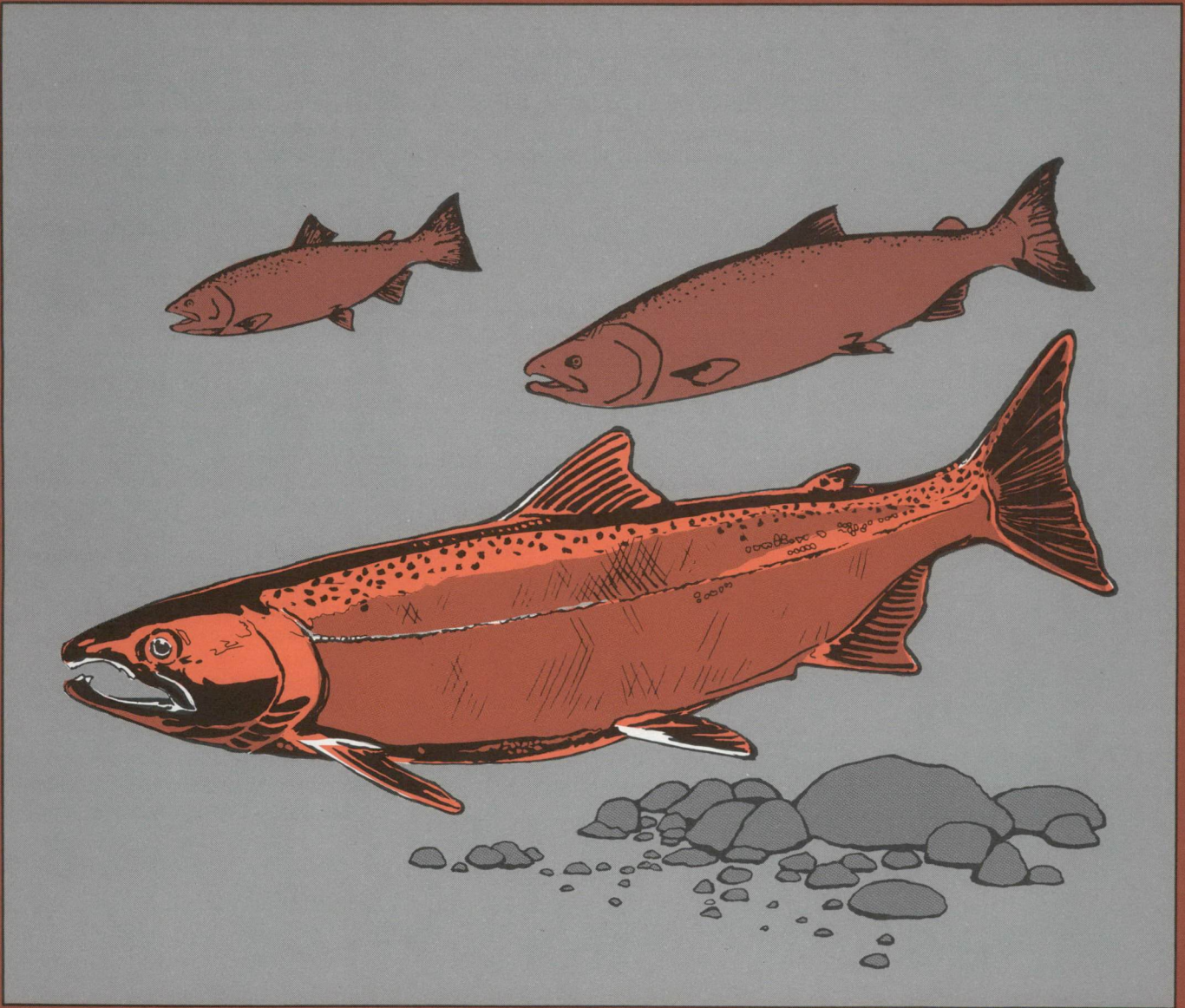


Underwater World

PACIFIC SALMON



PACIFIC SALMON

The grace and beauty of Pacific salmon are as legendary as the turbulent west coast rivers to which they return at the end of their life cycle. They are among the world's most exciting sport fish and anglers thrill to the landing of a dynamic chinook salmon. Some species battle swift currents and waterfalls to reach the place of their birth, there to spawn and die, thus renewing their species. Their flesh is rich and delicious, yet delicate enough to be an epicurian delight.

Before the arrival of the white man, whose dams, pollution, over-exploitation and destruction of habitat-protecting forests has altered the landscape and reduced the salmon population, they were abundant fish, predictably returning to their spawning streams in great numbers. For centuries they had provided a rich harvest for Indians along the coast of British Columbia, and each year as they returned to the rivers and streams, their numbers meant the difference between abundance and scarcity of food for the native people.

Pacific salmon belong to the genus *Oncorhynchus*, a combination of two Greek words meaning "hooked snout". The North American Pacific salmon consist of five species — chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*), chum (*Oncorhynchus keta*), sockeye (*Oncorhynchus nerka*), and pink (*Oncorhynchus gorbuscha*).

All are anadromous, spending part of their lives in fresh water, then travelling to the ocean to grow and develop before returning to spawn near their place of birth. Generally, the migration of all salmon of the eastern Pacific is north-westward on their outward journey, and southeastward when they return. Some chinook and coho remain in coastal waters, e.g. the Strait of Georgia.

Physical characteristics, life histories and spawning habits differ from species to species. The flesh colour of west coast salmon varies from the dark red of the sockeye and coho to the lighter shades of other varieties. The chinook, whose reputation among sport fishermen has won it the name of "king salmon", is the largest of the Pacific salmon, ranging between 2 and 14 kg, with a life span varying from two to eight years. The prolific pinks, on the other hand, live a predictable two years and reach an average weight of slightly more than 1.8 kg. An outstanding feature of the sockeye is their red flesh colour which they retain even when canned. The coho, because of its active nature and jumping ability, is a favourite of the salt-water sport fishermen. The chum has a low fat content and the Indian people (as well as the white population) find them ideal for smoking.

Distribution and Migration

Salmon spawn in rivers and lakes along the full length of the British Columbia coast. In fact, their range extends north around Alaska and as far east as the Mackenzie River in the Canadian Arctic, and as far south as California. Depending on the species, their feeding grounds encompass large areas of the Pacific Ocean. Some salmon are forced south by the cold of winter, even as far as the waters off San Francisco, but return to the north during summer months. Pink and coho travel as far as the waters off southern Oregon during

Fig. 1 Chinook



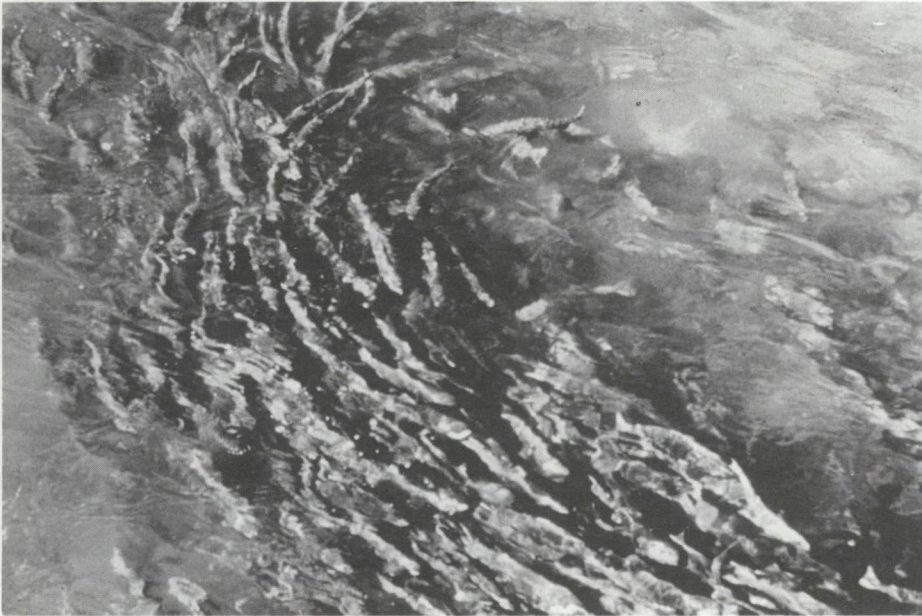


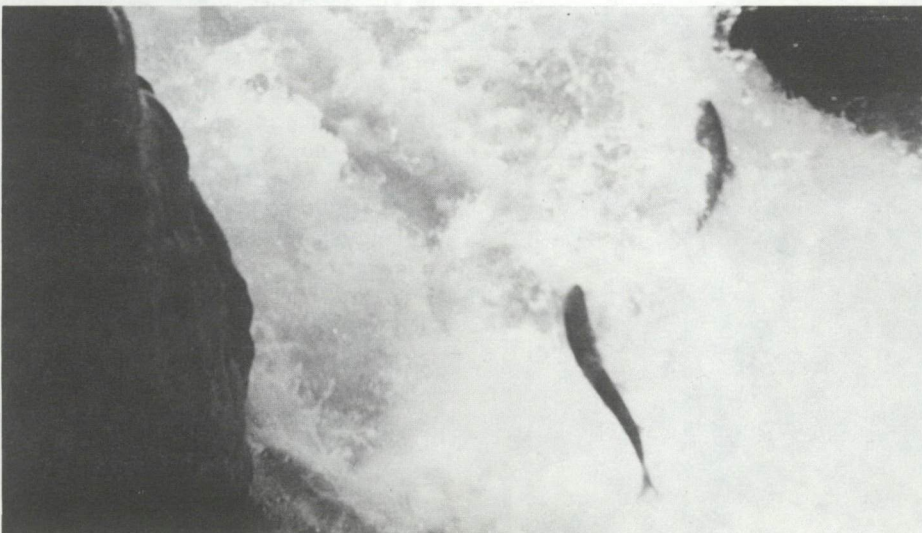
Fig. 2 A sockeye run

the winter months, then move northward with the warmth of summer. Chum, chinook, pinks and sockeye have been found far out in the Pacific.

It is in the sea that salmon attain rapid growth. Sockeye, pink and chum feed mainly on plankton and crustaceans, while coho and chinook eat squid and small fish for the most part. Catching salmon at this stage of their life cycle, before they have time to mature, results in a significant loss of potential product.

In their final year at sea, salmon begin to return to their native streams. Before they reach fresh water they stop feeding, and from that point to their death, live

Fig. 3 Coho swimming upstream



on stored body fats and protein. Considerable stored resources are needed to make the journey upstream, develop to full maturity and spawn. As they enter the streams and rivers, salmon change both in colour and form. Their bodies assume the various spawning colours and the males of species develop a hooked jaw, nose, and humped back due to hormonal changes. By the time many salmon reach their spawning territory, their bodies are scarred, their fins ragged, and they have lost much of their vigour.

Reproduction

Spawning takes place during the late summer, fall, and winter months in fresh water from tidewater to 3,200 km from the sea, depending on the species. Generally, sockeye, coho and chinook travel farther upstream, while pink and chum spawn close to the ocean. Salmon lay their eggs in the gravel of streams or spring-fed beaches of lakes. The female turns over on her side and by a vigorous fanning of her tail, scoops out a hollow or redd in which she deposits her eggs. Redds vary in size and may be up to half a metre in depth. As the female lays her eggs, they are fertilized by the milt from the male (a number of males may position themselves alongside the female at the last minute to fertilize the eggs). The nest or egg deposit is then covered with gravel by the female. A number of nests may be built by the female to form a redd before spawning is completed.

At the end of spawning, the exhausted adults live for as little as a few days up to a month, with their spent bodies often consumed by predators as they float downstream. Others decay thus providing nutrients to the freshwater life cycle. Death is caused by rapid aging of the body, brought about by excessive glandular activity directed at egg or sperm production.

Covered by gravel, the eggs are safe unless disturbed by later-spawning salmon, or buried by silt, frozen, or washed away by the flood waters of winter and spring. The surviving eggs incubate over the winter months and by late winter, while still buried in the gravel beds, they develop into alevins, tiny fish with relatively huge eyes and a sack-like appendage — the remaining egg yolk — to provide their immediate food supply.

By spring their nourishing yolk sack has been absorbed and they emerge from these spawning beds as 2.5 cm to 3.5 cm long fry — now vulnerable to herons, ducks, gulls, kingfishers and other fish predators. Young pink and chum fry leave immediately for the sea, but the others feed and grow in their stream, river, or nearby lake for a period of up to two years or more, depending on the species and stock, then head downstream to the sea in the spring. As they head downstream, they are called smolts and measure up to 12 cm. At this time physiological changes also take place, and a silvery coating appears on the scales of young migrating salmon partially to protect them through the change from fresh to salt water, but also as a camouflage from their enemies. They do not immediately go to the deep ocean where salinity is high. Many pause in the brackish waters of the river mouths to become accustomed to their new environment, and to feed in the nutrient-rich estuaries, while others migrate

north along the coast in the productive coastal waters.

The rate of survival from the time the eggs are laid until the young fish reach the sea depends on conditions — water quality, siltation of the streambed, temperature, predation.

Hazards

When the white man arrived on the Canadian Pacific coast in the late 1790s, only the native Indians harvested the salmon. Since that time the five species have suffered in a number of ways — from overfishing, pollution by logging, mining, dam building, urbanization and other construction, and waste.

Commercial fishing was started by the Hudson's Bay Company shortly after Fort Langley was established about 1825. They maintained a fishing station at the mouth of the Chilliwack River, and exported salted salmon to Hawaii and other places. In 1870, salmon exploitation by the white population began in earnest. Canned salmon, especially sockeye, was in demand all over the world, with the result that salmon stocks declined rapidly. Salmon were also exploited along the west coast of the United States as the frontiers opened, and the environment was ravaged indiscriminately. Salmon were captured in fish traps, fishing wheels, weirs, drift nets and seine nets. The deep red colour and oil content of sockeye made it the preferred species by the canneries, and often chum, pink, chinook and coho were tossed back into the water or left to rot on shore if they were not accepted by the canneries.

At the same time, the province was opened to both lumbering and mining. Hills were stripped bare of timber, resulting in topsoil being carried into streams and covering productive gravel beds with silt. Sawmills and pulp and paper mills compounded the trouble, spilling sawdust, wood fibre and poisonous wastes into the spawning streams. Logs and brush blocked waterways so that returning spawners could not reach their destination, and log drives ruined streams by gouging gravel beds. Some creeks were dammed in the search for gold in their gravel beds, or to utilize the gravel for roadbuilding, causing the death of thousands of migrating salmon or the exposure of salmon eggs.

Fig. 4 Spawning sockeye





Fig. 5 Seining for salmon

While most such excesses are curbed today and laws are in place to minimize overexploitation, logging is still a problem in many areas where careless operations denude stream banks and allow silt to cover productive gravel beds. In some areas, mining is still a problem where wastes are allowed to leach into the water. Dams still block homing migrations and deny water to spawning streams. Farming operations, manufacturing plants such as pulp and paper mills and food processing plants, pump their wastes into the streams enriching the water and nourishing algae and water plants. In their process of living and dying, algae rob the water of oxygen, which in turn affects eggs, juveniles and the food supply.

Commercial Fishing

The three types of gear used to harvest salmon commercially on the Pacific Coast are gillnets, purse seines and troll gear. Both gillnets and purse seines tend to concentrate their efforts on sockeye, pink and chum salmon while troll gear, until the last decade, tended to concentrate on chinook and coho salmon. Trollers are now very effective at catching all five species of salmon.

Gillnet and seine fisheries generally occur along the inshore salmon migration routes or near the mouths of the salmon's home stream. Troll fisheries tend to be concentrated in the offshore areas although troll fisheries do occur in the same areas as gillnet and seine fisheries.

A gillnet is suspended like a web curtain in the water with floats attached to the upper end and a lead line on the bottom so as to hold the net vertical in the water. Salmon swim into this curtain and they become entangled by their gills in the webbing. The fish are individually removed from the gillnet as it is retrieved onto a drum on board.

A purse seine is similar to a gillnet in that a web curtain is used to entrap fish. However in the case of a purse seine, a finer mesh curtain is set around a school of salmon and then the bottom of the net is closed like a purse string. The net is returned back on the vessel and the salmon trapped in its net enclosure are lifted on board. Purse seine boats are able to catch thousands of salmon in one set.

Trollers have six stainless steel lines that are suspended, three from each side of the vessel. These lines are weighted at the bottom and from each line are attached lures up to 10 to 12 per line. These lines are set at various depths and retrieved using power driven reels or gurdies as they are called. Salmon are removed from the lures as each stainless steel line is retrieved aboard the troll vessel.

Sport Fishing

Pacific salmon are well known among anglers the world over as the finest of sport fish. Chinook and coho are the most important species, although pinks, sockeye and chum are also caught. The great size of the chinook and the sheer thrill of fighting and landing such a huge fish is an irresistible lure for fishermen year after year. The swift and leaping coho is also a challenge to the angler. Sportsmen usually fish from a boat, but beach fishing is also popular, and there is some fishing from river banks. The tourist industry, in particular, benefits from the sport fishery.



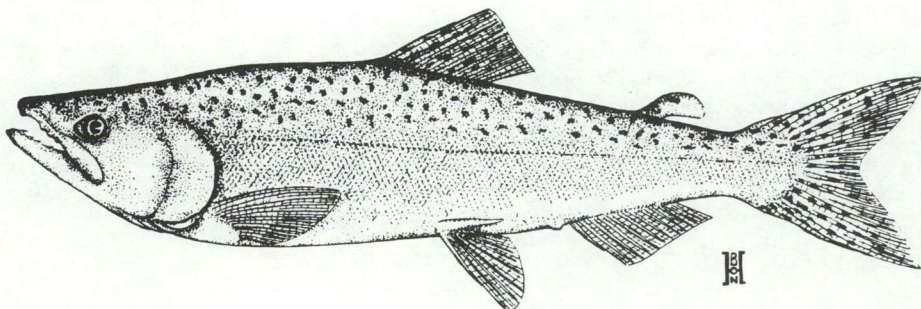
Fig. 6 Tidal sport fisherman

Food Fishery

For centuries the Indians of the Pacific coast have fished the salmon, welcoming them as they returned to their native streams. They honoured them by holding "First Salmon" ceremonies as gestures of admiration, respect and gratitude. In the years when salmon were plentiful, they were used for trade as well as food.

The Indians employed many fishing methods, including dipnets, spears, seines, weirs, traps, and hook and line. The fish were consumed fresh, smoked, dried, or made into pemmican, a concentrated food. It is estimated that the native people took millions of salmon each year.

Fig. 7 Chinook Salmon



Today, Indians employ new technology as well as many of the same methods as their forefathers. Food fishing is an important part of their livelihood, both at sea and on the west coast rivers. The Indian people are also deeply involved in the commercial fishery.

Chinook Salmon

The chinook, a favourite of sport fishermen, is the largest of British Columbia's five salmon species. The world record is 57.27 kg. The chinook is a powerfully built fish. While still feeding in salt water, the chinook has a dark back, with a greenish blue sheen. As it approaches fresh water to spawn, its colour darkens and it develops a reddish hue around the fins and belly. The teeth of adult spawning males become enlarged and the snout develops into a hook.

The major runs of chinook salmon are in the larger rivers of British Columbia, with the Fraser being one of the most important. A large number of runs are also found in the Canadian portion of the Yukon River.

Chinook are frequently dubbed "spring" salmon, because they return to some rivers earlier than the other four species of Pacific salmon. In the Fraser and Columbia rivers, the early run starts in April and continues into May. There may also be a summer run in June and July and another in August and September.

Some river systems have more than one stock of chinook, sometimes with the stocks migrating in spring, summer and fall. Fish in the early runs usually go farthest upstream, with those in later migrations spawning closer to salt water.

While the majority of chinook salmon head for sea a few months after they emerge from the gravel, some remain in their home stream for one or two years. Chinook returning to spawn vary greatly in age — from two to eight years. In southern areas, three, four and five-year-old chinook are most common, while farther north, five, six, and seven-year-olds are more abundant. In the Yukon River, a northern stream, almost all chinook spend their first year in fresh water. Here the females usually return to spawn as six or seven-year-old fish, and the males a year younger.

In the sea, chinook feed on large zooplankton, herring, sand lance, and many other fish, ranging widely in the ocean and growing rapidly during their last year in salt water. Those spawning after three or four summers of feeding at sea weigh from 6.75 to 25 kg. Smaller two or three-year-old male fish returning to spawn are called jacks.

Coho Salmon

Coho are swift, active fish, a favourite of the salt-water sport fisherman, who takes them by spoon, fly, spinner or bait. They have a well-developed ability to jump and will take a lure or bait even after they have returned to their streams to spawn.

These salmon are found in most B.C. coastal streams and in many streams from California to Alaska, but their major territory lies between Cook Inlet, halfway up the Alaska coast, to the Columbia River (which borders the states of Washington and Oregon). When mature in the late fall, they weigh up to 14 kg, although their average weight is between 2.7 and 5.4 kg.

Next to the pinks, they probably have the most consistent life history of west coast salmon. Juvenile coho are highly adaptable and can have varied life histories. Most stay from one to two years in coastal streams before emigrating seaward as smolts. But other fry are equally at home in lakes or in coastal estuaries.

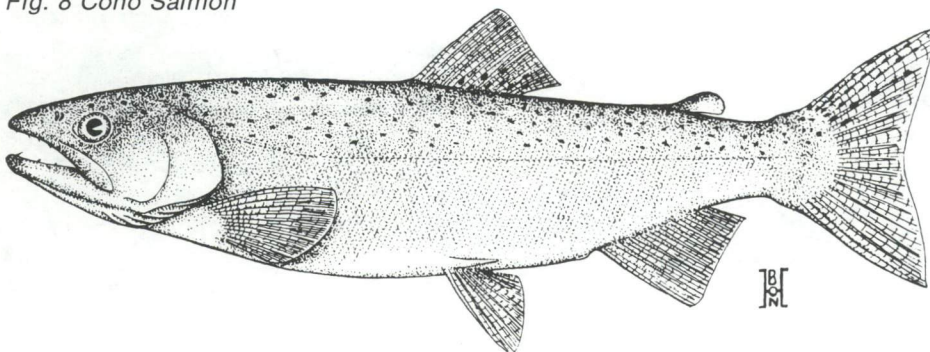
During early stages of growth, they have distinct parr markings (dark, vertical bars along each side) greenish brown backs, a white leading edge on the anal fin, and an orange tint on all but the dorsal fin. As they develop into

smolts, their parr marks gradually fade and their backs become green with dark spots. While a number, known as jacks, return to spawn after less than one year at sea, the majority spend two growing seasons in salt water before returning to their home stream to spawn.

While most coho tend to remain close to the coast, they have been found as far as 1,600 km from shore. Like the pink salmon, they prefer relatively warm water, often moving south in the fall and winter months. Their first ocean year is spent feeding on sand lance, herring, insects, copepods, amphipods, crab larvae and euphausiids. In the second year at sea, their growth rate increases due to heavy feeding on squid, herring, sand lance and large zooplankton, taking their weight from an average 1.3 kg in March to 5.4 kg in the fall and winter when they return to their home streams to spawn.

As adults, coho have silvery sides and a metallic blue back with irregular black spots. Spawning males in fresh water may exhibit bright red on their sides, bright green on their back and head, with darker colouration on their belly. They also develop a marked hooked jaw with sharp teeth. Females change colour and develop hooked snouts, but the alteration is less spectacular.

Fig. 8 Coho Salmon



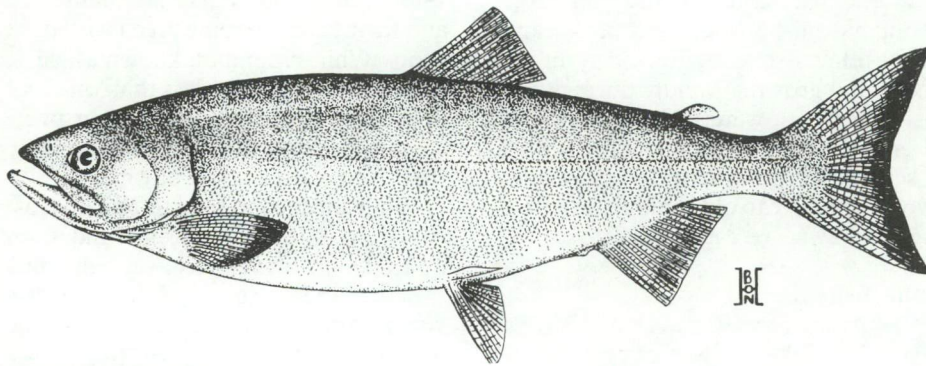


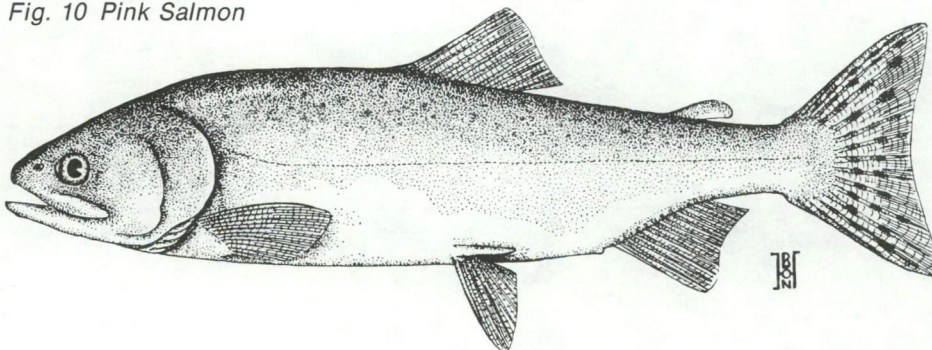
Fig. 9 Chum Salmon

Chum Salmon

Chum salmon are attractive fish. In salt water they are metallic blue and silver, with occasional black speckling on the back. They are the latest of the five salmon species to enter the southern streams and rivers to spawn, usually in late autumn and in some instances in late winter. In northern rivers, however, they arrive on the spawning beds as early as July.

Chums are widely dispersed along the Pacific coast from northern California up to the Aleutian Islands, in the Bering Sea and the Mackenzie River, inhabiting more than 875 rivers and streams in British Columbia alone. Although they usually spawn close to tidal waters, in some cases they migrate up larger rivers such as the Yukon where they travel more than 3,200 kilometres to Teslin Lake. Those spawned in shorter coastal streams move directly to into the sea, sometimes requiring only a day or two for their journey downstream. In the larger river systems, how-

Fig. 10 Pink Salmon



ever, the young fry may stay in fresh water for several months while making their way to the ocean. They remain in coastal waters until mid or late summer before going farther offshore. Their growth during this part of their migration is rapid. The young are green-backed, silvery fish with faint parr markings.

While some have been known to weigh 15 kg, chum salmon average 3.5 to 4.5 kg, and can measure more than 100 cm at maturity. They are harvested primarily on their return to their spawning streams.

As they near fresh water on the return to their home streams, their flesh quality and visual appeal deteriorate rapidly. Mature fish show reddish or dark bars across the sides and some have blotches of gray or black as well. The males also develop a sharply hooked nose and large, dog-like teeth (hence the common name "dog salmon") while are used to display and protect their territory during spawning.

Because their flesh is pale and low in fat content, chum salmon are not considered prime fish for canning. As a result, they are usually marketed fresh, frozen or smoked, although some canning takes place.

Pink Salmon

Smallest but most abundant of the west coast salmon, pink salmon are known to fishermen as "humpbacks" or "humpies" due to the extremely humped back developed by males as they return to spawn. The females do not exhibit this same change during spawning. Because of their fixed two-year lifespan, even-and-odd-year pink stocks are effectively isolated from each other.

This species is found in streams and rivers from California north to the Mackenzie River, with their principal spawning areas between Puget Sound, Washington, and Bristol Bay, Alaska. They migrate to their home stream from July to October, and while some go a considerable distance upstream, the majority spawn in waters close to the sea. During this time both sexes change from the blue and silver colours of the ocean to pale gray on the back with a white to yellowish belly.

When the young 2.5 cm fry emerge from the gravel beds the following spring, they go directly downstream to the ocean. During their first summer in salt water, they stick close to shore, moving offshore in September. Rich ocean feeding in subsequent months induces remarkably rapid growth, bringing their average weight to 2.25 kg at maturity with some reaching a weight of 4.5 kg and a length of 76 cm.

When pinks enter the ocean, they feed at first on plankton, but gradually turn to more active prey. In spite of their short life span and small size, their migrations are extensive, covering thousands of kilometres from their home streams. Millions are caught along the coast of B.C. and Alaska as they return to spawn. This species is fished by gill-nets, purse seines, and trolling gear. They are also caught by sport fishermen using artificial lures. Most pinks are canned; some are sold as fresh fish. Many more, especially of the troll catch, have been frozen in recent years.

While young, pinks are silver with no parr markings or spots as seen on other salmon. As they mature, they develop blue backs with heavy oval blotches on the tail and upper body.

The Fraser River, with its 20 lake systems, was one of the world's most productive areas for pink and sockeye salmon prior to 1913. Indeed, in that year the sockeye run alone was more than 37 million fish, providing a catch of 25 million. It was also in that year that railway workers dumped millions of tons of rock into the river at Hell's Gate Canyon, about 200 km upstream from the mouth of the Fraser. The following

year gigantic slabs of rock, loosened by blasting, fell into the narrow gorge, blocking the flow and preventing both pinks and sockeye from reaching their spawning areas further upstream. Consequently, many stocks of pink salmon either disappeared or drastically declined. Salmon that had formerly gone 1,000 km beyond Hell's Gate Canyon steadily decreased. Installation of fishways in later years has been successful and in the 80s some of the stocks have greatly improved.

Sockeye Salmon

Best known of the Pacific salmon, sockeye are the most sought after for their superior flesh, colour and quality. Their rich oil content and red colour are factors that make them a favourite with the Canadian and international public. Although all Pacific salmon feed on shrimps and other crustaceans, these are the main diet of the sockeye, which many believe induces the rich colour and oil content.

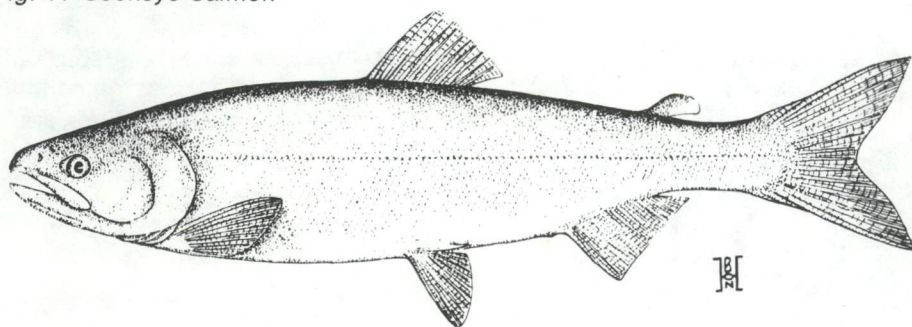
Sockeye is believed to be derived from the Indian name "sukkai", used by natives of southern B.C., with various versions according to different Indian dialects.

They were the first salmon to be canned in quantity and are still the mainstay of the canning industry, which started in British Columbia in 1870. By 1876 three canneries were established in the province and expansion was so rapid that by the turn of the century 65 canneries were in operation. The number peaked in 1917 with 84 canneries, but gradually declined as canning technology improved and salmon became scarcer, especially sockeye.

Stocks from B.C. river systems were heavily fished at the turn of the century as canning became the best method of preserving salmon. In the early 1900s, an average of 700,000 cases of canned salmon a year, each weighing 21.6 kg, were processed, with figures fluctuating year by year as the salmon runs varied.

Most sockeye spawn in rivers that feed into lakes, or in the outlets and spring-fed beaches of lakes, sometimes as far as 1600 km from the sea. Sockeye run from June to November, and after spawning, the young emerge from the gravel and spend up to three years in lakes generally downstream from

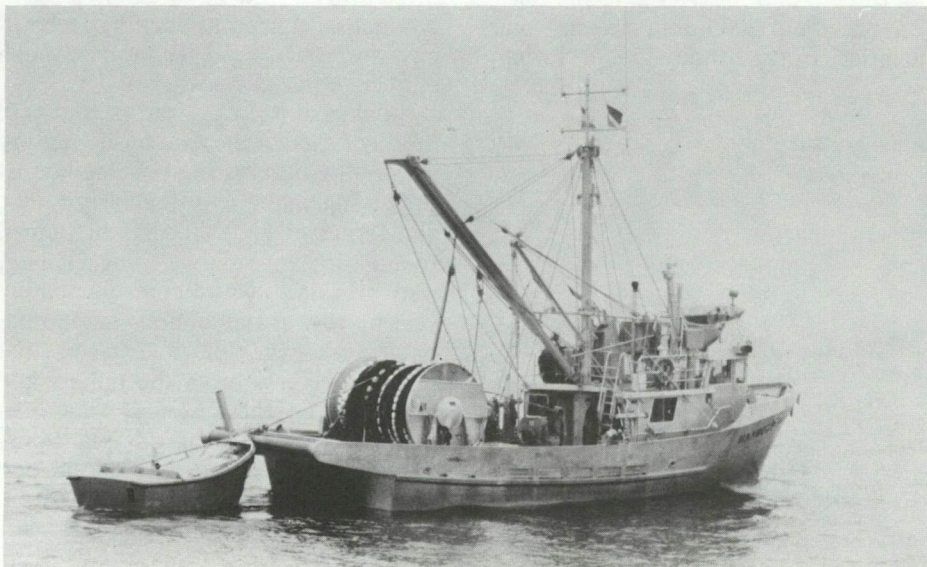
Fig. 11 Sockeye Salmon



their spawning area, where they feed on crustacean zooplankton and insects and their larvae. Migrating juveniles (called smolts) travel down to the ocean during May and June. When they reach the sea, they move rapidly outward or along the shore, feeding voraciously as they go. They develop into attractive fish with silvery bodies and blue-green backs, faintly-speckled with black, ranging far out into the Pacific and the Gulf of Alaska, thousands of nautical miles from their home streams. Their size varies with age: a four-year-old sockeye averages 3.0 kg, while older fish will run to 5.5 kg. After a number of years at sea, sockeye return to their home streams to spawn. In the majority of southern B.C. rivers and streams, sockeye return as four-year-olds, but in northern rivers of the province, five-year-olds are about as common, and still farther north in Alaska, six-year-olds are in the majority. Some eight-year-old sockeye are also found in northern rivers.

As sockeye approach their home streams, they turn varying shades of red — first a dull, brownish red, and as they progress upstream, a brilliant scarlet with pale green heads. The males develop large teeth and hooked jaws. Sockeye are caught by gillnet, purse seines, and trolling gear. In addition, there is a significant Indian food fishery in some rivers.

Fig. 12 Salmon seiner



Management

Management of Pacific salmon in Canada comes under the jurisdiction of the Department of Fisheries and Oceans (DFO) and the International Pacific Salmon Fisheries Commission. The five species have little regard for international boundaries. Salmon spawned in Canadian rivers, streams or lakes may well pass through American territory and be intercepted on their migrations by American fishermen and vice versa.

Today's fishing methods, if not strictly controlled, can eliminate entire stocks in one season. With the aid of modern equipment, fish can be scooped from the water quickly and efficiently by seiners and gillnetters. For that reason, some fisheries are opened for only short periods, sometimes only a few hours. This allows escapement back to the spawning grounds and protects the stock from extinction. DFO, after reckoning how many fish are available to the fishermen, makes the decisions on when to open and close the fishery. The department also determines the type and size of net that can be used in a particular fishery. If the fishing fleet is large and too many fish are caught too quickly, the fishery may be closed. A fishery may also be extended if too few fish are caught. Fishing boundaries are also established, especially in sensitive areas at river mouths. There are specified protection areas set aside to allow enough spawners to escape upstream.

Since settlement began on the west coast of North America, lumbering, mining, hydroelectric dams and other encroachments by modern civilization have been instrumental in reducing the numbers of Pacific salmon. With public concern high, government, mining and lumbering interests in the 1970s started working together on a far-reaching scheme to protect the environment. Mines now have waste-control systems to prevent pollution of streams, rivers and lakes, and logging companies are now more conscious of pollution control and environmental safety measures.

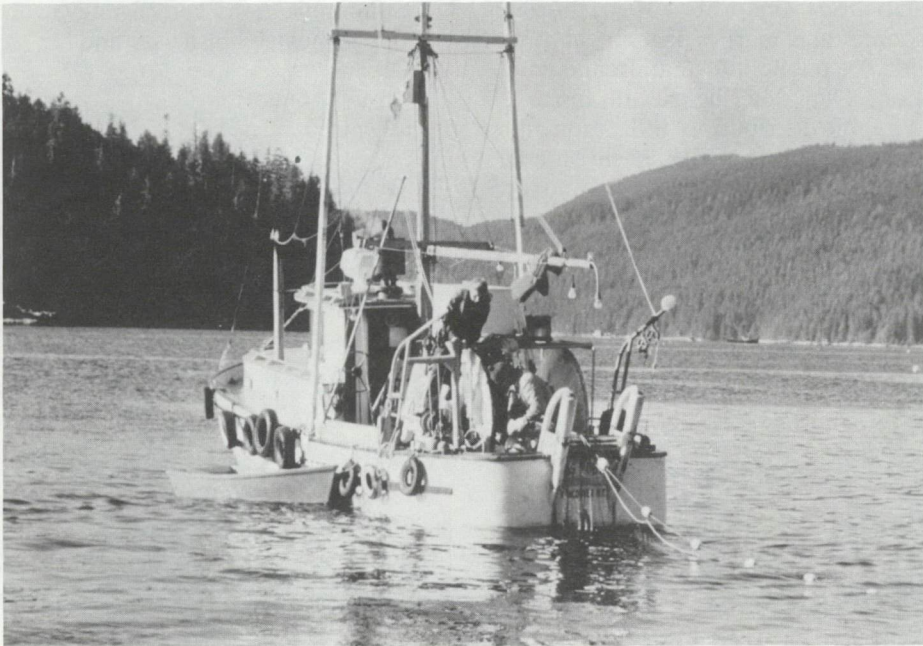


Fig. 13 Salmon gillnet

Salmonid Enhancement Program

An important project designed to increase the numbers of Canada's Pacific salmon is the Salmonid Enhancement Program (SEP), put into place in May 1977. The initial phase of the development program ran for seven years at a cost of \$150 million in federal funds and \$7.5 million from the B.C. government.

The SEP's overall objective is to double the catch of salmon, steelhead and sea-run cutthroat trout. Phase 1 of the program achieved 30 per cent of the SEP's long-term objective.

Specifically, the SEP is designed to improve and preserve the salmonid resource and its environment, while at the same time increasing national income and employment, promoting regional development, and enhancing the well being of native people. More than 700 volunteers are involved annually in some 100 small SEP projects, displaying the interest and concern of the public for the enhancement program.

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Underwater World factsheets are brief illustrated accounts of fisheries resources and marine phenomena prepared for public information and education. They describe the life history, geographic distribution, utilization and population status of fish, shellfish and other living marine resources, and/or the nature, origin and impact of marine processes and phenomena.

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