; adipose usually with orange or orange-red hue.

Young brown trout with 9–14 short, narrow parr marks and a few reddish spots along the lateral line.

Systematic notes The brown trout is a very clearly defined species, its closest relative being the Atlantic salmon, *Salmo salar*. In its native range it is most variable in rate of growth, shape, colour, and many other features, giving rise to the naming of a number of subspecies. The names applied to the brown trout introduced to North America were often derived from the name of the place of origin of the introduced stock. Thus, we hear of Lochleven trout, *Salmo trutta levenensis* (at one time called *Salmo levenensis*), German brown trout, *Salmo fario* or *S. trutta fario*, and so on. Despite the name applied, all are now recognized as forms of the brown trout, *S. trutta*.

Brown trout can be hybridized with brook trout to produce a strikingly marked stocky fish, sometimes called a "tiger trout," but the mortality of eggs and alevins is high. Brown trout have also been artificially hybridized with rainbow trout and other salmonids. *See* Buss and Wright (1956, 1958) for additional information.

Distribution The brown trout is native to Europe and western Asia, its range includes Iceland, the British Isles, and the Eurasian mainland from Cape Kanin to the Aral Sea and Afghanistan westward throughout Europe.

It was introduced into North American waters as early as 1883 (New York and Michigan) and the following year, 1884, it was introduced into Newfoundland. Introductions into Canadian waters commenced with Quebec in 1890, Ontario in 1913, New Brunswick in 1921, and Nova Scotia in 1923. Eventually all Canadian provinces have had successful introductions except Prince Edward Island, Manitoba, and the Northwest Territories (MacCrimmon and Marshall 1968).

For a review of brown trout introductions into Canada and other parts of the world *see* MacCrimmon and Marshall (1968) and MacCrimmon et al. (1970).

Biology Brown trout spawn in late autumn to early winter. Brook trout have usually completed spawning before brown trout begin, but Greeley (1932) noted both species used the same spawning grounds in Michigan between November 5 and 25. In Ontario, Mansell (1966) reported that spawning activities of the brown trout started about October 15 and continued through early November, during which period water temperatures were between 44°–48° F (6.7°–8.9° C). Spawning may extend into January, at least in British Columbia (Carl 1938).

Spawning requirements are basically the same as those of brook trout, that is, shallow, gravelly headwaters, but Eddy and Surber (1960) noted that, although they entered Lake Superior streams in October and November to spawn, many spawned on rocky reefs along the shore. For many years considerable doubt was expressed that brown trout were successfully reproducing in many Canadian waters (Catt 1950; Dymond 1955). It now seems clear that reproduction was taking place, and successfully, but was unobserved (Catt 1950; Carl 1938).

The female creates a shallow depression (redd) in the gravel, in which the spawning fish deposit the eggs and sperm. The process is repeated many times, but when spawning is completed, the female covers the redd with gravel.

The number of eggs deposited depends upon the size of the female for, as usual, larger fish deposit more eggs. In the Cowichan River, B.C., females at age 5 and 6 averaged 2020 eggs. The eggs tend to be amber coloured and to have a diameter of about 4–5 mm. In a recent study in Pennsylvania (McFadden et al. 1965), differences in fecundity were demonstrated to be related to differences in stream fertility. The authors also noted a difference in egg diameter between two populations.

More growth studies have been conducted on brown trout in United States waters than in Canadian. However, in a recent Ontario study, Marshall and MacCrimmon (1970) observed ages to 13 years. In southern Ontario brown trout attain a total length of about 6.5 inches (165 mm) at age 1, 9.8 inches (249 mm) at age 2, 15.3 inches (388 mm) at age 3, and 16.8 inches (427 mm) at age 4 (Mansell 1966). For information on growth rates in various parts of the world *see* Carlander (1969).

Brown trout grow to a large size. The often-quoted record for a sea-run fish is 39 pounds 4 ounces, for a 40.5-inch brown trout caught in Loch Awe, Scotland, in 1866. Two large fish were caught in recent years in Witless Bay, Nfld.; one weighed 28 pounds 8 ounces, the other 27 pounds 10 ounces (Williamson 1963). In Ontario, brown trout weighing up to 14 pounds 12 ounces have been caught. Although brown trout over 10 pounds in weight are not rare, the average size in inland streams is of the order of 1 or 2 pounds.

In Canada the brown trout has been introduced mainly into stream or river habitats, although a number of lake or sea-run populations now exist. Its requirements are essentially the same as for the native brook trout, with which it is usually in competition, but the brown trout can remain active and thriving at slightly higher temperatures than brook trout. Optimum temperature range for brown trout is said to be 65°–75° F (18.3°–23.9° C) (Brynildson et al. 1963). There has been a tendency to believe that brown trout do best in the slower-moving waters of the lower reaches of trout streams but such a view is not supported by the work of Marshall and MacCrimmon (1970) on the Sydenham River, Ont.

Brown trout are carnivorous and eat a wide variety of organisms, particularly aquatic and terrestrial insects and their larvae, crustaceans, especially crayfish, molluscs, salamanders, frogs, and rodents and, of course, a wide variety of fishes. Fishes and crayfish figure prominently in the diet of larger brown trout; indeed Idyll (1942) observed that even 4-inch brown trout would eat other trout; but fish is not usually considered to be significant in the diet of brown trout under 12 inches long.

The larger fish tend to feed at dusk and even later (Needham 1938), a point reinforced by Eddy and Surber (1960) who noted ". . . the large ones are seldom taken except at twilight and sometimes after dark."

Large brown trout may feed upon smaller trout, but such predation is deplored in heavily fished areas. Mergansers are also regarded as predators, especially during fall and winter in certain areas. Attempts in Michigan to reduce predation in a stream system by removing large brown trout and discouraging mergansers was not markedly successful (Shetter and Alexander 1970).

Sandeman and Pippy (1967) noted that the acanthocephalan *Echinorhynchus lateralis* was identified from 76% of the 23 brown trout examined in their island-wide survey of Newfoundland. Other parasites recovered were trematodes *Apophallus brevis* (8.7%), *Crepidostomum farionis* (8.0%), *Discocotyle salmonis* (4.3%); nematode *Metabronema salvelini* (8.0%); cestodes *Eubothrium salvelini* (4.3%), *Dibothriocephalus* sp. (4.3%); and protozoan *Trichophyra piscium* (4.3%).

Threlfall and Hanek (1970) noted all 22 specimens of brown trout examined from waters of the Avalon Peninsula, Nfld., were infected, and reported the first record of *Ergasilus* sp. for this species in Newfoundland.

See Davis (1953) for a discussion of furunculosis, *Bacterium salmonicida*, the bacterial disease affecting salmonid fishes, particularly brown and brook trout. The brown trout was suggested by Mansell (1966) to be a dormant carrier of furunculosis in Ontario waters.

Hoffman (1967) listed the parasites of the brown trout from the fresh waters of North America, Europe, and USSR.

Relation to man For many years the brown trout enjoyed only limited success as a game fish in Canadian waters. Many anglers objected to continued plantings because these trout were thought to be too difficult to catch. Biologists and management officers were concerned because browns were thought to displace native brook trout, either by competition or direct predation. Also browns were found to be carriers of a disease of brook trout, called furunculosis. Ontario maintained a brood stock and hatchery for brown trout culture but closed down this operation about 1960 (Mansell 1966). However, since that time, brown trout have become increasingly popular among both anglers and biologists alike. The larger ones especially, are somewhat more resistant to angling pressure than large brook trout. They can withstand the less favourable environment of the lower reaches of streams and rivers that are unsuitable to brook trout. They grow faster and also live longer than brook trout and, thus, a larger number of year-classes are available in a stream at any one time. Recent work by Marshall and MacCrimmon (1970) suggested that the introduction of brown trout to streams supporting native brook trout but subjected to heavy fishing pressure, should result in the establishment of self-sustaining populations of both species, and improve the overall harvest and quality of the angling. *See also* Shetter and Alexander (1965), Brynildson et al. (1963), Cooper (1952, 1953).

Nomenclature

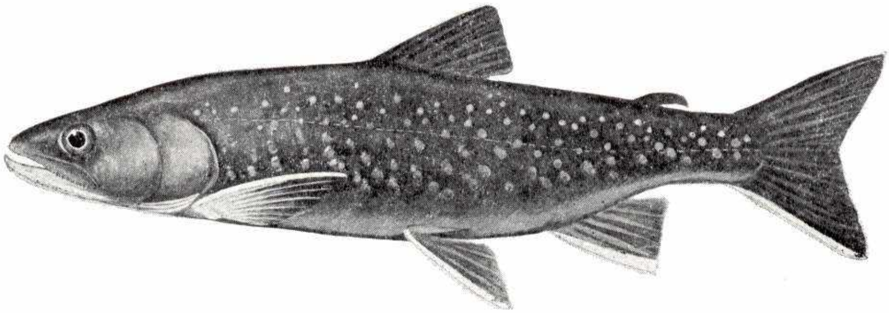
Salmo trutta	— Linnaeus 1758: 308 (type locality Europe)
Salmo fario	— Linnaeus 1758: 309
Salmo eriox	— Jordan 1926: 141
Salmo levenensis	— Günther 1866: 101

Etymology *Salmo* — Latin name for salmon of the Atlantic; *trutta* — Latin name for trout.

Common names Brown trout, German brown trout, German trout, German, English brown trout, von Behr trout, Lochleven trout, European brown trout, truite, breac, gealag, brownie. French common name: *truite brune*.

ARCTIC CHAR

Salvelinus alpinus (Linnaeus)



Description Body typically troutlike, elongate, average length to about 15–18 inches (381–457 mm) but variable, somewhat rounded, greatest body depth below dorsal fin origin but body depth variable dependent upon size, sex, and state of maturity, about 20% of total length. Head short, 22–25% of total length; eye large, its diameter equal to or less than snout length, but relative size most variable, approximately 16–30% of head length; snout somewhat rounded, its length greater than eye diameter on large fish (over 400 mm); mouth terminal, large, maxillary extending posteriorly to beyond posterior margin of eye of migratory char, but may not in freshwater char; mature males may develop a hook or kype on lower jaw (but Backus (1957) says rarely in Labrador); teeth developed on upper and lower jaws (premaxillary, maxillary, and dentary) on head of vomer only (not on shaft), on palatines, on tongue 10–24 in 2 rows, teeth on basibranchial bones variable, 20–85. Gill rakers on upper limb of arch 7–13, on lower limb 12–19. Branchiostegal rays total range 10–13 (10–12 + 10–13). Fins: dorsal adipose present; major dorsal rays 10–12 (all rays 12–16); caudal distinctly forked; major anal rays 8–11 (all rays 11–15); pelvic rays 9–11, a distinct pelvic axillary process present; pectoral rays 14–16. Scales cycloid, small, pores along lateral line 123–152, lateral line slightly decurved anteriorly then straight. Pyloric caeca, total range 20–74 (average in lower Yukon area about 29, elsewhere in North America about 44). Vertebrae 60–71.

(*See also* Vladykov 1954, 1957; McPhail 1961; Scott and Crossman 1964; McPhail and Lindsey 1970.)

Colour Arctic char may be exceedingly colourful, as when spawning, or may exhibit the relatively drab silvery colour of nonspawning, landlocked adults, or one of a myriad of colour combinations between these extremes. The startlingly brilliant colour assumed by spawning or near-spawning adults defies adequate verbal description. The colour plate facing page 218, depicts the colour of an anadromous male upon entering fresh water. Under these conditions the back is often dark green or blue-green, the sides silvery blue with scattered orange or red spots, and the belly whitish, or a brilliant orange-red may suffuse the sides and extend across the belly. Sea-run fish, or those caught in estuaries, may be steel-blue on the back, silvery blue on sides with numerous large red, pink or cream coloured spots on sides — Hudson Bay fish often display this colouration. The arctic char in Quebec lakes, sometimes called "Quebec Red trout," may also show this kind of colouration but the phase of orange-red flanks and underparts is most spectacular and better known. Some freshwater populations appear to remain highly coloured at all times (Upsalquitch Lake, N.B., and Kenai Peninsula, Alaska) whereas others, such as some on insular Newfoundland, are silvery with dark green backs and dusky fins. Fins of arctic char may be clear or transparent on small, young fish but are opaque and often dusky on adults; dorsal and caudal usually dusky, anal, pectorals, and pelvics light, but all lower fins usually of brilliant hue during spawning. The leading edges of pectorals, pelvics, anal, and, sometimes, caudal fins have a narrow margin of immaculate white.

Small char have 10–15 irregularly arranged oval parr marks on the sides.

The flesh of anadromous and most freshwater char is usually orange-red in colour but may be pink or even white. Flesh colour of Labrador specimens was discussed by Andrews and Lear (1956).

For additional colour descriptions *see* Backus (1957), Scott and Crossman (1964), and McPhail and Lindsey (1970).

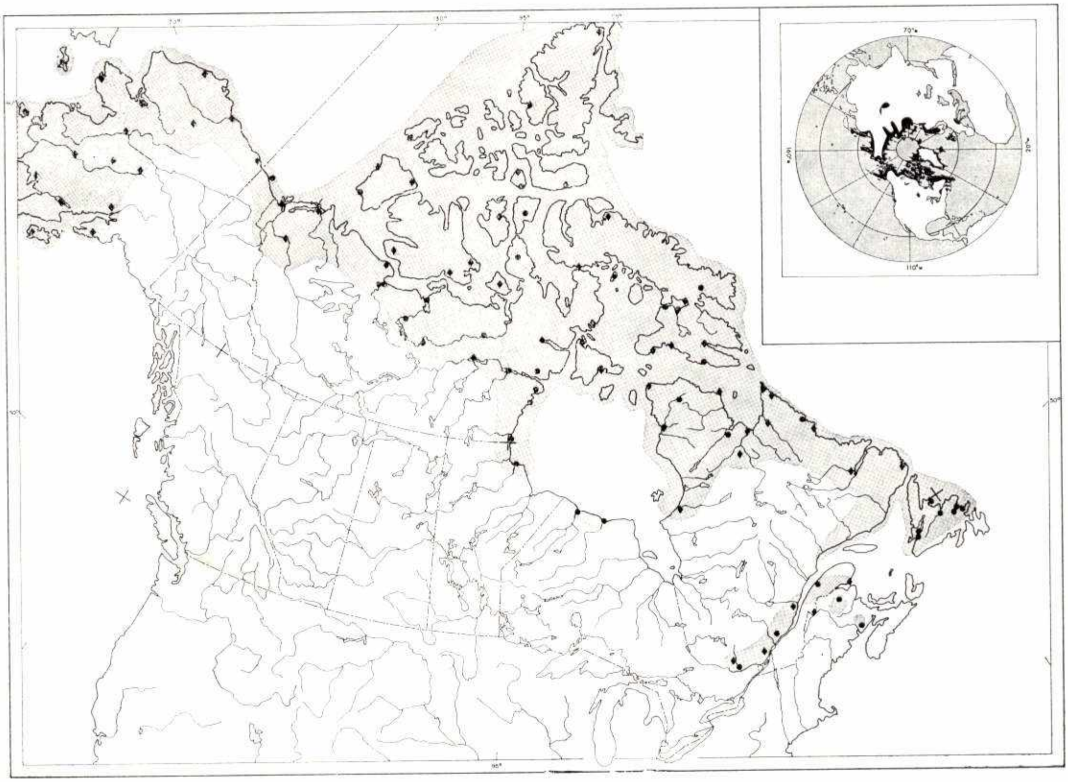
Systematic notes The species was named by Linnaeus (1758), based on specimens from Lapland. The first North American descriptions were of four species described by Sir John Richardson (1935) as *Salmo Rossii*, *S. Hearnii*, *S. alipes*, and *S. nitidus*. Most ichthyologists restrict the genus *Salmo* to the Atlantic salmon and its relatives, and place the chars in the genus *Salvelinus*, but some Europeans still use the genus *Salmo* for the arctic char. During the 1800's more species of North American char were described as exploration of new lands continued. Some relict freshwater populations, such as *Salvelinus marstoni* and *S. oquassa*, are still regarded as valid by a few ichthyologists although most place them in the synonymy of *S. alpinus*. A thorough review of the early nomenclature was given by Martin (1939).

The state of the systematics of the arctic char was clarified greatly by McPhail's (1961) review, in which he demonstrated the specific distinctness of *Salvelinus alpinus* and *Salvelinus malma*. His work also indicated that within *S. alpinus* were at least two recognizable groups that differed from each other in the *mean* number of gill rakers and of pyloric caeca. Central and eastern Canadian char have mean numbers as follows: gill rakers 15–17, pyloric caeca 36–53; northwestern Canadian and northern Alaska char, gill rakers 13 or 14, pyloric caeca 27–31. Char in southwestern Alaska resemble those in eastern Canada. McPhail recommended that subspecific designations for *Salvelinus alpinus* be avoided until the relationship of North American and Eurasian char has been determined.

Electrophoretic patterns of five protein groups from seven geographically isolated populations of arctic char from Canada and the United States were compared by Saunders and McKenzie (1971). These authors concluded that the populations sometimes named *S. marstoni*, *S. aureolus*, and *S. oquassa* were not specifically distinct from *S. alpinus*.

For additional information *see* McPhail (1961), McPhail and Lindsey (1970), and Saunders and McKenzie (1971).

Distribution The arctic char has the most northerly distribution of any freshwater fish. It has a circumpolar distribution and is



found in inshore marine waters, lakes, and rivers around the northern hemisphere, including northern North America, northern Asia, northern Europe (especially the Scandinavian countries), Iceland, Greenland, and innumerable arctic islands. It may be anadromous, or confined entirely to fresh water (landlocked). Freshwater populations occur in more southerly latitudes than anadromous forms and are found in Europe, including parts of the Alps, in the British Isles, and in North America in eastern Canada, Maine, and New Hampshire.

In Canada, arctic char occur in insular Newfoundland, Labrador, and extreme eastern Quebec, coastwise, and north along the Atlantic coast to Hudson Strait, Hudson Bay, and the arctic archipelago, west through the territories to Alaska, including the Aleutian Islands.

Throughout its northern coastal distribution, arctic char does not usually range far inland except in the larger rivers. Isolated freshwater populations occur in eastern Canada in insular Newfoundland, New Brunswick (3 lakes at least), and southeastern Quebec (many lakes).

Biology In arctic waters, char spawn in autumn, usually in September or October, over gravel or rocky shoals in lakes, or in quiet pools in rivers, at depths of 3–15 feet (1.0–4.5 m). Farther south, char may spawn as late as November or December, as in the Matamek River, Que. (Saunders and Power 1969). Although the males establish and guard territories, the nest or redd is prepared by the female who uses her caudal fin, paddle-like, to clear debris from the site. Actual spawning takes place during the day, at temperatures around 39° F (4° C). A spawning female is usually attended by one male during deposition and fertilization of the eggs. (*See* Fabricius and Gustafson 1954, for a discussion of spawning behaviour of Scandinavian char under laboratory conditions.) Males usually mate with more than one female. Anadromous females usually contain 3000–5000 eggs. Frobisher Bay females, having an average length of 22 inches (560 mm), averaged 3589 eggs, while females from George River, Ungava, 16.2 inches (412 mm) average length, contained an average of 2726 eggs. The eggs are large and when deposited are 4–5 mm in diameter. In some populations, the females mature at lengths of about 6–7 inches (152–178 mm) or less and, since the eggs are large, very few are produced (Backus 1957). Females spawn every second or third year, but seldom every year except in southern parts of the range. The eggs develop, buried in the gravel, over the winter, exposed to temperatures of about 32°–36° F (0.0°–2.2° C). The eggs are killed by temperatures above 46° F (7.8° C). Hatching is thought to occur around April 1, but emergence from the gravel probably does not take place until breakup of the ice about mid-July. At this time, fry are about 1 inch (25 mm) long.

Young anadromous char move out of the rivers and downstream to the sea when 6–8 inches (152–203 mm) long. Frobisher Bay char probably make their first downstream migration during the summer at ages 5–7, according to Grainger (1953).

Growth rates vary greatly among different populations but, in general, growth is slow. Ages are more accurately determined by using otoliths than scales, for although scales may be useful during the first 3 or 4 years of life, they do not usually form until about age 2. The use of otoliths was described, with illustrations, by Grainger who used the largest otolith, the sagitta, for aging Frobisher Bay char. However, the wide variations that exist across the Canadian arctic make generalizations misleading, for char in Labrador reach commercial size in 5 years, in the most northerly part of their range in 9 years, and in the central Canadian arctic in 16 years.

Growth rates for a number of Canadian localities are given in the table, p. 205.

Hunter (1966) observed that, on average, full size was attained at about 20 years of age, and although some may have lived as long as 40 years they did not become much larger than 20-year-old fish. The average weight of sea-run char is about 2–10 pounds. In 1960, a 15.8 pound char was caught in the Severn River, Hudson Bay, Ont. McPhail and Lindsey (1970) gave size to 38 inches (960 mm) and weight of 26 pounds (11.8 kg). The largest arctic char known to the present authors was one weighing over 27 pounds (12.2 kg), caught in the Tree River, N.W.T., in 1970 (J. G. Hunter, personal communication). A 20-pound 5-ounce char was reported caught in the Tree River, N.W.T., in 1962. A recognized angling record by *Field and Stream* magazine was a 19-pound 15-ounce char, 33.75 inches (856 mm) long, caught in Finger Lake, Que., in 1959.

Arctic char may be either anadromous, moving downstream to the sea in spring, returning in the autumn, or they may remain permanently in fresh water. Downstream migrants usually remain in the vicinity of the estuary, although tagged fish have been captured as far as 80 miles from the river of origin (Hunter 1966). Anadromous arctic char that overwinter in lakes, begin to run to sea before or during breakup, usually completing the run by the end of July and returning in the autumn of the same year. The young fish in the run are the last to move downstream or upstream. Char cannot leap like Atlantic salmon and depend on moving in with the tide to surmount obstacles. For additional information on movements of anadromous char, *see* Grainger (1953) and Andrews and Lear (1956).

Populations of char dwelling permanently in Canadian lakes have received little attention although some populations that exist in eastern Canada attain weights in excess of 2 pounds. Populations of freshwater arctic char in Newfoundland were described by Seabrook (1961) and in Maine by Everhart and Waters (1965). A very thorough study of char in Keyhole Lake, Victoria Island, N.W.T., was made by Hunter (1970).

Arctic char are carnivorous but have an exceedingly varied diet. A study of 450 char stomachs from Frobisher Bay, Baffin Island, revealed 30 different species of vertebrate and

	FL	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	21+	22+	23+	24+	>24+
		Age (*years*)																							
Baffin Is. (Frobisher Bay) (Grainger 1953)	*inches*	–	–	3.6	5.1	5.5	6.8	11.9	13.3	14.3	16.3	16.7	19.0	20.1	21.8	21.9	20	23.6	24.1	25.6	25.3	25.9	26.7	26.7	20.1–32.5
	mm	–	–	90	130	139	172	302	337	363	414	425	484	510	553	557	559	600	613	649	642	658	678	678	510–825
NE Labrador (5 locations on NE Coast) (Andrews & Lear 1956)	*inches*	–	–	–	17.5	17.9	18.4	18.9	18.9	19.5	19.3	20	20.2	20.8	22.5	27.3	–	–	–	–	–	–	–	–	–
	mm	–	–	–	445	454	468	480	480	495	490	507	512	529	571	692	–	–	–	–	–	–	–	–	–
Quebec (Matamek L.) (Landlocked populations) (Saunders & Power 1969)	*inches*	–	4.7	6.4	6.9	7.4	9.5	10.9	12.2	14.4	15.6	16	16.7	16.4	16	–	–	–	–	–	–	–	–	–	–
	mm	–	120	163	176	187	240	276	309	366	395	406	423	417	405	–	–	–	–	–	–	–	–	–	–
N.W.T. (W coast of Hudson Bay) (Sprules 1952)	*inches*	–	–	12.5	15	16.1	17.5	18.4	19.4	20.6	22.3	23.7	25.1	25	–	26.8	31	29.5	–	–	–	32.3	–	–	–
	mm	–	–	318	381	409	445	467	493	523	566	602	638	635	–	681	787	749	–	–	–	820	–	–	–
	Wt (*oz*)	–	–	12	24	32	36.6	42.9	54.1	60	78.2	100	106.7	118.1	–	132	185.3	192	–	–	–	256	–	–	–
N.W.T. (Little Fish L.) (Landlocked populations) (Sprules 1952)	*inches*	6.4	6.5	7.4	7.5	9.1	10.3	10.8	11.2	12.3	12.1	13.8	13.6	13.8	14.9	–	–	–	–	–	–	–	–	–	–
	mm	163	165	188	190	231	262	274	284	312	307	351	345	351	378	–	–	–	–	–	–	–	–	–	–
	Wt (*oz*)	1.0	1.5	2	2	4.3	4.5	7	8	9	10	12.7	14.3	15.7	20	–	–	–	–	–	–	–	–	–	–

invertebrate animals that had been eaten (Grainger 1953). Amphipods (of many species) and mysids were among the more important invertebrates consumed while sculpins (especially *Myoxocephalus groenlandicus*), lumpfishes, seasnails (*Liparis* sp.), and arctic char were the fishes eaten. Char stomachs from other arctic localities, examined by Grainger, contained the arctic cod (*Boreogadus saida*), *Triglops pingeli*, and the sand lance (*Ammodytes*). Study of 1318 stomachs from a Victoria Island lake by Hunter (1970) indicated that plankton, insects and algae were most frequently eaten. At Term Point, Hudson Bay, Sprules (1952) reported sand lance to be the most important single food item in 30 fish examined. In Labrador, Andrews and Lear (1956) reported the capelin to be the most important food item. Arctic char seem able to utilize for food any smaller creature that appears in their habitat.

A freshwater population of char was studied in Matamec Lake, Que., by Saunders and Power (1969), who reported that char under 8 inches (200 mm) ate aquatic insect larvae and small clams, whereas char over 8 inches long ate smelt (*Osmerus mordax*), brook trout (*Salvelinus fontinalis*), and sticklebacks. Smelt was the main food of larger fish, making up 60% of the diet.

Arctic char appear to suffer no serious natural predation, except cannibalism. Such predation is usually considered to be minor. Small young char are often eaten by their larger relatives and may also fall prey to terns and loons; larger ones are eaten by seals.

The parasites of arctic char from Canadian waters have received little attention in the literature except in studies in Labrador by Andrews and Lear (1956). These authors observed a light infection by the roundworm, *Philonema* sp. (except at Nain), adults of which occurred in the body cavity, and immature stages (of this or another species) were encysted in liver, gonads, spleen, peritoneum, and the viscera in general. Heavy infections by a tapeworm, *Eubothrium salvinale* were reported for nearly all localities.

Hoffman's (1967) list of parasites referred mainly to arctic char in waters of the USSR.

Relation to man Arctic char was the only fish of real economic importance to polar and central Eskimos (Rostlund 1952) and is still used as food by coastal Eskimos for themselves and their dogs. Most fish were caught in nets or traps in rivers or river mouths during the downstream or upstream runs. Where conditions permitted, such as below Bloody Falls on the Coppermine River, they were speared. Although summer was the most productive time for fishing, char were also fished through the ice either with a handline or using a lure and spear. They were eaten fresh, smoked, salted, or dried.

In recent years, arctic char has become a gourmet food for the restaurant trade in many large North American cities. Frozen char are shipped to southern markets from commercial fisheries operated in the Central Canadian Arctic and Labrador. Upward of 100,000–200,000 pounds are marketed annually. Char are classified as red, pink, or white according to flesh colour, red commanding the highest price. In Labrador, white-fleshed char are not marketed but are hung on poles and dried for local consumption.

Another highly priced delicacy is canned arctic char, now processed along with whitefish and other local products in a small cannery operated by Eskimos on the west coast of Hudson Bay.

A growing interest in the arctic char as a sport fish has become evident in North America as affluent anglers seek more exotic prey. Its magnificent colouration, excellent flavour and texture (better than the best salmon according to "experts"), rather typical char tactics when hooked, and relative inaccessibility, combine to make it a highly desirable quarry. Hopefully, arctic char stocks will be carefully monitored to prevent overexploitation, a real threat to the species in view of its slow rate of growth and its availability due to increased arctic traffic, not to mention the North American's unenviable record for the destruction of wildlife.

The greatest danger to the arctic char is the white man, not the Eskimo or Indian who, for centuries, have used but not destroyed the stocks. Rather, it is the uncon-