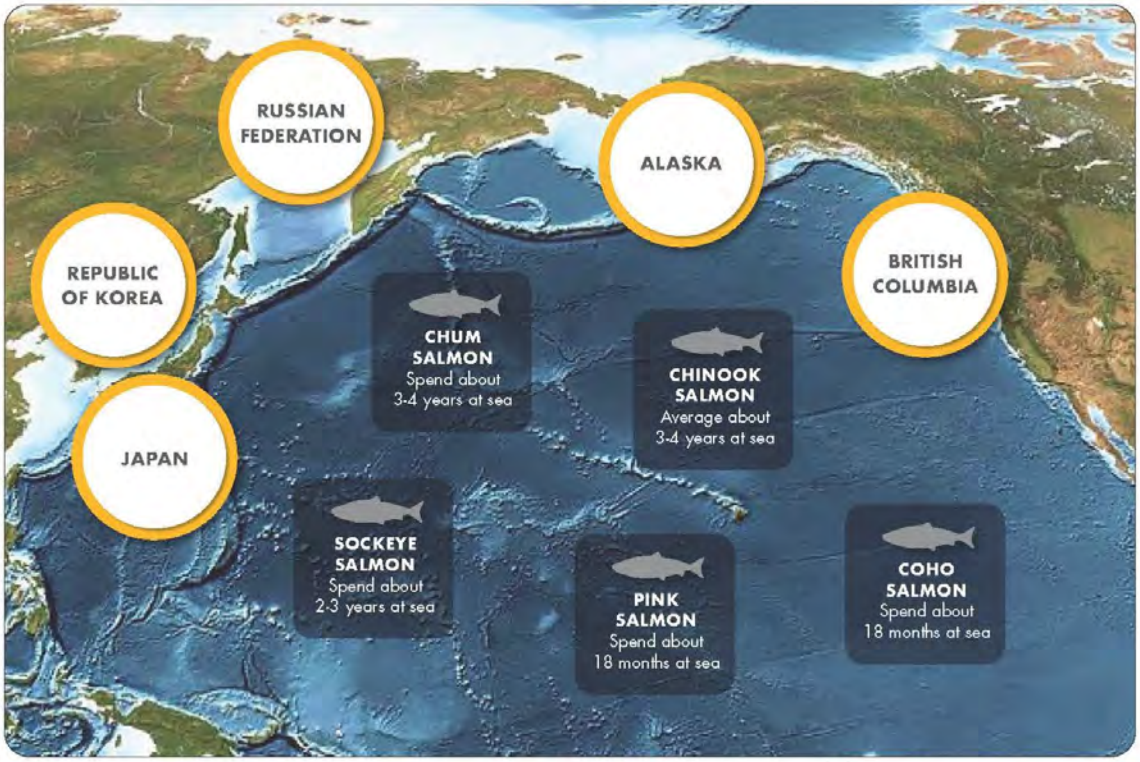
CHAPTER HIGHLIGHTS – CARING FOR WILD SALMON – THE BIG PICTURE



Canadian Pacific salmon are part of an ocean ecosystem that stretches from Korea to Alaska to California. Pacific salmon spend much of their lives in the ocean, yet their ocean lives remain largely a mystery to us.

For example, we know very little about the ecology of British Columbian pink and chum salmon in the ocean despite knowing that these two species represent about 80% of all salmon and spend most of their lives in the ocean.

We are in the midst of unexplained fluctuations in Pacific salmon abundance on an international scale. Declines in abundance and/or size have been reported in all five countries that have capture fisheries for Pacific salmon in the Pacific Ocean.

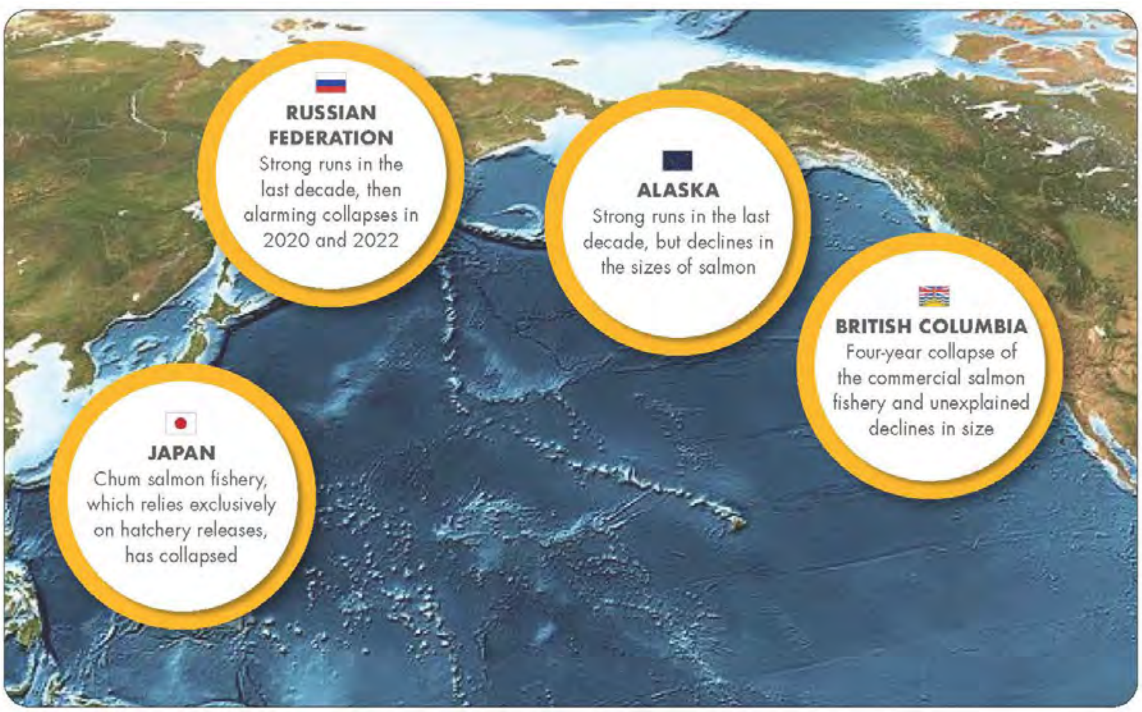
The chum salmon fishery in Japan, which relies solely on hatchery releases, has declined substantially since about 2007. This is occurring despite Japan's continued release of slightly less than two billion hatchery fish annually. British Columbia also experienced a collapse in the commercial fishery from 2019 to 2022.

In 2020, the total catch by all countries declined abruptly by 37%. In 2021, total catches returned to pre-2020 levels but collapsed again in 2022, only to go back to highs of the 2010s in 2023. These are unprecedented fluctuations that must result from large-scale climate and ocean influences throughout the North Pacific Ocean.

The Pacific Ocean is a massive ecosystem that is responding to climate change in powerful ways that we do not understand. The situation is an emergency for all countries that rely on salmon from the Pacific Ocean.

Oceans absorb 90% of the earth's excess heat. The warming of the Pacific Ocean, which alters salmon survival, is generally believed to be the reason for the increase in salmon production in Alaska and Russia and the decline in Japan and BC

The basin-wide large abundance of pink salmon in 2023, which may result in a historic high commercial catch by all countries, illustrates that large-scale climate and ocean events affect the ocean survival of salmon.



Still, there is hope. We know that salmon relied on their genetic diversity to survive freshwater and ocean changes in the past. It is possible they can do this again.

In order to conserve wild salmon, we need to learn what is happening in the high seas and near shore environments and the mechanisms that control Pacific salmon populations.

Our stewardship of Pacific salmon throughout the North Pacific region requires new ways of thinking and cooperation to address our knowledge gaps.

Photo by Brian Kingzett

We need to see a bigger picture.

This document provides recent dramatic changes in the abundance of Pacific salmon and discussion with the intent that international cooperation with Indigenous Peoples will identify how to ensure a future of professional stewardship.

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Photo by Brian Kingzett

PACIFIC SALMON IN THE NORTH PACIFIC OCEAN

Canadian Pacific salmon are part of an ocean ecosystem that stretches from Korea to Alaska to California (Figure 1). British Columbians are familiar with salmon that are found in rivers and coastal waters accessible to commercial and recreational fishing, but the ocean life of salmon is still largely a mystery. For example, very little is known about the ecology of pink and chum salmon in the open ocean despite knowing that these two species represent about 80% of all salmon, and most of their lives in the ocean.

Pacific salmon are almost the only group of fishes in the surface depths waters of the northern Pacific Ocean during the day. There could be up to about 700,000,000 salmon in an ocean area of 15,000,000 km^2 which is 1 and ½ times the area of Canada. Fresh water is the nursery area for salmon, but it is the ocean where abundances are determined.

Figure 1. North Pacific Ocean, Pacific salmon producing countries.

Five countries produce and commercially fish Pacific salmon in the Pacific region: the Republic of Korea, Japan, the Russian Federation (Russia), USA, and Canada. The most abundant species in the commercial catch is pink salmon, followed by the larger body size chum salmon (Figure 2). The smaller size and more abundant pink salmon also produce the largest weight of catch, but occasionally, the weight of the commercial catch of chum salmon will exceed pink salmon catch.

Consumption preferences vary by region. Pink and chum salmon are a less popular eating fish in North America but are valued commercially. Chum salmon are the most important species commercially and socially in Japan and pink and chum salmon are the most important in Russia. The recreational fishery in North America values Chinook salmon because of their large size and coho salmon because they are tasty and a challenging sport fish to catch. Sockeye salmon are esteemed because of their red flesh and taste.

Steelhead are the sea-going (anadromous) form of rainbow trout. They are scarce in the commercial fisheries of all countries. Cherry salmon are not found in North America and are rare in Asian commercial catches, with almost all catches by Japan. Steelhead and cherry salmon will not be discussed further in this chapter.

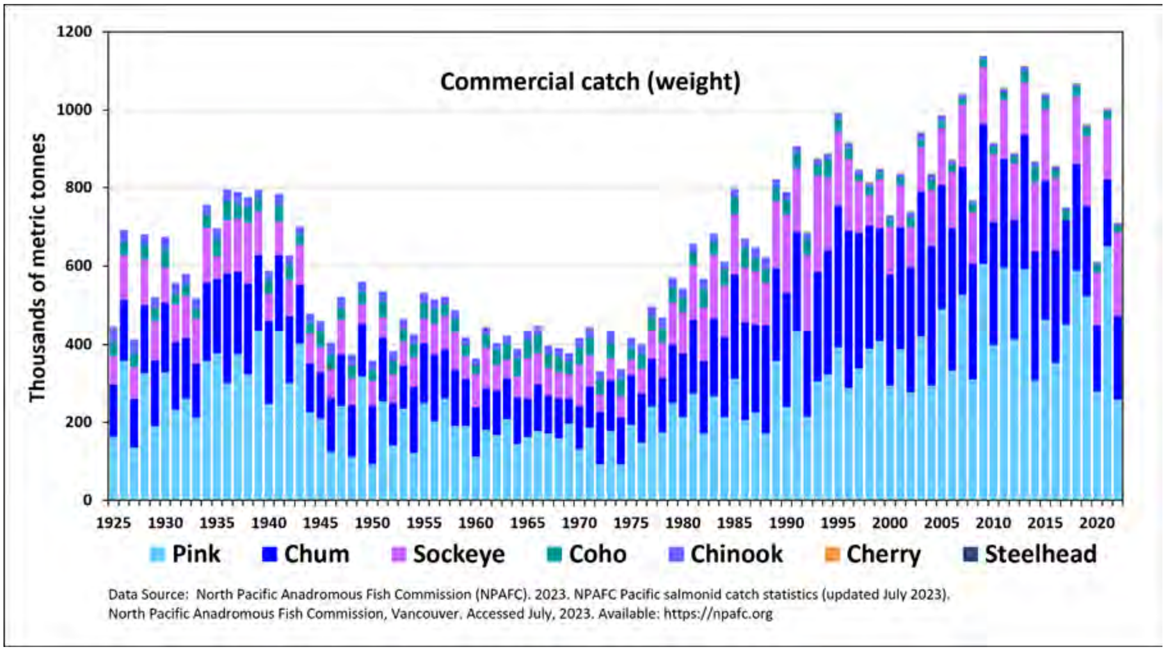


Figure 2. Annual commercial catch of salmon and steelhead trout by species in thousands of metric tonnes 1925 – 2022, all countries combined.
Source North Pacific Anadromous Fish Commission Statistics (2)

THE INTERNATIONAL PACIFIC SALMON EMERGENCY

The commercial salmon fishery has collapsed in British Columbia and Japan (Figures 3 and 4). In 2021, the commercial catch in BC was only 0.2% of the total salmon catch by all countries. In 2021, the Japanese commercial catch was 24% of their previous high catches. Catches were marginally higher in both countries in 2022.

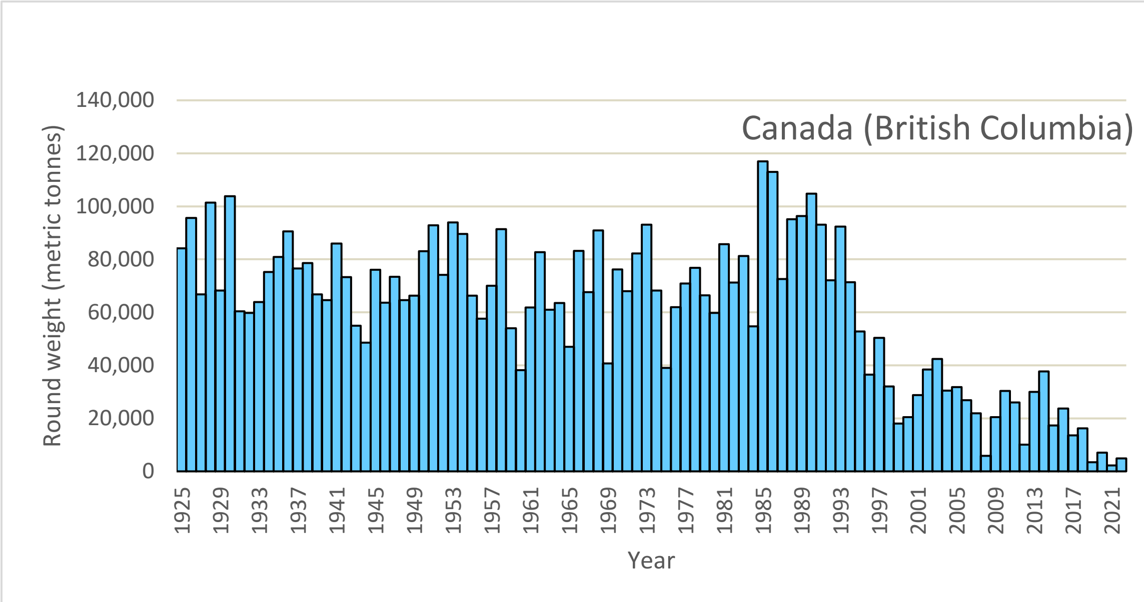


Figure 3. Total catch of Pacific salmon by British Columbia, including Yukon.
Source North Pacific Anadromous Fish Commission Statistics (2)

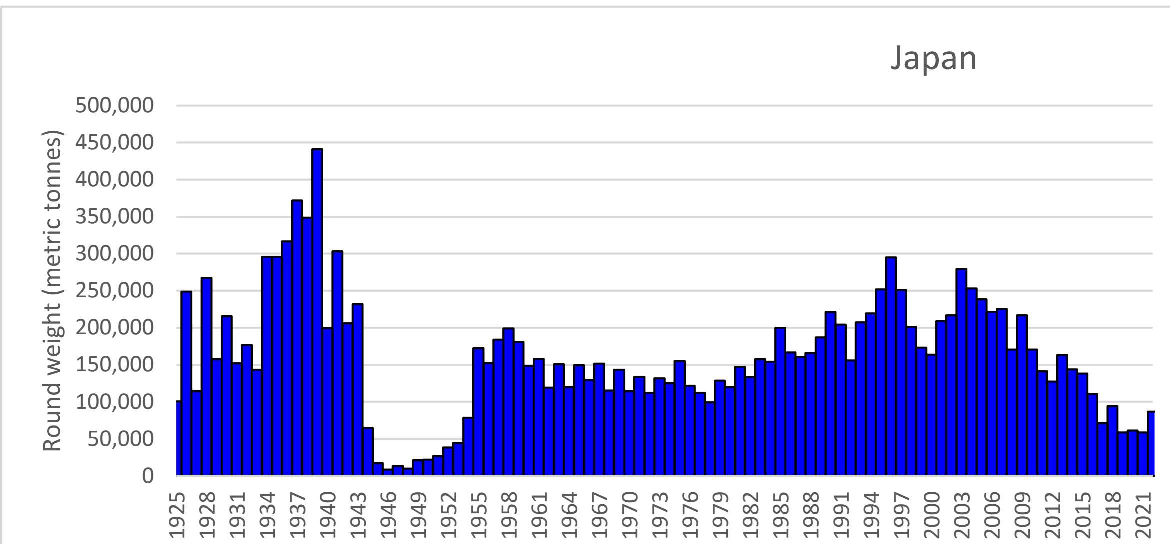


Figure 4. Total catch of Pacific salmon by Japan.
Source North Pacific Anadromous Fish Commission Statistics (2)

While these collapses were occurring, there were record-high commercial salmon catches in Russia and Alaska (Figures 5 and 6). In 2020 and 2022, there were sharp declines in the catches in Russia.

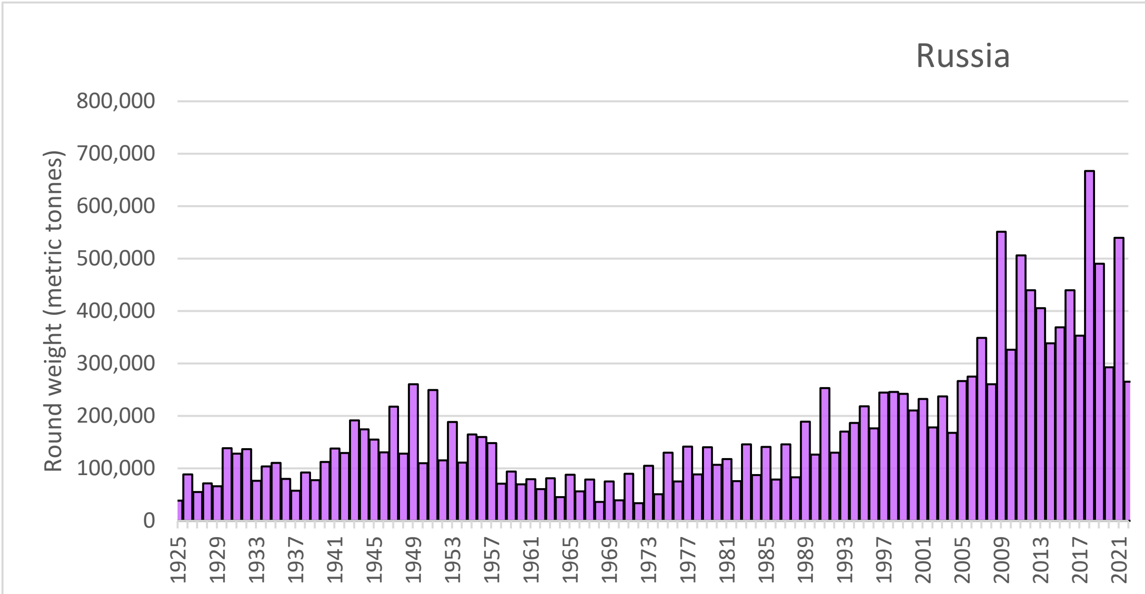


Figure 5. Total catch of Pacific salmon by Russia.
Source North Pacific Anadromous Fish Commission Statistics (2)

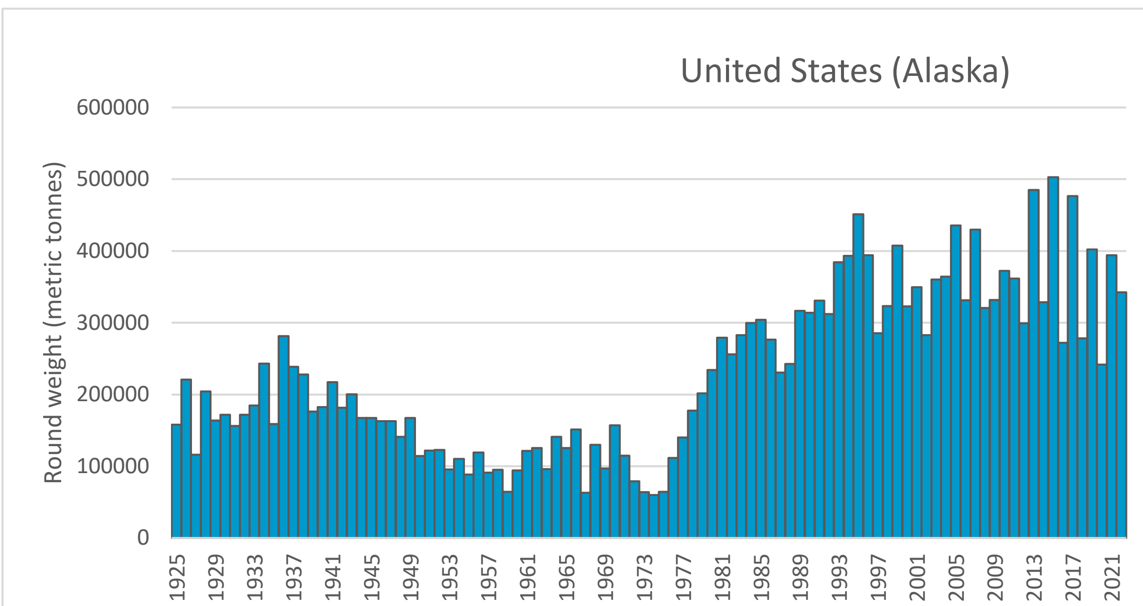


Figure 6. Total catch of Pacific salmon by Alaska.
Source: North Pacific Anadromous Fish Commission Statistics (2)

All countries' total catches of Pacific salmon are recorded back to 1925 with record high catches in the past 15 years (Figure 7). Despite the collapses in Japan and Canada, these record-high catches indicate that there are more Pacific salmon in the ocean today than in the past 100 years (Figure 7).

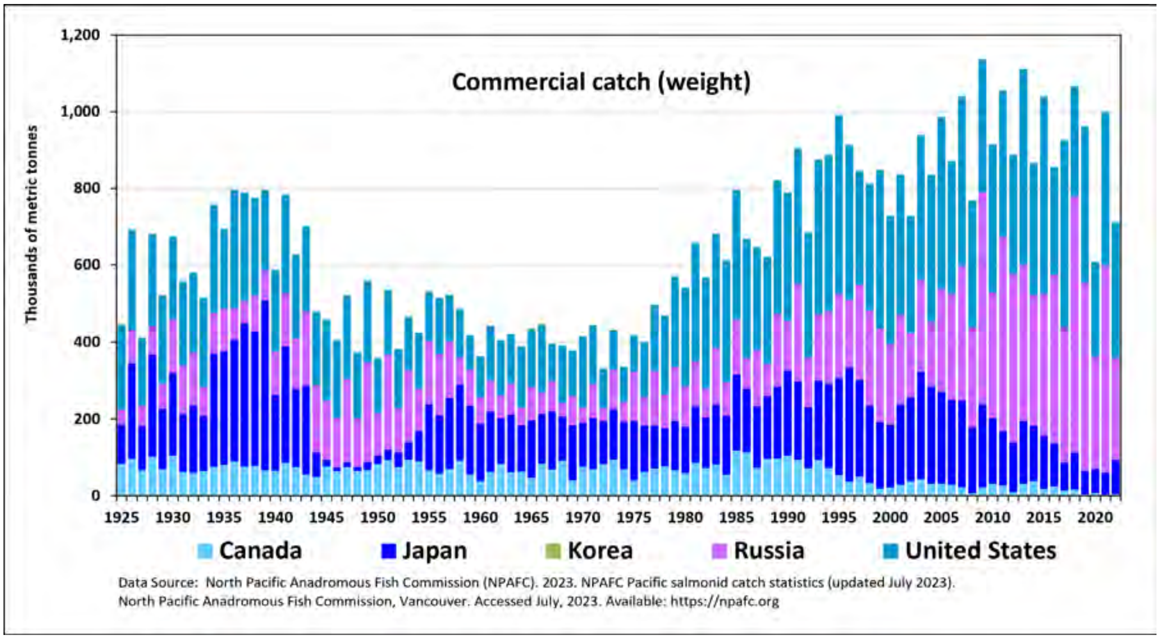


Figure 7. Annual commercial catch of salmon and steelhead trout by country 1925-2022.
Source North Pacific Anadromous Fish Commission Statistics (2)

Recent catch numbers, however, suggest the situation may be changing. The global abundance of Pacific salmon in 2020 was the lowest it has been since 1982. This was a 37% reduction in total catch by all countries and the largest single yearly decline ever quantified. About one-half of this total catch came from just two fishing regions, Bristol Bay (91,100 metric tonnes) and the coast of Kamchatka (194,400 metric tonnes) (3). Alaskan and Russian catches rebounded in 2021, but catches in 2022 by all countries indicate another major collapse similar to 2020 occurred. While the catch records for 2023 are currently being assembled; it appears that catches for pink and sockeye salmon have been high, but chum salmon catches appear to remain at low levels. There is no scientific consensus about what is causing the fluctuations.

The Canadian Government House of Commons Report of the Standing Committee on Fisheries and Oceans report recognized in a recent report that there may be a Pacific salmon emergency in BC and throughout all salmon-producing countries (1).

If we want to conserve wild salmon, we must unlock the secrets of the high seas. In 2009, Canadian scientists Drs Richard Beamish and Brian Riddell recommended the creation of an international research group to study the ecology of the entire North Pacific Ocean. These two scientists privately funded and organized three expeditions to study the ocean ecology of Pacific salmon in the Gulf of Alaska in the winters of 2019, 2020 and 2022. Their project also led to the formation of "The International Year of the Salmon (IYS)", an international group of scientists from Canada, Japan, the Republic of Korea, Russia, and the USA dedicated to working together to map the distribution throughout the North Pacific Ocean and discover the mechanisms that regulate survival (Figure 8).

Figure 8. Year of the Salmon - North Pacific 2022 IYS Pan-Pacific Winter High Seas Expedition (4)

A LESSON FROM JAPAN: CHUM SALMON AND OCEAN CARRYING CAPACITY

The decline in Japanese chum salmon catch is relevant to the general understanding of the production of all Pacific salmon. Japanese salmon catches are virtually all from fish produced in hatcheries. From 1981 to 2011, Japan produced about 1.8 to 2 billion chum salmon fry each year in hatcheries, which was approximately 40% of the hatchery production of all countries for all species of salmon (Figure 9). From 2012 to 2017, there was a slight drop in hatchery releases which would not affect returns until 2016 as most chum stay in the ocean for four years.

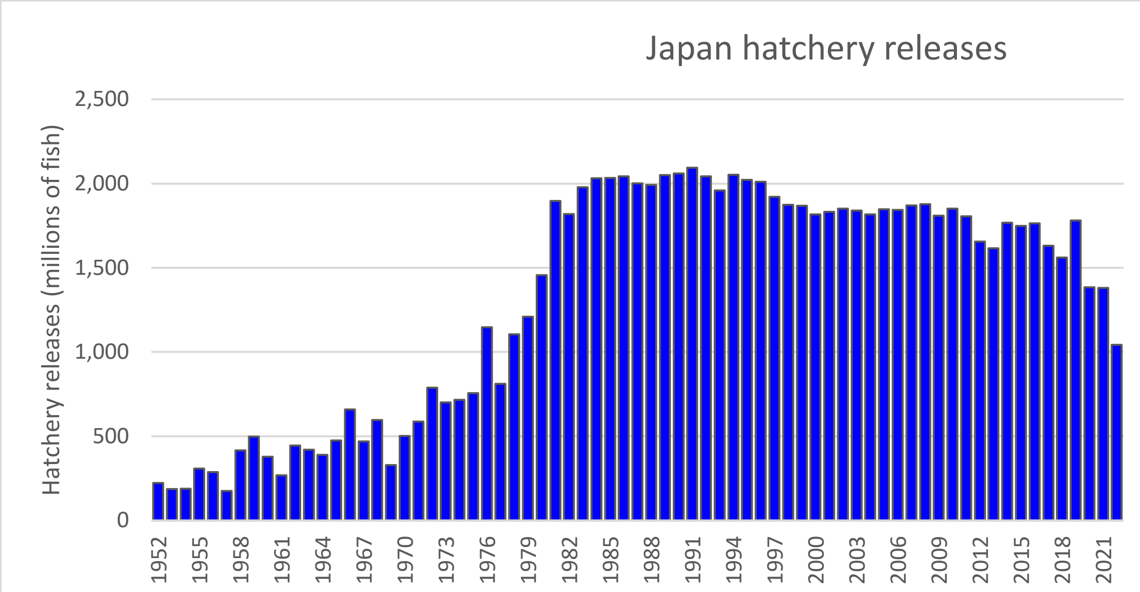


Figure 9. Annual hatchery release of chum salmon by Japan in millions of fish 1952 – 2022.
Source: North Pacific Anadromous Fish Commission (2)

The Japanese commercial chum salmon catch increased to a high of 81 million fish in 1996, then began to steadily decline in 2007 to a low of 17 million fish in 2021, with a slight rebound in 2022 (Figure 10). Importantly, this decline occurred without a significant decrease in the number of fry produced from hatcheries.

Virtually all the decrease in the commercial catch can be related to changes in the carrying capacity of the coastal ocean, as chum fry released from hatcheries spend only a few days in freshwater. Also, there was no evidence of a large increase in predators.

The history of Japanese chum salmon production can be seen as a large experiment showing that there was an ocean-carrying capacity capable of producing more chum salmon from the mid-1980s to the mid-2000s, and then the capacity declined.

While the ocean carrying capacity along the coastline of Japan was decreasing, the ocean carrying capacity near Russia and Alaska appears to have increased, as evidenced by record levels of commercial catches in the 2010s. The increasing abundances in Russia and Alaska must result from a combination of increasing juveniles produced in fresh water and increasing ocean survival.

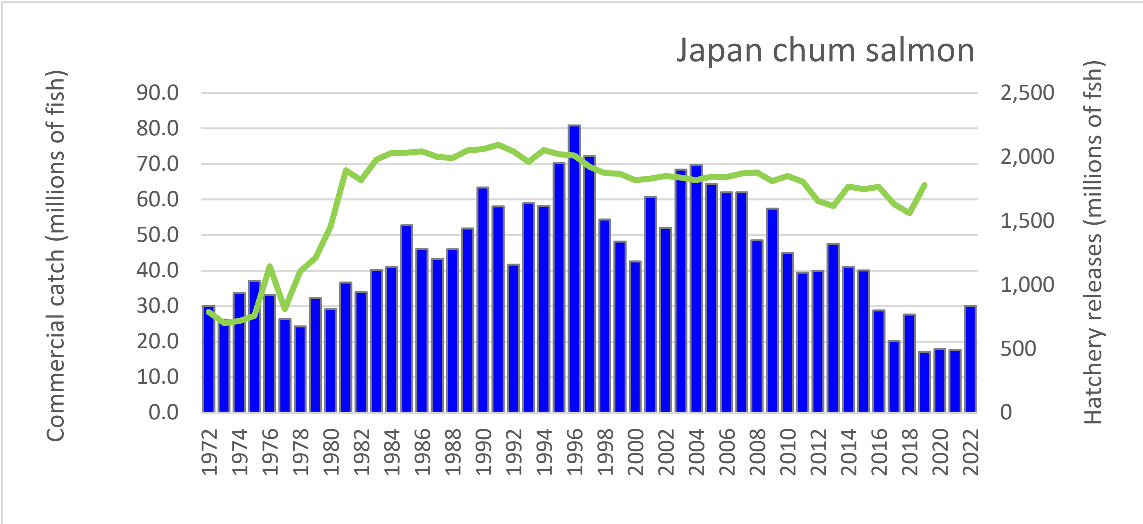


Figure 10. Coastal commercial catches of chum salmon in Japan, compared to hatchery releases, 1972-2022.
Note that hatchery releases in the last few years are not shown because the fish returns will occur in the future. Source North Pacific Anadromous Fish Commission (2)

WHAT HAS HAPPENED TO PACIFIC SALMON IN BRITISH COLUMBIA?

Photo by Chris Walling aka Steel_Snorkel

Commercial catch records for British Columbia for the past century are shown in Figure 3. Catch estimates generally show minimal year-to-year fluctuations with a long-term average of about 60,000 metric tonnes. There was a brief increase from 1985 to 1993, averaging about 95,000 metric tonnes, but catches declined after the mid-1990s. The historic low catches occurred in 2019 (3,388 metric tonnes), 2020 (7,031), 2021 (2,289) and 2022 (4,829).

The average of 4,384 for these three years is about 7 % of the long-term average and clearly shows that the commercial fishery has collapsed.

Photo by Brian Kingzett

THE SALMON ENHANCEMENT HYPOTHESIS

Modern Pacific salmon management in British Columbia probably can be considered to start when the Fisheries Research Board (FRB) was abolished in the early 1970s. FRB was abolished, in part, because the Canadian Federal Government recognized the importance of sustainable fisheries on the East and West coasts for jobs and food supply. More direct control of research and better integration of management and science were considered necessary for the future of sustainable fishing.

> In the 1970s , there was general agreement among a community with a passion for salmon that if more juveniles were produced, the abundance would return to what had occurred in the past.

Most people in BC associated with managing and fishing Pacific salmon, including very accomplished scientists, believed in the 1960s and 1970s that the abundance and catch of salmon were directly related to the number of juveniles produced in freshwater. It was known that huge abundances of salmon existed in the past, and it was reasoned that overfishing and freshwater habitat loss had diminished the number of juvenile salmon entering the ocean. There was general agreement among a community with a passion for salmon that if more juveniles were produced, the abundances would return to what had occurred in the past. More juveniles could be produced by reducing fishing or building hatcheries. Reducing fishing was not popular, so the Salmon Enhancement Program (SEP) was started in 1977.

The Treasury Board was told that the average catch in the 1970s of about 70,000 metric tonnes could approximately double by 2005. The BC salmon catch in the 1970s was about 15% of the total salmon catch by all countries. There was some expectation that the increased catch in BC could increase Canada's share of the total all-country catches to about 20%. Treasury Board was also told that taxes collected from fishing these increased abundances would help pay for SEP.

Hatcheries were considered a proven technology. Other Pacific salmon-producing countries also built hatcheries to increase the size of their salmon catches, releasing about 5 billion hatchery fish into the Pacific Ocean ecosystem each year since the 1980s (Figure 11).

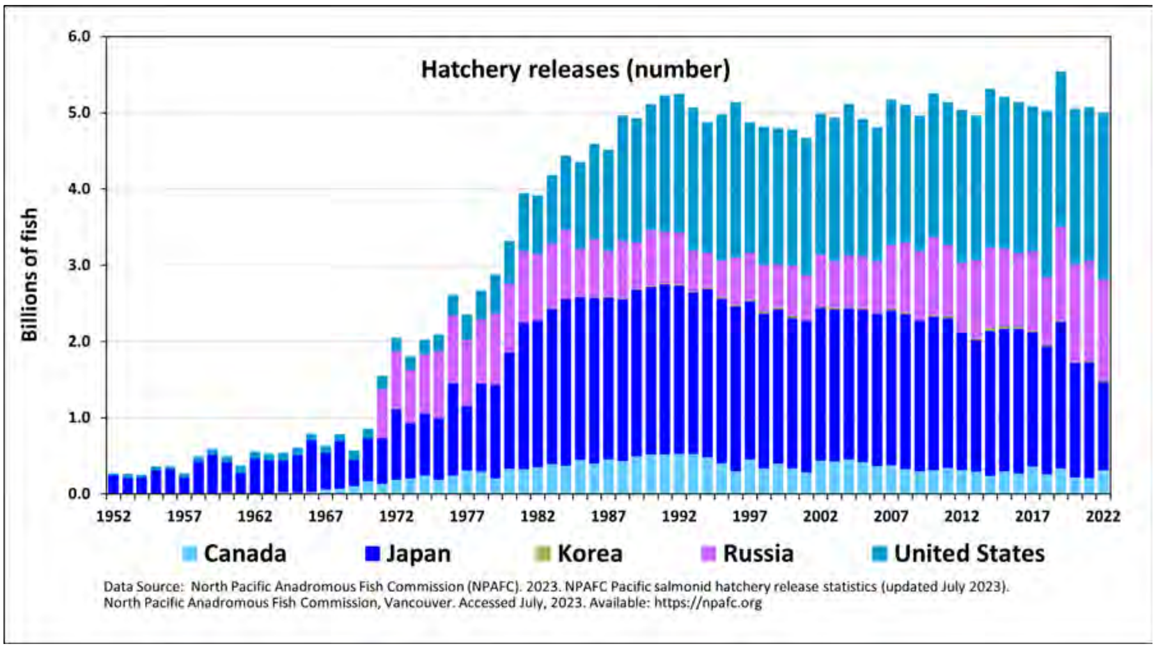


Figure 11. Pacific salmon hatcheries in the North Pacific Ocean; release approximately 5 billion fish per year into the ecosystem from five countries.
Source North Pacific Anadromous Fish Commission (2)

While Canadian scientists, who were some of the best fisheries scientists in the world, argued that SEP needed to be supported by scientific evaluations, they believed that adding more hatchery salmon to the ocean would restore abundance because there was "unused" capacity in the ocean to produce more salmon. For example, Dr. Peter Larkin wrote that there was still plenty of "headroom" in the ocean to produce salmon before food became limiting (5).

We now know there were several problems with the concept of SEP. Firstly, the concept of SEP was a hypothesis. SEP was a scientific experiment – and still is. There was no proof that unused ocean habitat existed and no understanding of how to measure unused capacity. All scientists agree that the environment would become limiting for salmon at some point, as this is true for all living things. When the environment becomes limiting, mortalities increase for a variety of reasons, and abundances decline. Scientifically, this is called density-dependent mortality. Another major problem (that still exists) is that protecting the natural ability of wild salmon populations to adapt to habitat changes (resilience) was mostly ignored, and when recognized, it was only applied to freshwater habitats.

Photo by Bill Pennell

We still have little understanding of how the resilience that evolved in thousands of populations relates to the ocean habitat. The potential consequences of diminishing the ability to adapt to *ocean ecosystem changes* worried some biologists but the promise of restoring past abundances was more appealing. However, there was some concern that adding abundances of hatchery fish would result in overfishing of stocks that biologically produced juveniles at a slower rate.

Commercial salmon catches declined in BC as salmon abundances declined. Management tried to maintain freshwater spawning abundances according to models built on past performances of populations. Despite reductions in fishing, there were still declining spawning abundances.

In the late 1980s and early 1990s the first estimates of ocean survival became available, and it was clear that the ocean survival was declining for most salmon species in BC. The reasons for the ocean related changes in survival were not (and are still not) understood (6); however, the changes were indisputable.

Photo by Brian Kingzett

By the late 1980s some scientists started to recognize that the ocean survival for salmon was declining in BC. Declining ocean survival was also occurring in Japan and some USA states. Despite all efforts to sustain fisheries, including a salmon enhancement effort that has spent over $1billion dollars, the commercial salmon fishery has collapsed in BC.

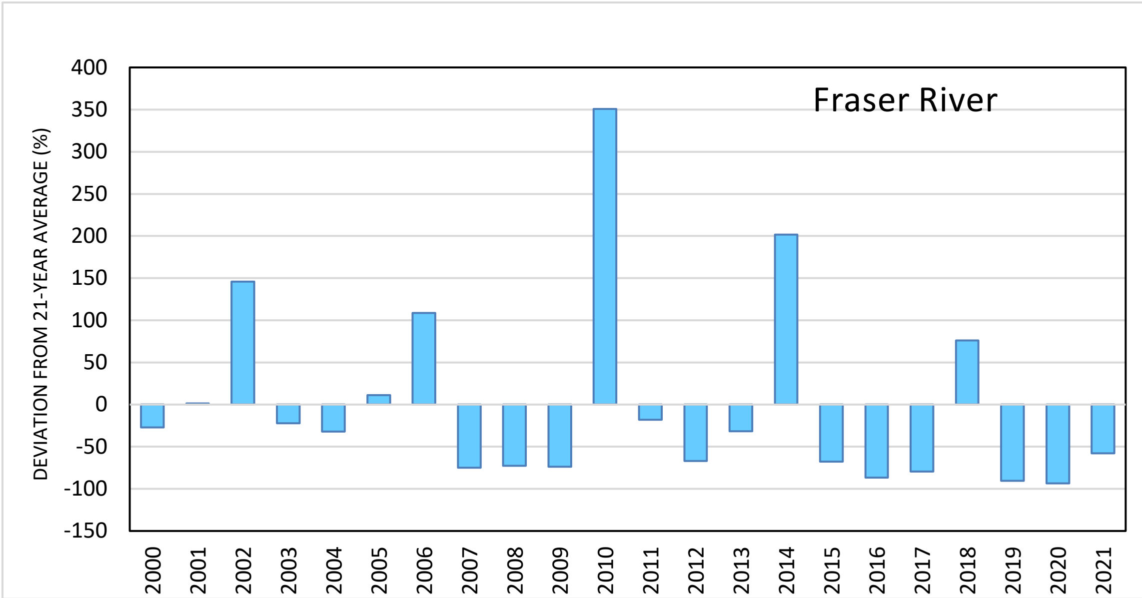
The most recent summary of total salmon abundances by the North Pacific Anadromous Fish Commission shows that, in general, total production of salmon in BC has been at historic low levels since about 2017. (7). From 2019 to 2022, the average total commercial catch in BC was 4,384 tonnes or about 7% of the catch that existed at the beginning of the SEP program. (3) Despite all efforts to sustain fisheries, including a salmon enhancement effort that has spent over 1 billion dollars, the commercial salmon fishery has collapsed in all BC regions. For example, as evidenced by the low catches of 2,289 metric tonnes in 2021 and 4,829 metric tonnes in 2022.

HOW IS THE OCEAN CAPACITY FOR PACIFIC SALMON CHANGING?

The abundance of all Pacific salmon changes from year to year. Different species have different ocean survival rates showing that they "use" the ocean differently. A major reason for the change in the total abundance of salmon by all countries among years is a consequence of the fixed 2-year life cycle of pink salmon. All pink salmon live for only two years meaning that there is no interbreeding between years. For reasons not understood more pink salmon return in years ending in an odd number than in years ending in an even number. This frequently results in the total catch by all countries being larger in odd-numbered years

The warming of the Pacific Ocean is generally believed to be the reason for the increases in salmon production in Alaska and Russia. Also, the declining abundance in Japan and British Columbia, where warmer waters have likely decreased the carrying capacity for salmon. This phenomenon is illustrated by the sockeye salmon runs in the Fraser River, which appear to be mirror opposites of catches in Alaska (Figure 12). This is interpreted by some as the ocean warming being good for salmon, at least at the northern limits of their distributions. However, at some point, the warming will reach a threshold that becomes harmful and "Russian" and "Alaskan" salmon production will diminish. In the short term, Pacific salmon may move into new ocean habitats in the Arctic, but the record abundances that exist now will begin to decline as they have in Japan and in British Columbia.

Photo by Bill Pennell



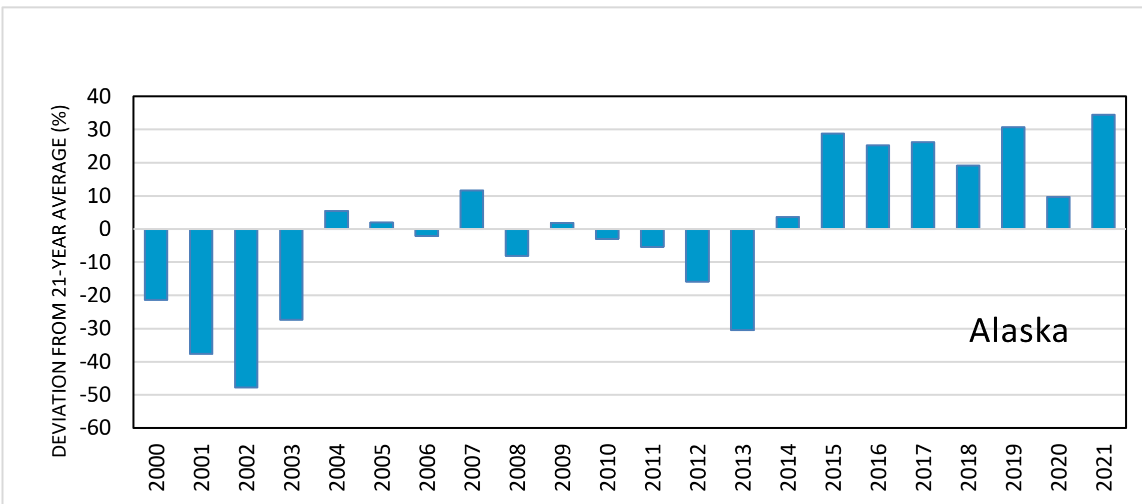


Figure 12. Comparison of total sockeye returns to the Fraser River and commercial catches of Alaska sockeye salmon 2000 -2021.
Source North Pacific Anadromous Fish Commission (2). Note significantly different X axis on Alaska graph showing much less percent variability.

WINTER WINDS AND MID-OCEAN UPWELLING

Beamish and Bouillion were one of the first to report the relationship between major changes in salmon abundance and climate in 1992 (8). They found a trend in the intensity of the winter winds in the North Pacific that matched the total catch of salmon by all countries. Very strong winter winds resulted in more mid-ocean upwelling of colder, nutrient-rich water that was then circulated into the coastal areas resulting in more food production for juvenile Pacific salmon migrating from rivers into the coastal ocean feeding areas. This appears to be the first explanation for large-scale changes in the ocean carrying capacity for Pacific salmon that was related to climate.

REGIME SHIFTS

The Pacific Ocean also experiences large-scale climate changes called regime shifts. The regime shifts are abrupt and vary in magnitude. In 1976-77, a regime shift had a massive impact on the ocean's ecosystems (9). In the Bering Sea, the ecosystem changed from a dominance of shrimp to a dominance of fishes with huge increases in the production of salmon, Pacific cod, walleye pollock, and halibut (9).

What we need to do in an emergency

Understand that the Pacific Ocean is a massive ecosystem that is responding to climate change in powerful ways that we do not understand.

It is possible that the ocean carrying capacity for salmon started to decrease at the southern limits of the range of salmon off the coast of British Columbia shortly after this regime shift. It may turn out to be an unfortunate coincidence that the year salmon enhancement program started was the year of the largest known regime shift in the North Pacific. The reason for these abrupt changes in ocean ecosystems remains to be discovered.

There were other regime shifts in 1989, 1998 and possibly in 2007 that had more regional impacts on salmon and some other fishes. While the reasons for the regime shifts are not known, it has been hypothesized that changes in wind patterns, ocean circulation and salinity affect plankton food webs, ultimately affecting Pacific salmon abundance. A well-documented regional impact is a synchronous decline in ocean survival of coho salmon in the Strait of Georgia, Puget Sound, and off the coasts of Washington and Oregon (10). Marine survivals of coho declined to about 1% in 1995 from 11% in the late 1980s and even higher levels in the 1970s. It is reasonable to accept that these abrupt regime shifts will continue.

THE "BLOB"

A recent climate-related ocean change that affected the capacity to produce salmon was the large-scale warming in the Gulf of Alaska and off the west coast of North America from 2014 to 2019. This vast area of warming was unprecedented and commonly known as "the blob" (Figure 13). There is no consensus for the cause, although there is some evidence that it relates to a weakening of the winter winds with less upwelling of cold water in the central North Pacific Ocean. This warming would affect salmon survival in the open ocean. If the cause was the weakening of winter winds, there would be a reduction in nutrients circulated into coastal areas that are necessary for plankton production. A reduction in coastal plankton would reduce growth and reduce ocean survival.

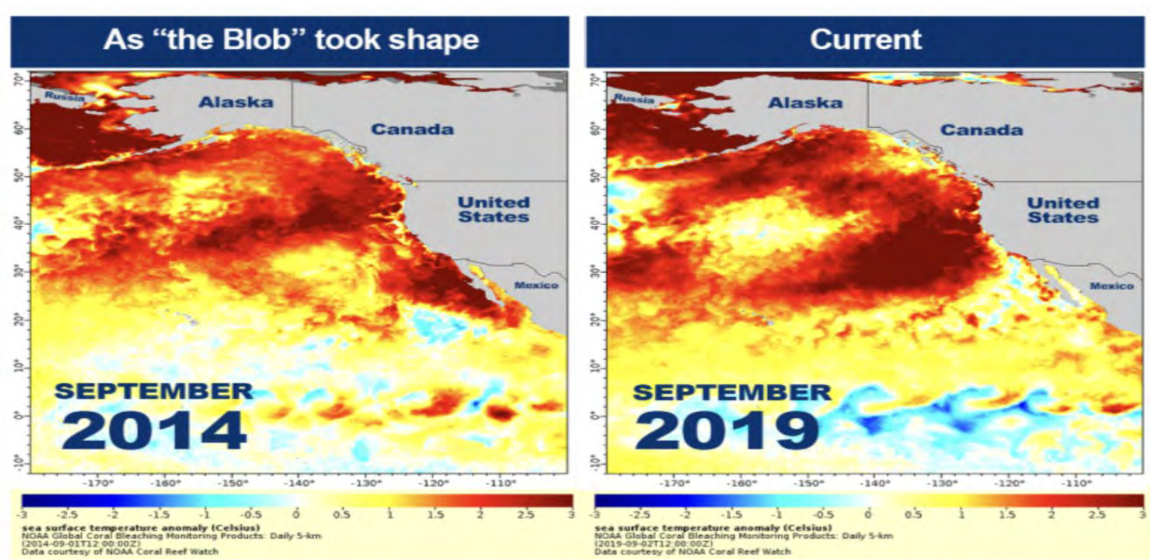


Figure 13. Area of ocean warming events.
Data courtesy of NOAA California Current Integrated Ecosystem Assessment (2)

GLOBAL WARMING IS OCEAN WARMING

There is no question that greenhouse gas increases are changing the climate. Warming affects freshwater habitats as well as ocean habitats for salmon. However, a major impact is the large-scale warming of the ocean feeding areas for salmon. Latent heat in the ocean is closely related with the planet's heat balance. This heat content is rapidly increasing with more than 90% of the excess heat produced through "global warming" being absorbed in the ocean. The measures of ocean heat content show a continued increase from about 1995 to the present (Figure 14). This is an increase to a depth of about 2000 m.

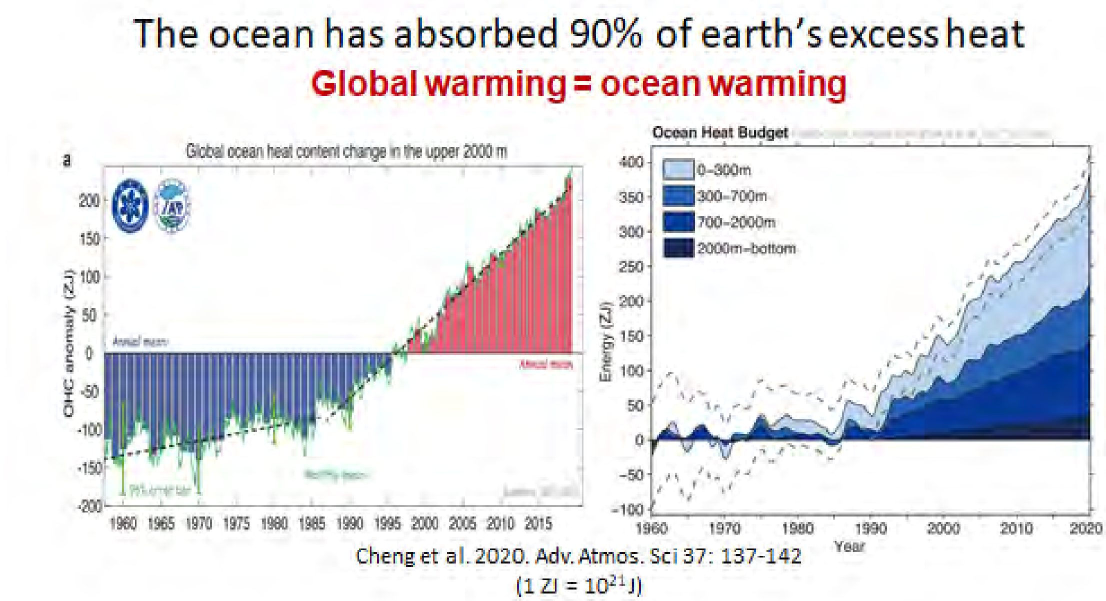


Figure 14. Increase of global ocean heat content.
Source: Record-Setting Ocean Warmth Continued in 2019 (11)

THE RECIPE FOR SURVIVAL THAT HAS WORKED FOR MILLENIA

Pacific salmon evolved hundreds of thousands of years ago and still are here, despite numerous changes to the planet, including glaciers. We know that about 15,000 years ago British Columbia was mostly covered in ice. As glaciers retreated, salmon moved into the developing rivers from the south and north and perhaps even from the east. It is well known that salmon home to their spawning rivers and specific spawning areas within the river. However, the very small percentage of the population that strayed into other rivers allowed salmon to expand into areas that became available as glaciers retreated.

Historically, some Pacific salmon stocks moved southward as glaciers advanced. When glaciers retreated, some stocks moved into the developing rivers. Today, some stocks are likely moving northward to avoid warming temperatures.

Photo by Brian Kingzett

In a general way, the natural regulation of Pacific salmon would be to "over fill" the capacity of the ocean to produce salmon with tens of thousands of populations originating from freshwater that varied in their ability to survive in the ocean.

What we need to do in an emergency

Recognize that stock diversity has always been the recipe salmon have used to survive ecosystem changes in freshwater and ocean habitats. We need to learn how different stocks use their ocean habitats.

As the ocean conditions changed, different groups of populations would survive better than others and dominate the aggregate of abundances. These dominating populations could also produce even better adapting populations. Notably, the populations that were less able to survive in current ocean conditions would diminish in abundance but would not disappear. These populations could essentially wait their turn for the ocean conditions to change and become more favourable.

By the early 1960s it was recognized that all species of salmon were made up of many separate subpopulations that are called stocks (12). The stocks exist in genetic isolation and this isolation preserves life history differences such as migration times, spawning times, spawning areas, growth, and other life-history traits. Stock diversity is recognized as key to their ability to survive ecosystem changes both in freshwater and the ocean (Figure 15).

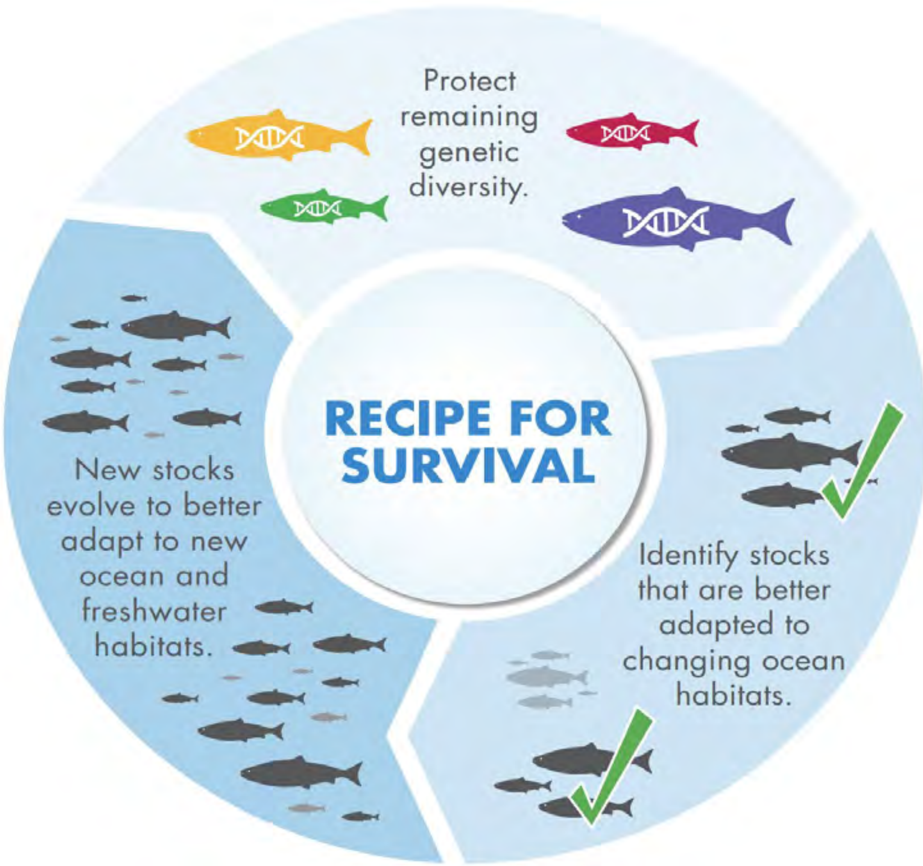


Figure 15. Genetic diversity has been the recipe for survival for Pacific salmon for millennia.

The abundance of Pacific salmon species is regulated by an ability to form distinct and genetically isolated populations while, at the same time, testing out new freshwater spawning areas. It is proposed by some scientists that the stock concept of utilizing and "testing new habitats" must also apply to how salmon use ocean habitats. However, we understand very little about adaptations to ocean habitats because we have very limited understanding of how salmon use the ocean.

The collapse of the abundance of BC Pacific salmon stocks threatens the recipe for survival. It is possible that the remaining stocks have enough diversity to continue and perhaps they are already adapting to changing ocean habitats.

There are reasons to hope. For example, scientists have recently discovered that a small number of populations of Chinook salmon from the south Thompson River are surviving better than many other Chinook salmon populations that enter the Strait of Georgia as smolts because the South Thompson populations enter the ocean 6 to 8 weeks later than the other populations (13).

PACIFIC SALMON ABUNDANCE HAS ALWAYS BEEN CONTROLLED IN THE OCEAN

Pacific salmon have historically been abundant because they rear in the ocean. If they were confined to fresh water, such as cutthroat trout, their abundances would be substantially smaller. Freshwater provides a safe spawning area for all salmon and a safe rearing area for juveniles. Freshwater is less important as a rearing area for pink and chum salmon as they quickly leave rivers after emerging from the gravel in the early spring.

What we need to do in an emergency

Understand that a decline in ocean carrying capacity may not be fixed by adding more fish into the sea.

If food density in the ocean is limiting survival, adding more juveniles above a threshold may reduce the number of adults and their size.

It is a basic principle in ecology that the abundance of plants and animals that produce many seeds or babies is regulated by available habitat, not the number of seeds or offspring. Salmon are a species that produce many eggs. Freshwater habitat is important, but the ocean's vast feeding and rearing areas represent the major "available" habitat for salmon.

We know that survival in ocean habitat is the major factor for salmon abundance. Generally, good ocean survivals are about 3% for chum, 5% for pink, 5% for Chinook, and about 7% for coho and sockeye salmon (14). A small change in ocean survival makes a big change in adult abundance.

The importance of feed in the ocean cannot be understated. There is a hypothesis that juvenile fish that grow faster in the first months in the ocean not only avoid predation but may also grow to exceed a threshold size or energy level by a critical calendar date cued by an external signal such as day length. If the threshold size is exceeded by a critical period, the fish may have a metabolic change that begins to store more energy as lipids to better survive the winter. Fish that do not exceed a threshold by a critical period may continue to survive, but they may be "dead fish swimming" as they are less likely to survive the first ocean winter.

BC PACIFIC SALMON IN THE HIGH SEAS

Photo by Bill Pennell

PINK AND CHUM SALMON

Pink and chum salmon are the most abundant Pacific salmon in British Columbia and generally represent about 55% of the total catch in the past 50 years. Total returns of these species have been poor in some areas since 2007 and in most areas since 2015. There are some exceptions. There were particularly poor returns in 2019, 2020 and 2021 and an exceptionally large return of pink salmon in 2023.

> The basin wide large abundance of pink salmon in 2023, that may result in a historic high commercial catch by all countries, is another illustration that large scale climate and ocean events affect the ocean survival of salmon. The synchrony of improved survival of pink salmon in 2023 also is an example that there is a common mechanism involved.

The large return of pink salmon in 2023 coincided with exceptional pink salmon returns in Russia and Alaska. As pink and chum salmon spend almost all their life in the ocean after they emerge from the gravel, the changes in abundances would result from large-scale changes in the ocean capacity to produce British Columbian pink and chum salmon.

Very little is known about what affects the survival of pink and chum salmon in the ocean off the coast of BC. High seas surveys of the winter ecology of salmon in the Gulf of Alaska in 2019, 2020 and 2022 have shown that pink salmon probably spend the winter in the warmer southern areas off the coasts of southern Vancouver Island, Washington, and Oregon. We also now know that BC pink and sockeye salmon distributions mostly do not overlap in the winter contrary to past interpretations. The reasons for the basin-wide exceptional production of pink salmon in 2022-23 remain to be explained but pink salmon are both benefitting and suffering from warming oceans. This highlights the urgency to understand the ocean life of pink salmon.

Photo by Brian Kingzett

Chum salmon mostly return to rivers in BC after spending four years in the ocean, with ranges of ages from three to five years. Commercial catches from 1925 to 2000 averaged about 18,000 metric tonnes. There was a decline in this average to about 8,000 metric tonnes from 2001 to 2018. The average commercial catch from 2019 to 2021 was 933 metric tonnes. The commercial catch in 2022 was only 180 metric tonnes.

Returns to the Fraser River have been poor since 2008, with very poor returns in 2019 and 2020. Returns to the mainland inlets and northeast Vancouver Island were very poor in 2019 and 2020. Farther north, returns of chum salmon to the Nass River were low from 2008 but may be improving in recent years. A recent study of spawning abundances of 25 populations in the central coast reported that there has been about a 90% decline in abundances since 1960 (15). The authors advised that "*the staggering decline of chum salmon we document here serves as a stark reminder of the dangers of inaction*".

Chum salmon commercial catches in British Columbia historically were the largest catches by weight and the collapse in 2022 represents about 1 % of the average annual catches from about 1950 to 1990. A similar decline in production occurred in Japan.

COHO SALMON

The coho salmon commercial fishery mostly collapsed after 1999. Efforts were made to increase spawning abundances, particularly for populations in the interior Fraser River; however, returns continued to decline on the south coast from 2015 and north coast since 2018.

> We now know that the carrying capacity of the Strait of Georgia to produce coho salmon controls their abundance. We need to learn the mechanisms that influence plankton food webs in the ocean.

A 20-year study of juvenile coho salmon in the Strait of Georgia showed a close relationship between early marine survival and plankton/food production (6). Beginning in 2007, a trend of increasing food abundance (plankton production in the ocean) that was related to an increase in the size and abundance of juvenile coho salmon was recorded. The increase was not related to the number of spawning coho salmon above a threshold minimum number of spawners. It was clear that the Strait of Georgia's capacity to produce coho salmon was regulating the abundance and not the number of smolts entering the ocean (above a threshold number). **It was also found that a 50% reduction in hatchery releases of coho salmon over the study period did not change the number of hatchery fish surviving to the end of the first ocean year.** Abundances of coho salmon continued to increase in the Strait of Georgia after 2009, with an abundance in 2023 that appears to be the largest in 30 years. This increase appears to relate to a regime shift like an increase in food production in the Strait of Georgia starting about 2008.

CHINOOK SALMON

Photo by Chris Walling aka Steel_snorkel

Chinook salmon abundances are declining throughout most of their distribution from Alaska to California (16) (17). Scientists are now reporting that climate and ocean changes are mostly responsible for the declines, and a dramatic increase in juvenile ocean survival is required to compensate for the losses (18). However, these authors also concluded that there is poor understanding of the mechanisms regulating Chinook salmon ocean survival.

In 2020, Wells et al. reported that there are several mechanisms in the ocean that affect the survival of Chinook salmon and they provided an example of predation (19). There is no doubt that predation can be a source of ocean mortality, but a basin-wide decrease in the ocean survival of Chinook salmon is unlikely a result of a simultaneous basin-wide increase in abundance and diversity of predators. There needs to be a more basin-wide mechanism.

Early in the marine life of Chinook salmon, a reduced growth rate has been linked to declining ocean survival of Chinook salmon populations in Alaska (20) and in Puget Sound (21). Thus, a mechanism fundamental to ocean survival appears to be related to growth in the early marine period. The need to discover the mechanisms becomes apparent in the predictions of a continued warming of the surface waters of the North Pacific Ocean with probability of frequent extreme states as realized in 2014 (22).

We now know that some populations of Chinook salmon survive better in the ocean than others. We need to discover the mechanisms influencing survival in the early marine period.

SOCKEYE SALMON

Sockeye salmon are the most highly valued commercial salmon species in BC. Abundance has declined since 2015-2016 (Figure 16). The very poor total return of 900,000 sockeye salmon to the Fraser River in 2009 resulted in the multiyear Commission of Inquiry into the Decline of Fraser River Sockeye Salmon Cohen Commission. Justice Cohen was looking for a "smoking gun" or reason for the decline in sockeye salmon to fix it. He concluded that the decline in returns in 2009 was a result of poor ocean and climate conditions when the smolts went to sea in 2007 (23).

Photo by Bill Pennell

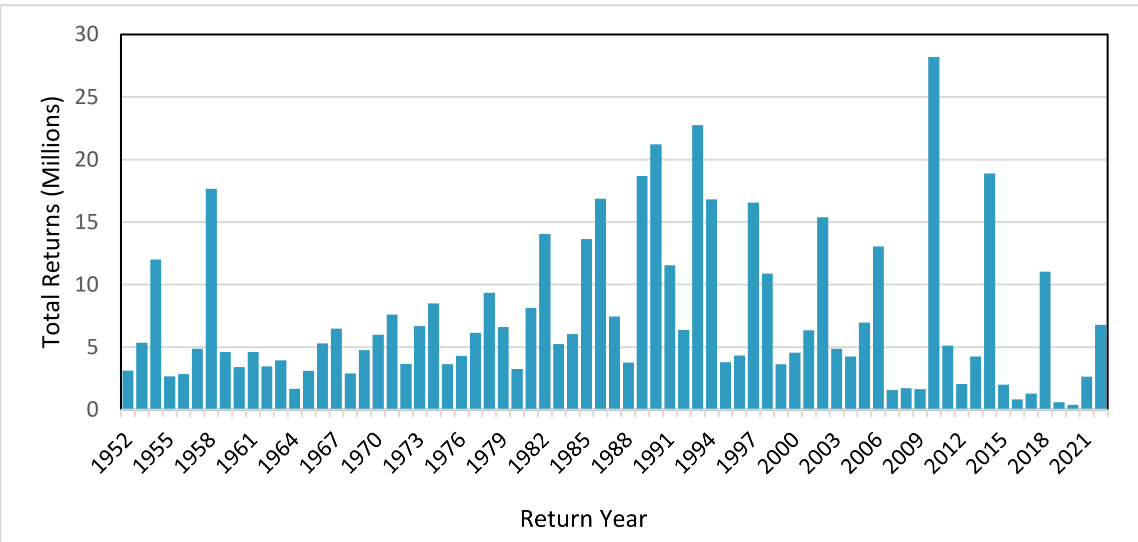


Figure 16. Total return (catch plus spawning adults) of sockeye salmon to the Fraser River in millions of fish 1952–2022.
Source North Pacific Anadromous Fish Commission (2)

Fraser River sockeye salmon predominately live for 4 years and produce a series of distinct 4-year cycles (24). One of these years is a persistent large dominant brood year as in 2018, 2014, 2010, 2006, 2002, 1998, 1994, 1990 etc. There is a second year with a smaller, subdominant abundance and two years of low abundance. There have been changes in the dominance within the pattern, but the 4-year pattern persists. There have been attempts to explain the biological basis for the pattern, but there is no consensus (24).

Scientific studies showed that there was poor plankton production in the Strait of Georgia in the spring of 2007. Other species of salmon also had poor survival in 2007 and there was almost a complete failure of larval Pacific herring that year.

Thus, there was scientific evidence that the very poor ocean conditions caused poor plankton production that reduced the growth of juvenile Fraser River sockeye in their first ocean year in 2007 that resulted in poor survival.

"I am also satisfied that marine conditions in both the Strait of Georgia and Queen Charlotte Sound in 2007 were likely to be the primary factors responsible for the poor returns in 2009. Abnormally high freshwater discharge, warmer-than- usual sea surface temperatures, strong winds, and lower-than-normal salinity may have resulted in abnormally low phytoplankton and nitrate concentrations that could have led to poor zooplankton (food for sockeye) production". The Honourable Bruce I. Cohen, Commissioner, The Uncertain Future of Fraser River Sockeye, vol. 3, p. 59.

Photo by Brian Kingzett

We are now recognizing a major reduction in the average size of spawning sockeye salmon throughout their distribution. In 2022, there were record catches of sockeye salmon in Alaska, but the fish were also at record-low sizes. Smaller sockeye are also returning to BC's Skeena and Fraser rivers as well as to Alberni Inlet. The decline in size of sockeye identifies a reduction in food available to sockeye in their last year in the ocean. The reduction could result from reduced food production, increased competition for food, or both. The similarity in trends from Alaska to British Columbia shows that large scale changes in growth are occurring in trends in the ocean. These declines in size also result in a reduction of eggs produced during spawning.

WE NEED TO THINK IN NEW WAYS

"When we eventually see the bigger picture, we will finally understand the simple mechanisms that regulate abundances and wonder why it took so long" Dr. Richard Beamish, Canadian Scientist.

We are unlikely to solve problems using the same approaches that got us to this point in the first place. Now is the time to recognize that in addition to our ongoing stewardship we need to think in new ways.

We have a lot to learn about these wonderful creatures we call Pacific salmon. To conserve wild salmon, we need to understand their full life cycles – from stream – to ocean – to stream. We need to see a bigger picture. This will require international cooperation and efforts from the five Pacific salmon producing countries. It will also require strong leaders to ensure that the necessary work gets done. We will eventually identify the mechanisms linking climate and ocean changes to salmon production; however, we will get there faster if we work together as teams.

Photo by Brian Kingzett

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CHAPTER 3

CARING FOR WILD SALMON

THE LOCAL PICTURE






This document summarizes some of what is known about the condition of local salmon habitat in British Columbia and discusses important initiatives that may help conserve salmon

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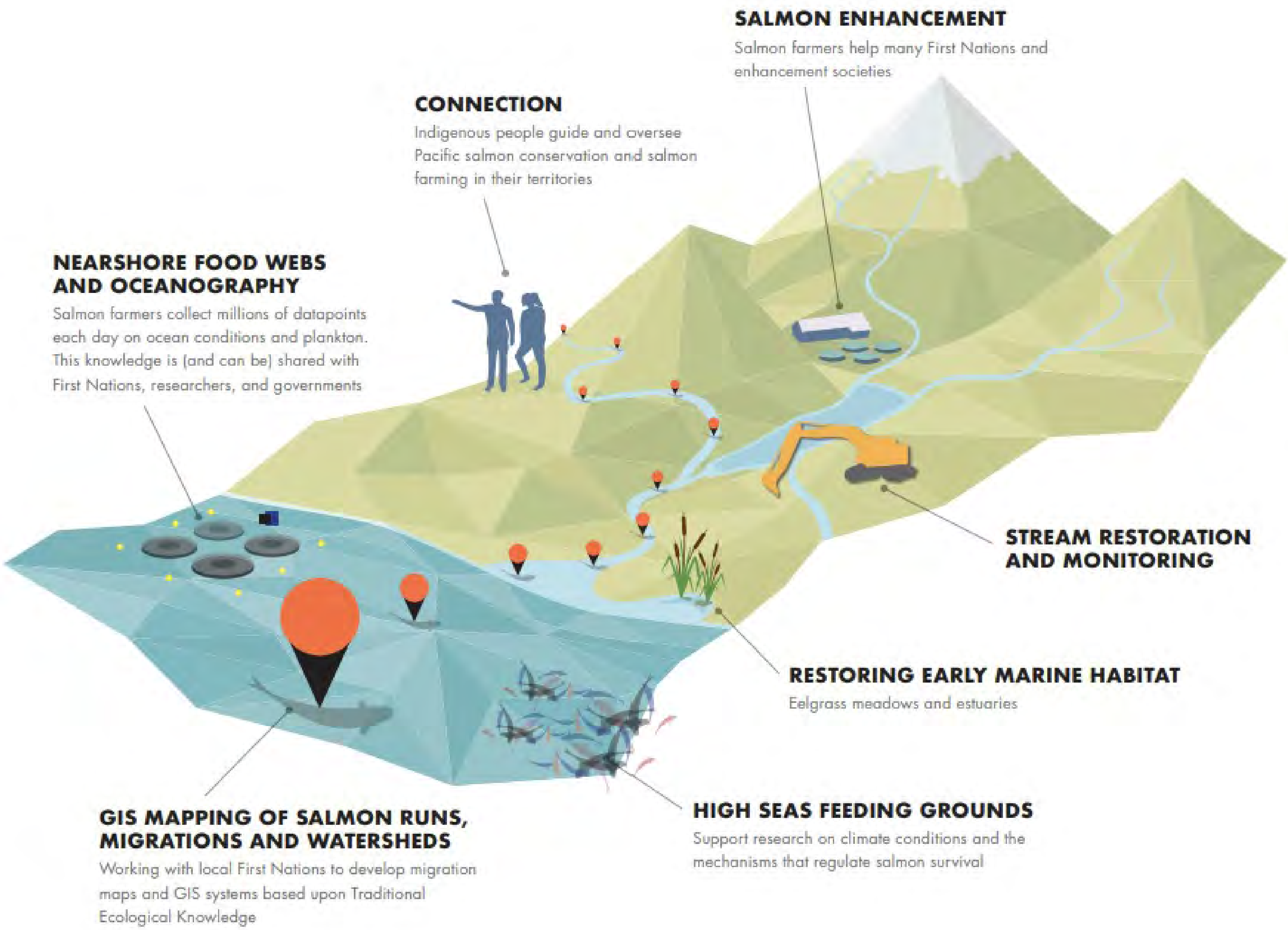
CHAPTER HIGHLIGHTS – CARING FOR WILD SALMON - THE LOCAL PICTURE

Wild Pacific salmon spend a portion of their lives within British Columbian watersheds and nearshore environments. There are conservation efforts that can be carried out locally to aid in their preservation.

Salmon farmers are uniquely positioned to help with conservation initiatives, given our expertise in salmon and oceanography and year-round presence in coastal BC waters.

The salmon farming sector has been actively involved in Pacific salmon conservation projects with First Nations, the scientific community, the Department of Fisheries and Oceans (DFO), and local coastal communities for many years.

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