



*Oncorhynchus gorbuscha* IMAGE © Scandinavian Fishing Year Book

**Pacific salmon are an important natural resource upon which the indigenous 'First Nation' people of the North Pacific rim have long relied for food and trade. Over the past century, Pacific salmon have also become an important commercial resource for North Pacific coastal states, and provide a high-value seasonal catch for many inshore fishermen and a sporting quarry for anglers.**

There are five main species of Pacific salmon that are commercially important: sockeye (*Oncorhynchus nerka*), pink (*Oncorhynchus gorbuscha*), chum (*Oncorhynchus keta*), coho (*Oncorhynchus kisutch*) and Chinook (*Oncorhynchus tshawytscha*). All occur in northern Pacific coastal areas extending from California to Japan and adjacent parts of the Arctic Ocean (1). The sixth species, the masu (*Oncorhynchus masou*), which is endemic to Asia, is not covered by this guide.

In 2009, around 330,000 tonnes (t) of Pacific salmon (chiefly pink and sockeye), were caught in the Alaska fishery (2), with an estimated value of US \$370 million. A further 18,500 t were caught in Canadian fisheries (3), and there is also a catch of mainly Chinook salmon taken south

of the US/Canada border, where fishing for coho salmon is severely restricted to protect critically depleted stocks (4). In the UK, 24,750 t of Pacific salmon (worth £56 million) was imported in 2005. This represents about 20% of all salmon (Atlantic and Pacific) consumed in the UK.

Many Pacific salmon are either ranched (hatchery-bred, then released to feed at sea before returning to coastal waters and caught) or farmed in sea cages. Production of coho salmon, the main aquaculture species, has been around 115,000 t pa since 2000 (5), mostly in Chile.

**The purpose of this guide is to outline the status of the five main Pacific salmon species and the management measures in place to protect the stocks.**

## BUYERS' TOP TIPS

### Know your source of supply

Pacific salmon comprise many thousands of wild spawning populations, each stock being unique to a particular river system; managed at the individual stock level, or as stock complexes within defined geographical areas. Find out where the fish have been caught and if they are farmed, wild-caught or hatchery reared. Traceability systems (6, 7) can help.

### Buying policy

The stock status of Pacific salmon varies from species to species and across their distribution. Stocks in certain areas support environmentally responsible and sustainable fisheries, some certified by the Marine Stewardship Council (MSC) (8), while other stocks, possibly of the same species, are designated as threatened or endangered. The quality of fish also varies seasonally and between fisheries. It is highly likely, however, that the status of local stocks taken by particular fisheries, and other stocks caught on passage to more distant spawning rivers, is fully accounted for in the management measures applied to that fishery. Consequently, supplies of Pacific salmon are only available from stocks that are being fished sustainably, according to the conservation and management objectives put in place by the relevant authorities.

### Seafish Responsible Sourcing Service

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## Biology, distribution and fisheries

All Pacific salmon species are anadromous, which means they spend some part of their juvenile life in fresh water before migrating to sea. There they feed and grow before maturing and moving inshore where they aggregate into 'salmon runs' to swim through estuaries into fresh water, usually their river of origin, where they spawn. All Pacific salmon spawn just once and then die. The life histories, distributions and fishing methods used for the five main species (1, 9, 10, 11, 12, 13, 14 and 15) are summarised below:

### Chum salmon

Chum salmon, also known as keta or dog salmon, is the second most abundant but most widely distributed of all Pacific salmon. It ranges from California and Canada in the eastern North Pacific, to the Arcto- Siberian rivers of Russia and the island of Kyushu in the Sea of Japan. Most chum salmon spawn in the lower reaches of rivers, and the fry migrate to sea within a few months of emerging from the redds (nests in the gravel created by female salmon) in which they were spawned. They remain at sea for two to five years before returning as 2–8kg adults.

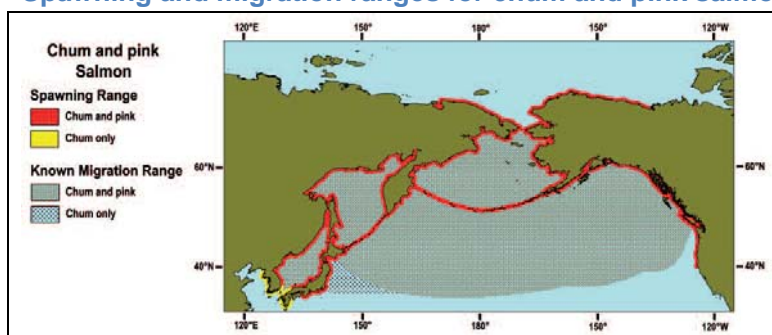
Chum salmon stocks are supplemented by rearing and releasing billions of juveniles from hatcheries in Alaska, Russia and Japan. This species accounts for about half the total catch of Pacific salmon, and is caught mainly by Japan and the USA in purse seines and gill nets, although some are taken by trolling. The total catch of chum salmon was small from the late 1940s into the 1970s, but increased in the 1980s, reaching historically high levels from the 1990s to the present.

### Pink salmon

Pink salmon, commonly known as the humpback salmon, is found from northern California to rivers entering the Arctic Ocean in northern Canada and Siberia, and south-westwards around Japan to Korea. Adults commonly spawn a few miles upstream from the river mouth, and the fry migrate to sea soon after emerging and then spend 15-18 months at sea. Adult pink salmon are the smallest (typically 1-2kg), but most abundant and widely distributed of the Pacific salmon. As all pink salmon mature in their second year, odd-year and even year populations are virtually unrelated, and one population can be markedly more abundant than the other.

Most pink salmon are harvested with purse seines, although some fish are taken using gill nets and by trolling. In 2009, 96 million pink salmon (140,000 t) were landed in Alaska, which accounts for more than 95% of the USA catch.

### Spawning and migration ranges for chum and pink salmon



**Table 1: Wild catch (2009) and farmed production (2008) (5)**

Species	Main season	Wild catch (t)	Farmed (t)
<b>Pink</b>	July - Sept	590,642	
<b>Chum</b>	July - Nov	385,658	
<b>Coho</b>	July - Oct	19,758	105,177
<b>Sockeye</b>	June - Sept	150,485	
<b>Chinook</b>	April - Sept	6,364	9,152

### Coho salmon

Coho salmon, also called silver salmon, range from California to Canada and Alaska and on the eastern coast of Russia and northern Japan. The species spawn in nearly all accessible fresh-water bodies, from large rivers to small tributaries, where the juveniles spend one to two years before migrating to sea. All coho spend just 18 months at sea and grow rapidly before returning to spawn at a weight of 2.5 – 5kg.

Coho salmon comprise about 5% of landings of Pacific salmon in the USA, around half being taken by trolling, with smaller quantities caught using gill nets and purse seines.

### Chinook salmon

Chinook salmon, also called king salmon, is the least abundant but largest of the Pacific salmon, often exceeding 20kg. The species' range extends along the American coast from central California to Alaska, and across the Bering Sea to Siberia and northern Japan. Juveniles spend from three months to a year or more in fresh water before migrating to sea. The fish may mature at anything from two to seven years old.

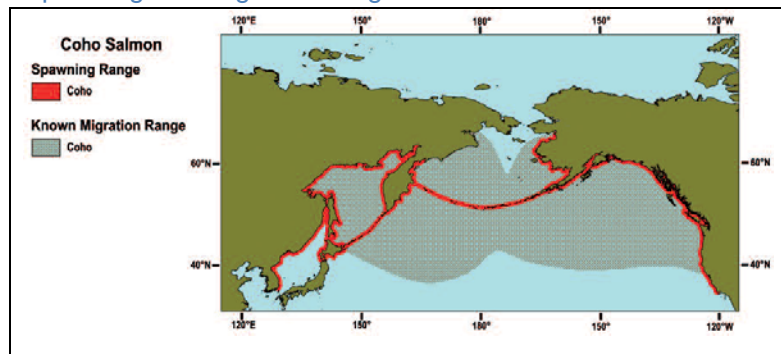
Many Chinook stocks are well below their historic abundance levels, and more than 50 stocks have become extinct.

Chinook salmon account for less than 3% of the overall Pacific salmon catch, and are commonly taken by trolling and gill netting, with troll-caught fish selling for a premium price. Over the past decade, commercial catches have fluctuated between one and two million fish annually with an additional 0.6–0.9 million fish caught in recreational, subsistence and aboriginal fisheries. About half of all commercial catches are made in the United States, particularly in Alaska and Pacific-Northwest states, with the remainder caught, in descending order, by Canada, Russia, and Japan. In a typical year, about 7,500 t are landed by USA fishermen, around half in Alaska.

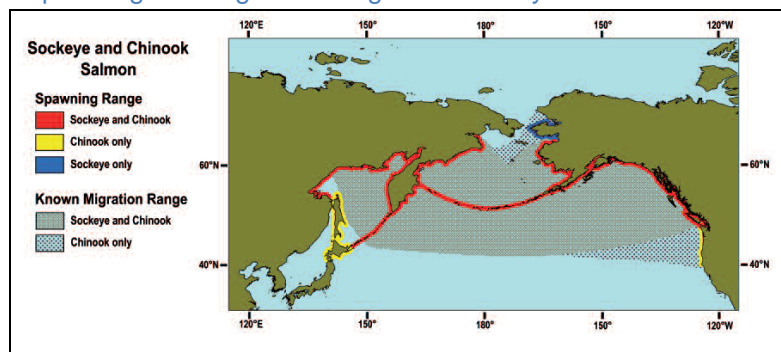
### Sockeye salmon

Sockeye salmon, also known as red salmon, range from British Columbia to the Canadian Arctic and Siberia, but do not extend further south in Asia than the island of Hokkaido. They exhibit a greater variety of life-history patterns than other Pacific salmon. During the juvenile stage they spend up to four years in freshwater (generally in lakes) before migrating to sea, where they can spend a further one to three years before returning to spawn at an average weight of between 1.5 and 3.5kg. Sockeye salmon are mainly taken by gill net and purse seine, with smaller quantities taken by trolling.

#### Spawning and migration ranges for coho salmon



#### Spawning and migration ranges for sockeye & chinook salmon



## Assessments and status

### Assessments

Scientific research, catch monitoring and stock assessment information underpin the management of Pacific salmon stocks. Various analytical models are used, according to the data available and the life history and production patterns of the different salmon stocks or stock groupings. Usually, the models rely on trends in the total number of returning and spawning fish, but data on environmental conditions and habitat availability are increasingly factored into the analyses.

Scientific advice is given as a forecast of the number of adults expected to return to a specific river system for the coming season. Attention is also given to the long-term trends of a given stock grouping, its current status, and the conservation measures required to maintain the viability of each stock for the future. The primary objective in managing Pacific salmon is to safeguard individual stock status, though considerations such as maximum sustainable yield, the allocation requirements of various fishery sectors (usually non-First Nation commercial, First Nation, and recreational) are also taken into account.

### Status of Pacific salmon stocks

Because there are around 10,000 local breeding populations of Pacific salmon, it is not possible here to describe the status of individual 'stocks'. Regional bodies are responsible for reviewing and evaluating the scientific information relating to stocks in particular areas, and for approval of management plans in consultation with resource users. In turn, various national and international bodies exist to coordinate management actions over wider geographic areas (see page 6).

NOAA NMFS (16) reports that most wild salmon stocks throughout the Northwest Pacific are at a fraction of their historic levels due to overfishing and, more recently, loss of freshwater and estuary habitat. Ocean conditions have a major impact on returning salmon abundance, which has recently been helped by improvements in habitat and hatchery management.

Of the 17 Evolutionarily Significant Units (ESUs: defined by genetic relationships; page 7) of Chinook salmon identified in Washington, Oregon, Idaho and California by NOAA Fisheries: nine are currently listed and designated as either endangered or threatened. Two of the four chum ESUs are listed and designated as threatened. Four of the seven coho ESUs are listed and designated as endangered or threatened. One of the seven sockeye ESUs is listed and designated as endangered, and one as threatened. Neither of the two pink salmon ESUs (even year and odd year) is designated.

The current listing of 17 ESUs as endangered or threatened appears to be an improvement on the 1990s, when the USA listed 26 stocks of salmon as endangered or threatened.

## Management authorities

**The principal intergovernmental bodies and agreements responsible for the management of Pacific salmon are:**

**Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean:** came into force in 1993 to promote the conservation of anadromous stocks in the Convention area (waters of the North Pacific Ocean and its adjacent seas). Contracting Parties are Canada, Japan, the Russian Federation and the USA. The executive body for the Convention is the North Pacific Anadromous Fish Commission (NPAFC) (17). The Parties to the Convention co-operate in the conduct of scientific research under the NPAFC Science Plan.

**Pacific Salmon Treaty (1985):** developed through co-operation by the USA and Canadian federal governments, First Nation indigenous people, state governments, and sport and commercial fishing groups. It is implemented by the Pacific Salmon Commission (PSC) (18), which does not regulate salmon fisheries, but provides regulatory advice and recommendations. It is a forum for the contracting parties to set long-term goals for the conservation of salmon and their fisheries.

**North American Agreement on Environmental Co-operation (NAAEC, 1994):** signed by Canada, Mexico and the USA, it creates a framework to conserve, protect and enhance the North American environment through co-operation and effective enforcement of environmental laws. The agreement is implemented by the North American Commission for Environmental Co-operation (CEC) (19).

**North Pacific Marine Science Organisation (PICES):** an intergovernmental scientific body comprising Canada, People's Republic of China, Japan, Republic of Korea, Russian Federation, and USA. It aims to promote and co-ordinate marine research, and to advance scientific knowledge about the ocean environment, global weather and climate change, living resources and their ecosystems, and the effects of human activities in the northern North Pacific and adjacent seas (20).

**North Pacific Fishery Management Council:** one of eight regional fishery management councils in the USA, it is responsible for managing salmon fisheries off the coasts of California, Oregon and Washington State (21). The large Alaskan salmon fisheries are managed primarily by the State of Alaska (22).

At a national level, the Department of Fisheries & Oceans (DFO) in Canada (23), the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) (16) and the Alaskan Department of Fish and Game (2) in the USA, the State Committee for Fisheries in the Russian Federation (24) and the Ministry of Agriculture, Forestry and Fisheries in Japan (25), all manage domestic Pacific salmon fisheries.



## Management and conservation

### Ensuring adequate numbers of spawning fish

The overriding objective of management of Pacific salmon fisheries is to ensure that adequate numbers of adult fish reach the spawning grounds to maintain stock abundance and fishery viability. This is done through a variety of legislative measures including: licensing, limited entry to the fishery, defining the methods, means and location of capture, closed seasons (including real-time closures day-by day), catch quotas, limits in the number of fish caught by anglers (often linked with mark-selection rules to allow hatchery origin rather than wild fish to be retained), and sex and size limitations. There are also wide-ranging Pacific salmon stock enhancement programmes to mitigate the effects of human activities such as dam construction and habitat degradation. These include hatchery rear and release, lake enrichment, the installation of fish passes and artificial spawning channels, and other habitat improvements.

### Genetic diversity and multiple stock and species management

Because Pacific salmon return to spawn in the river where they hatched, breeding populations can have a unique genetic identity in an individual catchment, river or tributary. Managing at such a fine scale presents significant challenges. In practice, wild stocks are commonly managed by Conservation Units (23) or Evolutionary Significant Units (26) that reflect geographic and genetic diversity of groups of stocks.

### Mixed stock fisheries

While different stocks and species of Pacific salmon may migrate to different parts of the north Pacific to feed, there is substantial mixing in near-shore waters during their return migration. As a result, many commercial fisheries exploit a mix of species and stocks and may intercept fish destined for rivers in other countries. This highlights the importance of international co-operation, and management that seeks to control the harvest of the weaker stocks.

### Environmental impacts

Pacific salmon are mainly caught by fixed or mid-water gears, so habitat damage from fishing practices is generally minimal. Nevertheless, there is a lack of quantitative information on the by-catch of non-salmon fish species, birds and marine mammals in Pacific salmon fisheries. The by-catch in Alaskan fisheries is not believed to be significant to species conservation (26).

### Certified fisheries

All five species of Pacific salmon caught in Alaskan waters and managed by the Alaskan Department of Fish and Game in the USA are from fisheries certified by the MSC as being managed sustainably and in an environmentally responsible manner (27).

## Climate change and salmon

Pacific salmon are key species in the North Pacific Ocean ecosystem, where a number of “regime shifts” (climate change, accompanied by shifts in ecosystem functioning) have been identified during the last century, the most notable occurring around 1949, 1977, 1989 and 1998. A decline in the abundance of sockeye salmon in Russia and Alaska occurred coincident with a regime shift in 1949, and the overall abundance of Pacific salmon was low during 1960–76. From 1977 until the early 1990s the abundance of most species of Pacific salmon increased, and chum, sockeye and pink salmon maintained high abundance at the beginning of the 21st century, supported by an increase in hatchery-raised populations. However, the abundance of coho and Chinook salmon, which spend more than one year in fresh water, has declined sharply since the 1980s due to degraded environmental conditions in freshwater habitats (28, 29, 30, 31).

Over the past decade, fluctuations in the growth and survival of populations of Asian and North American salmon that make feeding migrations into the Bering Sea have been attributed to changes in the marine ecosystem there (32). The Bering Sea’s capacity to support the three most abundant species (sockeye, chum and pink salmon) is positively correlated with the Far Eastern and Aleutian Low pressure systems, the respective positions of which led to anomalously warm spring and summer conditions in 2002 to 2005, whilst a shift in the position of these low pressure systems during 2006, resulted in a period of anomalously cold temperatures in the Bering Sea during 2006 to 2008. The productivity of prey species in the eastern Bering Sea was highest during “warm” years, when juvenile salmon and Alaska pollock were much more abundant than during the “cool” years (33). In fact, pollock dominated the diet of juvenile pink and sockeye salmon on the eastern Bering Sea shelf during the warmer summers from 2004 to 2005, but were nearly absent from the diet in the cooler spring and summers that occurred in 2000, 2001, 2006 and 2007 (34, 35).

There is general agreement that climate change strongly affects the dynamics of marine ecosystems around the North Pacific and that regime-scale changes in climate affect salmon production and fisheries. However, global warming impacts are thought to be less important in the medium term than are the natural cycles in atmospheric circulation and sea temperatures that influence physical and biological processes in the ocean (36). Because the impacts of climate and ocean changes vary among areas and species, and the mechanisms that regulate recruitment are poorly understood, it is only possible to speculate on the impacts of global warming on Pacific salmon production at present.

## Aquaculture

### Background

The ranching of coho salmon as a means of enhancing commercial fisheries started in the USA in around 1900 (12), whilst sea-cage farming of coho salmon started some 50 years ago. Annual farm production remained below 1,000 t until cage farms were established in Chile and Japan around 1980. By 1994, Japanese production had stabilised at 8,000–13,000 t per year, but it continued to increase in Chile, peaking at nearly 137,000 t in 2001. This resulted in oversupply and a sharp drop in prices, though Chile still produced about 92,000 t in 2008, equivalent to about five times the typical North American harvest of wild coho salmon (5). Other producers are Canada and the USA, though production has largely ceased in the latter due to local opposition, lack of suitable sea-farm sites and falling market prices. The major markets for farmed coho salmon are Japan, where it represents over half the imported frozen salmon, and the USA.

Chinook salmon are farmed in British Columbia and Chile, with about 11,500 t produced in 2007 (13); whilst production of chum salmon is virtually zero (9). It is important to recognise that over 100,000 t of farmed Atlantic salmon (*Salmo salar*) is produced each year in the Pacific, mostly in Chile, but also in Canada. It should also be noted that the provision of Pacific salmon produced in sea cages may help to relieve pressure on wild stocks.

### Ecological interactions due to ranching

Three main areas of controversy surround the extensive hatchery rearing-release programmes that enhance wild runs of Pacific salmon for harvest. These are: (a) mixing of stocks in fishery areas and ensuing difficulties in managing the harvest to safeguard vulnerable wild stocks; (b) potential adverse effects of large releases of juvenile fish in near-shore rearing areas on growth and survival of wild stocks; and (c) 'stray' hatchery fish interbreeding with wild stock, which affects the genetic fitness and productivity of wild populations. These concerns also apply to escaped farmed salmon, though most farm production of Pacific salmon is in Chile, outside the species' native range.

### Environmental effects of aquaculture

Priorities for improved farming of Pacific salmon include selective stock rearing, feed quality, and disease control and prevention – all factors that directly affect production costs and profit margin (12). Other concerns are: nutrient loading from organic wastes (feed and faeces) and accumulation of contaminants in the water column and the sea-bed around the farm-site; transmission of diseases and parasites; and contamination of farmed salmon with excess pharmaceuticals and other chemicals used in the farming operations.

The Food and Agriculture Organisation (FAO) Code of Conduct for Responsible Fisheries (38) advocates safe and high-quality fishery products, and calls for the global aquaculture industry to promote responsible aquaculture practices and methods that reduce the above hazards.



## Product characteristics

Pacific salmon vary widely in their size, condition and flesh quality, depending the species, season and method of capture. They are typically regarded as an 'oily fish' rich in omega 3, although this varies markedly between species, with pink salmon having the lowest oil content and Chinook salmon the highest (Table 2). Flesh colour is an important attribute, and the Alaska Seafood Marketing Institute provides appropriate guides (38). Processors of farmed salmon offer many products, including: fresh and frozen; headed and gutted; with or without skin; de-boned fillets and portions; steaks; and smoked. Portions and fillets can be vacuum packed, which increases shelf life. These products compete directly with products derived from farmed Atlantic salmon.

**Table 2: Main food products of the principal Pacific salmon species**

Common name	Flesh colour	Typical capture size –(kg)	Main food products
Pink salmon	Pink	1-2	Canning, frozen, low oil
Chum salmon	Pink to dark pink	2-8	Fresh, frozen, low oil
Coho salmon	Red	2.5-5	Fresh, frozen, medium to high oil
Chinook salmon	Dark pink	5-10	Fresh, smoked, high oil
Sockeye salmon	Deep orange/red	1.5-3.5	Fresh, frozen, canned, smoked, high oil

### Supply chain standards

Responsible practice in the chilled and frozen supply chain depends on correct catching, gutting, washing, chilling or freezing, processing and handling practices throughout the chain. Seafish has developed standards which cover these aspects from capture to retailer:

- **Responsible Fishing Scheme.** Sets best practice standards for fishing vessels, based on British Standards Institution specifications (BSi: PAS 72:2006);
- **British Retail Consortium (BRC) Global Standard & Safe & Local Supplier Approval (SALSA) certification.** Designed to raise standards in the seafood processing and wholesaling sectors.

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