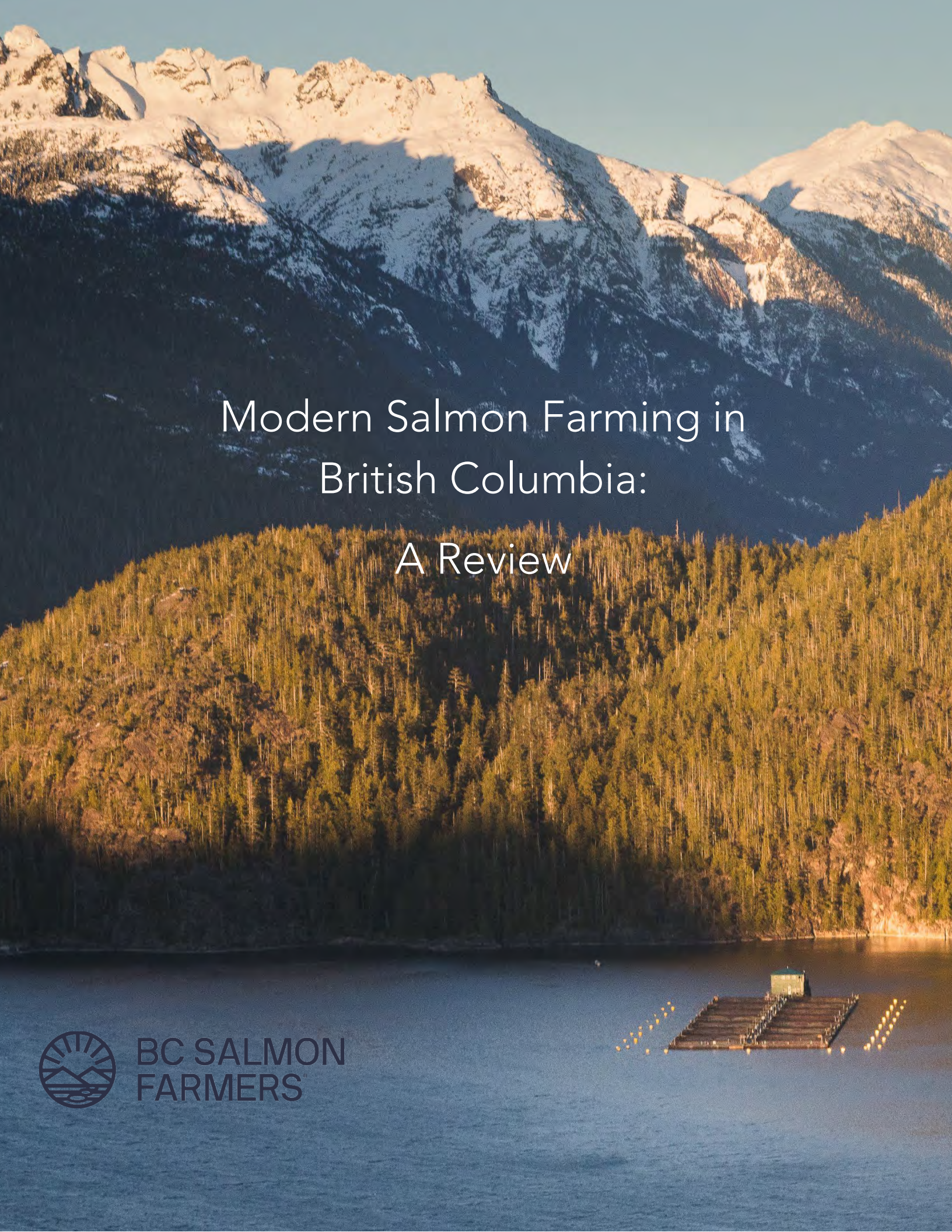




Modern Salmon Farming in British Columbia: A Review



BC SALMON
FARMERS



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Citation: BC Salmon Farmers Association. 2024. Modern Salmon Farming in BC: A Review. BC Salmon Farmers Association, Campbell River, British Columbia. 518 pages. available at www.bcsalmonfarmers.ca

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FORWARD BY DALLAS SMITH



When First Nations leaders are provided with fulsome and transparent information, they are positioned to make the best decisions for their communities, membership, and territories.

When they do not have that information, or that information is lacking, decisions based on misunderstood issues, like salmon farming, often lead to divided communities and quarrels within the membership. The concept for this publication, *Modern Salmon Farming in BC: A Review*, stemmed from this scenario.

What started as a request from First Nations leaders for better information on salmon farming to take back to their communities evolved into a 500+ page publication built by topic specialists. From wild Pacific salmon scientists, biologists, benthic experts, feed specialists, food safety experts, regulatory experts and veterinarians, this report has engaged with authorities across many fields to create the

most fulsome collection of information possible on the current state of wild salmon, their environment, and finfish aquaculture in BC.

Modern Salmon Farming has become a rich resource that we, First Nations leaders, can present to our communities, knowing that we can trust the detailed information it contains and, therefore, make better decisions for operations and conservation efforts in our waters. This report will help encourage more meaningful dialogue within our membership as we, as coastal communities, build and roll out our marine management plans.

It can also help other Nations better understand why some of our communities include finfish aquaculture in our marine management operations. As contentious and misunderstood as the topic is, we do not question why other First Nations might be upset by our decision to host finfish farms; instead, we question why they wouldn't be. There just has not been enough detailed and transparent information in one place for them to access and understand – until now.

To avoid appropriation, the Coalition developed and authored Chapter 4: Connecting with First Nations, the Original Stewards of the Coast. You will notice that, at this chapter, the voice of the document shifts from first to third person.

It is our hope that this document can answer some of those Nations' questions



and concerns and, therefore, enable us to have more constructive Nation-to-Nation dialogue in the future as the sector transitions in our territories under our watch and with our guidance.

As neighbours and communities that share access to wild salmon, we understand our role in protecting that precious resource and reiterate that, as salmon people, there is nothing more important to us than protecting the lifeblood of our coast. We also know that having access to the most detailed and current information on both salmon and the environment will arm us with more ways of revitalizing and protecting them.

We have been the stewards of our lands, waters, and elements since time immemorial on this coast. The traditional knowledge we hold and pass on to future generations is invaluable to us, but only now is its value being understood and acknowledged by others, like governments, scientists, and companies that operate in, or rely on, our territories.

By blending our traditional ecological knowledge with the Western science and methodology highlighted in this report, Indigenous peoples can paint the most fulsome picture of what is happening in our waters, including understanding and

monitoring the impacts of industries and better predicting and combatting climate change. Working together in this way, we can conserve and preserve our marine space while building up our ocean-based economies and economic autonomy. We strongly believe both can exist in the same space.

While there is so much more work to be done to understand our oceans and the operations that impact them, this report is a good start. We are grateful to the BC Salmon Farmers Association and all the contributors who went above and beyond to create this report for our communities.

Gilakasla,

Dallas Smith
Spokesperson, Coalition of First Nations for Finfish Stewardship



FORWARD BY BRIAN KINGZETT

Welcome to , *Modern Salmon Farming in BC: A Review*, a comprehensive report dedicated to shedding light on the world of salmon farming in the beautiful province of British Columbia. This report aims to provide clarity and transparency by utilizing data, research findings, and input from many researchers, scientists, and subject matter experts to address thirteen distinct topics related to salmon farming in BC.

Modern Salmon Farming started with the request from the First Nations, whose territories we operate in, to be provided transparent information about the sector so they can make the best decisions for their communities and territories. *Modern Salmon Farming* aims to be a valuable resource for all individuals seeking to understand the reality of salmon farming in British Columbia comprehensively. This report endeavours to foster transparency, encourage open dialogue, and contribute to the sustainable development of this important sector.

Salmon farming plays a crucial role in British Columbia's economy, environment, and food production. However, it has also been a subject of intense scrutiny, with various perspectives and concerns. With *Modern Salmon Farming*, we strive to delve into these topics with an informative approach, empowering readers with the knowledge needed to make well-informed decisions and foster constructive conversations surrounding this vital sector.



This project took over a year to complete, and I would personally like to thank the many researchers, subject matter experts both internal and external to the sector, as well as First Nations, who took the time to contribute and review *Modern Salmon Farming* and provide their expertise in order to build this project.

We will look forward to updating this document as new information becomes available. Thank you for your taking an interest in this sector.

Brian Kingzett, M.Sc., MBA
Executive Director
BC Salmon Farmers Association



**BC SALMON
FARMERS**



FORWARD BY DR. AHMED SIAH

Our goal at the BC Centre for Aquatic Health Sciences (CAHS) is not only to advance our understanding of aquatic sciences, but also to honour the Indigenous peoples who have lived in harmony with nature for generations. We aim to harness the strength of inclusion, collaboration, innovation, and above all, respect for the land and its people.

At CAHS, we strongly feel like this collaborative effort, *Modern Salmon Farming in BC: A Review*, aligns with many of our values, goals, and priorities at CAHS, and serves as an inspiring example of what happens when First Nations are given a leadership seat at the table of Western science, especially when it concerns their traditional territories.

Located in the territory of the Laich-kwiltach-speaking peoples and operating in the territories of the Wei Wai Kum and We Wai Kai First Nations, CAHS, now an Indigenous-governed organization, is dedicated to offering science-based insights, particularly exploring the relationship between wild salmon and Indigenous cultures in the context of climate shifts and aquaculture.



Moving forward, we aim to cultivate a grassroots Indigenous-led scientific capability, dedicated to fostering scientific knowledge and promoting understanding regarding the preservation of wild salmon, innovation in industry stewardship, and the critical monitoring of environmental and aquatic animal health in the context of shifting oceanic dynamics and climate variations. Through this approach, we endeavor to establish a robust framework for evaluating emerging marine-driven economic opportunities, while also prioritizing environmental conservation and meeting cultural needs for future generations.

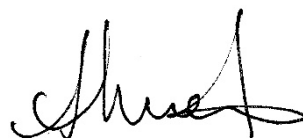
Central to this endeavor is the acknowledgment of the invaluable contributions of Indigenous knowledge and scientific insights to our comprehension of the aquatic ecosystem. Through collaborative and open research, hands-on learning, and active community engagement, CAHS aims to bridge the gap between traditional knowledge and contemporary scientific methodologies, fostering a holistic understanding of experiential.

Moreover, CAHS serves as a dynamic platform for dialogue and exchange, inviting individuals, corporations, organizations, Guardians and First Nation groups from diverse backgrounds to engage with Indigenous Elders, Chiefs, scientists, industry and community leaders in discussions about conservation, sustainability, industry prospects and preserving traditional cultures. Through these exchanges, we aspire to foster a greater sense of stewardship of our natural resources and an appreciation of the connectivity of all living beings in the contemporary era.

Modern Salmon Farming is a great step in this process of building trust, transparency, and collaboration between Indigenous communities, Western

Science, and industry. The future in this regard is an exciting one, as is the future of CAHS which is in its own transition into iCAHS, the Indigenous Centre for Aquatic Health Sciences & Stewardship.

I invite you to join iCAHS and the First Nations with whom we work on this extraordinary journey that will lead us all towards a more sustainable and harmonious future for generations to come.



Dr. Ahmed Siah
Managing Director,
BC Centre for Aquatic Health Sciences
<https://www.cahs-bc.ca/>





GUIDE TO CHAPTERS

Each chapter in this document has been written as a stand-alone document to ease access and reading of the materials.

CHAPTER 1 – CARING FOR COASTAL BRITISH COLUMBIA

This document summarizes how salmon farming brings positive benefits to coastal British Columbia by operating in harmony with Indigenous peoples, coastal ecosystems and communities. This chapter summarizes all the following chapters.

CHAPTER 2 – CARING FOR WILD SALMON: THE BIG PICTURE. WHAT IS HAPPENING TO BRITISH COLUMBIA SALMON IN THE OCEAN

This document summarizes some of what is known about the ocean life of Pacific salmon and may forge a pathway towards a more rewarding stewardship.

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.

CHAPTER 4 - CARING FOR INDIGENOUS STEWARDSHIP. CONNECTING WITH THE ORIGINAL GUARDIANS OF THE COAST

This document describes some of the history of First Nations stewardship of coastal British Columbia and discusses how conservation and guardian initiatives can support marine-based economic opportunities for Indigenous communities.

CHAPTER 5 – CARING FOR THE ENVIRONMENT. PREVENTING ESCAPES

This document describes important measures salmon farmers take to prevent escapes and discusses what is known about the likelihood that farm-raised salmon will be established in British Columbia.

CHAPTER 6 – CARING FOR THE ENVIRONMENT. MINIMIZING INCIDENTAL CATCH

This document describes the measures salmon farmers take to minimize interactions with wild fish and provides important statistics on the incidental catch at farms in British Columbia.

CHAPTER 7 – CARING FOR THE ENVIRONMENT. FEED SUSTAINABILITY

This document describes the feed and feeding practices at salmon farms and discusses important sustainability initiatives.

CHAPTER 8 – CARING FOR THE ENVIRONMENT. PROTECTING BIODIVERSITY

This document describes important measures salmon farmers take to protect biodiversity and discusses what is known about the effects on the seafloor beneath the cages and along the shoreline.

CHAPTER 9 – CARING FOR THE ENVIRONMENT. MINIMIZING WILDLIFE INTERACTIONS

This document describes measures salmon farmers take to minimize interactions with wildlife interactions at farms in British Columbia.

CHAPTER 10 – CARING FOR WILD SALMON. SEA LICE MANAGEMENT

This document describes sea lice management at salmon farms and discusses important results from juvenile wild salmon feedback loops.

CHAPTER 11 – CARING FOR FISH HEALTH

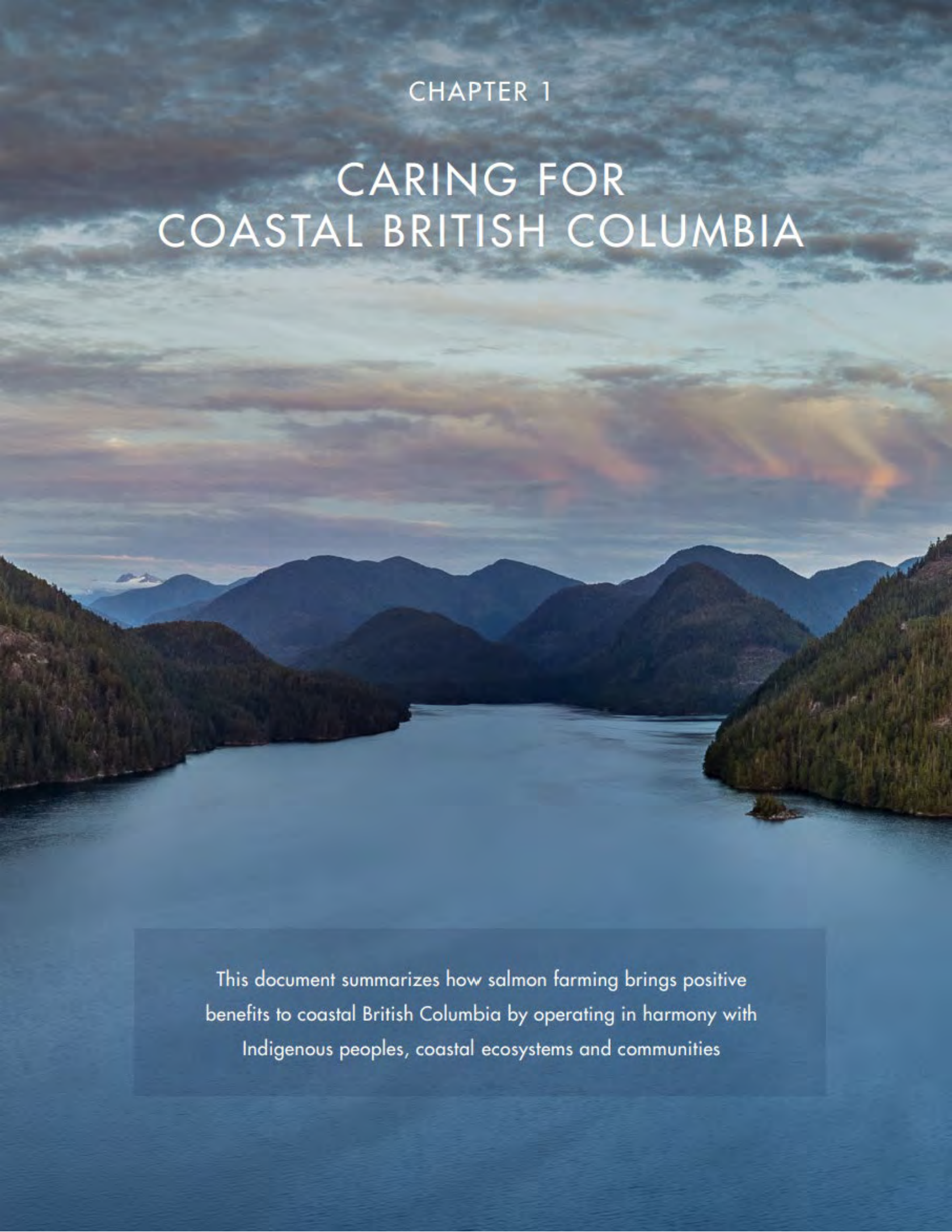
This document describes holistic measures that keep salmon healthy now and into the future.

CHAPTER 12 – CARING FOR COMMUNITIES. FOOD SAFETY AND SECURITY

This document describes the health benefits of farm-raised salmon and measures farmers take to ensure food safety.

CHAPTER 13 – CARING FOR COMMUNITIES. SALMON AQUACULTURE IN COASTAL COMMUNITIES

This document describes the benefits to communities from salmon farming in coastal British Columbia.



CHAPTER 1

CARING FOR COASTAL BRITISH COLUMBIA

This document summarizes how salmon farming brings positive benefits to coastal British Columbia by operating in harmony with Indigenous peoples, coastal ecosystems and communities

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BC FARM-RAISED SALMON



Community

1000's of coastal jobs, with a diverse and skilled work force and support for up to 375 community organizations and charities each year



Indigenous Reconciliation

100% of farm-raised salmon in BC is raised in partnership with local First Nations



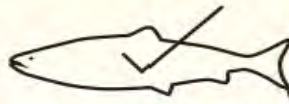
Climate Friendly

Farming the ocean identified as one of the five priorities to address climate change, with the power to help reduce global climate emissions by up to 20%



Food Security

\$1 billion dollar economy activity - BC's top seafood and agri-food export - producing 38 million meals per year



Transparency and Third-Party Certification

Site performance data is publicly available and all salmon raised in BC farms is subject to third-party certification programs



Superfood

Salmon is packed with essential vitamins, minerals, protein and long-chain omega-3-fatty acids



Farm-raised Salmon are Healthy

Dedicated fish health teams apply robust veterinary safeguards that keep farm-raised salmon healthy, minimizing potential interactions with wild salmon



Wild salmon

Support wild salmon conservation and 27 enhancement societies and communities



Continual Innovation

In veterinary medicine and practices; farms and feeding with transferable technologies to other aquaculture and ocean industries



Food Efficiency

About 1 to 1.5 million pounds of salmon per hectare with an average 3-month fallow between each crop

Far less land, feed, and freshwater compared to farming pork or beef



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INTRODUCTION

BC salmon farmers believe our role is to grow salmon in harmony with nature and the communities of coastal British Columbia. We need healthy oceans to grow our fish. Knowing this, we are focused on being part of the solution for climate change, feeding the world, and conserving wild salmon by taking pressure off wild stocks. We are committed to seeing the ocean and coastal communities thrive and supporting the Nations in whose territories we operate.

In this 13-chapter series, we will discuss the measures and progress we have made to reduce our environmental footprint and increase our community footprint. We will describe practices, equipment, and processes we use to minimize our effects to the surrounding environment and to wild salmon - as well as data evaluating the results of those measures. In this first chapter, we summarize our footprint and innovations, and explain how the salmon farming sector brings positive benefits to coastal British Columbia.





INDIGENOUS GUIDANCE AND STEWARDSHIP

Through generations of close connections with the environment, Indigenous peoples safeguard an estimated 80% of the world's remaining biodiversity (4). Together, the global community has an opportunity to reorient the way it interacts with nature and combat climate change through collaborating with, and learning from, Indigenous peoples, the stewards of nature and their territories.

While, in 2023, not all BC First Nations are fully in support of finfish net-pen aquaculture, many Nations and salmon farming companies are on a journey of reconciliation, developing a range of relationships that recognize the Rights and Title of First Nations in the coastal environment on their own terms (Figure 1) (5).



Figure 1. Kitasoo Xai'xais Nations community of Klemtu on the BC Central Coast where one in two households are employed in salmon farming.

Today, 100% of farm-raised salmon in BC is raised in partnership with local First Nations, and the input, guidance, and oversight of First Nations in salmon farming has evolved from generally non-existent to expected.

“Salmon farming is a small drop in the bucket of the overall holistic approach we will take to managing our marine spaces. It is a part of the whole. We will be weaving Indigenous Traditional Ecological Knowledge (TEK) with Western science, while advancing technologies and the oversight of our Guardian Watchmen to help lead aquaculture in Canada, all while benefitting our communities via own-source revenue.” Dallas Smith, spokesperson, Coalition of First Nations for Finfish Stewardship

“The partnership has been tremendous. We have First Nations people from our reserve working on these boats. Plus, many of them are working at the processing plant. It’s absolutely great for our people”. James Walkus, James Walkus Fishing Company.

Repairing, strengthening, and advancing relationships with First Nations has moved to the forefront of priorities for salmon farming companies. In the past two decades, we have formed partnerships and formal agreements in the territories where we operate to increasingly recognize Indigenous interests and needs in supporting their coastal communities. Companies have taken considerable steps to ensure that the future path of the sector is created with First Nations, not apart from them (for example, Gratitude Seafood by Nuu-chah-nulth Seafood Company – Figure 2).

We have also learned that we need to exit the territories where we are not welcomed, and as of 2023, we have done that. As of 2023, 100% of farmed salmon in BC, Atlantic or Chinook, was done in partnership with First Nations.

While there is still work to be done and much to learn, First Nations and the sector are feeling their way forward, and finding that, by working together, transparency, shared best practices, and opportunities can be achieved – and, in

turn, coastal communities and the environment will benefit.



As of February 2022, the sector directly and indirectly employed over 700 Indigenous people, provided \$120 million in total annual direct and indirect economic benefits to First Nations, with \$42 million going directly to Indigenous communities (5). The sector also infused \$24 million annually into Indigenous-owned businesses.

For most of these communities, those benefits cannot be replaced, and the threat of losing them via government closures is a real threat to their social safety. The incomes and economic benefits from salmon farming has the ability to lift entire families away from dependence on social assistance and, by providing meaningful year-round employment, helps prevent significant social issues in communities, including addiction, poverty, and suicide.

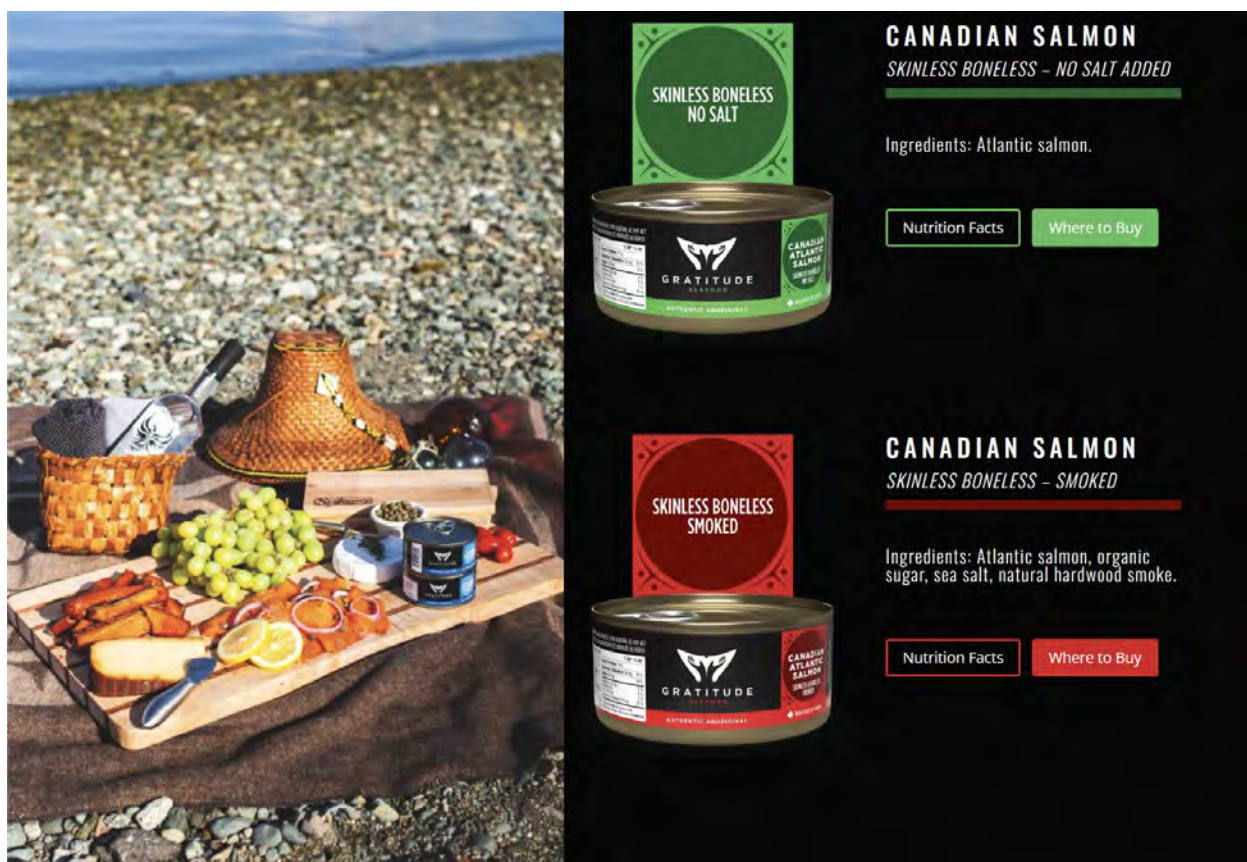


Figure 2. Gratitude smoked Atlantic salmon by Nuu-chah-nulth Seafood.
Source: [Gratitude Seafoods](#) (6)

First Nations involved in finfish aquaculture are finding unique ways to not only benefit from the sector, but to create Indigenous-led business opportunities from their partnerships. Indigenous-led businesses include processing & value-added opportunities, (smoked and canned salmon), transport boats, crew boats, and net washing services.

In communities like Klemtu, located 800km north of Vancouver, the Nation has

found a way to lead and benefit from the entire farm-to-table process thanks to their own early venture into salmon farming in the 1990s. This led to a partnership with a global company (Mowi) in exchange for their expertise in net-pen aquaculture and feeding. Today, Mowi and the Kitasoo Xai'xais have the longest-standing salmon farming agreement in Canada. Today, the installation of a smokehouse by their partner, Mowi, has gifted the Nation a value-added product now sold across North America. (Figure 3).

“Fifty-one per cent of our economy is fish farms. We would go back to the 70s – alcoholism, all those social issues. Hearing from other leaders about the suicides that were just rampant, I, as a young leader, do not want to go down that path”. Isaiah Robinson, Councilor, Kitasoo Xai'xais Nation

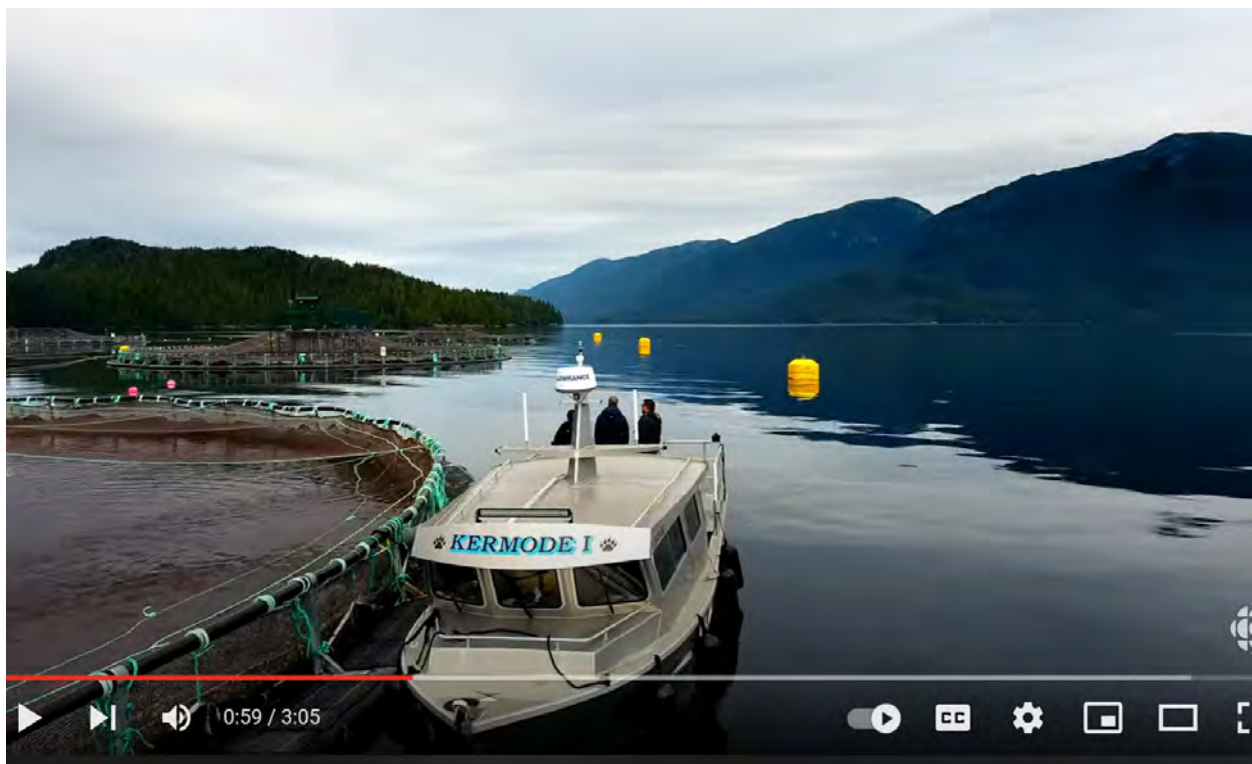


Figure 3. Farmed salmon from Kitasoo Xai'xais: raised to preserve local natural resources | We Are The Best - YouTube



CONNECTING WITH COASTAL COMMUNITIES

Salmon farmers live and work in many coastal communities in British Columbia. People involved with salmon farming raise families, are involved in community events, socialize and have developed relationships with their neighbours, friends, and colleagues in these communities.

Farmed salmon is BC's number one seafood commodity export and its top agri-food commodity export. The average sector wage is 30% higher than the provincial median employment income. These jobs are typically created in areas of higher unemployment, particularly North Vancouver Island (7). A June 2023 report for BCSFA estimates that the salmon farming sector currently generates approximately \$1 billion in total economic activity, \$358 million in GDP, and \$223 million in income for families within BC annually, and creates 3,950 good paying jobs in the province (8).

Salmon farms are sprinkled along the BC coastline, in total, 13 hatcheries and 82 sea sites. Although the actual footprint of farms in the ocean is extremely small (less than the size of Stanley Park in Vancouver), the community footprint is large (Figure 4).



Each year, BC salmon farmers support hundreds of individual initiatives for education, health and well-being, arts, and sports. In 2018, BC salmon farmers made 375 contributions to organizations and charities, totaling over \$750,000 and over 30,000 pounds of farm-raised salmon.

Salmon farmers also support habitat restoration and conservation efforts during all life stages of Pacific salmon (watersheds, estuaries, near shore and high seas). This includes funding and/or collaborating with 27 enhancement societies and communities in BC.

For more information see Chapter 13.

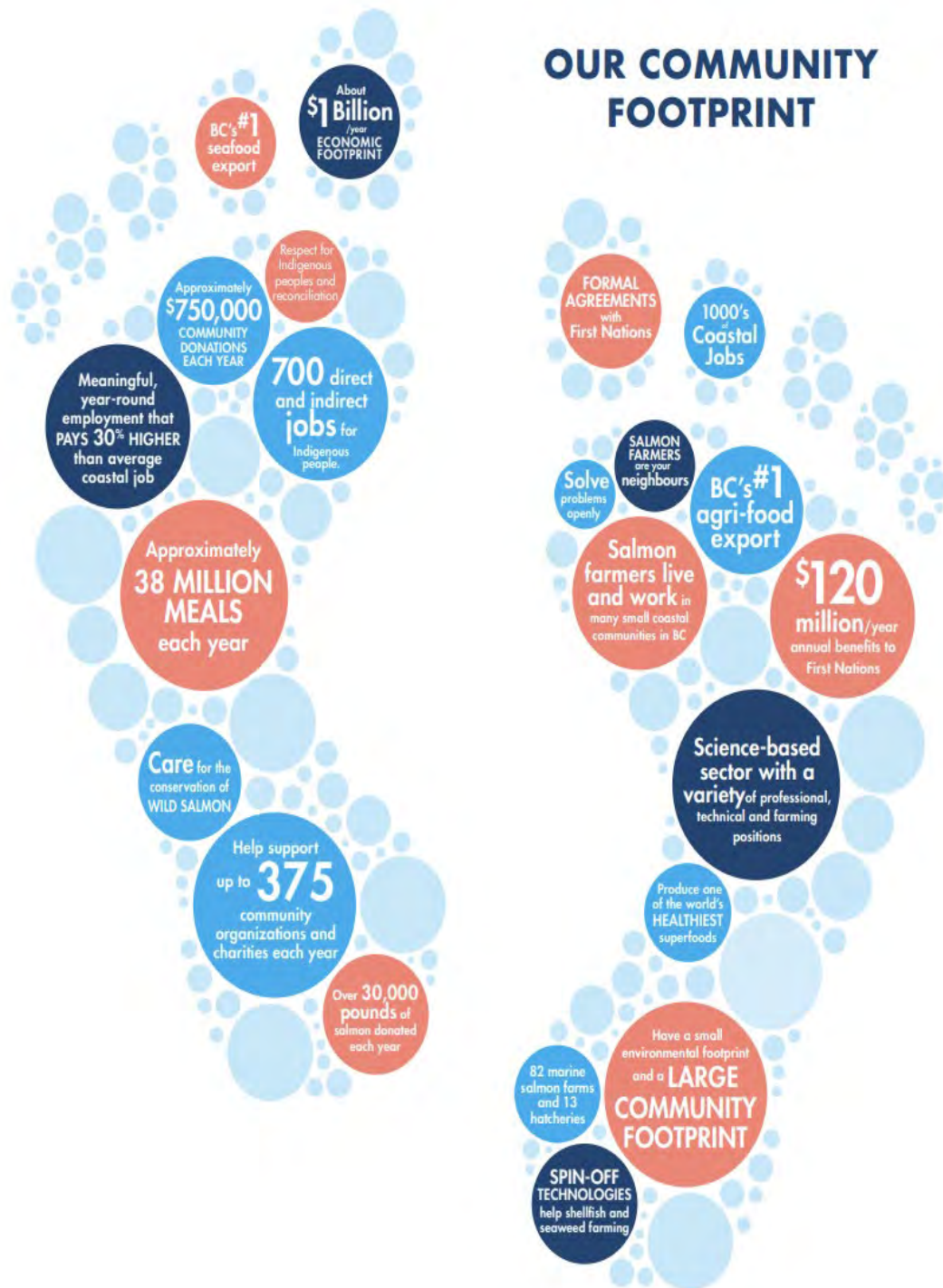


Figure 4. The community footprint of salmon farming in BC.



GROWING SALMON SUSTAINABLY

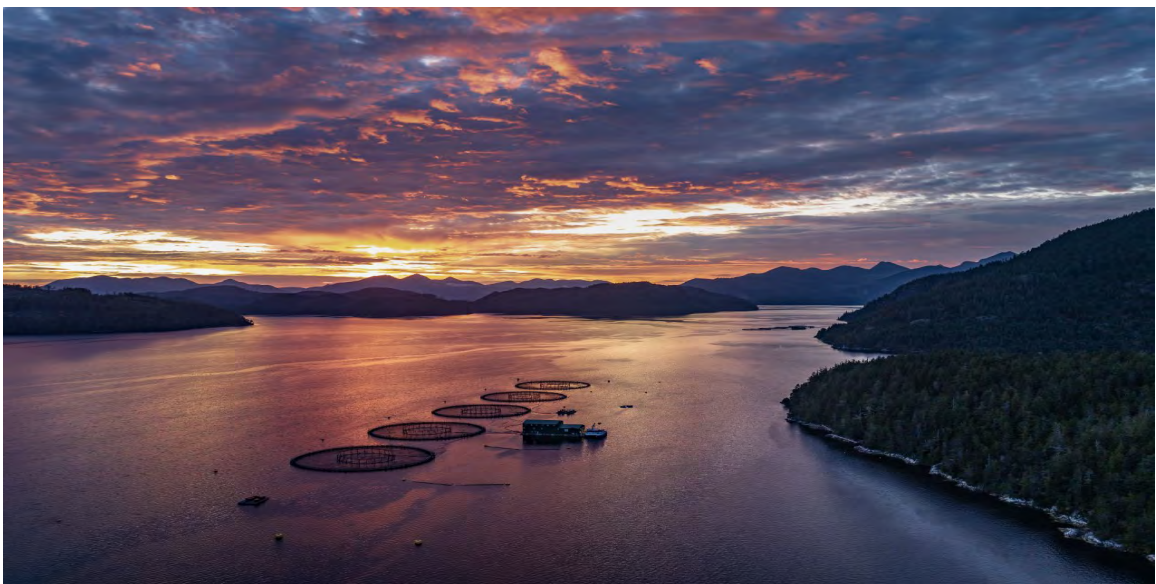
Coastal health is at the heart of sustainable aquaculture development. Salmon farming requires healthy ocean ecosystems to grow healthy salmon. It also requires healthy coastal communities to provide the labour force, supplies and supports. Together with our Indigenous Rightsholder partners, we seek to operate our sector wisely with consideration for the biodiversity of our coastline and its coastal people.

Salmon are grown in hatcheries and in the sea. It takes about six years to grow salmon, including the planning phase (Figure 5). A typical salmon farm has eight to twelve cages anchored in a grid pattern. The cages may be circular or square and vary in size from 30 metre squares to 200 meter diameter circles. The amount of fish grown at a site depends upon the oceanographic and biodiversity conditions at each site as described in “Chapter 8 – Caring for the Environment –

Protecting Biodiversity”. Water quality and seafloor protection are two of the key variables influencing how many fish can be grown at each site. The average farm has about 800,000 fish. Salmon occupy less than four per cent of the space in their net pen and are provided plenty of room to mimic natural schooling patterns.

As salmon grow, there are many innovations and safeguards along the way to ensure optimal fish health and performance and to minimize environmental costs (Figure 6).

Over the past 40 years, salmon farmers have been listening and learning and innovating and implementing. This has significantly improved our environmental and community sustainability, as discussed in detail in the chapters of this series, and highlighted below.



HOW FARMED SALMON GROW

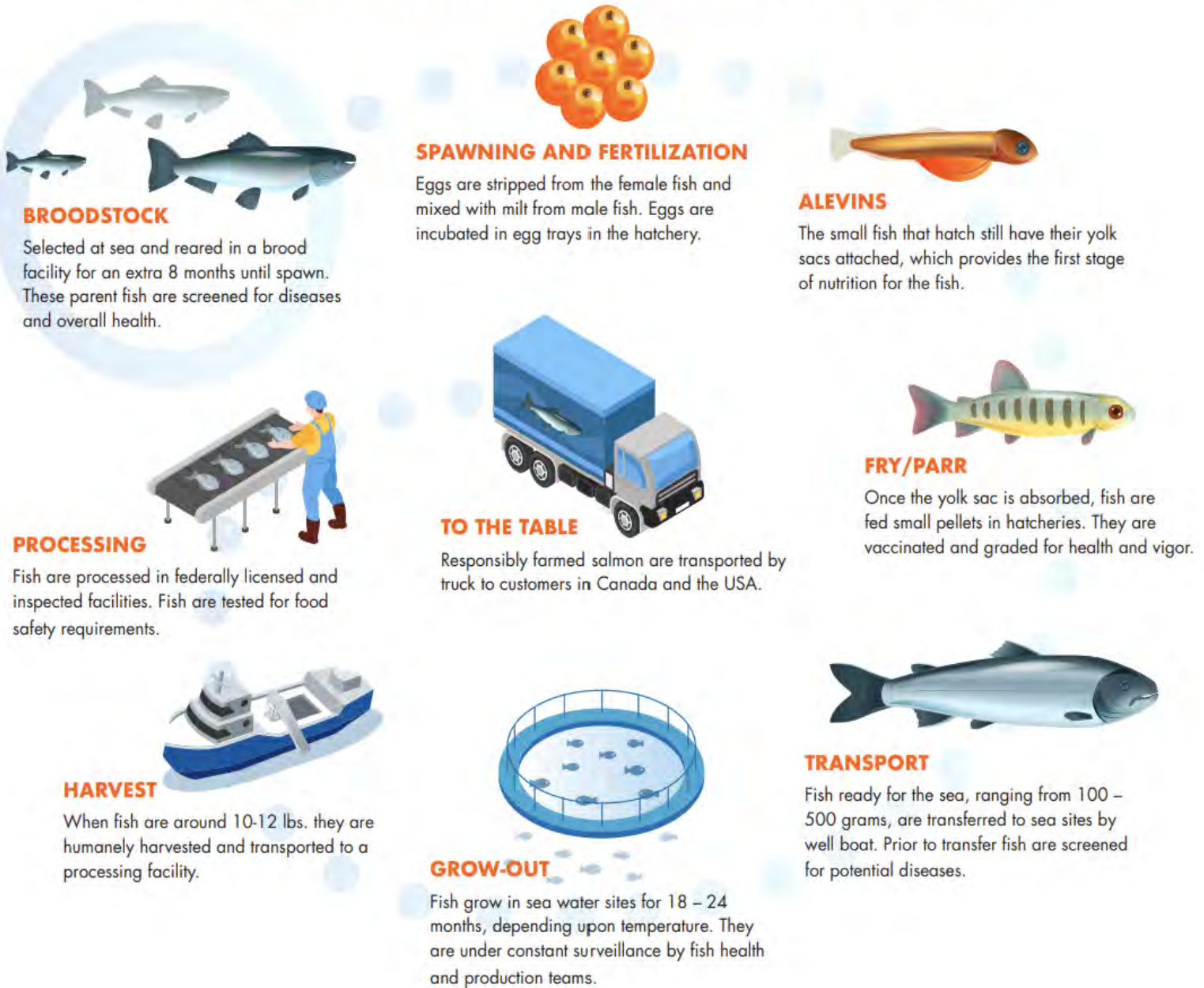


Figure 5. The six-year cycle of farm-raised salmon.

INNOVATIONS AND SAFEGUARDS THROUGHOUT THE VALUE CHAIN



Breeding & Genetics

1. Domestic BC broodstock only; most grown in land-based closed containment systems
2. Brood fish are screened for pathogens and disease
3. Selected for disease resistance, growth, stress tolerance, reproductive performance
4. Maintain genetic diversity, advanced genomic selection
5. Fish are tagged and tracked
6. Licensed veterinarians oversee brood selection



Feed Production

1. Local BC feed mills
2. Raw materials selected for sustainability, nutrition, availability
3. Continual innovation, testing and tracking of novel materials to minimize the use of wild fish ingredients
4. Optimal nutritional ingredients to reduce waste



Freshwater Hatcheries

1. Tens of millions invested in state-of-the-art recirculating aquaculture systems (RAS)
2. Most hatcheries use groundwater; water is filtered and disinfected to keep fish pathogens out
3. Strict biosecurity to keep pathogens out
4. All fish are vaccinated
5. Continuous monitoring of water quality, fish behaviour, and growth; protocols for early detection of disease
6. Licensed veterinarians oversee fish health
7. Best feeding practices and strategies to improve fish performance and reduce waste
8. *Installation of solar panels to offset greenhouse gas emissions

Seawater Pens

1. Robust anchoring and netting materials and inspections maintain system integrity
2. *Secondary predator nets, bird nets, and exclusion fences on walkways keep predators away from fish
3. Improvements in pen lighting, environmental monitoring, net cleaning, artificial and machine learning and real-time surveillance
4. Advanced feed and feeding protocols to optimize nutrition and reduce waste to the environment
5. Seafloor monitoring of each crop, sites must meet regulatory requirements or fallow
6. Grader systems on vessels to separate incidental catch and return wild fish to the sea
7. Robust plankton monitoring and mitigation
8. Fish health must be approved by federal and provincial government before transfer to sea sites, pre-transfer screening for viruses and bacteria
9. Strict biosecurity and hygiene protocols on transfer vessels and receiving sea site
10. Fish health teams continuously monitor fish health, early detection of disease
11. Medicinal treatments only as prescribed by licensed veterinarians according to best practices and regulations
12. Extensive veterinary records, fish health tracking and reporting
13. Ongoing research to develop additional vaccines and refine physical barriers
14. The Coast-wide Integrated Pest Management agreement for Atlantic salmon sea lice treatments ensures a coordinated approach to parasite control
15. Tens of millions of dollars invested in greener, prevention, and non-medicinal treatments for sea lice on Atlantic salmon
16. *Exploring alternative farming such as semi-closed containment



Processing

1. Humane harvesting of fish which is carefully monitored for fish welfare and product quality
2. Best practices to ensure product safety
3. All facilities are federally approved and inspected
4. Routine testing of product for quality and food safety

*Technologies not available at all sites

Figure 6. Innovations and safeguards along the value chain of farm-raised salmon in BC.



Photo by Brian Kingzett

WILD SALMON IN THE PACIFIC OCEAN

Wild Pacific salmon are iconic in British Columbia.

Recent wide swings in Pacific salmon abundances throughout the north Pacific Ocean ecosystem are affecting BC First Nations' food security and capture fisheries in all five countries that rely on Pacific salmon (Republic of Korea, Japan, Russian Federation, USA, Canada) suggesting large, basin-wide mechanisms are influencing fish stocks.

Very little is known about the mechanisms that control Pacific salmon abundances in

the ocean and the effects of climate change on those mechanisms. The situation is concerning for the ecosystems and coastal people of the north Pacific Ocean.

New thinking and collaborations are needed to address the big picture on what is happening to wild Pacific salmon throughout the north Pacific Ocean ecosystem.

For more information and sources see Chapter 2.



CONSERVING WILD SALMON

We believe everyone in British Columbia has a role in respecting, understanding, and conserving wild salmon.

BC salmon farmers are experts in oceanography and raising salmon and have valuable knowledge to share.

We support research to understand Pacific salmon in the high seas, monitor nearshore oceanography, collaborate on mapping and restoring estuaries and

watersheds, and are involved in numerous enhancement projects throughout coastal BC.

Scope may include sharing expertise on salmon husbandry, veterinary medicine, equipment, and near-shore oceanography.

For more information and sources see Chapter 3.



RESPECT FOR INDIGENOUS PEOPLES

Today, 100% of farmed salmon in BC is raised in partnership with local First Nations, and the input, guidance, and oversight of First Nations in salmon farming has evolved from generally non-existent to expected.

First Nations involved in finfish aquaculture are finding unique ways to not only benefit from the sector, but to create Indigenous-led science, employment, and business opportunities from partnerships and agreements. Indigenous-led businesses and economic diversification opportunities include processing (value added like smoked salmon and canned salmon), transport boats, crew boats, and net washing services. Wild salmon revitalization and Guardian Watchmen programs, supported by BC salmon farmers, provide essential eyes on the

water for Nations in their traditional territories.

As of February 2022, the industry directly and indirectly employed over 700 Indigenous people, provided \$120 million in total annual direct and indirect economic benefits to First Nations, with \$42 million going directly to Indigenous communities. The sector also infused \$24 million each year into Indigenous-owned businesses

For most of these communities, those benefits cannot be replaced, and the threat of losing them via government closures is a real threat to their social safety.

For more information and sources see Chapter 4.



MINIMIZING FISH ESCAPES



Preventing fish escapes is a top priority. Salmon farmers' goal is to not lose any fish to escapes.

When the fish are biologically ready to move to salt water, farmers move them to ocean pens that have been specifically engineered to withstand weather and tides based on international farming standards ([Norwegian Standard N9415](#)) (9).

Fisheries and Ocean (DFO) requires that all finfish containment systems must be able to withstand local weather and ocean conditions. Containment systems must be regularly inspected and maintained to ensure integrity and control factors contributing to failures, including biological matter buildup, ice buildup and marine mammal interactions (10). There are required actions in the unlikely event of an escape.

These measures have been very effective.

Atlantic salmon farmers have significantly reduced escapes by 97% since 2010, averaging 12 fish/year from 2011 to 2018. A catastrophic fire in 2019 at a farm resulted in the escape of 20,973 fish. From 2020 to 2022, 121 individual Atlantic salmon escaped from farms.

Since 2012, 2,998 Pacific salmon have escaped from farms. During the same time period more than 2.7 billion Pacific salmon were released from enhancement hatcheries in BC.

Escaped Atlantic salmon have not established reproducing populations in BC. Atlantic salmon are very sensitive to habitat changes and this limits their ability to succeed in new habitats. The Atlantic Salmon Watch Program, first established in 1991, has not found evidence of established feral populations of Atlantic salmon in BC.

For more information and sources see Chapter 5.



MINIMIZING INCIDENTAL CATCH

Similar to commercial capture fisheries, salmon farmers must manage incidental catch.

At a farm, incidental catch is any wild finfish caught during handling events such as harvesting, during the movement of fish between facilities or while removing nets. Incidental catch results after wild fish swim through the nets containing the farmed salmon and either choose to find refuge in the nets or grow to a size that they can no longer swim out.

DFO requires that farmers design all equipment and practices in manners that cause the least amount of harm to incidental catch. There are also requirements for releasing incidental catch and reporting incidental catch mortalities. DFO publicly reports incidental catch mortalities (10).

Salmon farmers continually invest in equipment, farming practices and staff

training to minimize interactions with wild fish. These measures have been very effective in reducing incidental catch at farms. Measures include improving ways to separate and release incidental catch alive and modifying lighting systems to avoid attracting wild fish to the pens.

From 2011 to 2022, 94.4% of incidental catch mortalities at salmon farms were Pacific herring. These herring mortalities represented 0.014% of the BC commercial fishery herring catch during the same period (not including the roe, food, bait, and special-use fisheries). The highest number of Pacific herring incidental catch mortalities occurred in Clayoquot Sound in 2022 - the same year the West Coast Vancouver Island herring fishing saw its largest spawn event since 2013. The total Pacific herring incidental catch mortality at all salmon farms combined for all areas was equivalent to 0.086% of the herring spawning biomass for West Coast Vancouver Island that year.



From 2011 to 2022, the average incidental catch mortality of other (non-herring) wild fish species was 97 wild fish per year per farm - which is less than two wild fish mortalities per week.

There were 402 Pacific salmon incidental catch mortalities at salmon farms from

2011 to 2021. During the same period, the recreational and commercial salmon fisheries in BC captured 73,694,320 Pacific salmon.

For more information and sources see Chapter 6.

FEED SUSTAINABILITY



Feed is the number one cost of salmon farming. Nutrition and feeding efficiency are top priorities.

Farm-raised salmon eat nutrient-dense, dry pellets that are delivered into the pens using specialized feeding systems. Underwater cameras and sensors monitor feed delivery to avoid overfeeding and minimize waste.

With recent gains in efficiency of feeding and growth, BC farm-raised salmon now produce more high-quality marine protein than they consume. It takes about 1.15 to 1.2 kilograms of feed to produce 1

kilogram of farm-raised salmon. This is more efficient than chicken, beef, or pork.

Feed is formulated to optimize salmon health and there are no added steroids or hormones. Carotenoids – the same natural ingredients found in carrots and egg yolks – are added to their diet to provide salmon with antioxidants, vitamin A, and to give them their pink colour.

Fish meal and oil – once the primary ingredients in Atlantic salmon feed, have been mostly replaced with plant and land-animal ingredients. All fish trimmings used in BC for Atlantic salmon feed come from

sustainably managed Alaskan pollock and Pacific hake fisheries, landed in Canada and the United States.

75-80% of the fish meal and oils used to feed farm-raised Chinook salmon are derived from the by-products of the BC herring and hake fisheries.

Feeds are locally made in BC – with an average of about 80% of the ingredients coming from Canada and the United States. The remaining is sourced globally from sustainable sources.

For more information and sources see Chapter 7.



PROTECTING BIODIVERSITY

Protecting biodiversity is a legal and ethical responsibility of salmon farmers in BC. Federal, provincial and local governments have legislation and processes that protect wildlife and biodiversity.

Finding suitable places for salmon farms is a complex process that takes years. It begins with discussions with First Nations Rightsholders. Farms must meet the various government criteria in order to be approved. Once operational, farms must follow all laws to protect fish, fish habitat and wildlife.

Farm-raised salmon are very sensitive to water quality. Only specific areas of the coast are suitable to grow salmon. Each farm location is carefully chosen in areas with the right water temperature, depth, and currents.

The nutrient footprint associated with salmon farms is regulated to protect biodiversity. For more than 20 years, regulated thresholds have limited the size and intensity of the salmon farm footprint. Farms that do not meet the thresholds must be followed until they do. In this manner, company fish production

schedules rely on sustainable seafloor performance.

Maintaining water quality and the growing environment is essential for raising healthy salmon. Sites are operated to minimize effects to the seafloor and shoreline near salmon farms.

Registered Professional Biologists monitor the seafloor for each crop of salmon. From 2010 – 2022, 86% of sites in BC met regulated thresholds at peak production and did not require any additional fallowing (11).

Most farms are fallowed for about three months to allow the seafloor to rest and

prepare the site for the next crop. The majority of nutrients released from a farm settle within 150 meters of the cages.

A typical salmon farm produces 4 to 6 million pounds of salmon every two years in a cage array that is about 4 hectares in size. This is an incredibly efficient method of animal farming.

All salmon farming companies are also involved in third-party certification programs which have additional criteria to protect biodiversity.

For more information and sources see Chapter 8.

MINIMIZING WILDLIFE INTERACTIONS



The majority of interactions between wildlife and salmon farms consist of viewing each other from a safe distance. On occasion, wildlife comes into close proximity to farms. Care must be taken to ensure wildlife, people, and infrastructure are not harmed during these events.

Farmers focus on preventing interactions by minimizing attractants and excluding wildlife access to infrastructure. If exclusionary devices do not work, non-lethal deterrents that have been authorized by DFO may be used to encourage wildlife to avoid the farm. No underwater acoustical deterrents are permitted in BC.



Photo by Brian Kingzett

From 2011 to 2022, there were 431 megafauna mortalities at salmon farms in BC. Almost all (98%) were California sea lions and Harbour seals, reflecting increasing population growth in both species.

In 2012, BC salmon farmers implemented a sector-wide management policy for seals and sea lions that included the implementation of mandatory prevention measures and a “no-kill” policy.

Innovations in infrastructure and staff training have significantly reduced mortalities at farms. From 2013 to 2022, there were, on average, 10 mortalities per year at salmon farms in BC, which is approximately one mortality per seven operating farms each year (12).

Sea lion and seal population growth will continue to challenge salmon farmers, given that salmon is naturally a part of the diet of these very intelligent animals. Salmon farmers are working with seal/sea

lion biologists to further develop non-harmful deterrents and exclusionary infrastructure.

Six humpback whales interacted with salmon farms in BC from 2011 to 2022. Prior to the development of the DFO database, an additional two interactions occurred with farms: one in 2008 and another 2009. Of the eight entangled humpback whales over the thirteen year period (2008 to 2022), five were successfully released unharmed (13). Unfortunately, the other three did not survive.

These events were related to mooring lines or nets located under farms. Contributing factors to entanglement included facility design, anatomy and age: all whales entangled were young (13). Researchers concluded that this could be due to naivety and inexperience, as well as developing new feeding methods compared with adults. The entanglements



accounted for less than six per cent of all entanglements in B.C.

Operational changes to mooring lines were made after 2018 to reduce these interactions. DFO whale experts and regulatory personnel provide guidance/instruction to farmers in the event of an entanglement.

There have been no reported mortalities of sharks, turtles, otters, porpoises or dolphin at BC salmon farming operations.

For more information and sources see Chapter 9.

MANAGING SEA LICE



Photo by Steel_Snorkel

Sea lice naturally evolved alongside Pacific salmon. They occur on all species of wild Pacific salmon and are called *k̓at̓a'yat'si* by coastal Kwak'waka peoples, and *daaga* by Hlgaagilda X̱aayda Kil (Haida) peoples.

There are two main species of sea lice in BC: the "salmon louse" (*Lepeophtheirus salmonis oncorhynchi*), which mainly infests salmon; and the "herring louse" (*Caligus clemensi*), which infests at least 12 fish species besides Pacific herring. The salmon louse is the larger and more

harmful species and the subject of regulatory management programs.

Susceptibility to sea lice and the ability to reject sea lice vary considerably among species of salmon. Atlantic salmon appear to be the most susceptible salmon species in BC to sea lice. Chum and sockeye salmon are the next most susceptible to sea lice followed by Chinook, pink, and coho salmon. Coho salmon skin mucus can engulf and disintegrate sea lice.

In controlled laboratory experiments, sockeye salmon at 40 grams can host 19 attached “salmon lice” with no significant harm. By about 90 grams, sockeye salmon appear to become more vulnerable to the “salmon louse”, similar to Atlantic salmon.

Pink salmon develop the ability to shed sea lice within a few weeks after entering seawater. Based on laboratory trials, it takes an average of seven or more “salmon lice” to kill a 0.7-gram pink salmon. All researchers have reported that

rapid shedding of sea lice makes it challenging to study sea lice effects on pink salmon in controlled laboratory and field settings.

Newly emergent pink salmon can swim well above the typical cruising speed of one body length per second while infested with three pre-adult “salmon lice.” It takes two or more pre-adult/adult “salmon louse” to compromise maximum swimming speed in small pink salmon 0.5 – 0.7 grams in size.



Farm-raised salmon are sea lice-free when they are stocked in ocean pens. Although Atlantic salmon are the most sensitive salmon species, observations of significant harm to farm stock caused by sea lice have been extremely rare.

Farm-raised Pacific salmon are robust against sea lice infestation and almost

never require treatment. For example, there were no sea lice treatments for farm-raised Chinook salmon between 2016 - 2021. Creative Salmon, who specialize in raising organic Chinook salmon, have never treated for sea lice in the 34 years they have grown Chinook salmon in BC.



Farmers have treated for sea lice infestations on farm-raised Atlantic salmon in British Columbia since at least 1991. In 2003, the BC government instituted a precautionary management threshold for Farmers have progressed to sophisticated and effective measures to minimize sea lice transmission from farm-raised salmon to wild salmon that focus on integrated pest management using a suite of prevention and treatment tools, and an industry agreement to cooperate, innovate and improve.

Under the guidance of licensed veterinarians, Atlantic salmon farmers have successfully managed sea lice populations during the juvenile wild salmon outmigration window, with very few exceptions (14). Sea lice levels at most farms have been below the regulated management threshold; all farms that exceeded the threshold initiated management measures to reduce sea lice.

Sea lice levels on juvenile wild salmon are monitored in every salmon farming region in BC. Sea lice are also monitored by other organizations. We compiled a dataset from this monitoring which includes 320,177 fish juvenile wild salmon that were examined for sea lice (2001 to 2022). Pink and chum salmon comprised 96% of the fish examined; coho (2%), Chinook (1%) and sockeye salmon (<1%).

- o Over a two-decade period, 86.0% of wild salmon had zero or one sea louse.
- o Sockeye salmon were the most infested species; however, the majority of sea lice were "herring louse"; only 1% of sockeye salmon had pre-adult/adult "salmon lice".

sea lice that was twice as stringent as Norway at that time. The regulatory sea lice management threshold has been in place for 20 years.

- o Among pink salmon larger than 0.7 grams, 99% had no adult "salmon lice".

It takes several weeks for a sea louse to develop into a pre-adult on host fish. During that time, juvenile pink salmon are also growing and rapidly developing resistance to sea lice. By the time sea lice are large enough to harm pink salmon, most pink salmon are large enough to defend themselves.

Comparing the coastal dataset to published laboratory-derived thresholds of harm revealed that: 0.1% of pink salmon might have been directly killed by sea lice, 0.17% might have had their natural cruising swimming speed impeded, and 5.1% might have experienced a reduction in maximum speed swimming abilities. It is not known if the pink salmon that were potentially harmed by sea lice would otherwise have survived to adulthood, as naturally only 5% of pink salmon survive to spawn in BC. It is also not known what proportion of sea lice originated from farms versus natural sources.

Researchers focusing on the Broughton Archipelago concluded that despite higher infestation rates in chum salmon compared to pink salmon, there is no evidence of reduced productivity on chum salmon populations with either the expansion of salmon farming in the 1990s or sea louse infestations on farm-raised salmon.

Sea lice infestations of pink and chum salmon in the Broughton Archipelago and Discovery islands appear to be unchanged after the removal of salmon farms.

Wild salmon returns have been highly variable both before and after the introduction of salmon farms, but average adult returns of iconic salmon species did not decline during the salmon farming years, suggesting an independence.

For example, total Fraser River pink salmon adult returns averaged 11.9 million per year before salmon farming began (1963 – 1987) and 13.2 million per year during the salmon farming years (1989 – 2021). Thus, wild salmon returns will continue to fluctuate regardless of whether salmon farms are present.

For more information and sources see Chapter 10.

MANAGING FISH HEALTH

Salmon farmers, their fish health teams, and their regulatory agencies, under the guidance of First Nation Rightsholders, keep farm-raised fish healthy by selective breeding, minimizing pathogen entry and spread into hatcheries and marine net

pens (e.g., vaccines), fish health monitoring and record keeping, prescribed treatments, and being subject to fish health audits by government regulators.



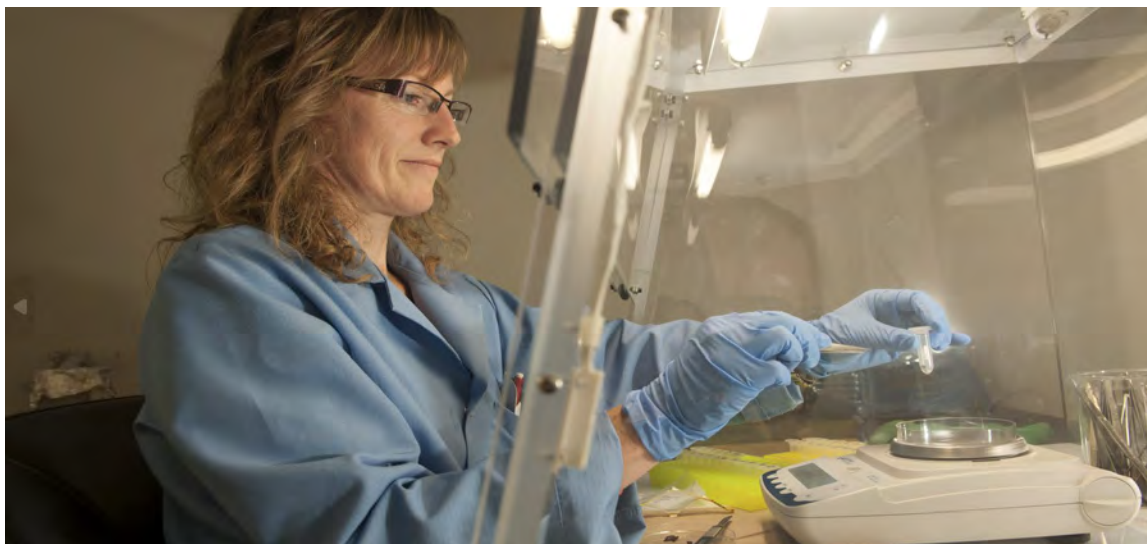


Photo courtesy of CAHS

Licensed salmon farm veterinarians base their fish health management decisions on validated test results generated by independently accredited diagnostic laboratories that follow established testing protocols.

Advances in salmon farming methods have decreased infectious diseases on salmon farms over the past 40 years. This minimizes the transmission of infectious diseases from farms to wild salmon.

Salmon farm fish health teams have successfully decreased the prevalence of high-risk diseases. For example, outbreaks of the IHN virus decreased from 36 farms over 23 months (2001 – 2003), to 3 farms over three months (2012). Since 2012, all farm-raised Atlantic salmon are vaccinated

against IHN, and no other outbreaks have occurred.

Antimicrobial treatments of farm salmon in the marine environment have decreased to less than 20% of peak usage in 1997 (15).

Today, only about 3% of farm-raised salmon in the marine environment die each year from infectious diseases. About 17% of farm-raised Atlantic salmon and 10% of farm-raised Pacific salmon die each year from other causes, mostly from low dissolved oxygen, toxic algal blooms, and damage from mechanical treatments used to control sea lice on Atlantic salmon. The remaining farm-raised Atlantic (80%) and Pacific (87%) salmon survive and grow to be harvested as one of the world's most sustainable animal proteins.



Many variables need to align for disease to occur within an individual fish, and other variables need to align for disease to spread to a population of fish. Safeguards reduce pathogen spread within farms. If pathogens do not spread, then disease does not spread.

Principles of population medicine inform us that if only 3% of salmon confined in the farms over an entire year die of infectious disease, we expect that even fewer wild salmon—dispersed in the environment—will die from farm-source diseases.

Pathogens shed by farms are diluted and degraded in the environment; this decreases the chance of wild fish getting infected from a farm-source disease.

Extensive salmon farm data over the past decade supports Justice Cohen's 2012 conclusion that "Data presented during this Inquiry did not show that salmon farms were having a significant negative impact on Fraser River sockeye."

Formal assessments of nine salmonid pathogens that occur or have occurred on farm salmon in British Columbia concluded "minimal risk" of each pathogen to Fraser River sockeye salmon abundance and diversity (16).

As evidence that accounts for all salmon farm threats—known and unknown—iconic salmon populations did not decrease during the salmon farming years. Indeed, total Fraser River sockeye salmon adult returns averaged 6.8 million per year before salmon farming began in the Discovery Islands region (1962 – 1989) and 8.0 million per year during the salmon farming years (1990 – 2022).

Total adult returns of pink salmon to rivers in the Broughton Archipelago averaged 0.8 million per year before salmon farming began (1950 – 1987) and 1.1 million per year during the salmon farming years (1988 – 2014; DFO records are incomplete after 2014).

For more information and sources see Chapter 11.



FOOD SAFETY AND SECURITY

Three-quarters of the salmon harvested in British Columbia yearly is raised on farms.

BC produces approximately 56,000 tonnes of farm-raised salmon annually, or about 38 million healthy, nutritious meals.

Farm-raised salmon is a healthy food, recommended by experts, as it is rich in essential fatty acids and low in mercury. Studies have demonstrated the many health benefits of omega-3 fatty acids found in farm-raised salmon, including reducing the risks of heart disease and supporting eye health.

Safeguards ensure that BC farm-raised salmon is safe to eat. No artificial dyes, steroids, or growth hormones are used – and the salmon is not genetically modified. Any antimicrobials administered to the fish are prescribed by licensed veterinarians.

Fish can only be processed in licenced processing facilities. Farm-raised salmon are regularly tested for residues, including antibiotics and pesticides, heavy metals, and PCBs, by the sector and the Canadian Food Inspection Agency.

Farm-raised salmon can be traced back to the original farmer and hatchery where the fish were raised, including records of what they ate and how the farmer cared for them. All BC salmon farming companies are involved in third-party certification programs that evaluate farming processes – both marine and on land, as well as feed manufacturing and fish processing to ensure quality seafood and responsible production.

For more information and sources see Chapter 12.

There are many regulations that govern salmon farming in BC. The main responsibilities of the provincial and federal governments are described in Table 1 below. For more details, please see Chapters 5 to 12 that describe the regulatory framework for managing escapes, incidental catch, feed sustainability, seafloor performance, wildlife interactions, sea lice, fish health, and food safety. For performance data on the sector, please see summaries provided by DFO through the [Open Government Portal](#) (17).

Table 1. Summary of federal and provincial jurisdictions for salmon farming in BC. Adapted from the Library of Parliament, Ottawa, Canada, 2021 (18)

Management area	Federal or Provincial Government
Site approval – determining where a farm can be located, including considerations for navigation	Federal
Land management – overseeing the land where a farm is located	Provincial
Day to day operations and oversight, monitoring of farm activities	Federal
Introductions and transfers – managing the planned movement of fish	Shared
Drug and pesticide approvals – determining which medicines are approved for use	Shared
Feed safety – monitoring and ensuring the safety and quality of fish sold to markets	Federal



CONCERN FOR THE PLANET – THE BIGGER PICTURE

Our planet is facing two daunting issues: climate change and population growth. Our oceans, which cover about 70% of the planet, have absorbed more than 90% of Earth's excess heat since at least 1971 (19). At the same time our planet is warming, the world's population is predicted to increase from 8 billion to about 10 billion people by 2059 (20). Climate change and population growth are both global problems and local problems. We know that what happens elsewhere affects what happens here – climate change and human population growth are everyone's problem.

Recent wide swings in Pacific salmon abundances throughout the north Pacific Ocean ecosystem are affecting capture fisheries in all five countries that rely on Pacific salmon (Republic of Korea, Japan, Russian Federation, USA, Canada) suggesting large, basin-wide mechanisms are influencing fish stocks.

In BC, our coastal waters are warming, and our population is growing. BC's population is expected to increase to 6,515,558 by 2041, with much of the growth in the Lower Mainland and coastal regions (21). These are huge concerns for the survival of wild Pacific salmon. More people likely means more greenhouse gases and additional climate change pressures. It will bring additional stresses to coastal BC, particularly to the natural habitats that Pacific salmon rely on. With respect to the mechanisms that control Pacific salmon abundance in the ocean, we know very little about how those mechanisms are affected by climate change.

The total global food demand is expected to increase by 35% to 56% between 2010 and 2050 (22). **This is creating food security concerns when we consider that there are about 35 growing seasons until the world population hits 10 billion people.**

**“Over the next 50 years,
we’ll have to produce as
much food as we have ever
produced in human history”**

Megan Clark, Australian
Commonwealth Scientific
and Research Organization
[Can We Grow More Food in
50 Years Than in All of
History? - ABC News](#)

Feeding the world in a sustainable manner is a formidable task. Approximately two thirds of the land on earth is either barren (glaciers, deserts, salt flats), already actively farmed, or developed as cities and towns (Figure 7). The enormous pressures on productive land and freshwater resources are pushing agricultural ecosystems to the limit; the United Nations Food and Agriculture

Organization estimates that land degradation now affects 34% of the cropland and pasture (23). Only 37% of the landmass remains as forest or shrubland.

Freshwater, at 1% of the land base and essential for life, is the world's most precious resource.

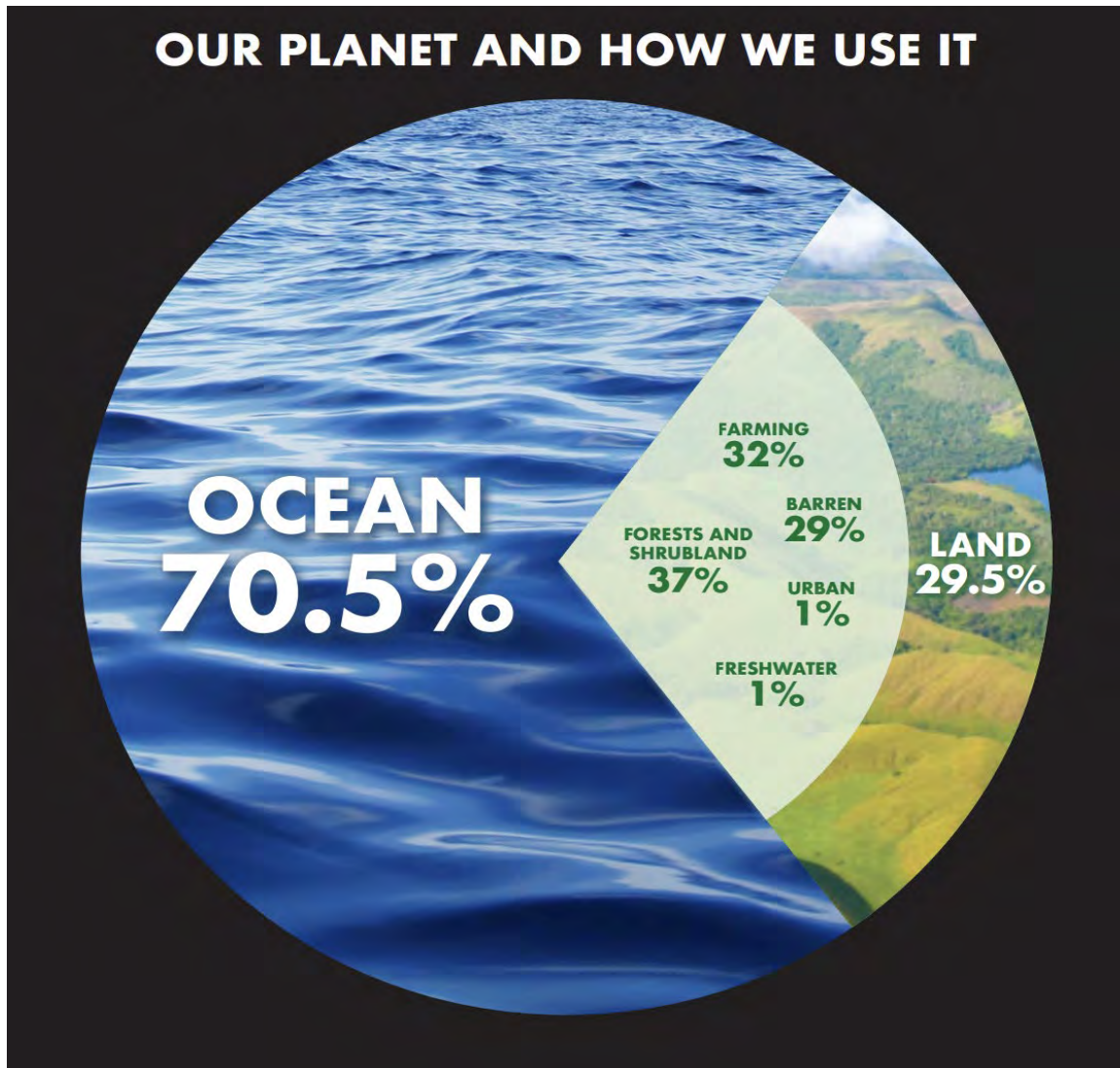


Figure 7. Global land use, display of the proportion of ocean compared to land, and the uses of the land by percentage of the total land mass on earth.

Adapted from the United Nations Food and Agricultural Organization (23-25)



These statistics are sobering, and these problems are bigger than what one group or person can tackle alone. However, aquaculture has a role in both mitigating climate change and sustainably feeding people.

According to G20 Rome Declaration of 2020, Canada recognizes “that promoting sustainable food systems, including by strengthening global, regional and local food value-chains and international food trade, will contribute not only to food security, but also make a major contribution to tackling the interlinked global challenges of climate change and biodiversity loss” (26).

“The single biggest threat of climate change is the collapse of food systems” Jerry Hatfield, the director of the U.S. Department of Agriculture’s National Laboratory for Agriculture and the Environment [What Climate Change Will Do to the Global Food Supply | TIME \(2\)](#)

ADVANTAGES OF AQUACULTURE

Global food production contributes about 30% of the total greenhouse gas emissions driving climate change (27). About 70% of those emissions come from land-based agriculture and associated land use/land-use change activities (27).

By comparison, oceans produce about 17% of the world's per capita consumption of animal protein (28, 29). On a caloric basis, food from the sea is only about 2% of the total global food supply (30). The rest of our food comes from the land. It’s clear there is room in the sea to grow food to take pressure off the land.



SMALLER CLIMATE CHANGE AND ENVIRONMENTAL FOOTPRINT

We know that foods are not equal in terms of nutrition and their environmental footprint. Food production from the sea is advantageous from a climate change perspective for four reasons:

1. **Less land** – it does not require land conversion like land-based food systems (e.g., conversion from forests to farms and areas for raising livestock). Even when including the production of feed for farm-raised salmon (31).
2. **Less feed** – fish from the sea are cold-blooded and buoyant, so they require less food (32). They do not need to be kept warm and require far less energy to maintain. Fed aquaculture species, such as salmon, convert feed much more efficiently than terrestrial production systems (33, 34) and unfed aquaculture species, such as oysters, do not require feed inputs.
3. **Less feed means less fresh water** - salmon have a lower feed conversion ratio (FCR) compared to beef, pork, and chicken (35); a lower FCR means that per kilogram the animal requires less water, because water use per kg is almost entirely based on the amount of water required to grow crops to produce feed (36). Species such as trout and salmon have the lowest freshwater use among cultivated fish (37).
4. **Less greenhouse gas emissions** – capture fisheries of large pelagic, small pelagic and white fish, and aquaculture species such as shellfish and salmon, have lower emissions compared to terrestrial animal production (38) (39).

Aquaculture species grown in the sea use the naturally provided oxygen and heat provided by the sea to flourish. Unfed aquaculture species uptake their nutrients naturally from the surrounding waters.

When comparing the carbon footprint of BC farm-raised salmon to other agricultural proteins, farm-raised salmon (all species) have the lowest average [carbon footprint](#) compared to chicken, pork, and beef as measured as kilograms of CO₂ per typical 40g serving (Figure 8) (40).

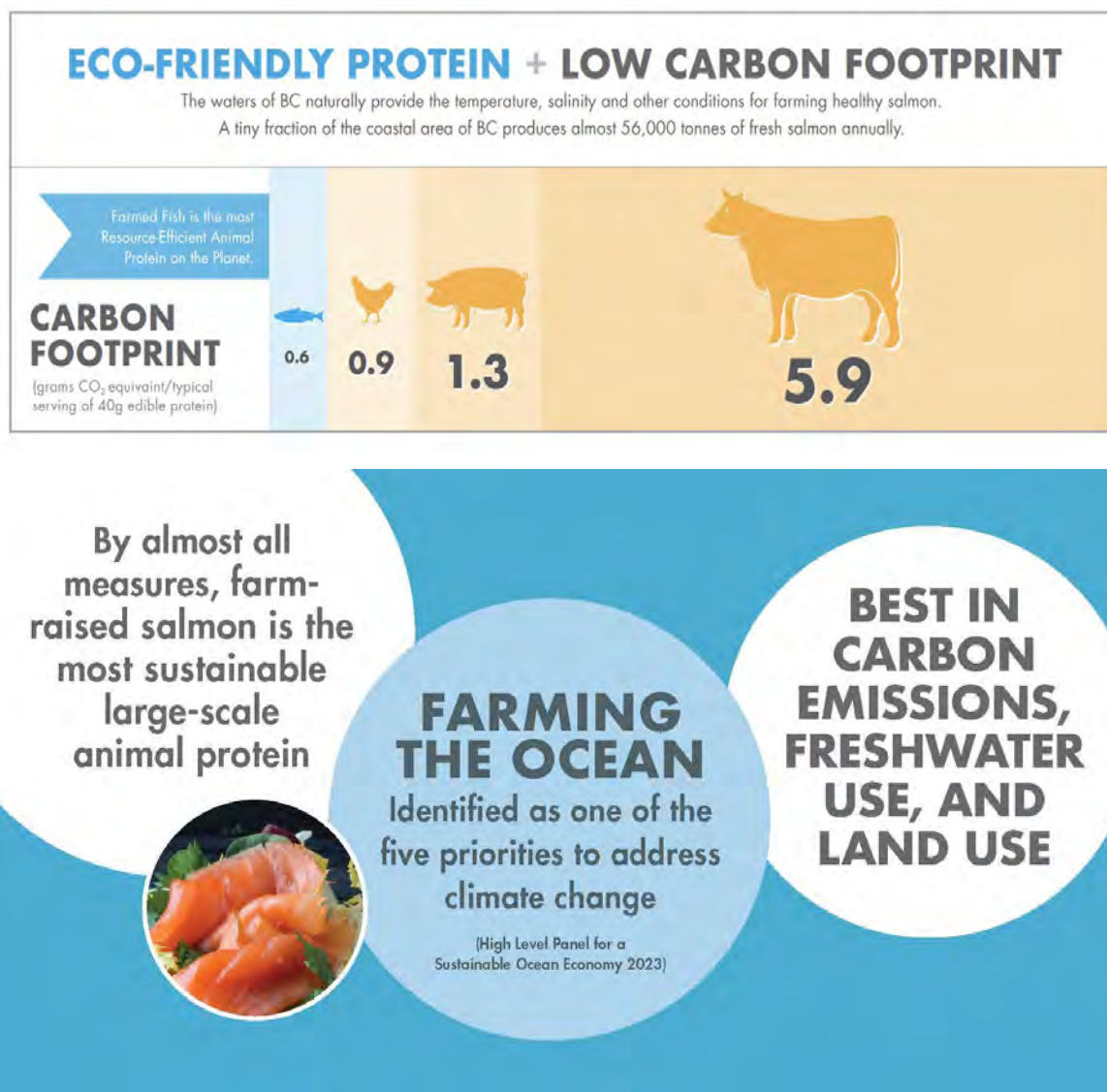


Figure 8. Sustainability advantages: less land, less feed, less freshwater and lower greenhouse gas emissions with farm-raised salmon.

NUTRITIONAL SUPERFOODS

To solve the world's food crisis, most experts agree that production efficiencies, innovations, waste reduction, dietary changes, and fair food distribution and security are all needed. It's not just about increasing food supply, it's about what to produce, how to grow it, and how to distribute it.

"A shift in the global narrative from feeding people to *nourishing* people is necessary in order that the full benefits of aquatic superfoods can be recognized." United Nations, Food and Agricultural Organization (2022)



Human health and environmental health are inseparable. The global food system needs to find a way to secure both for nearly 10 billion people by 2050. The recently published EAT-Lancet report calls for "... adopting a Half-Earth strategy for biodiversity conservation (i.e. conserve at least 80% of preindustrial species richness by protecting the remaining 50% of Earth

as intact ecosystems)" (41). While focusing on ways to shift global diets away from terrestrial meats, they call for improvements in the management of the world's oceans and sustainable seafoods. Shifting towards a vegetarian diet has planetary advantages; however, it would be difficult for many populations to obtain

adequate quantities of micronutrients from plant-source foods alone (42).

Food from the sea provides essential vitamins, minerals, long chain omega-3 fatty acids and other nutrients not found in plant-source foods or other animal proteins (43, 44). Salmon, in particular, is a superfood (Figure 9).

There is an ethical responsibility to grow nutritious food. A recent comparison of the nutritional value of 2,370 species of wild-capture fisheries, 624 species grown in aquaculture, and domesticated land animals found that the top seven categories of nutrient rich animal-source foods in the world are all aquatic foods (45) (Figure 10).

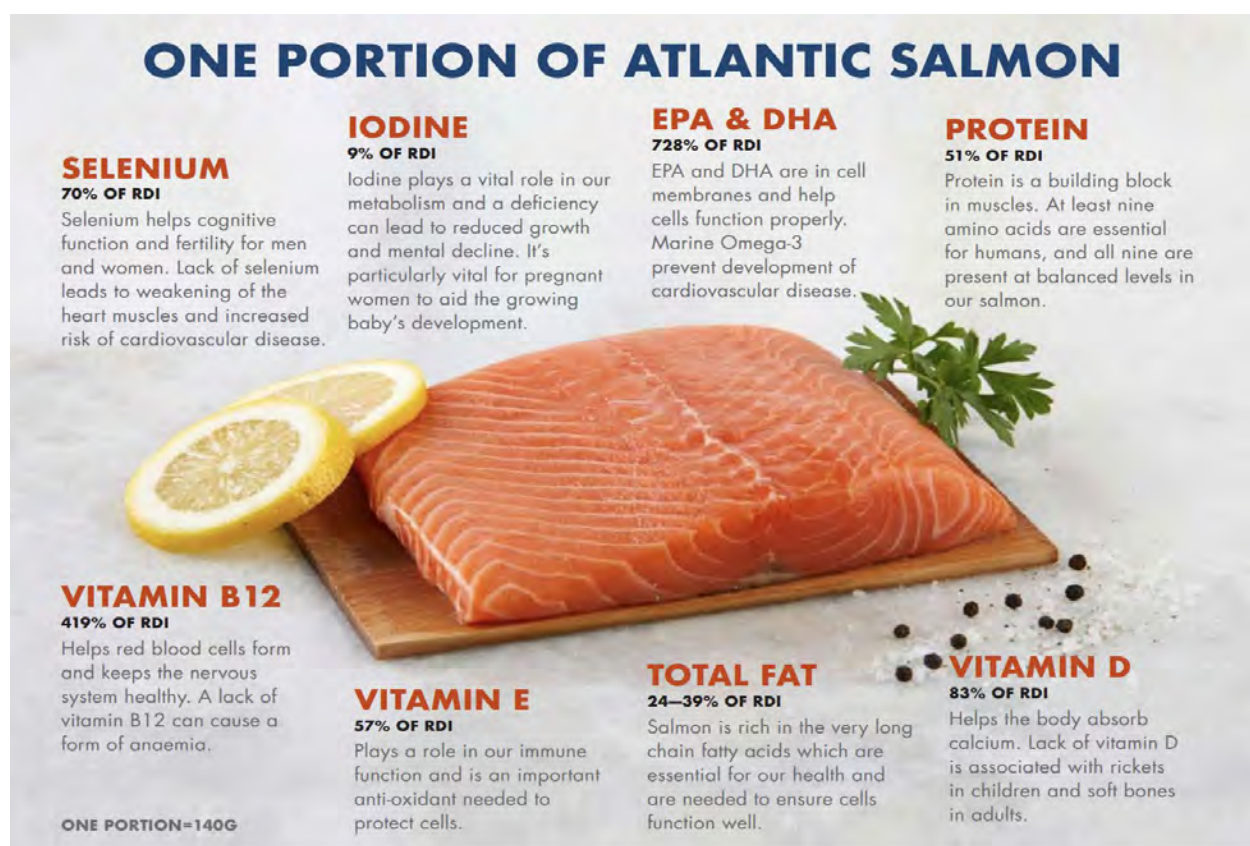


Figure 9. Health benefits of one portion of farm-raised Atlantic salmon.

Note RDI = Recommended Daily Intake. Source [MOWI Annual Report 2018](#) (46)

Researchers predict that an 8% increase in farmed or wild-caught aquatic foods could result in a 26% decrease in human diseases (primarily heart disease and cancers) and prevent about 166 million cases of malnutrition from micronutrient deficiencies. [Aquatic foods to nourish nations | Nature](#)

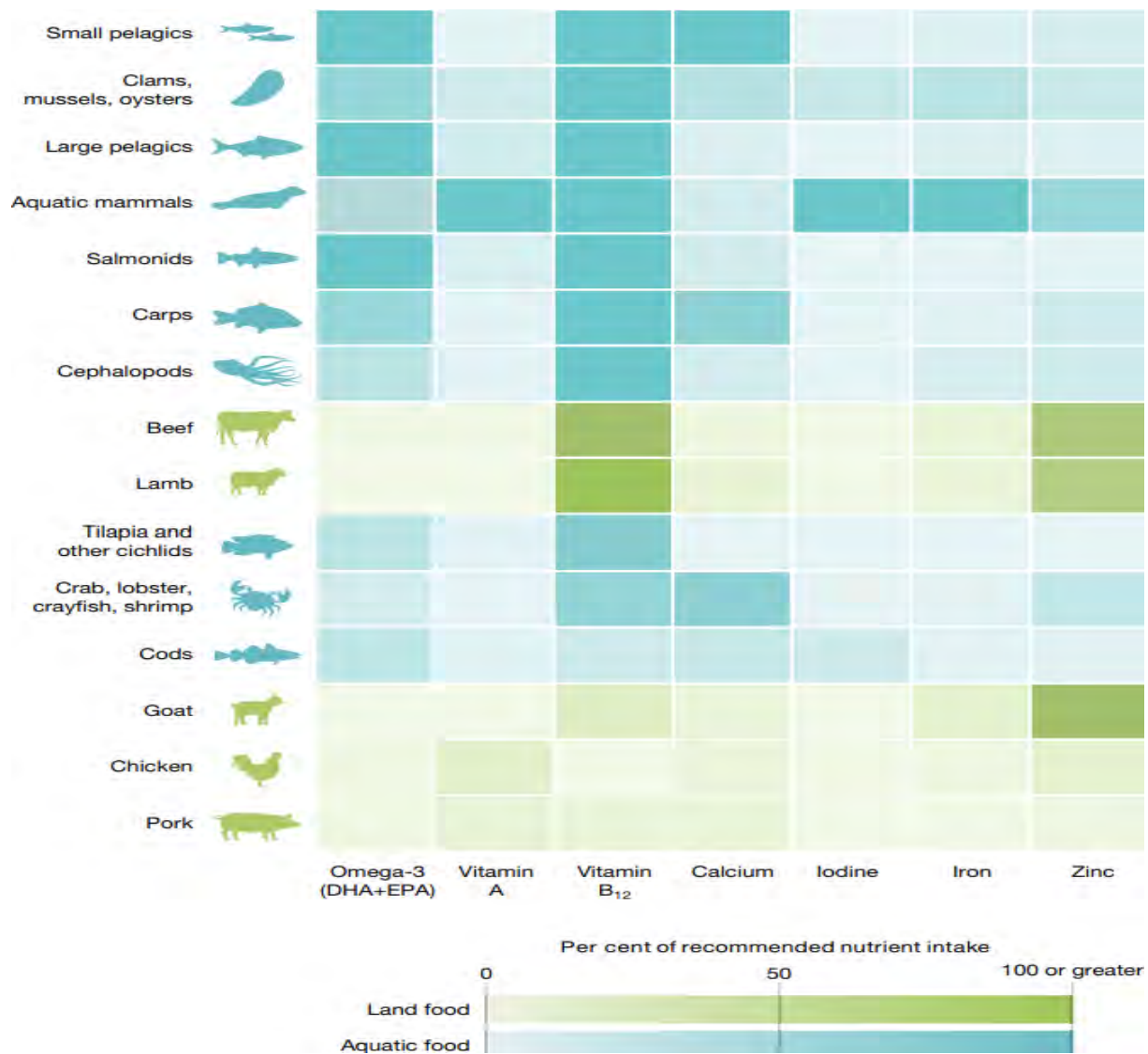


Figure 10. Nutrient diversity of aquatic animal-source foods in relation to terrestrial animal-source foods. Note the top seven most nutritious animal-source foods are aquatic.

Source *Aquatic foods to nourish nations* (45)



WORLD LEADERS EMBRACE AQUACULTURE

Globally, aquaculture has been the fastest growing protein sector over the past few decades. As of 2018, nearly half of all seafood consumed originated from aquaculture. Worldwide, the demand for blue foods is predicted to increase from 54.7 million tonnes in 2015 to 100 million tonnes in 2050. According to the Fisheries and Oceans Canada (DFO) “Outlook for 2027 for Canadian Fish and Seafood”, global consumption of seafood products is projected to grow approximately 9% by 2027, and the world consumption of salmon is projected to increase by 40%, or almost 2 million tonnes, by 2027 (47).

Aquaculture has been recognized by world leaders as part of the solution for climate change and food production (Figure 11). A discussion on some of the key initiatives currently underway follows.

In 2015, the United Nations General Assembly adopted 17 [Sustainable Development Goals](#) (SDGs) to improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.

“Marine aquaculture, or farming the sea, is a promising opportunity to leverage the ocean to complement responsible land-based agriculture and well-managed fisheries to increase the global supply of nutritious food with minimal impacts on the ocean and the environment. It must be done using the best and most appropriate science and technology.” Schubel and Thompson, Aquarium of the Pacific (2019)

In 2017, the United Nations General Assembly adopted a resolution to protect ocean health and preserve our planet (48). In 2022, the Food and Agricultural Organization (FAO) of the United Nations released their plan, the “Blue Transformation”, which recognizes the increasing role fisheries and aquaculture will play in feeding the world to meet the Sustainable Development Goals designed to safeguard the planet by 2030 (49). It describes the transformations required to ensure that growth goes hand in hand with safeguarding ecosystems, reducing pollution, protecting biodiversity and ensuring social equity (Figure 12) (49).



Figure 11. Aquaculture has been recognized by world leaders as part of the solution for climate change and food production.



Figure 12. Blue Transformation for sustainable aquaculture. United Nations, Food and Agriculture Organization, 2023.

Source [Food and Agriculture Organization of the United Nations](#) (50)

In 2020, Canada joined “The High-Level Panel for a Sustainable Ocean Economy”, a group of 17 countries with a shared goal of developing a sustainable ocean economy in which effective protection, sustainable production and equitable prosperity go hand in hand (51) (Figure 13). A panel of 250 experts from 48 countries identified five initiatives that can help overcome these challenges:

- o ocean-based renewable energy,
- o ocean-based transport,
- o protection of coastal and marine ecosystems,

- o ocean-based food systems (wild capture and aquaculture), and
- o carbon storage on the seabed (39).

“Shifting diets away from terrestrial animal-based protein, particularly beef cows and other ruminants, towards plant- and ocean-based options is one of the most significant ways to address climate change.”
(Hoegh-Guldberg et al 2019)

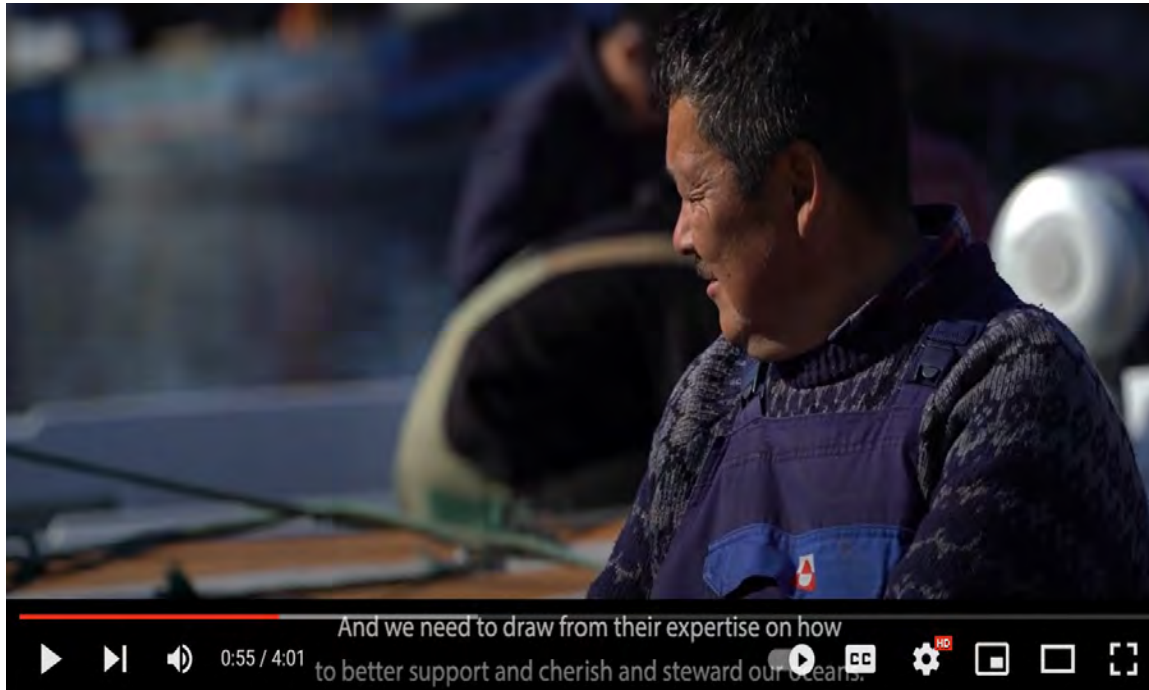


Figure 13. *Towards a sustainable ocean economy.*

Source [High Level Panel for a Sustainable Ocean Economy](#) (52)

Increasing sustainable aquaculture as part of a five-part plan, could reduce global greenhouse emissions by 20% and prevent the average global temperature from rising by more than 1.5°C by 2050. (3)

In 2022, the World Economic Forum developed “The Road to Sustainable Aquaculture Report” for The High-Level Panel on a Sustainable Ocean Economy (53). They estimated that if the demand for seafood continues to grow at the current rate, “aquaculture will be required to supply more than 55 million tonnes of new farmed marine finfish annually by 2050: nearly 20 times the throughput of today’s global salmon industry” (53).

In 2023, the World Economic Forum through its Blue Food Partnership published “The Global Sustainable Aquaculture Roadmap: Pathways for Systemic Change” stating “...One of our key opportunities, and indeed challenges, will be delivering on the responsible growth of aquaculture to scale the sector within nature’s limits, all while achieving greater social, economic and environmental benefits” (54).

They identified four key actions to shift aquaculture systems towards the sustainable future that is needed for our planet:

- o responsible production (environmental improvements),
- o better livelihoods (empowering communities),
- o healthy consumption (nutritional benefits of seafood), and
- o an enabling social-political environment.

A video describing the Blue Food Partnership goals is presented below (Figure 14).



Figure 14. The critical role of blue food, transforming food systems, 2022

Source: [The Blue Food Partnership](#) (55)

In support of the initiatives described above, the government of Canada has been developing a comprehensive Blue Economy Strategy to “enable Canada to grow its ocean economy in order to create jobs and opportunity for coastal communities, while advancing our conservation objectives” (56). Canada’s ocean industries generate about \$30 billion per year, which is considered to be a small fraction of the overall potential. The Blue Economy Strategy focuses on several ocean-based sectors:

- o Fish and seafood – commercial fisheries, processing and aquaculture
- o Marine transport – ports and harbours, shipbuilding and boat building
- o Tourism
- o Ocean-based energy
- o Technology and future-oriented sectors.

In 2022, DFO released a report entitled “Engaging on Canada’s Blue Economy Strategy What We Heard”, which discusses the results of a multi-year Canada wide engagement (56).

Engaging on Canada’s Blue Economy Strategy What We Heard

To position for sustainable growth and prosperity, it was recommended that DFO:

- o Agree on and take action to further develop Canada’s seafood strengths
- o Develop a five-year sustainable seafood development plan with measurable objectives
- o Recognize the diversity of aquaculture across Canada
- o Foster sector certainty and predictability through government recognition
- o Collaborate with other departments and agencies (and levels of government) to ensure consistent decision making and streamlined regulations
- o Expedite development of an aquaculture act
- o Appoint a federal industry champion for economic seafood sector growth
- o Recognize aquaculture as a valid user of small craft harbours
- o Proactively support financing and capacity building for Indigenous-led operations
- o Accelerate actions to conserve, protect, restore and rebuild marine ecosystems, including to protect aquaculture operations and species from the impacts of climate change
- o Fill knowledge gaps regarding sustainable use of ocean spaces and new opportunities
- o Fill policy and regulatory gaps for aquatic plant farming (e.g., seaweed, kelp, etc.)
- o Quicker and more supportive policy development
- o Continue to help industry adopt new technologies, including through research and development funding programs

(DFO, 2022) <https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41030503.pdf>



In 2022, The Coalition of First Nations for Finfish Stewardship formed to ensure that the voices of their communities are heard, "... Nations retain jurisdiction over their lands, waters, resources, and interests through unextinguished Aboriginal title. Title holder First Nations should have the right to decide if, when, or how we want to operate finfish aquaculture in our traditional waters" (57).

Coalition member Nations have negotiated relationships and agreements with salmon farming companies in their traditional territories.

They call for the Canadian federal government to adhere to the:

- o commitment to reconciliation and the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), and
- o the recent promise to support First Nations in their right to manage their ocean resources, including fisheries and aquaculture.

In 2023, The [Coalition of First Nations for Finfish Stewardship](#) developed a framework for Indigenous-led finfish aquaculture transition in BC, which includes an Indigenous Centre for Aquatic Health Sciences (iCAHS) as a training hub for First Nations, using western Science and traditional knowledge (see video, Figure 15 and Figure 16).



Figure 15. The Coalition of First Nations for Finfish Stewardship present the Indigenous-led Finfish Aquaculture Transition Framework for BC, November 28, 2023.

Source [CPAC YouTube](#) (58)

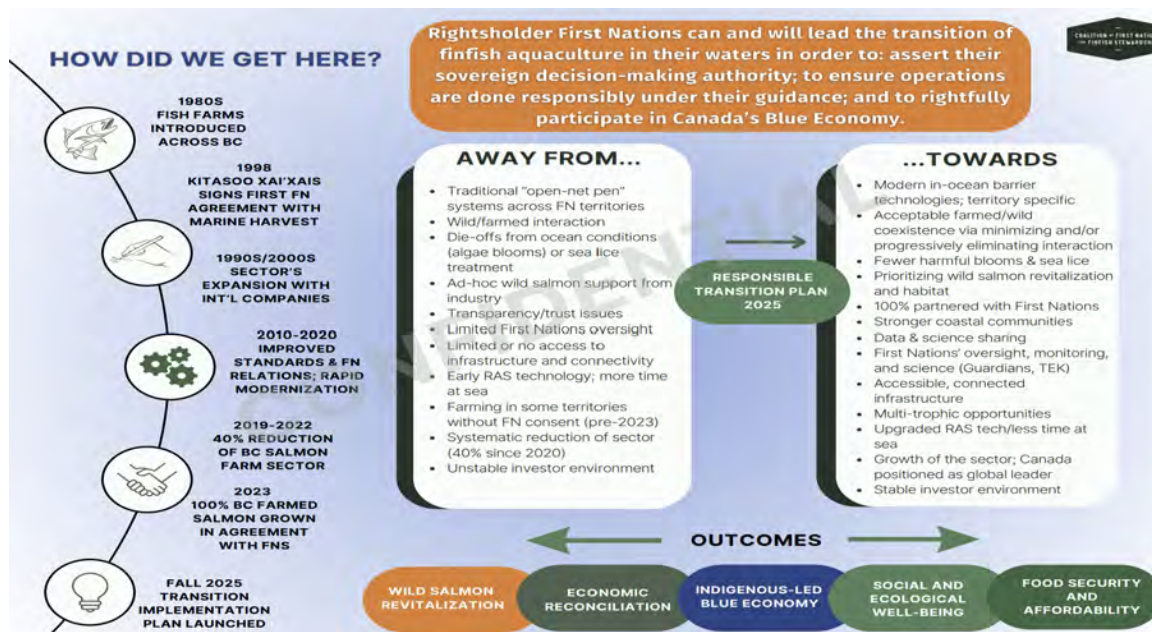
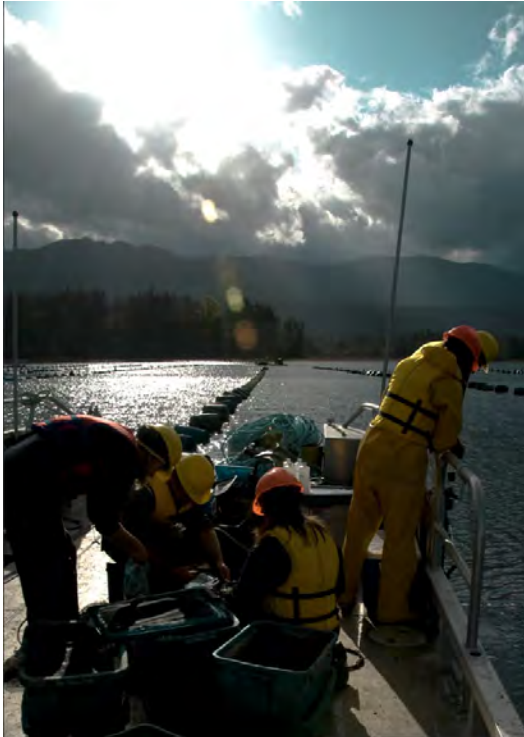


Figure 16. Framework for Indigenous-led finfish aquaculture transitions for BC,

Source: The Coalition of First Nations for Finfish Stewardship, November 2023.



In late 2023, at the United Nations Climate Change Conference (COP28) in Dubai, more than 130 world leaders signed the Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action that focuses on transforming food-systems to meet the long-term goals of the Paris Agreement(59). The Declaration was also supported by a [Non-State Actors Call to Action for Transforming Food](#)

[Systems for People, Nature, and Climate](#)

that has been signed by more than 150 organisations. On December 9 and 10, 2023, delegates met at COP28 to “discuss the necessary measures to achieve the food systems transformation and the role **aquatic foods** and alternative proteins can play in this vision” (60).

The [Race to Zero Climate Champions](#) (61), an organization representing over 13,000 non-government members (over 9,000 companies, 600 financial institutions, 50 regions, 1100 cities, 1100 educational institutions, 70 healthcare institutions and 30 other organisations) launched their [Ocean Breakthroughs](#) transformative pathway to reduce greenhouse gas emissions by focusing on five ocean sectors, including aquatic food (62). Further, they have developed The Ocean for Climate Declaration, describing how key ocean sectors can provide solutions to significantly reduce greenhouse gases and associated climate change impact (63). Their vision aligns with that of the High-level Panel on a Sustainable Ocean Economy (39).

"What is happening now is the promising first steps of actual food system transformation. If countries commit to working together on issues, including food waste, food security, dietary shifts we can significantly reduce global emissions." Wenche Gronbrekk, UN Global Compact Senior Ocean Advisor (2023)

HELP TAKE PRESSURE OFF WILD FISH

Wild-capture fisheries will continue to supply food in every region of the world. Unlike other seafood categories, the global marine finfish supply continues to be dominated by wild-capture fisheries (Figure 17).

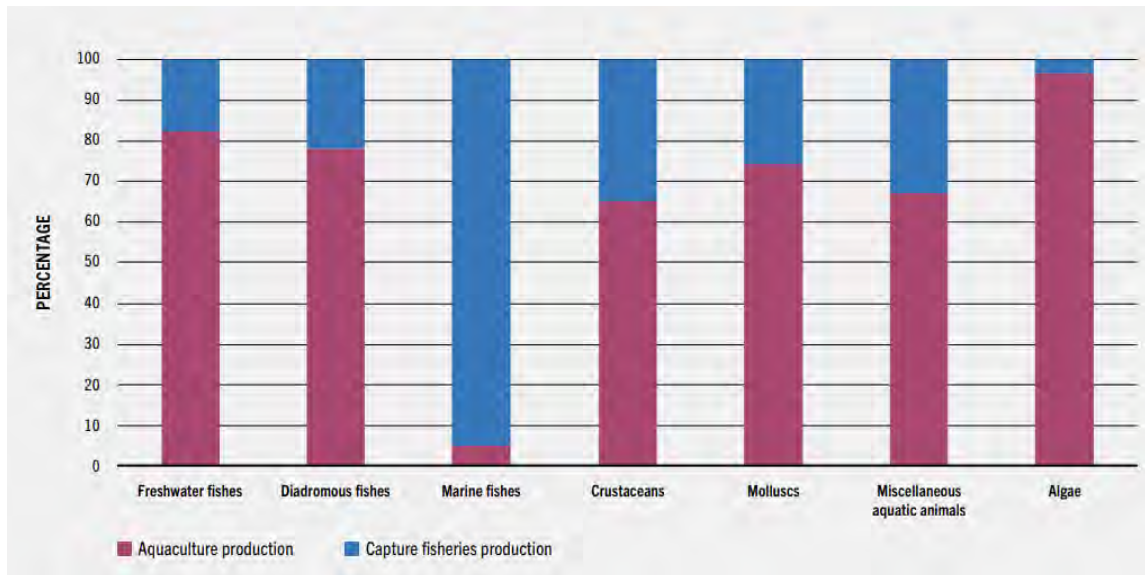


Figure 17. World capture fisheries and aquaculture production by percentage, 2020

Source. The State of World Fisheries and Aquaculture, 2022 (25)

Wild fish are under enormous pressure. According to the United Nations Food and Agriculture Organization (FAO), the world's remaining wild fisheries that are considered to be 'underfished', declined from about 40% in 1974 to just 7.3% in 2019 (Figure 18). Sustainable capture fisheries have also declined from 90% in 1974 to 64% in 2019.

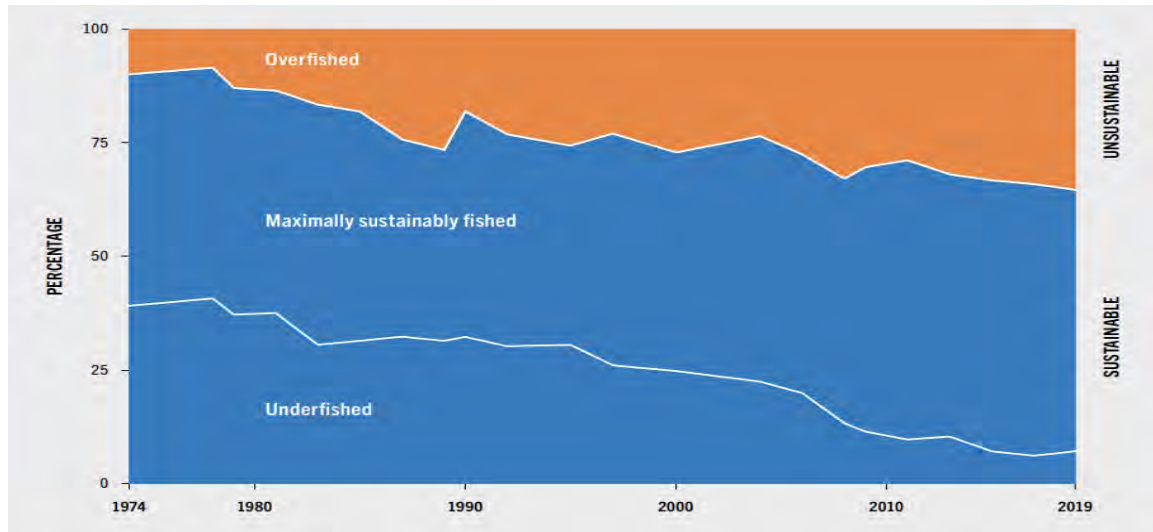


Figure 18. Global trends in the state of the world's marine fishery stocks 1974 – 2019.

Source. *The State of World Fisheries and Aquaculture, 2022* (25)

As sustainable fisheries have stagnated or declined, aquaculture has helped to fill the demand for fish (Figure 19).

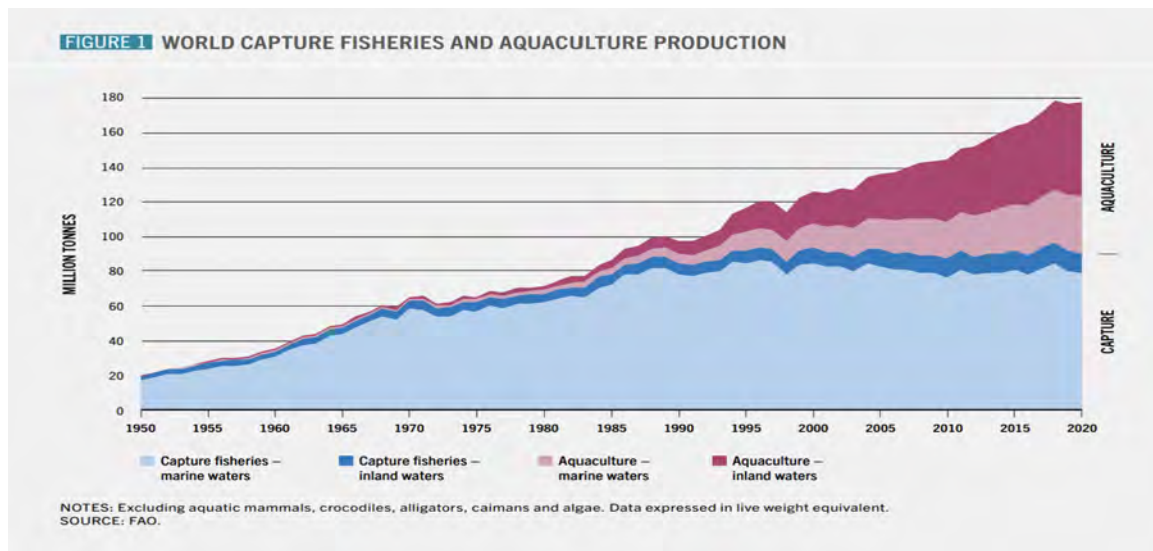


Figure 19. World capture fisheries and aquaculture production (1950 – 2020).

Source. *The State of World Fisheries and Aquaculture, 2022* (25). Source of population figures: United Nations. 2019. 2019 Revision of World Population Prospects. In: UN. New York (64).

What does this mean for fisheries in BC? While the answer to this question is best left to wild fisheries managers to answer - broad patterns have emerged. As of 2019, overall fishery landings within the Northeast Pacific region appeared relatively stable with 86.2% of the assessed stocks being fished within biologically sustainable levels, the highest among fishing areas in the world (Figure 20). Alaskan pollock represented about 50% of the commercial catch, with Pacific cod (*Gadus microcephalus*), hakes and soles also strong contributors.

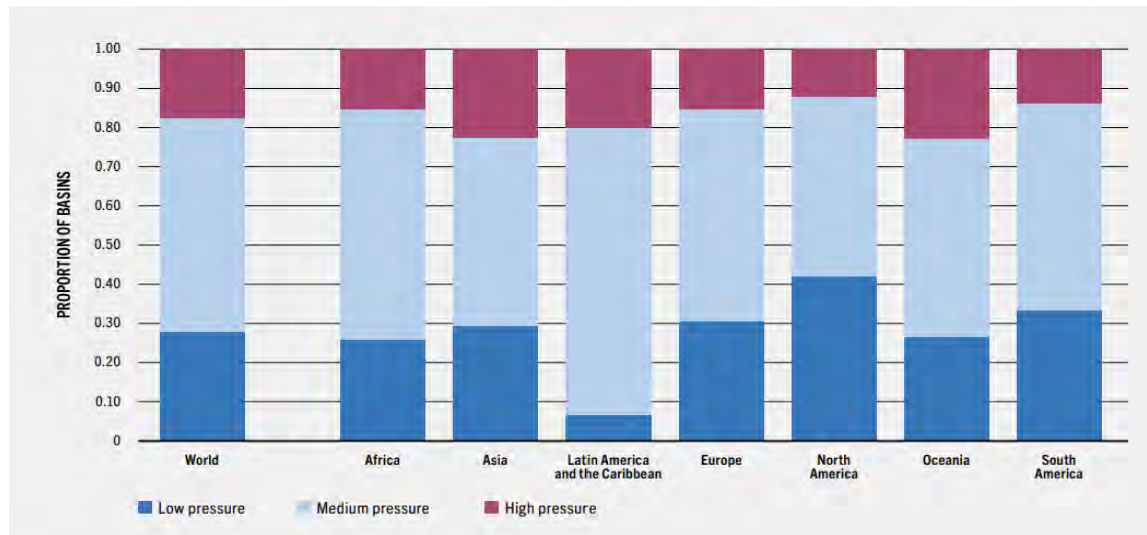


Figure 20. State of major fisheries by region, 2019.

Source. *The State of World Fisheries and Aquaculture, 2022 (25)* FAO NOTE:

Proportional threat status of the basins most important for inland fisheries and their catch ($n=45$ basins) is averaged by region and across regions. SOURCE: Land and Water Lab, University of Florida.

However, by 2020, the Pacific cod fishery in the Gulf of Alaska collapsed. This was due to extreme heating of the Pacific Ocean from 2013 to 2015 (65) and again in 2019 (66) which reduced juvenile cod survival (65).

According to the United Nations, more than 90% of the world's wild fish are fished at or above sustainable levels. While there will continue to be wild-capture fisheries, and improvements in fisheries management can improve catches - it is not reasonable to expect that wild fish can meet *increasing* future demands. This leaves two options for fish consumption: reduce demand or increase aquaculture.



Pacific salmon fisheries have also been exhibiting wide swings in abundances in all five countries in the North Pacific (see “Chapter 2 - Caring for Wild Salmon – The Big Picture” for more details). 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.

In 2022, the United States National Oceanic and Atmospheric Administration

issued a release describing multiple fishery collapses in Alaska. (67)

These are unprecedented fluctuations that must result from large scale climate and ocean influences throughout the North Pacific Ocean. Basin-wide changes in the ocean’s carrying capacity for wild fish are a huge concern for capture fisheries and the people that rely on them for food and employment.

HELP WITH TECHNOLOGY TRANSFER

Aquaculture has fed people for thousands of years. Examples include the common carp (*Cyprinus carpio*) that has been grown in China for about 8,000 years (68), and clam gardens farmed by North American Indigenous peoples for at least 3,500 years (69).

Today, there are about 494 species grown by aqua-culturalists throughout the world, of which 313 are finfish (49). Atlantic salmon is by far the largest marine finfish aquaculture sector, comprising 32.6% of the global production of finfish as of 2020 (49).

Growing food within the sea requires substantial knowledge, infrastructure, and long-term funding. There is a steep learning curve; consider that the majority of salmon farms were not successful

during the first decade of farming within BC (Figures 21 and 22).

It is difficult for new or small operators to develop new products. It takes many years to develop the infrastructure design (e.g., cages and anchoring systems), species-specific biological requirements (e.g., feed and veterinary requirements), and develop local expertise and experience.

It is also difficult to access funding for new products. The perception of high risk (of failure) and a lack of familiarity with how to grow new aquaculture products are the biggest challenges for investors(70). Emerging aquaculture products can be priced out of the market when their small capital footprints cannot absorb start-up costs (70).



Figure 21. View of one of the first salmon farms in British Columbia.

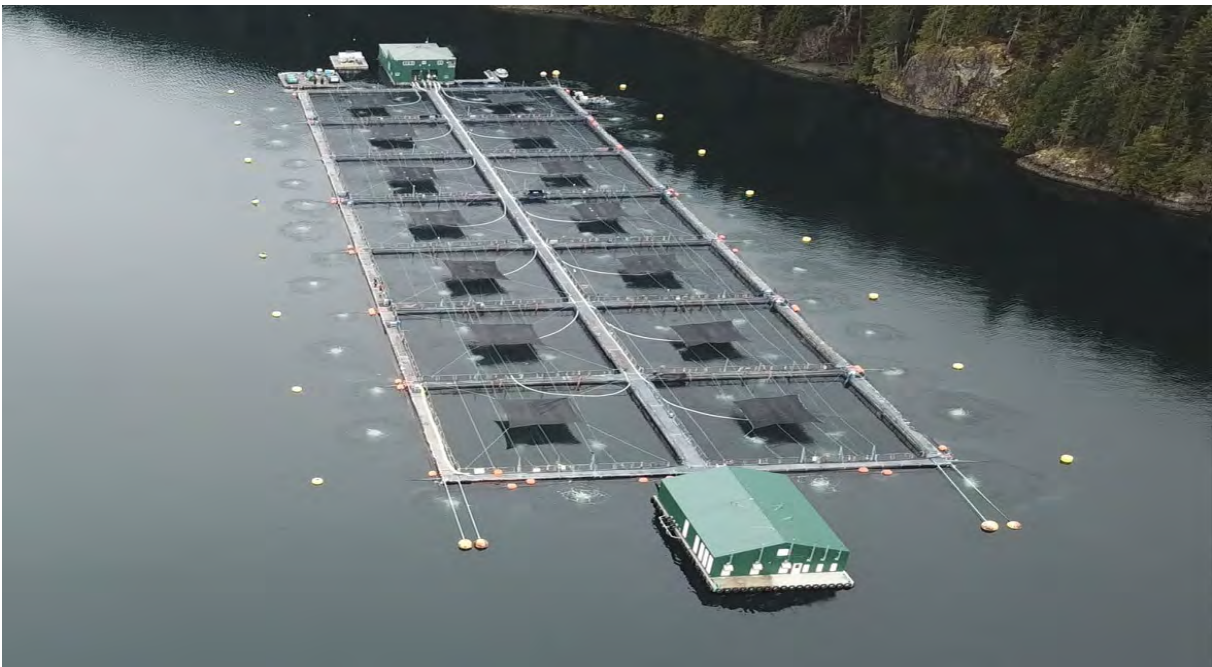


Figure 22. View of typical salmon farm today in British Columbia.

The size of an aquaculture business and its history of success help it invest in its future. Cage culture, such as salmon farming, is among the most established farming systems and offers a precedent on which investors can predict risk (70).

Larger scale helps to spread costs over a much larger revenue base, which fuels incentives for longer-term thinking, and investment in value-adding activities such as research and development, sustainability-label certification, and corporate social responsibility activities (70).



Larger, more established aquaculture companies can offer products and services to help smaller scale operators succeed. Technological advances made within the salmon farming sector have helped pave the way for the other types of aquaculture - as the costs of innovation have already been borne by the salmon farming sector. For example, many of the vaccination techniques, technologies and procedures

from the salmon industry are now being applied to commercial tilapia farming in West Africa (70).

BC salmon farmers and suppliers are innovating world leading precision ocean technologies that are in demand around the world. Innovation is tackling key topics, some of which are listed below:

- o Innovation in resource efficiency
 - o BC salmon farmers have developed some of the most advanced hatcheries in the world using high efficiency, low-water-use recirculating aquaculture systems (RAS) (Figure 23),
 - o Advanced feed formulations that further reduce reliance on fishmeal and fish oil (Figure 24), and
 - o Centralized feeding stations using advanced artificial intelligence (Figure 25),
- o Innovation to reduce greenhouse gases – advanced aeration systems to replace diesel compressors (Figure 26)

Innovation in greener technology - specialized vessels (Figure 27) and technologies have been purpose built for non-chemical sea lice treatments,

- o Innovation in fish welfare – specialized vessels have been purpose built for fish harvesting (Figure 28),
- o Innovation in semi-closed-containment systems – several systems are currently being trialed to improve fish husbandry, with the goal to reduce time at sea and interactions

between wild and farm-raised fish (Figures 29 and 30),

and analyze up to one million of data points per day per farm (Figure 31).

- o Innovation in digital information - advanced in-pen environmental monitoring of cage conditions, collect

“Growth in demand for salmon has outstripped other fish categories in almost every region and Atlantic salmon aquaculture has risen to become one of the most profitable and technologically advanced industries.”
United Nations, Food and Agricultural Organization (2022)



Figure 23. Innovation in resource efficiency: view of advanced recirculating aquaculture system for farm-raised salmon. This technology reduces freshwater use by 90%.

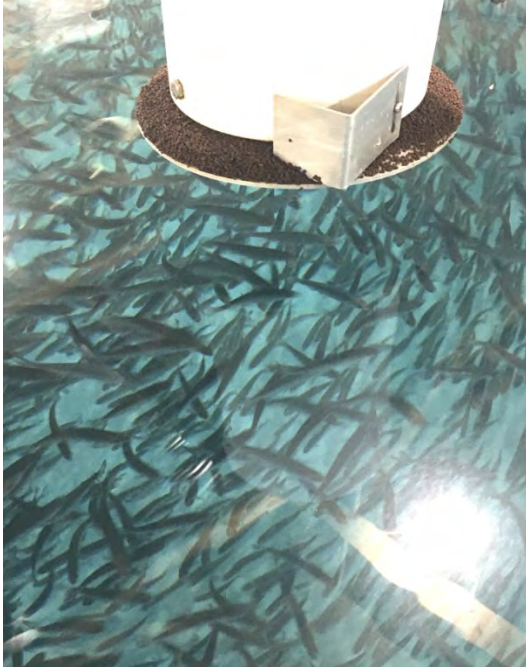


Figure 24. Innovation in resource efficiency: view of feed formulation trial.

While companies farming Atlantic salmon are substituting marine ingredients with different sources of fats and proteins, Chinook-producer Creative Salmon faces

strict guidelines on feed ingredients because the company – and its feed suppliers – are certified to the Canadian Organic Aquaculture Standard.

One feed alternative study at Creative Salmon aimed to determine whether black soldier fly larvae meal and algal oil substitutions were viable as a way to reduce marine dependency in the Chinook diet while also adhering to the organic certification and maintaining high nutritional quality feed and superior fish health.

Another study, a feed trial at a marine site, tests feed containing organic canola oil. The plant oil replaces some of the fish oil in the experimental diet. The trial monitors growth, fatty acid profile, and other factors including flesh quality and taste to determine whether canola oil could become a routinely used non-marine ingredient addition to the Chinook diet.



Figure 25. Innovation to improve resource efficiency and protect biodiversity: new centralized feeding stations in the village of Klemtu and Pt. Hardy use state-of-the-art technology to support local farms.

The technology includes artificial intelligence that tracks individual feed pellets and fish activity levels, which further reduces the amount of feed needed and the amount of feed wasted – further protecting biodiversity near the farms.



Figure 26. Innovation to reduce greenhouse gases: view of Poseidon's new Flowpressor™ aeration system, which slashes greenhouse gas emissions by 60% compared to conventional diesel compressors used to mitigate plankton blooms.



Figure 27. Greener technology innovation: specialized ships, such as the Aqua Tromøy, generate freshwater from the sea and bathe farm-raised salmon in the freshwater to remove sea lice under the supervision of licensed veterinarians. This technology reduces the use of chemical treatments for sea lice.



Figure 28. Innovation in fish welfare: specialized vessels have been purpose built to harvest salmon safely and humanely from marine pens.



Figure 29. Innovation in semi-closed containment: view of in-sea-closed-containment system in Millar Channel, Clayoquot Sound, British Columbia.

An impervious barrier surrounds the farm-raised salmon and separates them from their external environment, reducing the risk of escapes and dramatically limiting potential interactions between farm-raised salmon and wild populations. Deep seawater is pumped into the cage to provide optimal water quality for the cultured fish.



Figure 30. *Innovation in semi-closed containment: view of CO2L Flow System, which allows for farmers to raise or lower custom designed farm enclosures. Trials have demonstrated better growth, lower mortality, better feed conversion rates and a dramatic reduction in the need for sea lice treatments. [Video link](#) (71).*

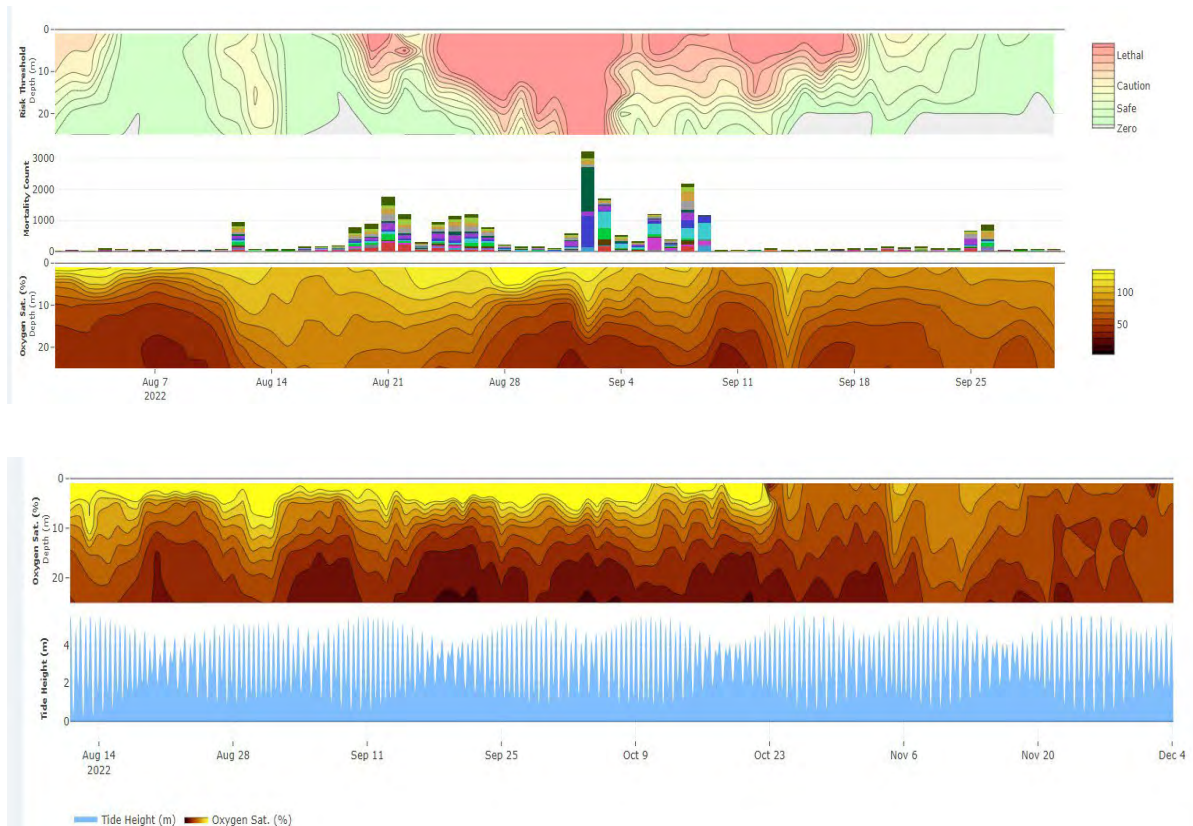


Figure 31. *Innovation in digital information - example of pen tracking data, which charts oxygen saturation, tidal heights, documented fish mortality and calculates the potential risks for salmon in each pen.*

BC salmon farmers have expertise and innovations that may benefit other aquaculturalists, wild salmon conservationists, and other ocean sectors (Figure 32).



Figure 32. Technology sharing that occurs between BC salmon farmers and other aquaculturalists, wild salmon conservationists, and other ocean sectors.

With the right support, we are poised to become the home of Ocean Tech in Canada - delivering bigger and bolder ideas to continuously evolve salmon production on the coast

(72). Cutting edge technologies, such as those shown in Figures 33 and 34, offer exciting opportunities for the future of salmon farming and several are in trials around the globe. They are currently unavailable in BC due to a variety of pressures, both politically and logistically. Research, development and implementation of innovative solutions in BC requires a network of support spanning municipal, provincial, federal and First Nation governments; this is a complex network to build out and takes time.



Figure 33. Greener technology innovation: intelligent technology from Stingray Marine Solutions combines stereo machine vision, advanced monitoring software, and a high precision laser to safely remove sea lice from farm-raised salmon. This technology helps reduce reliance on chemical treatments for sea lice. [Home - Stingray Marine Solutions AS](#) (73)

For more information on technological innovations, please see the BC Salmon Farmers most recent [BCSFA Innovation and Technology Report](#), [BCSFA Tech Document 2021.pdf \(bcsalmonfarmers.ca\) \(1\)](#)

WELFARE

Healthier fish. Better predictions.

WISE

Automatic lice counting and welfare scoring provides important knowledge for decision making around fish welfare. Overview of welfare development and trends. Less handling and stress for the fish.

WELFARE INDICATOR SCORING

We continuously monitor, identify, and measure all observable welfare indicators (OWIs), allowing continuous monitoring of the welfare status in the pen. We also provide information for data-driven decision making across all key welfare indicators to increase quality and revenue.

VALUE FOR YOU

- Representative data on welfare status in the pen
- Reduced mortality risk
- Accurate downgrading predictions
- Increased revenue



LICE

VALUE FOR YOU

- Accurate daily counting of sea lice across different life stages
- Continuous surveillance of lice loads delivers key information for early decision making
- Daily sea lice development gives insight into key trends
- Reliable measurement of the effect of sea lice treatments and other sea lice initiatives
- Reduced handling and fish stress





CLIMATE & ENVIRONMENT

BETTER FISH FARMING TECHNOLOGY BORN IN BATHTUB

2:00 / 2:39

4:48

Figure 34. Innovation in digital information: Aquabyte® - a shift to individualized farming that utilizes advances in machine learning **means less handling and overall healthier farm-raised salmon**. See video [Aquabyte: Camera born in San Francisco bathtub helps to optimize fish farming - ABC7 San Francisco \(abc7news.com\) \(74\)](https://www.youtube.com/watch?v=UW3333333333)



“Companies including Lerøy Seafood Group and Grieg Seafood, are looking at decarbonisation routes such as cutting emissions from the feed used for farmed fish, powering their fleets with alternatives to diesel and switching to renewable electricity for refrigeration.” [How the world's largest seafood companies can help tackle climate change - Climate Champions \(unfccc.int\)](https://unfccc.int/news/how-the-worlds-largest-seafood-companies-can-help-tackle-climate-change)

RESPONSIBILITY AND GOVERNANCE

More fish and seafood production can provide abundant climate friendly proteins for a growing population. However, growth must go hand in hand with safeguarding ecosystems, reducing pollution, protecting biodiversity and ensuring social equity. As stated by the Global Salmon Initiative, “increases in production need to be matched with reductions in environmental impact and improvements in resource efficiency” (75).



Although aquaculture exhibits some of the best feed conversion rates in animal-source foods, expansions in fed aquaculture (such as salmon), will require continued focus on feed to ensure that production is not limited by capture fisheries, and

Aquaculture must be done in ways that respect biodiversity, ocean health and coastal communities.

does not harm forage fish populations (51). Forage fish are essential for marine ecosystems, as they feed on plankton and transfer energy from lower trophic levels to the seabirds, marine mammals and larger fish that feed on them (51).

With this in mind, current feed formulations for fish farms have significantly reduced the fish meal component through replacement with fish wastes, plant material, insects, rendered animal proteins, microbial proteins, and algal oils (76). These

improvements in feeds have supported a tripling of global fed fish production between 2000 and 2017 while the annual catch of forage fish used to make fishmeal and fish oil decreased from 23 to 16 million tonnes (77). Fishmeal and fish oil inclusion rates in Atlantic salmon diets have dropped by about 75% since 1990 (78).



Unfed seafood, such as oysters, mussels and seaweed have high potential to provide nutritious food with little negative impact on the environment (Figure 35). Multi-trophic or co-culture aquaculture, which combines unfed species with higher-trophic-level finfish (such as salmon), may provide solutions for reducing waste and improve resource efficiency – while helping to capitalize infrastructure and stabilize revenues (79).



In a report released in November 2021, an expert working group led by The Nature Conservancy (TNC), defined restorative aquaculture as follows “restorative aquaculture occurs when commercial or subsistence aquaculture provides direct ecological benefits to the environment,

with the potential to generate net positive environmental outcomes.” The full report, with more information on the set of global principles, can be accessed [here](#) (80). The potential for restorative, multi-trophic and/or co-production operations is immense in Canada.



Photo courtesy of Cascadia Seaweed

Figure 35. View of a small seaweed farm in Barkley Sound, BC.

[Cascadia Seaweed](#), founded in 2019, has grown to be the largest vertically-integrated ocean seaweed cultivator in Canada in partnership with coastal First Nations.

Future growth in aquaculture will depend upon good governance and public perception. Aquaculture systems are “often located in shared spaces or dependent on shared water resources, it is vitally important that good relations are maintained with local communities and

other stakeholders.” (53). Trust, transparency and accountability are essential aspects of social and environmental responsibility of the sector. Responsible governance must ensure that practices are sustainable at local ecosystem carrying capacities.

Indigenous oversight of salmon farming in BC provides continuous stewardship of local ecosystems and biodiversity within traditional territories. This advanced governance model is unique within the global salmon farming sector.

Governance of the BC salmon farming sector is shared between First Nations, federal, provincial and municipal governments – providing the highest possible level of oversight to promote responsible use and protection of natural resources such as land, water, coastal habitats and aquatic living resources.

Unfortunately, according to High-level Panel for a Sustainable Ocean Economy 2023 update there has been little progress in realizing the potential of low-carbon sustainable protein from the ocean since 2019, "...more must be done to raise awareness, send clear policy signals and invest in the enabling environment to take advantage of these opportunities." (39)

"With the world's longest coastline and connected to three oceans, Canada is well positioned to be a global leader in the blue economy – an economy that creates good, middle-class jobs, while ensuring healthy oceans and sustainable ocean industries." Bernadette Jordan, Minister of Fisheries, Oceans and the Canadian Coast Guard (2021)



Photo by Brian Kingzett



CARING FOR COASTAL BRITISH COLUMBIA

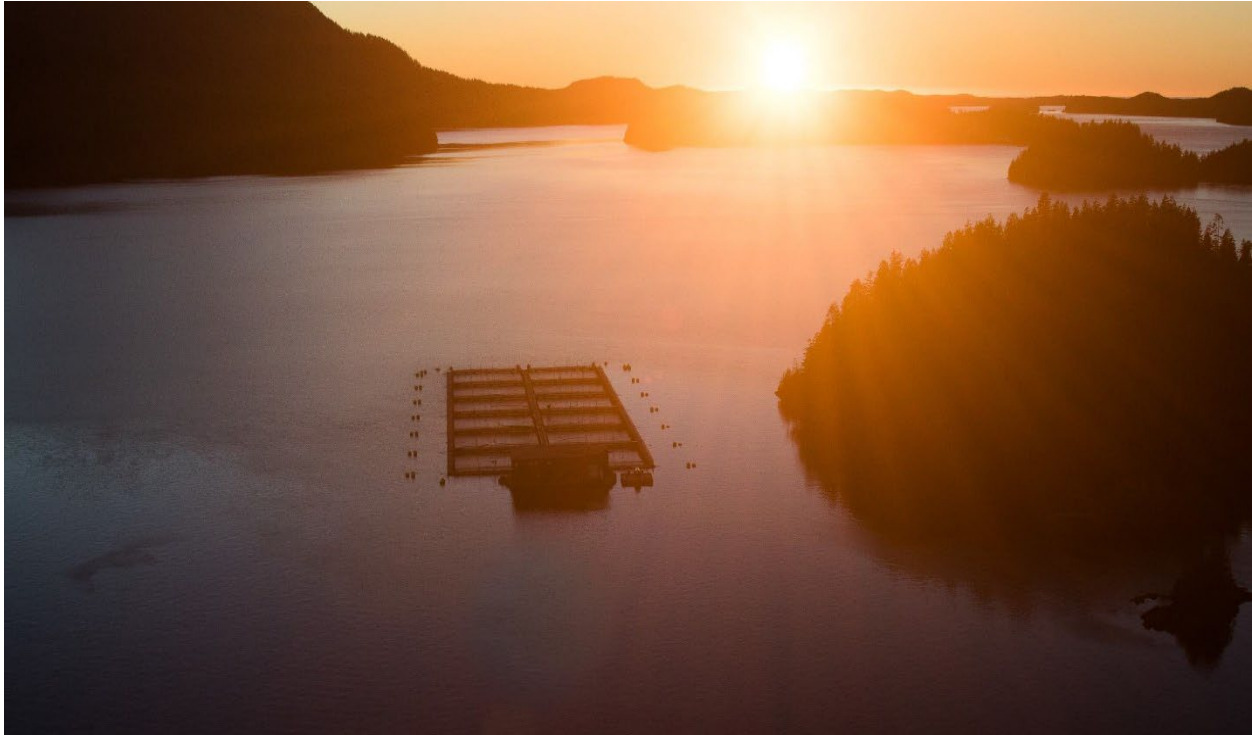


The coastline of British Columbia is one of the world's great natural treasures. It is also home to thousands of First Nations and coastal people. Living and working in this special place comes with great responsibility. It also comes with a unique potential to combine thousands of years of Indigenous knowledge and western science to solve sustainability challenges in new ways.

We believe that protecting the earth and her people comes with the need to look at issues with urgency and also long-term wisdom, to assess both the local and the big picture. And both the local and the

big picture are demonstrating that climate change and population growth are threatening the natural environment.

Aquaculture, done respectfully and responsibly, has the power to help both locally and globally. Salmon farming, while providing some of the world's most nutritious food, can stabilize coastal communities, help offset climate change and enhance food security both locally and globally. Salmon farmers, as experts in growing salmon and oceanography, can help conserve and enhance wild salmon and unlock the mysteries of the ocean habitats.



We imagine a bright future for aquaculture in British Columbia. This future envisions a harmonious coexistence between aquaculture and the natural world for generations to come. We are confident that with First Nation guidance and responsible innovations and practices, salmon farming can succeed in new ways in British Columbia.

While we have come a long way in the past 40 years, there is still more to do. We are very excited for our next steps:

- o First Nation reconciliation – further development of relationships with Nations to achieve the sustainability goals of each Nation; support for communities and business opportunities.
- o Wild salmon – sharing of knowledge and resources to advance wild salmon conservation and restoration.
- o Reduction of interactions between wild and farm-raised salmon - continued improvements to the seven safeguards for fish health described in Chapter 11, with a focus on refining barriers such as the development of additional vaccines.
- o Sea lice – continually improve Integrated Pest Management program for sea lice management, including area-based management, innovations to improve management tools, and sea lice monitoring on juvenile wild salmon.
- o New technology trials – continued investment in semi-closed containment technologies to progressively minimize and/or eliminate wild and farm-raised salmon interactions.



- o Digital advances – expansion of machine-learning, data-logging, artificial intelligence, data analytics and communications to further improve oversight of environmental conditions, fish growth and health.
 - o Improved efficiency in resource use - support the accelerated development and adoption of sustainable alternative feed ingredient sources that optimize fish health, prioritizing Canadian suppliers where possible.
 - o Support Canada's commitment to net-zero by achieving a 35% reduction in GHGs by 2030 -continued advancement of alternative energy supply (for example, hybrid generators and solar), incorporation of electric equipment, and advances in feeding practices.
 - o Eliminate waste by utilizing 100% of the product to support a circular economy. A circular economy retains and recovers as much value as possible from resources to reduce or eliminate waste. In the food system, this involves reducing food spoilage and waste through utilization of by-products and food waste and nutrient recycling. One example is fish by-products being used in pet food and fertilizers. This concept includes working with partners to investigate and adopt new technologies and innovative practices to manage waste produced by fish.
 - o Innovate packaging - work with governments, suppliers, and international partners towards using 100% reusable, recyclable, or biodegradable packaging.
 - o Support restorative aquaculture, multi-species and/or co-production opportunities at applicable locations.
 - o Develop consumer-friendly digital traceability systems - consumers will be able to follow the movement of BC farm-raised salmon through all steps in the supply chain, both backward and forward.
 - o Build trust and transparency with our partners and the public – regularly communicate our environmental and community performance to others.
- We are excited to share our story and aspirations with you in more detail in the next chapters.



We have developed a passion for growing one of the world's most iconic animals in one of the world's most iconic places. And we realize it is both a privilege and a responsibility to be here right now, doing this.



The background of the image is a photograph of a coastline. In the foreground, a grassy cliffside slopes down towards the ocean. The ocean is a deep blue with white foam from waves crashing against dark rocks. In the distance, a range of mountains is visible under a sky filled with large, white, and grey clouds. A bright light source, likely the sun, is breaking through the clouds on the left side, creating a lens flare effect. A large, semi-transparent yellow circle is centered in the upper half of the image, containing text.

[The Ocean Is Our Best Chance To Survive Climate Change | TIME](#)

"There can be no fulfillment of the Paris Agreement without the ocean. To meet the 1.5°C goal, the world must make a massive pivot towards investment in ocean science, innovation, and the development of a truly sustainable and socially responsible ocean economy. **We must make that pivot as if our grandchildren's lives depend on it, because for many of them, that will be the case.**"

Peter Thomson, United Nations Secretary-General's Special Envoy for the Ocean and co-chair of Friends of Ocean Action at the World Economic Forum - COP 28, November 23, 2023

REFERENCES

1. BC Salmon Farmers Association. 2021. Innovation and Technology Report. BCSFA.https://bcsalmonfarmers.ca/wp-content/uploads/2021/08/BCSFA_Tech_Document_2021_F2.pdf
2. Little A. 2019. Climate Change Is Likely to Devastate the Global Food Supply. But There's Still Reason to Be Hopeful. TIME [Internet]. March 2024 [cited 2024]. Available from: <https://time.com/5663621/climate-change-food-supply/>.
3. Stuchtey MR, Vincent A, Merkl A, Bucher M, Haugan PM, Lubchenco J, et al. 2023. Ocean Solutions That Benefit People, Nature and the Economy. In: Lubchenco J, Haugan PM, editors. The Blue Compendium: From Knowledge to Action for a Sustainable Ocean Economy. Cham: Springer International Publishing. p. 783-906.https://doi.org/10.1007/978-3-031-16277-0_20
4. Trewin B, Morgan-Bulld D, Cooper S. 2021. Climate Canberra ACT: Australian Government; [Available from: <https://soe.dcccew.gov.au/climate/introduction>].
5. First Nations for Finfish Stewardship. 2022. The Reality is: Salmon Farming is a path to self determination and reconciliation for many First Nations in coastal BC. 2022.https://firstnationsforfinfish.ca/wp-content/uploads/2022/03/FNFFS_report_web.pdf
6. Gratitude Seafood. 2023. Our Products: Gratitude Seafood; [Available from: https://gratitudeseafood.com/our_products/].
7. Collins B, McCannel J. 2019. Aquaculture on Vancouver Island. Nanaimo, BC: Vancouver Island Economic Alliance.<http://viea.ca/wp-content/uploads/2019/07/Aquaculture.pdf>
8. RIAS Inc. Economic and Financial Impacts of Minister Murray's Transition Plan for BC Salmon Farms. Ottawa, Ont.: Prepared for the BC Salmon Farmers Association; 2023. p. 7
9. Aqua Kompetanse. 2023. Technical Requirements for Aquaculture Installations NYTEK23-regulations and NS9415 Norwegian standard for Marine Fish Farms Norway: Aqua Kompetanse; [Available from: <https://nytekandns9415.com/introduction>].
10. Fisheries and Oceans Canada. 2023. Marine finfish B.C. aquaculture licence and conditions of licence. Nanaimo: Government of Canada.<https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/licence-cond-permis-mar/index-eng.html>
11. Fisheries and Oceans Canada. 2023. Benthic performance at marine finfish aquaculture sites in BC. Ottawa: Government of Canada.<https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/benth/index-eng.html>
12. Fisheries and Oceans Canada. 2023. Marine mammal (megafauna) fatalities at marine finfish aquaculture facilities in British Columbia. Ottawa: Government of Canada.<https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/mar-mam/index-eng.html>
13. Storlund RL, Cottrell PE, Cottrell B, Roth M, Lehnhart T, Snyman H, et al. 2024. Aquaculture related humpback whale entanglements in coastal waters of British Columbia from 2008–2021. PLOS ONE.19(3):e0297768.10.1371/journal.pone.0297768



14. Fisheries and Oceans Canada. 2023. Average number of lice per fish on BC salmon farms. Ottawa: Government of Canada. <https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/lice-ab-pou/index-eng.html>
15. Fisheries and Oceans Canada. 2023. Use of therapeutants. Ottawa: Government of Canada. <https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/therapeut/index-eng.html#antibacterial-data>
16. Fisheries and Oceans Canada. 2022. Summaries of the risk assessments for the Discovery Islands area. Ottawa: Government of Canada. <https://www.dfo-mpo.gc.ca/cohen/iles-discovery-islands-eng.html>
17. Open Government. 2024. National Aquaculture Public Reporting Data Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/288b6dc4-16dc-43cc-80a4-2a45b1f93383>].
18. Lafrance D. 2021. Canada's Aquaculture Industry. Ottawa, Ont.: Library of Parliament, Parliamentary Information and Research Service <https://lop.parl.ca/staticfiles/PublicWebsite/Home/ResearchPublications/BackgroundPapers/PDF/2021-03-e.pdf>
19. Durack PJ, Gleckler PJ, Purkey SG, Johnson GC, Lyman JM, Boyer TP. 2018. Ocean warming, from the surface to the deep in observations and models. *Oceanography*.31(2):41-51, <https://www.jstor.org/stable/26542650>
20. United Nations Department of Economic and Social Affairs. 2022. World Population Prospects 2022: Summary of Results. New York,: United Nations. Report No.: 978-92-1-148373-4. https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf
21. Ip F, Lavoie S. 2020. PEOPLE 2020: BC Sub-Provincial Population Projections. Victoria: Government of British Columbia. https://www2.gov.bc.ca/assets/gov/data/statistics/people-population-community/population/people_population_projections_highlights.pdf
22. van Dijk M, Morley T, Rau ML, Saghai Y. 2021. A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. *Nature Food*.2(7):494-501.10.1038/s43016-021-00322-9
23. FAO. 2021. The State of the World's Land and Water Resources for Food and Agriculture 2021 – Systems at breaking point. Rome, Italy: FAO. 393 p. <https://www.fao.org/documents/card/en/c/cb9910en>
24. Ritchie H, Roser M. 2019. Land Use How is humanity using the Earth's land? And how can we decrease our land use so that more land is left for wildlife? Oxford: Our World in Data; [Available from: <https://ourworldindata.org/land-use#breakdown-of-global-land-use-today>].
25. FAO. 2022. The State of World Fisheries and Aquaculture, 2022. Rome, Italy: FAO. 266 p. <https://www.fao.org/documents/card/en/c/cc0461en>
26. Government of Canada. 2021. G20 Rome Leaders' Declaration. Ottawa: Government of Canada. https://www.international.gc.ca/world-monde/international_relations-relations_internationales/g20/2021-10-31-g20-rome.aspx?lang=eng

27. Crippa M, Solazzo E, Guizzardi D, Monforti-Ferrario F, Tubiello FN, Leip A. 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature Food*.2(3):198-209.10.1038/s43016-021-00225-9
28. FAO. 2018. FAO Yearbook. Fishery and Aquaculture Statistics 2016. Rome, Italy: FAO. Available from: <https://www.fao.org/documents/card/en/c/I9942T>.
29. Bennett A, Patil P, Kleisner K, Rader D, Virdin J, Basurto X. 2018. Contribution of Fisheries to Food and Nutrition Security: Current Knowledge, Policy, and Research. Durham, NC: Duke University. Available from: https://nicholasinstitute.duke.edu/sites/default/files/publications/contribution_of_fisheries_to_food_and_nutrition_security.pdf.
30. FAO. 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome, Italy: FAO. Available from: <https://www.fao.org/documents/card/en?details=I9540EN>.
31. Nijdam D, Rood T, Westhoek H. 2012. The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. *Food Policy*.37(6):760-770.<https://doi.org/10.1016/j.foodpol.2012.08.002>
32. Hall SJ, Delaporte A, Phillips M, Beveridge M, O'Keefe M. 2011. Blue frontiers: managing the environmental costs of aquaculture: WorldFish. Available from: <https://hdl.handle.net/20.500.12348/1150>.
33. Hall SJ. 2011. Blue frontiers: managing the environmental costs of aquaculture: WorldFish.
34. Huntington T, Hasan MR. 2009. Fish as feed inputs for aquaculture—practices, sustainability and implications: a global synthesis. FAO Fisheries and Aquaculture Technical Paper.518:1-61, https://www.researchgate.net/profile/Mohammad-Hasan-12/publication/284307162_Fish_as_feed_inputs_for_aquaculture-practices_sustainability_and_implications_A_global_synthesis/links/5e58ff28a6fdccbeba0818fa/Fish-as-feed-inputs-for-aquaculture-practices-sustainability-and-implications-A-global-synthesis.pdf#page=19
35. Fry JP, Mailloux NA, Love DC, Milli MC, Cao L. 2018. Feed conversion efficiency in aquaculture: do we measure it correctly? *Environmental Research Letters*.13(2):024017.10.1088/1748-9326/aaa273
36. RIAS Inc. 2016. Comparing the Environmental Footprint of B.C.'s Farm-Raised Salmon to Other Food Protein Sources. Ottawa, ON: RIAS Inc.,.
37. Gephart JA, Henriksson PJG, Parker RWR, Shepon A, Gorospe KD, Bergman K, et al. 2021. Environmental performance of blue foods. *Nature*.597(7876):360-365.10.1038/s41586-021-03889-2
38. Hilborn R, Banobi J, Hall SJ, Pucylowski T, Walsworth TE. 2018. The environmental cost of animal source foods. *Frontiers in Ecology and the Environment*.16(6):329-335.<https://doi.org/10.1002/fee.1822>
39. Hoegh-Guldberg O, Caldeira K, Chopin T, Gaines S, Haugan P, Hemer M, et al. 2023. . "The ocean as a solution to climate change: Updated opportunities for action." Special Report. Washington, DC: World Resources Institute. Available from: https://oceanpanel.org/wp-content/uploads/2023/09/Ocean_Panel_Ocean_Climate_Solutions_Update_Full.pdf.



40. Global Salmon Initiative. 2024. Farmed Salmon's Role in Sustainable Food Systems: Global Salmon Initiative; [Available from: <https://globalsalmoninitiative.org/en/sustainability-report/sustainable-food-systems/>].
41. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*.393(10170):447-492, [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(18\)31788-4/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)31788-4/fulltext)
42. Golden CD, Koehn JZ, Shepon A, Passarelli S, Free CM, Viana DF, et al. 2021. Aquatic foods to nourish nations. *Nature*.598(7880):315-320.10.1038/s41586-021-03917-1
43. Kawarazuka N. 2010. The contribution of fish intake, aquaculture, and small-scale fisheries to improving food and nutrition security: a literature review. Penang, Malaysia: The WorldFish Center. Available from: <https://digitalarchive.worldfishcenter.org/handle/20.500.12348/1273>.
44. Golden CD, Allison EH, Cheung WWL, Dey MM, Halpern BS, McCauley DJ, et al. 2016. Nutrition: Fall in fish catch threatens human health. *Nature*.534(7607):317-320.10.1038/534317a
45. Golden CD, Koehn JZ, Shepon A, Passarelli S, Free CM, Viana DF, et al. 2021. Aquatic foods to nourish nations. *Nature*.10.1038/s41586-021-03917-1
46. MOWI. 2018. Integrated annual report 2018. Bergen, Norway.https://issuu.com/hg-9/docs/mowi_annual_report_2018_4e0dacb83168e4?e=19530043/68703955
47. Fisheries and Oceans Canada. 2018. Outlook to 2027 for Canadian Fish and Seafood. Ottawa: Fisheries and Oceans Canada.<https://www.dfo-mpo.gc.ca/ea-ae/economic-analysis/outlook-to-2027-perspectives-jusqu-en-2027-eng.html>
48. General Assembly Adopts Resolution Underlining Protection of Ocean Health, as Delegate Calls Declaration Step towards Preserving Planet's Ecosystem [press release]. Rome, Italy, July 6, 2017 217.
49. FAO. 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome: FAO. 266 p.<https://www.fao.org/documents/card/en/c/cc0461en>
50. FAO. Blue Transformation – Sustainable Aquaculture. Youtube2023.<https://www.youtube.com/watch?v=vn3u1ypnRjs>
51. Costello C, Cao L, Gelcich S, Cisneros-Mata MÁ, Free CM, Froehlich HE, et al. 2020. The Future of Food from the Sea. Institute WR, Washington DC.www.oceanpanel.org/future-food-sea
52. High Level Panel for a Sustainable Ocean Economy. Towards a Sustainable Ocean Economy. Youtube2020.<https://www.youtube.com/watch?v=S8RHgCvKb6E&t=241s>
53. Bunting S, Pounds A, Immink A, Zacarias S, Bulcock P, Murray F, Auchterlonie N. 2022. The Road to Sustainable Aquaculture: On Current Knowledge and Priorities for Responsible Growth. Cologny, Switzerland: World Economic Forum.https://www3.weforum.org/docs/WEF_The_Road_to_Sustainable_Aquaculture.pdf
54. World Economic Forum. 2023. The Global Sustainable Aquaculture Roadmap: Pathways for Systemic Change. Geneva, Switzerland: World Economic Forum. Available from: https://www3.weforum.org/docs/WEF_Global_Aquaculture_Roadmap_2023.pdf.

55. Action FoO. The Blue Food Partnership. Youtube; 2022.https://www.youtube.com/watch?v=v87dGZ_ILRE
56. Fisheries and Oceans Canada. 2022. Engaging on Canada's Blue Economy Strategy: What We Heard. Ottawa, Ontario Fisheries and Oceans Canada. Report No.: 978-0-660-39807-5.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41030503.pdf>
57. First Nations for Finfish Stewardship. 2024. First Nations have the right to make their own decisions in their territories. Campbell River: First Nations for Finfish Stewardship;; [Available from: <https://www.firstnationsforfinfish.ca/>.
58. CPAC. B.C. First Nations coalition releases plan to reform salmon farming industry – November 28, 2023. Ottawa, Ont2023.<https://www.youtube.com/watch?v=mQViQw2aXkU>
59. Leader's Declaration on Food System a milestone moment in climate action, but global commitment must translate to local action [press release]. Gland, Switzerland: World Wildlife Fund, December 1, 2023 2023.
60. United Nations Climate Change. 2023. Programme - MP Ocean Action Events. COP 28; Dubai, United Arab Emirates: United Nations Climate Change, <https://climatechampions.unfccc.int/wp-content/uploads/2023/11/Programme-MP-Ocean-Action-Events-@-COP28.pdf>
61. United Nations Climate Change. 2022. Race to Zero: United Nations Framework Convention on Climate Change; [Available from: <https://racetozero.unfccc.int/system/race-to-zero/>.
62. Anon. 2022. Ocean Breakthroughs Rome: United Nations Framework Convention on Climate Change; [Available from: <https://climatechampions.unfccc.int/system/oceanbreakthroughs/>.
63. Picourt L, Beguin I. 2021. The ocean for climate declaration. Change UNFCCC: Marrakech Partnership for Global Climate Action.<https://climatechampions.unfccc.int/wp-content/uploads/2022/04/The-Ocean-for-Climate-Declaration-V9-16.12.2021.pdf>
64. Anon. 2019. World Population Prospects 2022 Rome: United Nations, Department of Economic and Social Affairs; [Available from: <https://population.un.org/wpp/>.
65. Barbeaux SJ, Holsman K, Zador S. 2020. Marine Heatwave Stress Test of Ecosystem-Based Fisheries Management in the Gulf of Alaska Pacific Cod Fishery. *Frontiers in Marine Science*.7.10.3389/fmars.2020.00703
66. Cornwall W. Is 'The Blob' back? New marine heat wave threatens Pacific. *Science*2019.<https://www.science.org/content/article/blob-back-new-marine-heat-wave-threatens-pacific>
67. Secretary of Commerce issues multiple fishery disaster determinations for Alaska [press release]. US Department of Commerce, January 21, 2022 2022.
68. Harland J. 2019. The origins of aquaculture. *Nature Ecology & Evolution*.3(10):1378-1379.10.1038/s41559-019-0966-3
69. Smith NF, Lepofsky D, Toniello G, Holmes K, Wilson L, Neudorf CM, Roberts C. 2019. 3500 years of shellfish mariculture on the Northwest Coast of North America. *PLOS ONE*.14(2):e0211194.10.1371/journal.pone.0211194

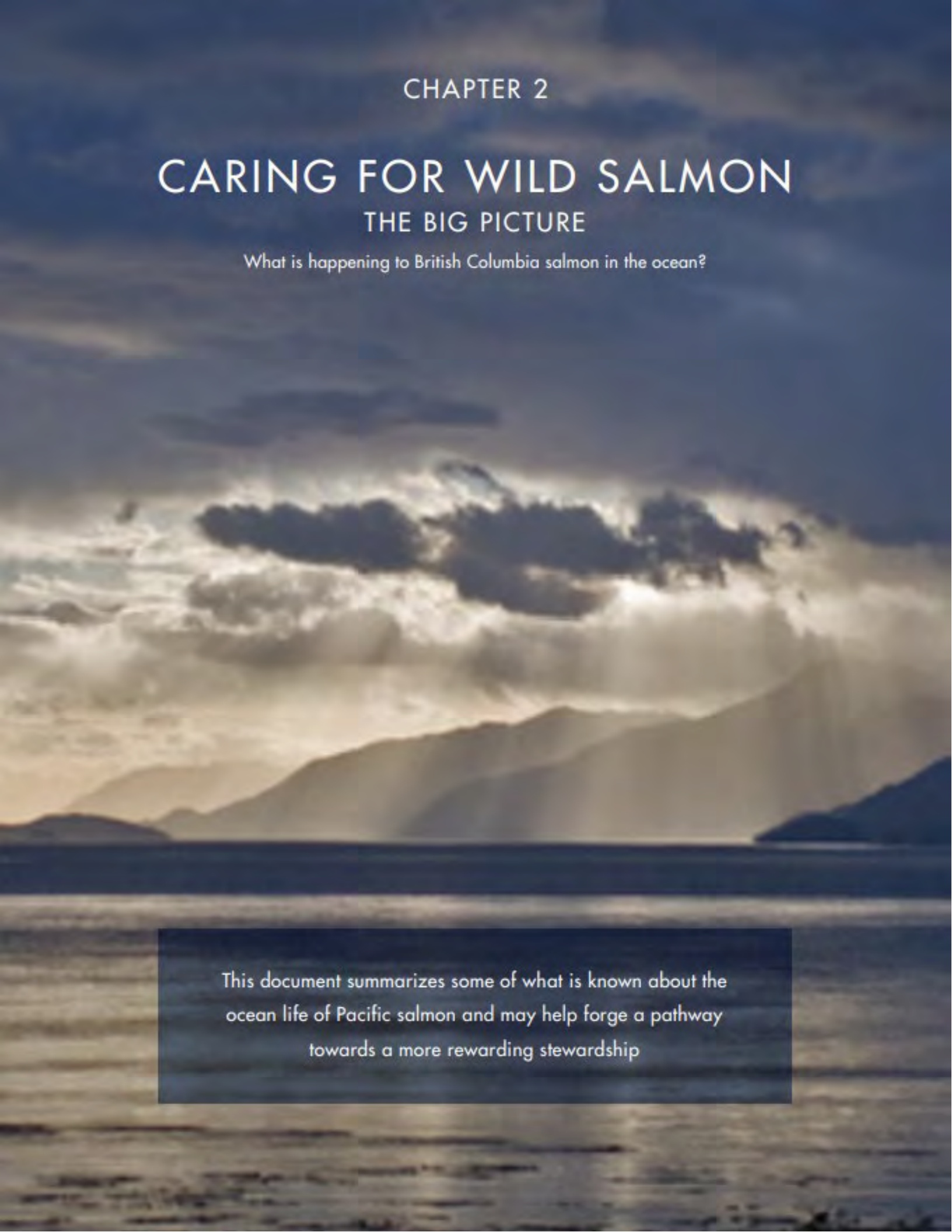


70. Bunting S, Pounds A, Immink A, Zacarias S, Bulcock P, Murray F, Auchterlonie N. 2022. The Road to Sustainable Aquaculture: On current knowledge and priorities for responsible growth. Cologny, Switzerland.: World Economic Forum. Available from: https://www3.weforum.org/docs/WEF_The_Road_to_Sustainable_Aquaculture.pdf.
71. Grieg Seafood ASA. Semi-closed containment technology at Grieg Seafood. 2021. <https://vimeo.com/501829519>
72. Anon. 2017. Ocean technologies Ottawa, Ont: Government of Canada; [Available from: <https://ised-isde.canada.ca/site/shipbuilding-industrial-marine/en/ocean-technologies>.
73. Stingray Marine Solutions AS. 2024. The Stingray Solution Oslo, Norway [Available from: <https://www.stingray.no/?lang=en>.
74. Ashley D, Didion T. Camera born in San Francisco bathtub helps to optimize fish farming. San Francisco CA: ABC, Inc., KGO-TV; 2023. <https://abc7news.com/aquabyte-startup-artificial-intelligence-fish-farming-bathtub/13800815/>
75. Global Salmon Initiative. 2024. The Future of Aquaculture: Global Salmon Initiative; [Available from: <https://globalsalmoninitiative.org/en/our-work/the-future-of-aquaculture/>.
76. Schubel JR, Thompson K. 2019. Farming the Sea: The Only Way to Meet Humanity's Future Food Needs. *GeoHealth*.3(9):238-244. <https://doi.org/10.1029/2019GH000204>
77. Tacon AGJ. 2020. Trends in Global Aquaculture and Aquafeed Production: 2000–2017. *Reviews in Fisheries Science & Aquaculture*.28(1):43-56.10.1080/23308249.2019.1649634
78. Aas TS, Åsgård T, Ytrestøyl T. 2022. Utilization of feed resources in the production of Atlantic salmon (*Salmo salar*) in Norway: An update for 2020. *Aquaculture Reports*.26:101316. <https://doi.org/10.1016/j.aqrep.2022.101316>
79. Chopin T, Troell M, Reid GK, Knowler D, Robinson S, Neori A, et al. 2010. Integrated Multi-Trophic Aquaculture Part I. Responsible practice provides diversified products, biomitigation. *The Global Aquaculture Advocate*.13:38-39, https://www.researchgate.net/publication/257827598_Integrated_Multi-Trophic_Aquaculture_Part_I_Responsible_practice_provides_diversified_products_biomitigation
80. The Nature Conservancy. 2021. Global Principles of Restorative Aquaculture. Arlington, VA: The Nature Conservancy. https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_PrinciplesofRestorativeAquaculture.pdf

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The background of the entire page is a photograph of a coastal landscape. In the foreground, there is a body of water with some rocks visible. In the middle ground, there are dark, silhouetted mountains. The sky is filled with large, dramatic clouds, with some light breaking through near the horizon, creating a golden glow. The overall mood is somber yet hopeful.

CHAPTER 2

CARING FOR WILD SALMON

THE BIG PICTURE

What is happening to British Columbia salmon in the ocean?

This document summarizes some of what is known about the ocean life of Pacific salmon and may help forge a pathway towards a more rewarding stewardship

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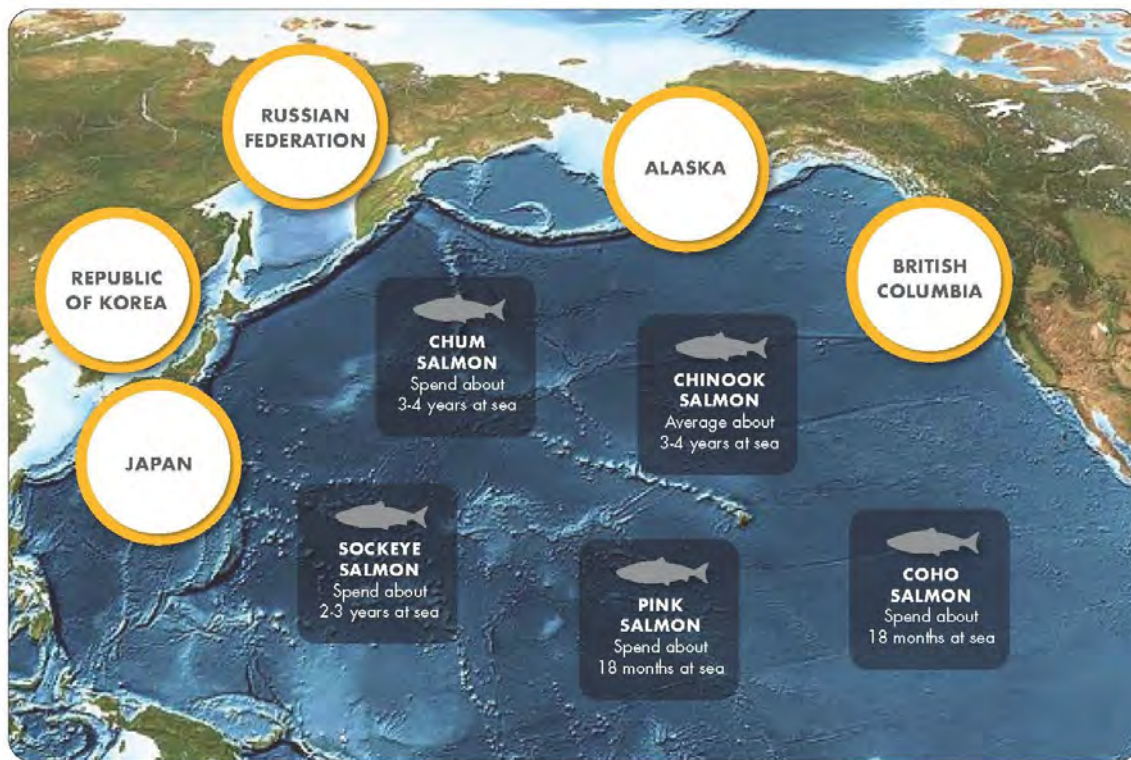
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CHAPTER HIGHLIGHTS – CARING FOR WILD SALMON – THE BIG PICTURE



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.



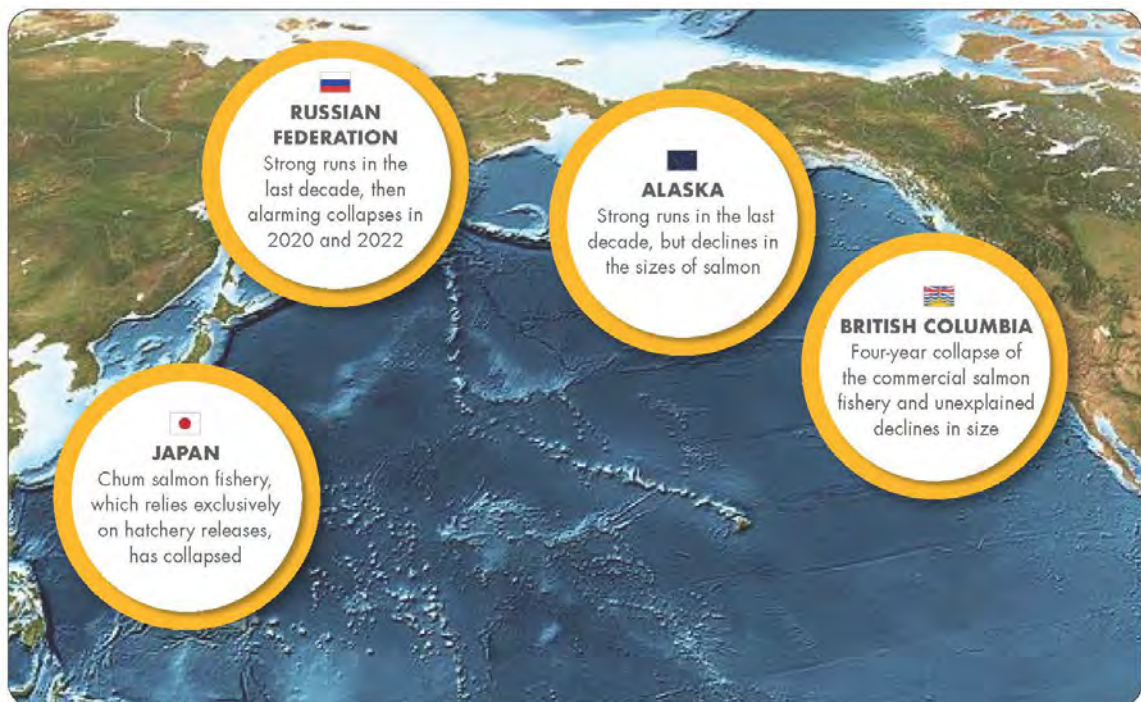
The chum salmon fishery in Japan, which relies solely on hatchery releases, has declined substantially since about 2007. This is occurring despite Japan's continued release of slightly less than two billion hatchery fish annually. British Columbia also experienced a collapse in the commercial fishery 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 km² 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.

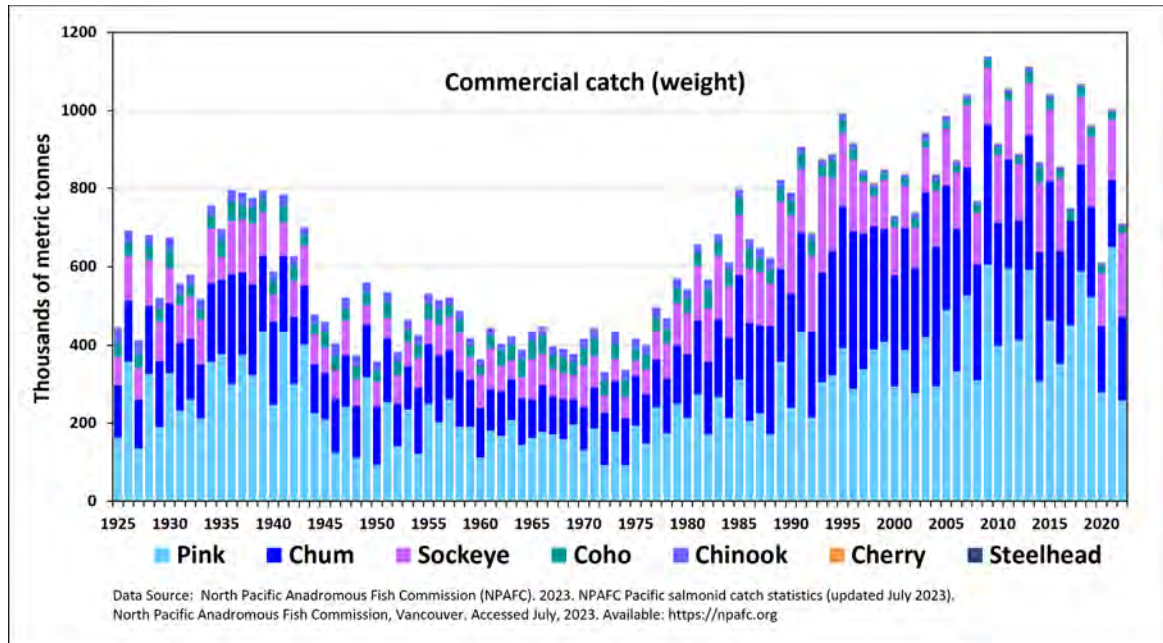


Figure 2. Annual commercial catch of salmon and steelhead trout by species in thousands of metric tonnes 1925 – 2022, all countries combined.
Source North Pacific Anadromous Fish Commission Statistics (2)

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.



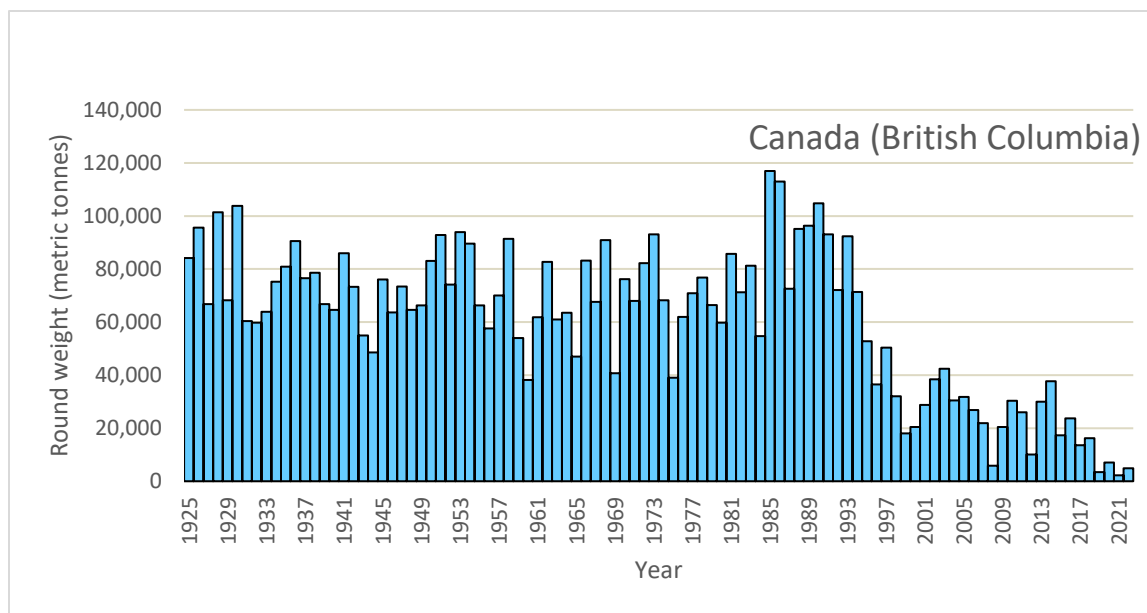


Figure 3. *Total catch of Pacific salmon by British Columbia, including Yukon.*
 Source North Pacific Anadromous Fish Commission Statistics (2)

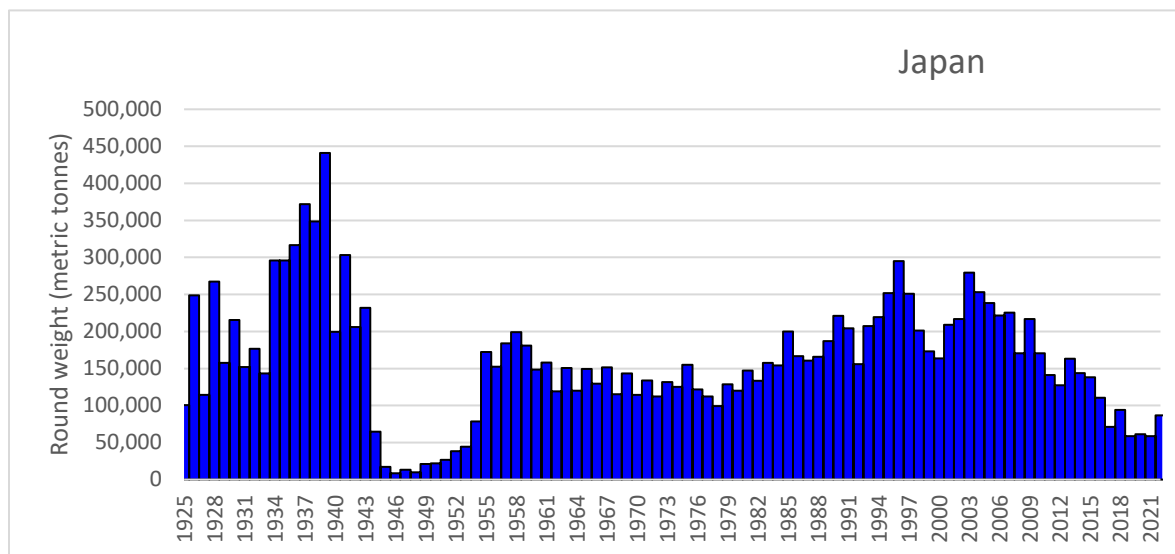


Figure 4. *Total catch of Pacific salmon by Japan.*
 Source North Pacific Anadromous Fish Commission Statistics (2)

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.

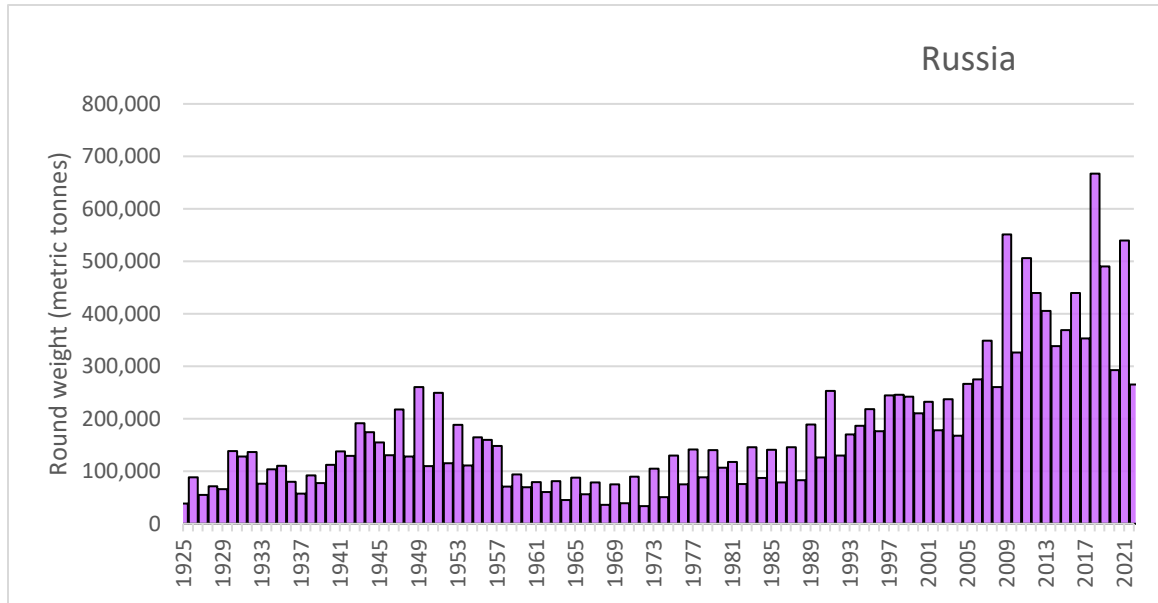


Figure 5. Total catch of Pacific salmon by Russia.

Source North Pacific Anadromous Fish Commission Statistics (2)

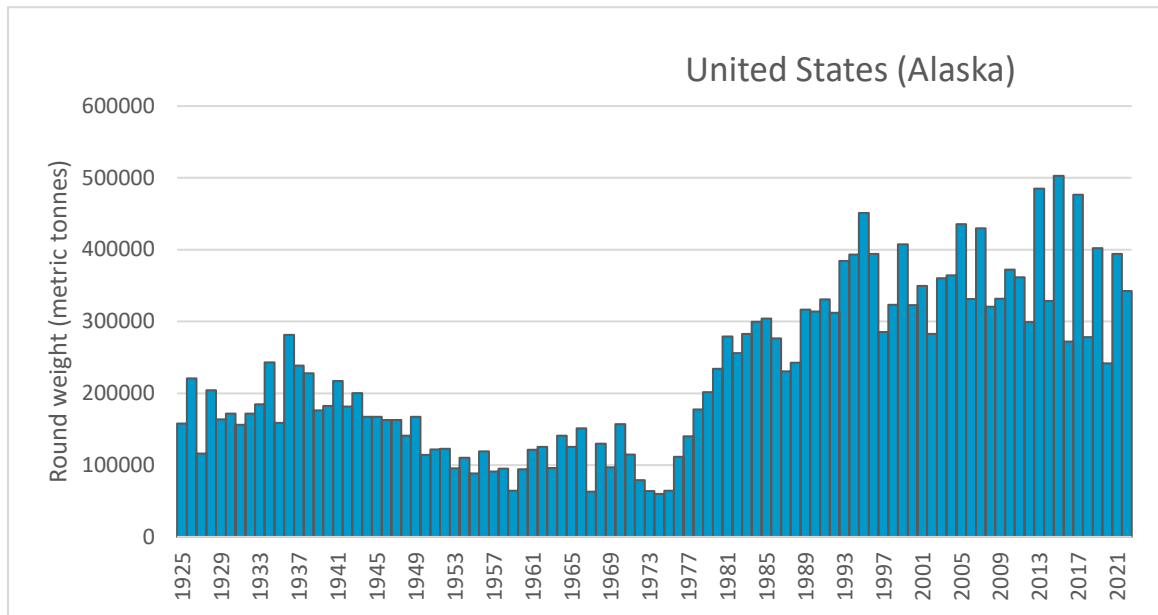


Figure 6. Total catch of Pacific salmon by Alaska.

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).

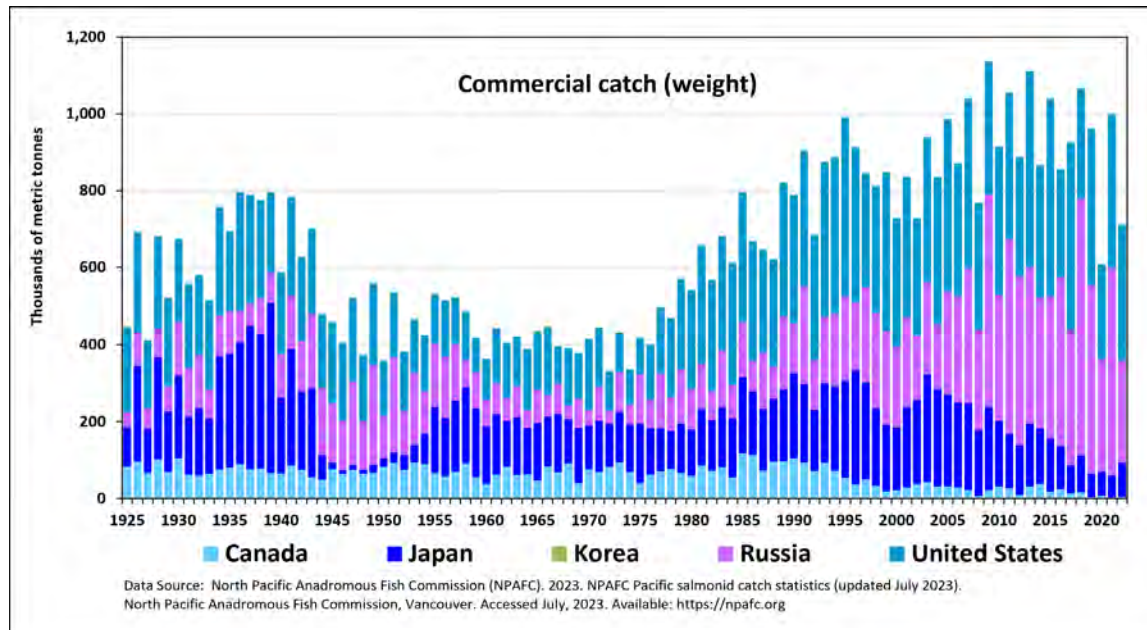


Figure 7. Annual commercial catch of salmon and steelhead trout by country 1925-2022.

Source North Pacific Anadromous Fish Commission Statistics (2)

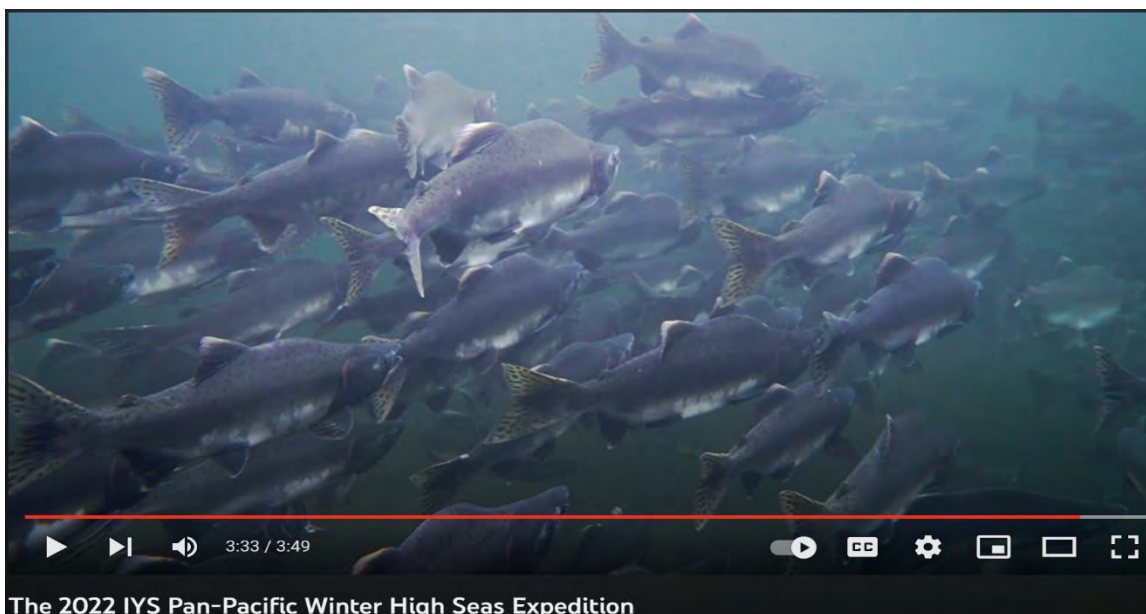
Recent catch numbers, however, suggest the situation may be changing. The global abundance of Pacific salmon in 2020 was the lowest it has been since 1982. This was a 37% reduction in total catch by all countries and the largest single yearly decline ever quantified. About one-half of this total catch 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).



The 2022 IYS Pan-Pacific Winter High Seas Expedition

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.

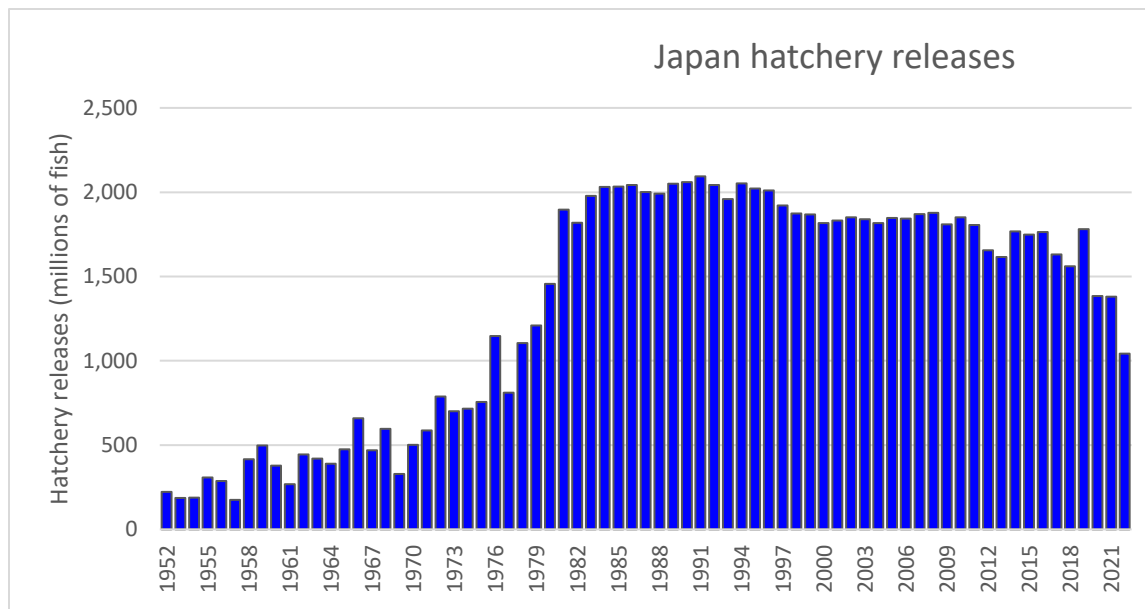


Figure 9. Annual hatchery release of chum salmon by Japan in millions of fish 1952 – 2022.

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.

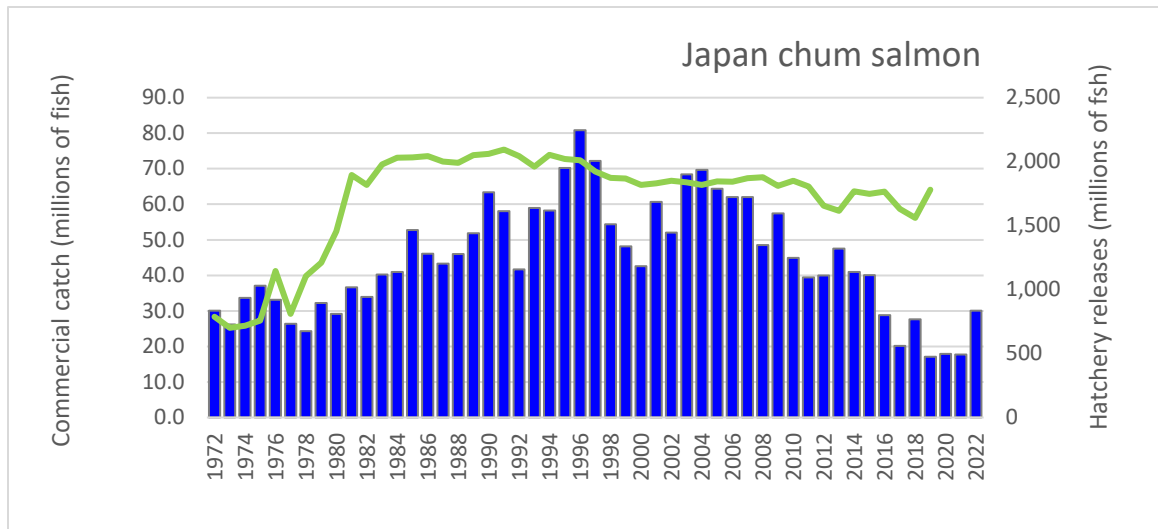


Figure 10. Coastal commercial catches of chum salmon in Japan, compared to hatchery releases, 1972-2022.

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).

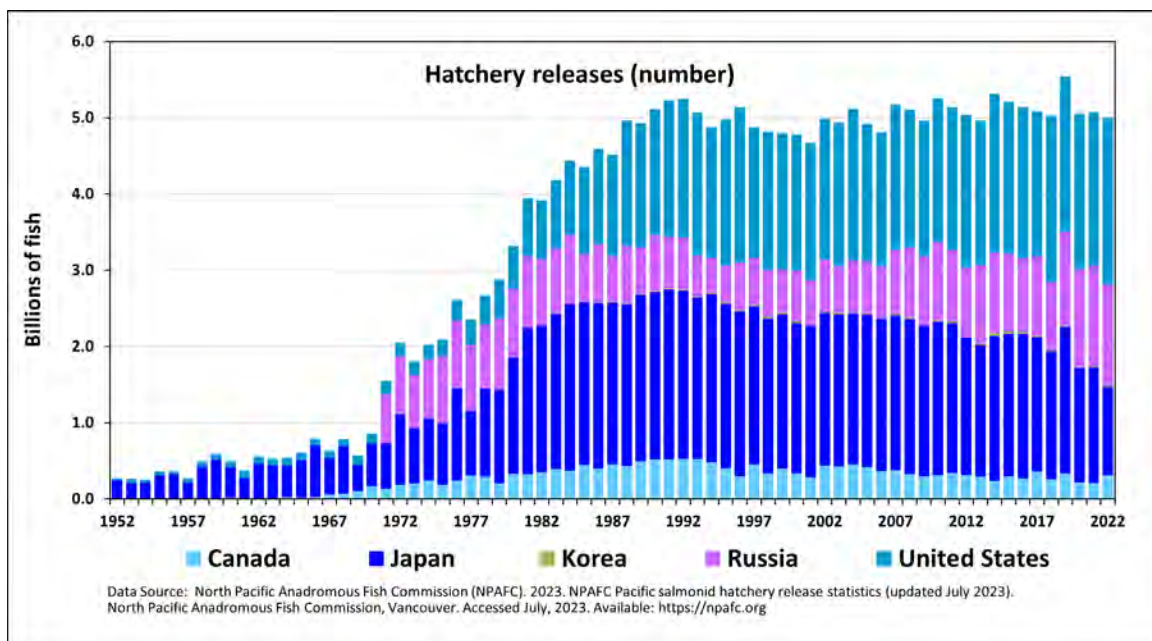


Figure 11. Pacific salmon hatcheries in the North Pacific Ocean; release approximately 5 billion fish per year into the ecosystem from five countries.

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 \$1 billion 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

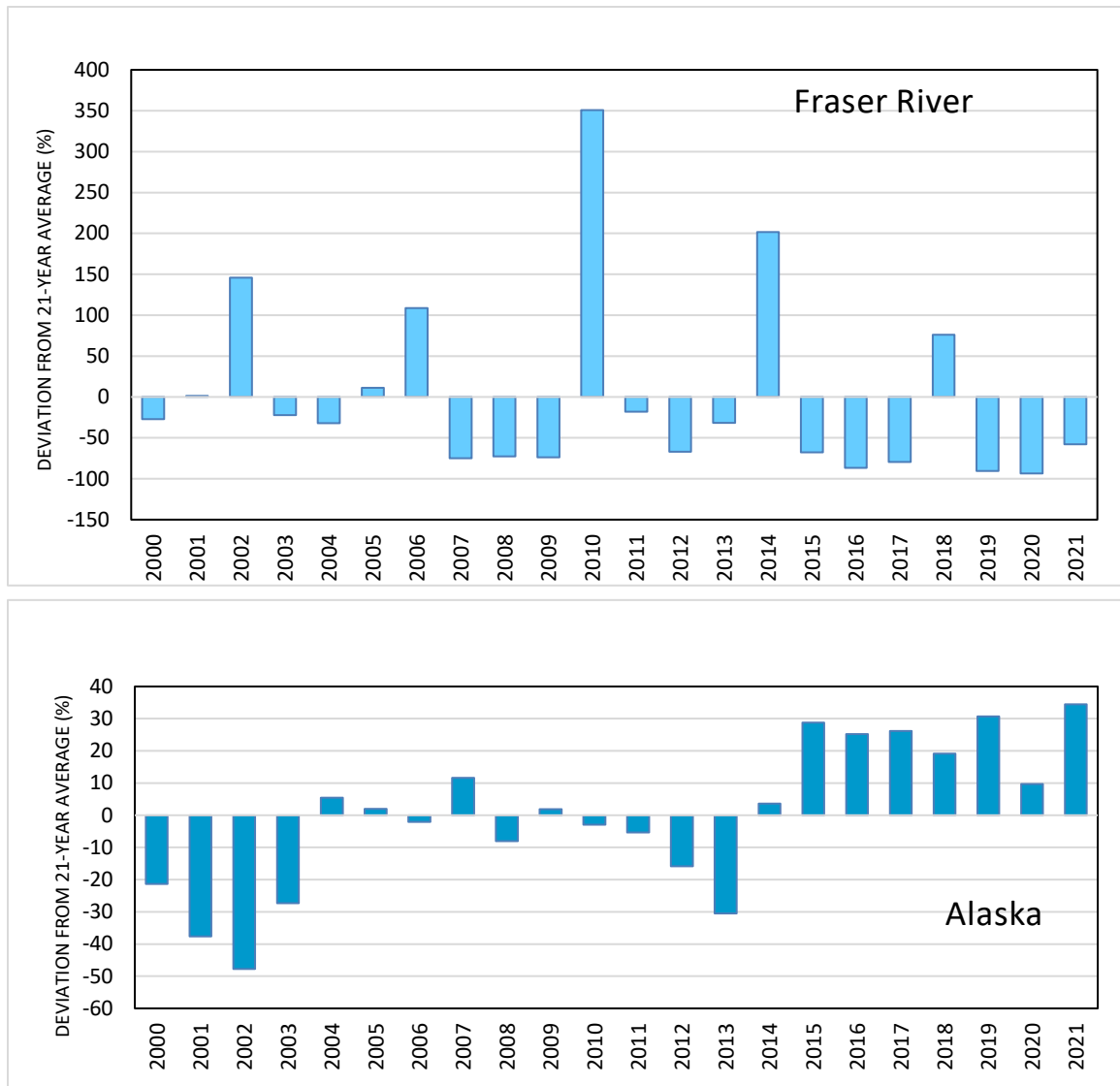


Figure 12. Comparison of total sockeye returns to the Fraser River and commercial catches of Alaska sockeye salmon 2000 -2021.

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.

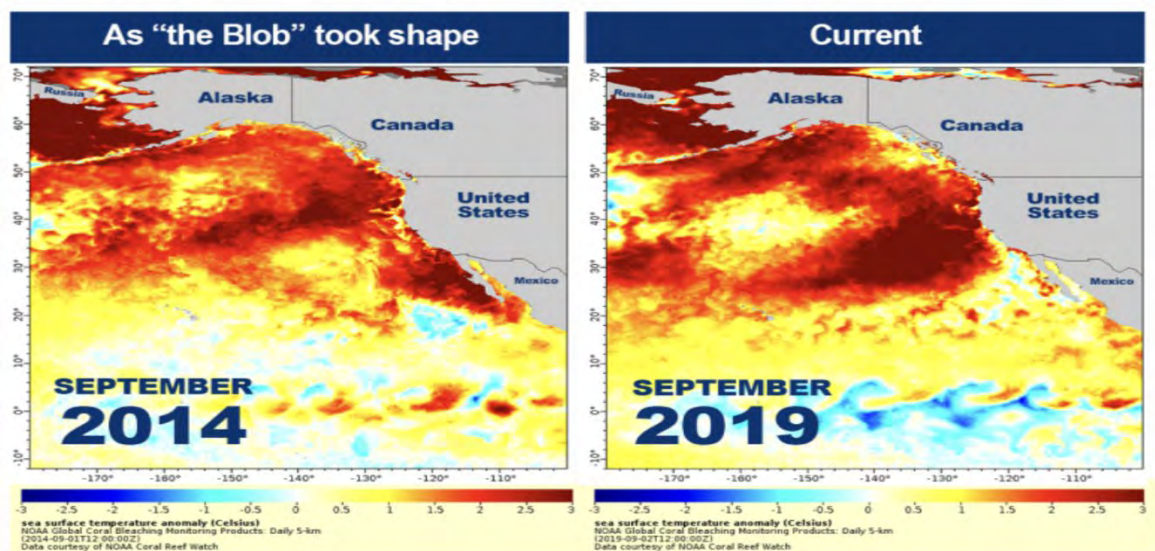


Figure 13. Area of ocean warming events.

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.

The ocean has absorbed 90% of earth's excess heat

Global warming = ocean warming

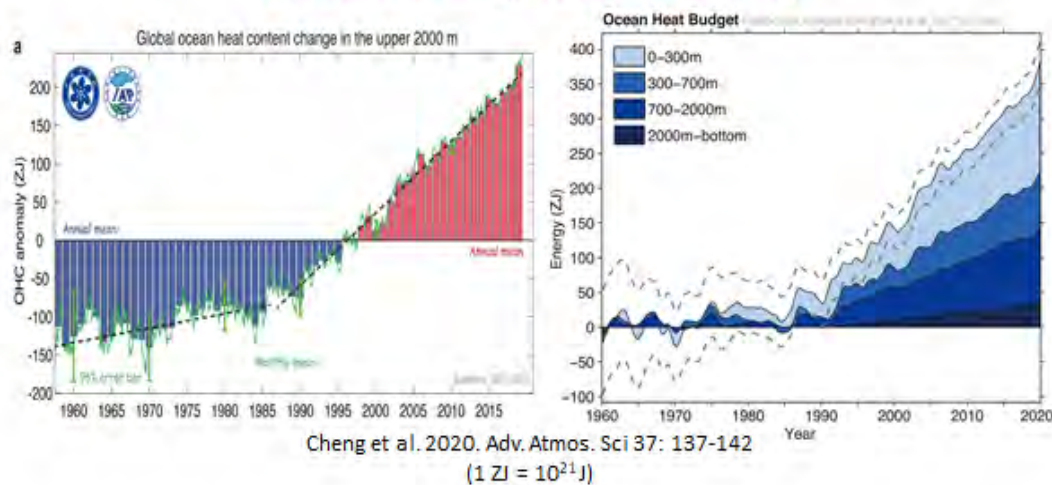


Figure 14. Increase of global ocean heat content.

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).

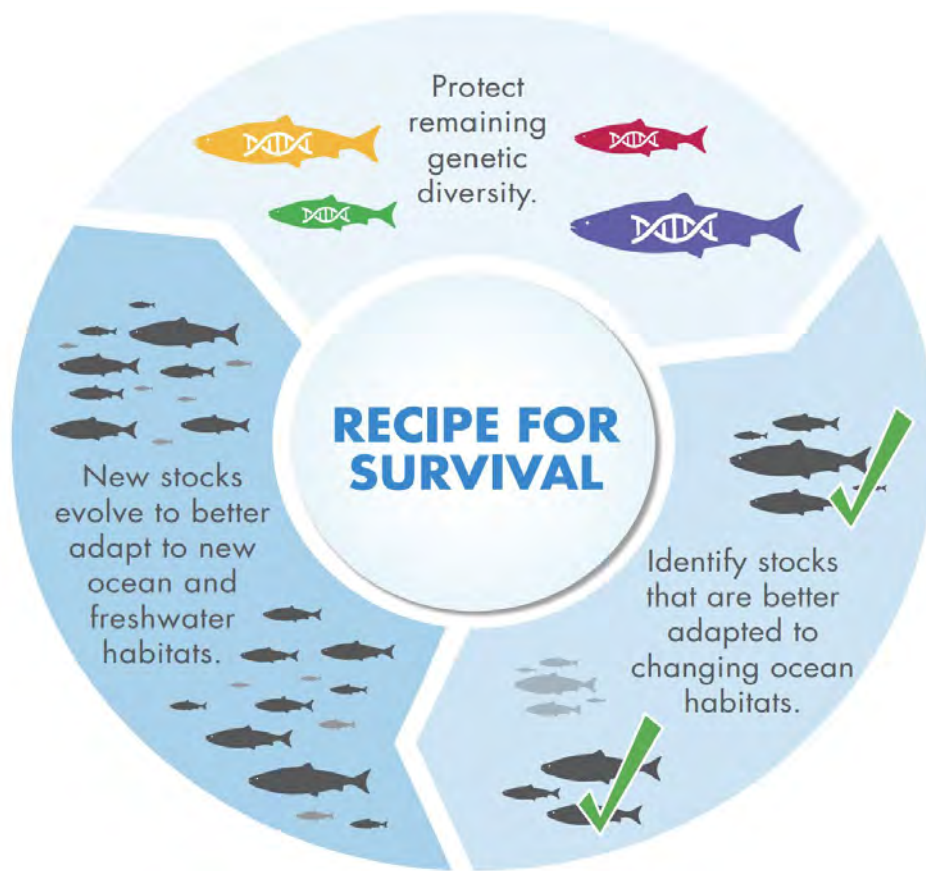


Figure 15. Genetic diversity has been the recipe for survival for Pacific salmon for millennia.

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.

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.

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

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 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.

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.

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

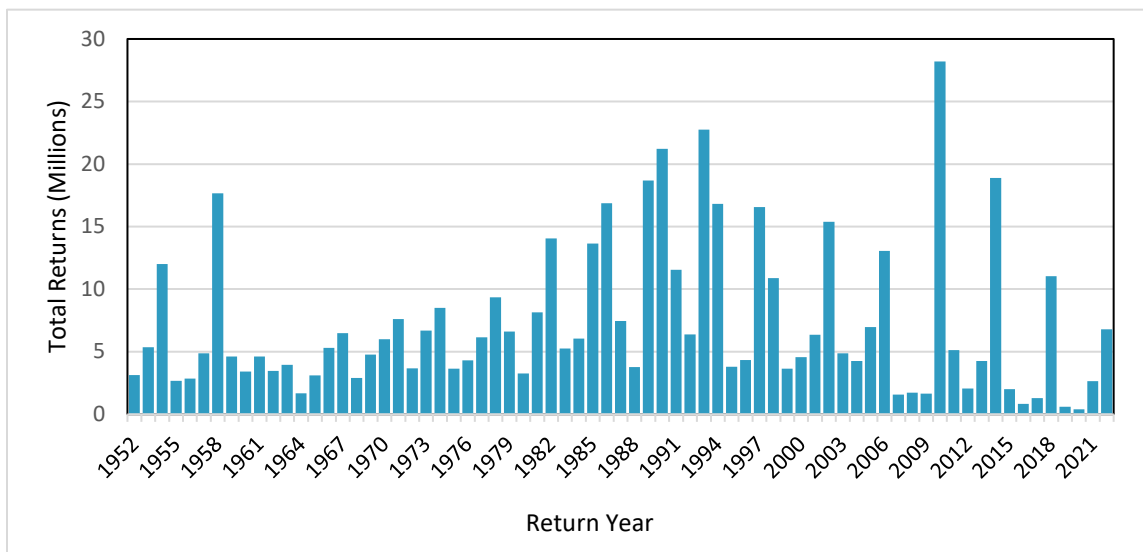


Figure 16. Total return (catch plus spawning adults) of sockeye salmon to the Fraser River in millions of fish 1952–2022.

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.

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.

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



Photo by Brian Kingzett



REFERENCES

1. Government of Canada. Pacific salmon: ensuring the long-term health of wild populations and associated fisheries. Report of the Standing Committee on Fisheries and Oceans, . Ottawa, Ont.: House of Commons; 2021. p. 58.<https://www.ourcommons.ca/DocumentViewer/en/43-2/FOPO/report-5/>
2. North Pacific Anadromous Fish Commission. 2023. NPAFC Statistics: Pacific Salmonid Catch and Hatchery Release Data: North Pacific Anadromous Fish Commission,, [Available from: <https://www.npafc.org/statistics/>.
3. Beamish R. 2022. The need to see a bigger picture to understand the ups and downs of Pacific salmon abundances. ICES Journal of Marine Science.79(4):1005-1014.10.1093/icesjms/fsac036
4. Pacific YotS-N. 2022 IYS Pan-Pacific Winter High Seas Expedition,. 2022.<https://www.youtube.com/watch?v=d-YicJQnsJw>
5. Larkin PA. 1974. Play it Again Sam — an Essay on Salmon Enhancement. Journal of the Fisheries Research Board of Canada.31(8):1433-1456.10.1139/f74-174
6. Beamish RJ, Mahnken C, Neville CM. 2004. Evidence That Reduced Early Marine Growth is Associated with Lower Marine Survival of Coho Salmon. Transactions of the American Fisheries Society.133(1):26-33.10.1577/T03-028
7. Riddell BE, Howard KG, Munro AR. 2022. Salmon Returns in the Northeast Pacific in Relation to Expedition Observations (and Next Steps). N Pac Anadr Fish Comm Tech Rep.18:105-129,
8. Beamish RJ, Bouillon DR. 1993. Pacific Salmon Production Trends in Relation to Climate. Canadian Journal of Fisheries and Aquatic Sciences.50(5):1002-1016.10.1139/f93-116
9. Hare SR, Mantua NJ. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography.47(2):103-145.[https://doi.org/10.1016/S0079-6611\(00\)00033-1](https://doi.org/10.1016/S0079-6611(00)00033-1)
10. Beamish RJ, Noakes DJ, McFarlane GA, Pinnix W, Sweeting R, King J. 2000. Trends in coho marine survival in relation to the regime concept. Fisheries Oceanography.9(1):114-119.<https://doi.org/10.1046/j.1365-2419.2000.00126.x>
11. Cheng L, Abraham J, Zhu J, Trenberth KE, Fasullo J, Boyer T, et al. 2020. Record-Setting Ocean Warmth Continued in 2019. Advances in Atmospheric Sciences.37(2):137-142.10.1007/s00376-020-9283-7
12. Ricker W. 1972. Hereditary and environmental factors affecting certain salmonid populations, p In: Simon RC, Larkin PA, editors. The stock concept in Pacific salmon HR MacMillan Lectures in Fisheries , . Vancouver, BC: University of British Columbia Press. p. 19-160
13. Beamish R, Neville C. 2016. Applying the Krogh Principle to find shortcuts to understanding Pacific salmon production. North Pacific Anadromous Fish Commission Bulletin.6:455-468,
14. Beamish RJ. The Ocean Ecology of Pacific Salmon and Trout. Bethesda Maryland: American Fisheries Society; 2018. p. 1147

15. Atlas WI, Wilson KL, Whitney CK, Moody JE, Service CN, Reid M, Sloat MR. 2022. Quantifying regional patterns of collapse in British Columbia Central Coast chum salmon (*Oncorhynchus keta*) populations since 1960. *Canadian Journal of Fisheries and Aquatic Sciences*.79(12):2072-2086.10.1139/cjfas-2022-0013
16. Riddell BE, Brodeur RD, Bugaev AV, Moran P, Murphy JM, Orsi JA, et al. 2018. Ocean ecology of Chinook salmon. In: Beamish RJ, editor. *Ocean Ecology of Pacific Salmon and Trout*. Bethesda, Maryland: American Fisheries Society. p. 555-696.https://www.researchgate.net/profile/Marc-Trudel-2/publication/324784113_Ocean_ecology_of_Chinook_salmon/links/5aeafb2745851588dd829e4e/Ocean-ecology-of-Chinook-salmon.pdf
17. Welch DW, Porter AD, Rechisky EL. 2021. A synthesis of the coast-wide decline in survival of West Coast Chinook Salmon (*Oncorhynchus tshawytscha*, Salmonidae). *Fish and Fisheries*.22(1):194-211.<https://doi.org/10.1111/faf.12514>
18. Crozier LG, Burke BJ, Chasco BE, Widener DL, Zabel RW. 2021. Climate change threatens Chinook salmon throughout their life cycle. *Communications Biology*.4(1):222.10.1038/s42003-021-01734-w
19. Wells BK, Huff DD, Burke BJ, Brodeur RD, Santora JA, Field JC, et al. 2020. Implementing Ecosystem-Based Management Principles in the Design of a Salmon Ocean Ecology Program. *Frontiers in Marine Science*.7.10.3389/fmars.2020.00342
20. Graham CJ, Sutton TM, Adkison MD, McPhee MV, Richards PJ. 2019. Evaluation of Growth, Survival, and Recruitment of Chinook Salmon in Southeast Alaska Rivers. *Transactions of the American Fisheries Society*.148(2):243-259.<https://doi.org/10.1002/tafs.10148>
21. Duffy EJ, Beauchamp DA. 2011. Rapid growth in the early marine period improves the marine survival of Chinook salmon (*Oncorhynchus tshawytscha*) in Puget Sound, Washington. *Canadian Journal of Fisheries and Aquatic Sciences*.68(2):232-240.10.1139/F10-144
22. Di Lorenzo E, Mantua N. 2016. Multi-year persistence of the 2014/15 North Pacific marine heatwave. *Nature Climate Change*.6(11):1042-1047.10.1038/nclimate3082
23. Cohen BI. 2012. *The Uncertain Future of Fraser River Sockeye: Volume 2, Causes of the Decline: Final Report*. Ottawa. ON: Canada. Privy Council Office.<https://publications.gc.ca/site/eng/9.696129/publication.html>
24. Ricker WE. 1997. Cycles of abundance among Fraser River sockeye salmon (*Oncorhynchus nerka*). *Canadian Journal of Fisheries and Aquatic Sciences*.54(4):950-968.10.1139/f97-047

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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.

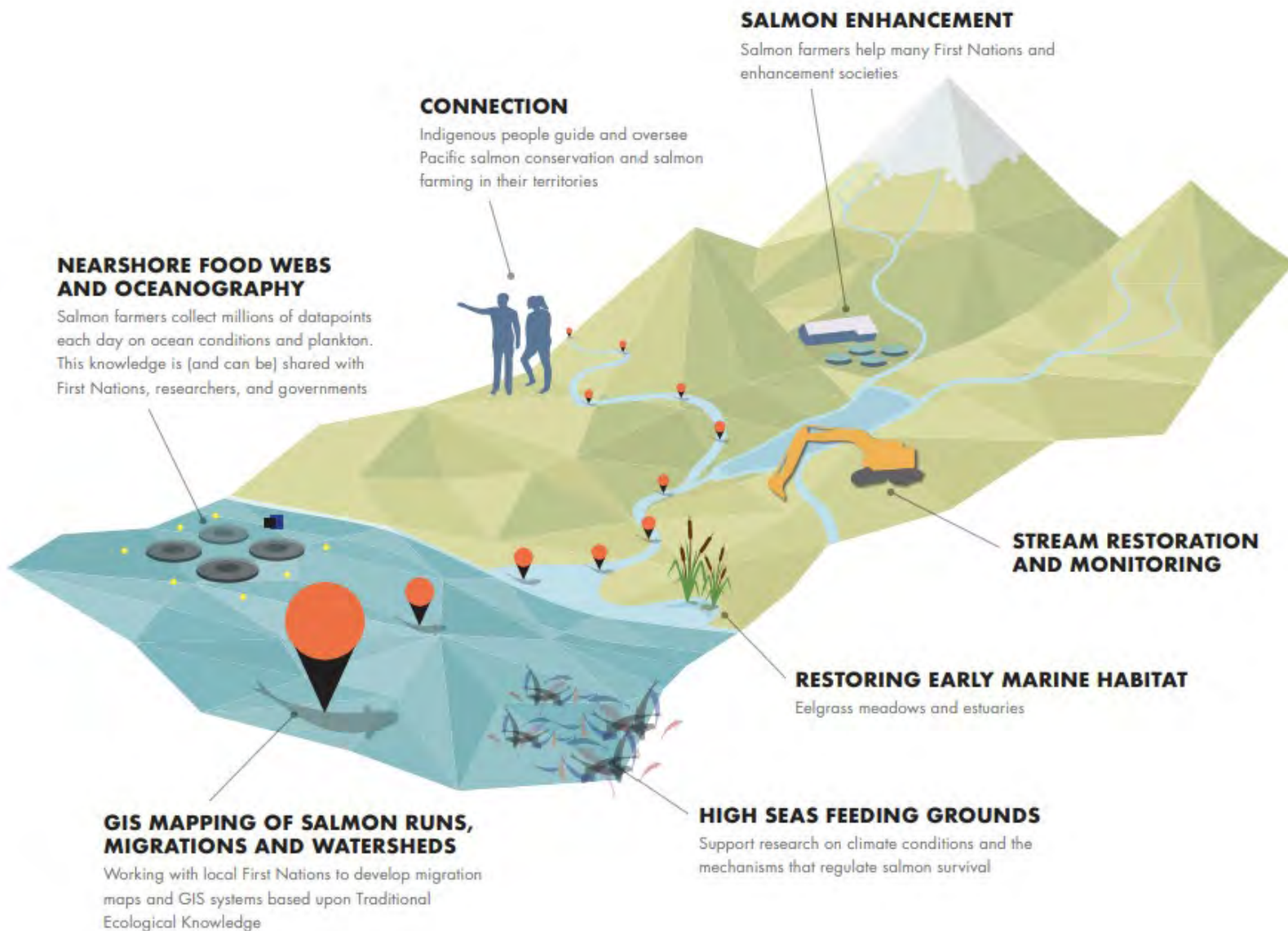




Photo by Brian Kingzett

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Photo by Bill Pennell

CONNECTIONS AND LEADERSHIP

There is a connection between nature and the well-being of society. Pacific salmon link forests, streams, estuaries, and the entire North Pacific Ocean through their complex life cycle. There are thousands of years of Indigenous culture and a substantial commercial and recreational fishing and tourism economy built upon the ecosystem benefits of Pacific salmon.

Pacific salmon require healthy freshwater and marine habitats to survive and flourish. Management of salmon habitat falls to a myriad of international, federal, and provincial jurisdictions that crisscross marine and freshwater habitats.

According to DFO, "During the past decade, the management of Pacific salmon has become progressively more challenging for various reasons. Supreme Court decisions, varying ocean productivity, conservation concerns, habitat loss, international agreements, new Canadian legislation governing species at risk, shifts in global markets, and altered public expectations have all contributed to this dynamic operating context." (3).

Conserving wild Pacific salmon requires effective leadership that understands the importance of connections and collaboration. There are some recent initiatives in Canada to help wild Pacific salmon:

Canada's Wild Salmon Policy has three objectives: safeguard genetic diversity of wild salmon, maintain habitat and ecosystem integrity and manage fisheries for sustainable benefits.

- o In 1987, the [Pacific Salmon Foundation](#) (PSF) was established as an independent foundation that could complement the community-based work of the federal Fisheries Ministry. The PSF believes there are three major opportunities to positively impact salmon: habitat, harvest/fishing, and hatcheries (4).
- o In 2005, Canada's [Policy for the Conservation of Wild Pacific Salmon](#) (the 'Wild Salmon Policy') was enacted with the goal to restore and maintain healthy and diverse salmon populations and their habitats for the benefit and enjoyment of the people of Canada in perpetuity. Importantly, Principle 2 of the Wild Salmon Policy includes honouring obligations to First Nations (5).
- o In 2017, a major international collaboration called "[International Year of the Salmon](#) (IYS)", began its work to encourage international cooperation to better understand the ocean ecology of salmon (6). It is governed by the North Pacific Anadromous Fish Commission (NPAFC) in the North Pacific. It focuses on understanding oceanic habitats and the extreme and uncertain climate conditions that threaten the survival of wild salmon from all five Pacific salmon-producing countries (Canada, USA, Japan, Russia, and the Republic of Korea).
- o In 2019, the Province of British Columbia partnered with the federal government to co-fund the \$285.7M [British Columbia Salmon Restoration and Innovation Fund](#) to protect and restore Pacific salmon and other priority wild fish stocks (7). The fund also supports projects that will ensure the fish and seafood sector in British Columbia is positioned for long-term environmental and economic sustainability.
- o In 2021, DFO committed an additional \$647M to the [Pacific Salmon Strategy Initiative](#) (PSSI) to reverse historic declines in key salmon stocks. The PSSI will focus on four key areas: conservation and stewardship, salmon enhancement, harvest transformation, and integration and collaboration (i.e., partnerships and collaborations) (8).
- o In March 2023, the provincial government committed an additional \$100M to the [Watershed Security Strategy](#) – Government of British Columbia to restore abundant wild salmon populations (9). This was boosted by an additional \$17.25M in



June 2023 primarily to help support wild salmon recovery and Indigenous People's capacity through the Pacific Salmon Foundation and First Nations Fisheries Council.

First Nations communities connect the wild salmon initiatives together. Their governance provides a pathway to unite efforts and rekindle focus toward preserving and restoring Pacific salmon and their habitats. The Coastal First Nations Great Bear Initiative is one such example of advanced land and marine spatial planning on a massive scale (10).

The [First Nations Fisheries Council](#) (FNFC) represents communities from 14 geographic regions of British Columbia (11). They share a collective vision to increase First Nations access, allocation, and involvement in fisheries management

and decision-making, pursuant to their Aboriginal Title and Rights and Treaty Rights. The FNFC Salmon Coordinating Committee has worked directly with DFO to jointly draft the 2018-2022 Wild Salmon Policy Implementation Plan (WSPIP), which outlines nine overarching approaches and 48 actions DFO has committed to over this 5-year period.

There are many other initiatives, including hundreds of smaller organizations and thousands of volunteers working to help wild salmon in British Columbia. BC salmon farmers share this passion for wild salmon and have been actively involved in Pacific salmon conservation projects with First Nations, the scientific community, DFO, and local coastal communities for many years.



Photo by Bill Pennell

CONNECTING WITH FIRST NATIONS, THE ORIGINAL STEWARDS OF THE COAST



New ways of thinking, new governance models, and new collaborations are required to safeguard the future of wild salmon. First Nations, as the original stewards of Pacific salmon, are uniquely positioned to lead conservation efforts through governance connections and traditional knowledge.

First Nations have been the stewards of their lands, waters, and elements since time immemorial. They are the original environmentalists and have been successfully managing environmental stressors and changes to their ecosystems for thousands of years.

Harmonizing Indigenous knowledge, stewardship, and Western methods is the path toward ecological health while encouraging economic growth on the coast. It will give wild salmon their best chance to survive climate change and human impact stressors now and in the future.

Some ways in which coastal First Nations are protecting their marine spaces and the wildlife within it are by implementing:

- o Guardian Watchmen and Indigenous Stewardship programs
- o Traditional Ecological Knowledge (TEK) and Indigenous-led Western Science
- o Indigenous Marine Protected Conservation Areas
- o Wild salmon revitalization efforts (hatchery programs, watershed restoration, recreational fishing restrictions).

These initiatives are described in detail in "Chapter 4 - Caring for Indigenous Stewardship - Connecting with the Original Guardians of the Coast".

In a period of new challenges collaboration of traditional and new knowledge will help ensure a future of responsible stewardship.



THE OVERARCHING STRESSOR - CLIMATE CHANGE

Researchers generally agree that climate change may now be the major influence affecting the production of wild Pacific salmon in fresh water and the ocean. In fresh water, temperature increases and decreased water flows are of major concern. Temperature changes and increasing heat are directly and indirectly of concern in the ocean, but impacts are poorly understood because factors affecting ocean survival are poorly understood. Hatchery salmon provide important opportunities to study mechanisms in the ocean that influence

survival as climate-related impacts on hatchery salmon will be in the ocean.



Photo by Brian Kingzett

Climate changes occurred in past centuries and salmon adapted to these changes by establishing stocks that were genetically adapted to specific conditions in fresh water and the ocean ecosystems. As changes occurred, there would always be some stocks that were better adapted to the new habitat. The issues today are that the climate-related changes are occurring substantially faster than in the past, and salmon were not managed over the past 100 years to protect their evolved

ability to adapt to rapid ecosystem change. However, if we had a much better understanding of exactly how the rapidly changing ecosystems are now affecting salmon survival, we could manage the existing populations to optimize their collective productivity. Teams that integrate their biological and oceanographic abilities will be one way to expedite acquiring the necessary understanding quickly.

HELPING UNDERSTAND OCEAN HABITAT FOR WILD SALMON

Salmon farmers are concerned about the impacts of climate change on oceanic habitats for both wild and farm-raised fish. The BC Salmon Farmers Association (BCSFA) has been a major funder of the winter high-seas expeditions of the International Year of the Salmon (IYS) (6). This research group is comprised of an international group of scientists from Canada, Japan, the Republic of Korea,

Russia, and the USA who are mapping the distribution of salmon throughout the North Pacific Ocean in the winter and working to discover the mechanisms that regulate survival. This work is important to understanding wild Pacific salmon, considering that the Pacific Ocean where wild salmon spend much of their lives, remains largely a mystery.



Photo by Bill Pennell



On a more local scale, we need to understand how ocean food webs for salmon in the ocean are shifting with climate change. Evidence is accumulating that the availability and quality of food for salmon during their first few weeks in the ocean affects their ability to store fats needed to grow and survive (12).

The Strait of Georgia is now 1.5°C warmer than 60 years ago which results in reduced upwelling and, ultimately, less zooplankton for salmon (13). The effects of temperature changes in freshwater spill over into smolt migrations, which occur earlier due to warmer stream waters, when ocean and estuary conditions have not caught up (14).



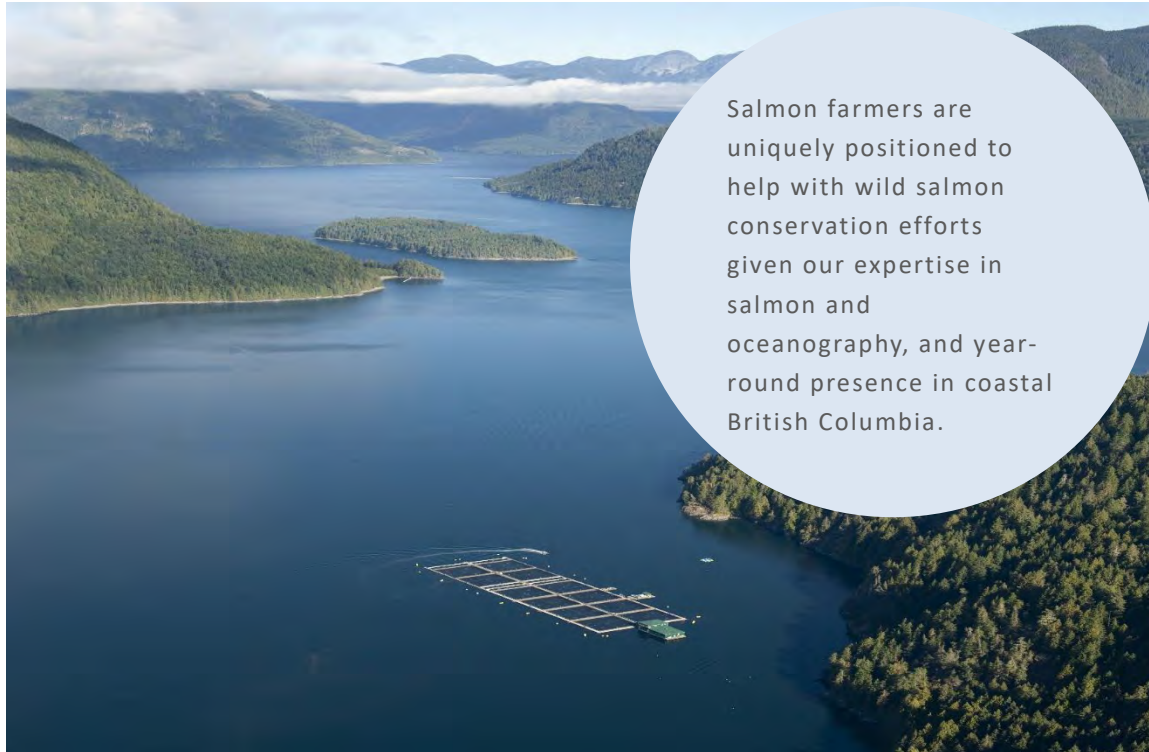
Photo Chris Walling aka Steel_Snorkel

Salmon farmers have important information to contribute to these conservation efforts. Data collection at farms is currently undergoing a digital revolution. With the arrival of in-sea data loggers, wireless point-to-point communication towers and artificial intelligence, farmers are installing technology that collects millions of data points each day, recording oceanic conditions.

Salmon farmers have monitored plankton daily at each active farm and remote areas prone to plankton blooms for at least two decades.

Projects can be developed with others to utilize this data to monitor and evaluate climate change in the nearshore ocean environment. One such project is the multi-year Discovery Passage plankton monitoring program which provided needed insight into matching the salmon release with available food in the ocean

for coho salmon from the Quinsam River (15). This important project was a collaboration between the A-Tlegay Fisheries Society, BC Center for Aquatic Health Sciences, Campbell River Salmon Foundation, DFO Quinsam River Hatchery, and funders such as BC salmon farmers.



Salmon farmers are uniquely positioned to help with wild salmon conservation efforts given our expertise in salmon and oceanography, and year-round presence in coastal British Columbia.

HELPING MAP SALMON WATERSHEDS, SALMON RUNS, AND MIGRATIONS

A critical step in potentially reversing the declining trend in salmon is to improve the understanding of the present state of salmon returns, the migration routes of both juvenile and adult salmon from and to their natal streams, and the condition of stream habitats. Salmon farmers, using GIS systems, have been building summaries of these topics in many of the coastal areas where salmon farming occurs. Ultimately, these datasets can help with the second step of DFO's Wild Salmon Policy, where deepening the understanding of habitats and runs will inform strategies to conserve and restore salmon populations (5).



The GIS database includes information layers for fish farm locations, stream locations and associated salmon returns, out-migration routes, and other industrial activities such as deforestation. This is a valuable tool to assist with understanding

salmon returns and human activities through time. For example, Figures 1(a), 1(b), and 1(c) indicate the progression of forest harvesting along the mainstem of the Quatam River watershed from 1951 – 2000.

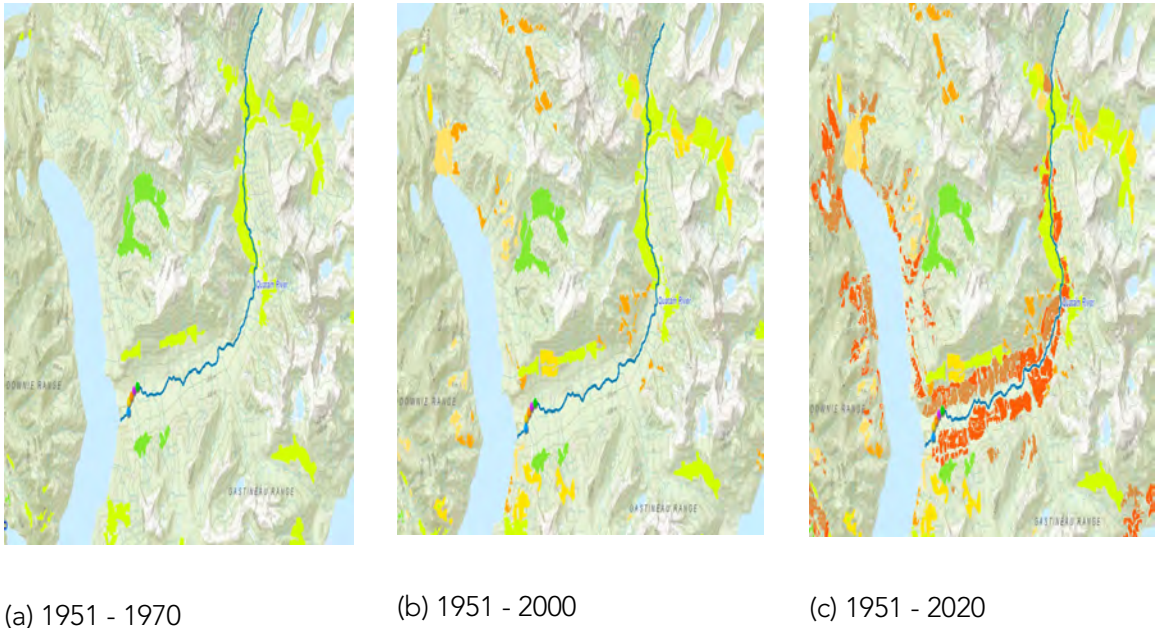


Figure 1. Quatam River watershed cumulative forest harvesting cut-blocks.
Progression shown by years: (a) 1951 – 1970; (b) 1951 – 2000; and (c) 1951 -2020(16).

The development of salmon farms and salmon returns have been assessed for many watersheds and coastal areas. For example, the total chum salmon spawner returns to streams in the Discovery Islands from 1953 to 2021 is shown in Figure 2.



Photo by Bill Pennell

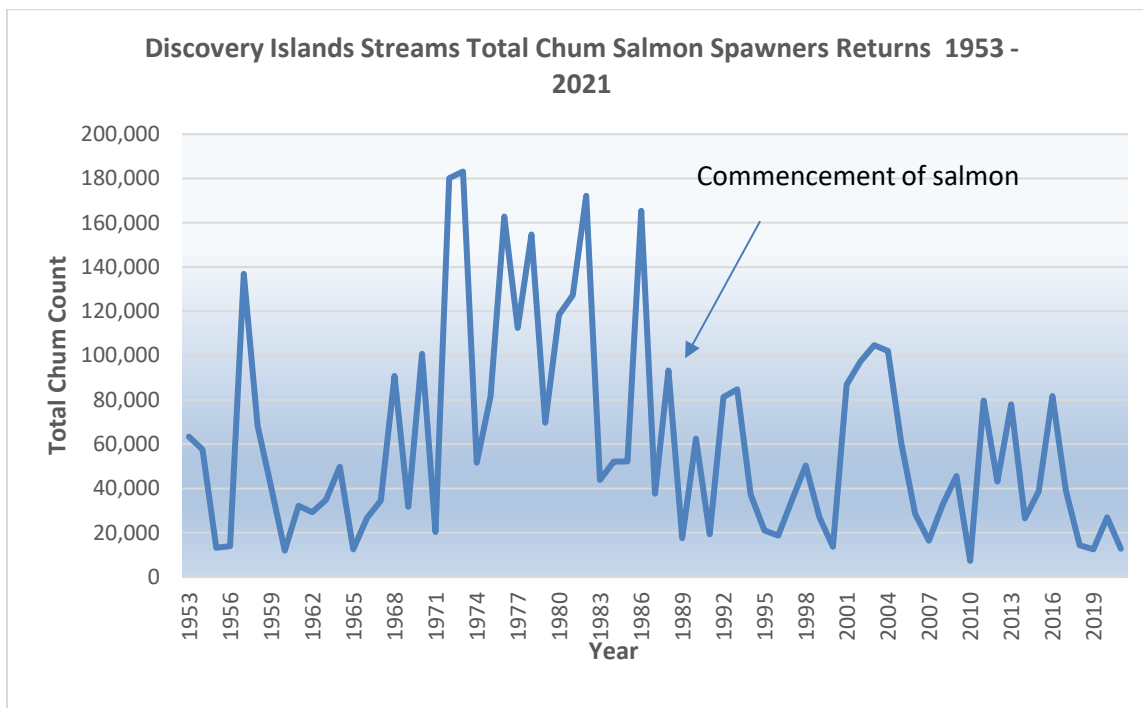


Figure 2. Discovery Islands area cumulative chum salmon spawner returns (1953 – 2021) and the commencement of commercial salmon farms.
Source DFO Open Data NuSEDS(17).



The GIS tool can also be used to map major out-migration routes that juvenile wild salmon follow when leaving their natal streams. Salmon farmers have developed juvenile out-migration route

maps for several production areas based upon knowledge from First Nations. An example is Figure 3 which shows the major out-migration routes in the Discovery Islands as described by First Nations.

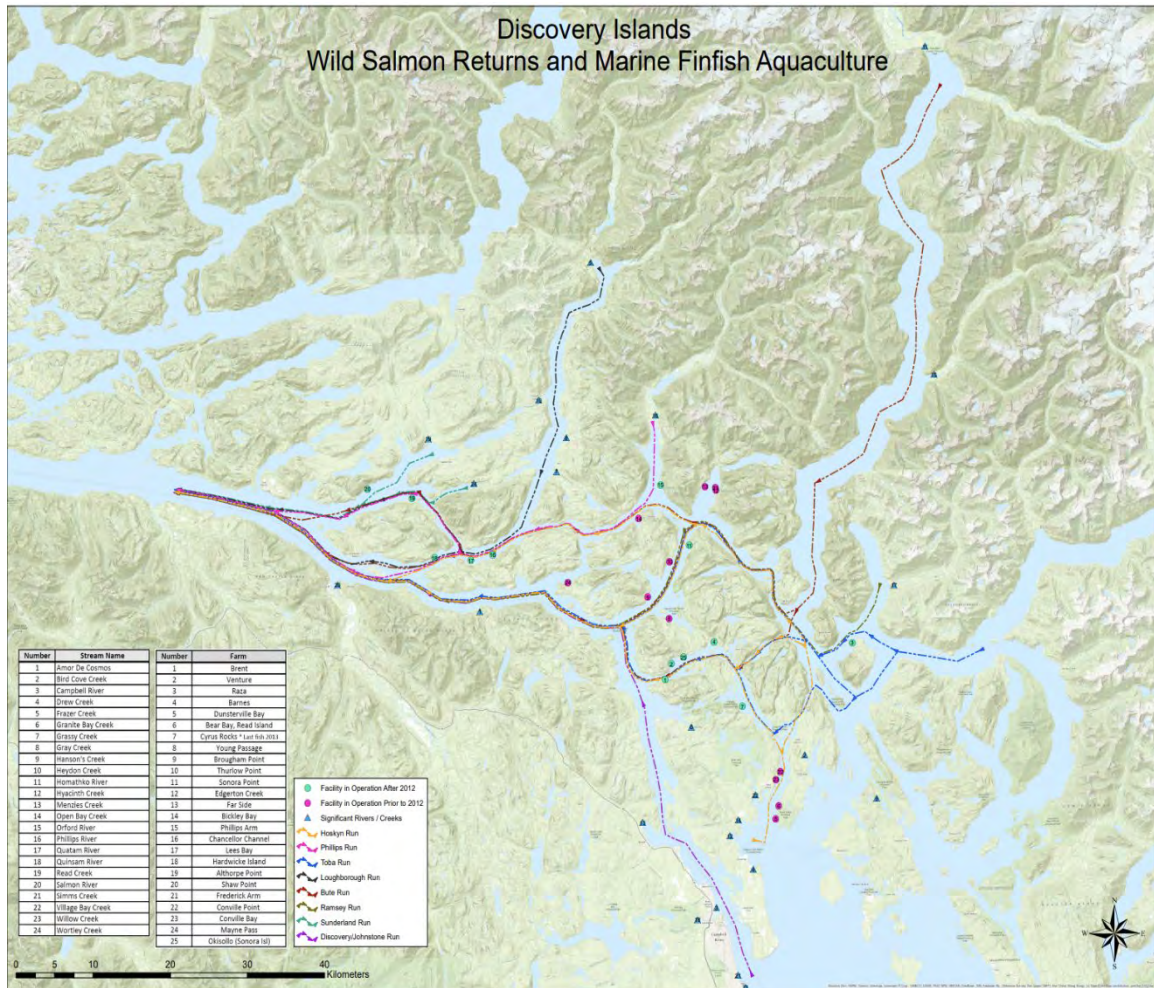


Figure 3. Discovery Islands wild juvenile salmon outmigration routes.

LOCAL HABITAT STRESSORS AND POTENTIAL REMEDIES

There are many stressors to freshwater habitats including the effects of climate change, hydroelectric dams, water and gravel extraction, urbanization, road crossings, pollution, residues from rubber tires, agriculture, forestry, mining, stream removals/blockages, loss of stream-side vegetation, changes in hydrology and precipitation (rainfall and snowpack), invasive species and others.

HUMAN POPULATION GROWTH

Pacific salmon populations and habitats have degraded considerably over the past 100 years following the migration of people to the province. In 1900 the province had less than 200,000 people, by 1951, about 1.2 million, (18) and as of July 2021, 5,214,805 people were living in BC(19). Most people live along the coastline and within watersheds – the very places that are essential for Pacific salmon.

Experts predict that the Pacific Northwest population of Canada and the USA will grow from 14 million to 85 million by 2100. This will put enormous pressure on salmon habitat.

The population growth is expected to continue, with some experts predicting that the Pacific Northwest population of Canada and the USA will grow from 14

million to 85 million by 2100 (20).

Inevitably, this will bring additional stress to salmon habitat and likely more pressure on capture fisheries. Maintaining sustainable populations of Pacific salmon over the next hundred years will require strong leadership, governance, and the collective knowledge of all British Columbians.

Salmon aquaculture has the potential to feed this growing population without adding additional pressure to capture fisheries.





Photo by Brian Kingzett

LAND DEVELOPMENT

The Fraser River watershed, greater Vancouver area and east coast of southern Vancouver Island have experienced the bulk of land development in BC over the past century (21). Along with these areas, there are other rivers and estuaries in the province that have sustained habitat impacts. Estuaries are important habitats for juvenile

Using 170-year-old field manuals, scientists have concluded that 85% of the lower Fraser River salmon habitat is no longer accessible to declining fish populations, from Delta to Hope, BC.

salmon emerging from their natal streams, and dredging, dike construction, and the smothering of the sea floor by woody

debris from booming grounds can impact wild salmon.

Forest harvesting is the primary land development elsewhere along the British Columbia coast and its effects on freshwater habitat have been well documented. These include changes to stream hydrology as the removal of trees reduces the uptake of water from the soil resulting in an increase of run-off to streams. In coastal BC, this results in an increase in high flows and flooding events during the wet times of year and lower stream flows in the dryer parts of the year. Water quality is also degraded due to increased sedimentation from erosion.

Depending on the extent of the harvesting, there could also be changes to the instream habitat through decreased shading, leading to an increase in water temperature.

The provincial government passed the [Riparian Areas Protection Act](#) in 2004 (formerly the Fish Protection Act of July 1997) (22) and the Forest and Range Practices Act (23) in 2002 to protect stream flow and habitat for fish. There have been vast improvements in awareness, knowledge, and practices since these protections came into effect. Many forestry companies are working with local First Nations to restore watersheds, and numerous salmon runs are now recovering from these disturbances.

It should be noted that salmon farms do not have the potential to impact habitat in estuarine or freshwater areas as they are anchored in marine waters, typically over 40m in depth. Typically, farms only contact the shoreline through a series of anchor pins that help hold the cages in place. This does not block passage for fish, birds, and other marine life.

The average size of a cage array and grid at a marine fish farm is about four hectares; overall BC salmon farms occupy less space than Stanley Park in Vancouver.



Photo by Brian Kingzett



Figure 4. Eelgrass meadow.

HELPING RESTORE ESTUARIES AND EELGRASS MEADOWS

Restoring estuaries and eelgrass meadows are other ways to help juvenile salmon in the early marine phase (Figure 4). Eelgrass meadows provide important habitat for migrating salmon and many other fish and invertebrates such as crab. The plant also stabilizes the shoreline, cleans the water, and helps offset the impacts of climate change by storing carbon. Many First Nation communities have been actively restoring both estuaries and eelgrass meadows. Salmon farmers have also been active in this initiative. For example, salmon farmers have supported eelgrass restoration in Klemtu and Sechelt.

WATER EXTRACTION

Water extraction from streams to supply domestic drinking water, to support industrial activities such as pulp mills, and for agricultural purposes occurs in many areas of the province. Extraction can occur by pumping water directly from a stream or lake or by pumping groundwater from freshwater aquifers.

In the last few years, low or historically low flows have occurred in areas of the

province including parts of Vancouver Island and the south coast due to changes in temperature and precipitation, leading to droughts and minimal snowpack in the mountains. As a result, once water is extracted for the purposes listed above, there are times when there is not enough water left to support both juvenile salmon and adults returning to spawn. The water that remains in the streams is likely to have a higher temperature which also negatively affects salmon.

Salmon farmers currently have minimal freshwater uses at marine sites; their primary use of water is for hatcheries. There are thirteen hatcheries that grow fish for marine farms. Three of the hatcheries have fully developed recirculating aquaculture systems (RAS) which have a water reuse efficiency of 95-99%.

An additional six hatcheries have partially transitioned to RAS. Nine hatcheries use groundwater, one hatchery obtains water from a combination of groundwater and surface water, and three hatcheries rely on surface water sources to grow fish.



Freshwater use would substantially increase if salmon farmers were land-based and would put pressure on surface and/or groundwater resources. It is estimated that the average land-based RAS farm producing 5,000 tonnes per year would use 10,000 m³ of water per day (1). This is an enormous amount of water, considering the City of Campbell River provides approximately 21,917 m³ of drinking water to its residents each day. Approximately 33,600,000 m³ of additional water would be required to depurate each crop of fish for two weeks to remove the off taste from tank production prior to sale. [This is about four times the annual water use of the City of Campbell River.](#) (2)



STOCK MANIPULATION

Stock manipulation occurs both by removing fish through capture fisheries and adding fish through enhancement activities.

CAPTURE FISHERIES

The commercial fishery for salmon has collapsed in BC despite efforts to double catches. Collapses have also occurred in Japan. This is an alarming situation for people and communities that depend upon Pacific salmon. See Chapter 2, Caring for Wild Salmon – The Big Picture for a summary of what is happening to Pacific salmon throughout the North Pacific Ocean.

Commercial fishing has been and is critically important for coastal communities. Gill net, seine, and troll fisheries have historically occurred in the waters surrounding Vancouver Island, including Discovery Passage/Johnstone Strait. Most fisheries are mixed stock and focus on larger rivers such as the Fraser and Columbia system runs.

There are some directed fisheries that primarily focus on specific runs associated with enhanced stocks, such as those from the Somas River and Conuma River hatcheries. Having a directed fishery on non-enhanced runs in the Vancouver Island/ south coast region is rare. There have been some terminal fisheries (focused on one species from a specific river) for pink salmon in Johnstone Strait when there are abundances, with the last fishery being in 2014.

The recreational fishery for salmon occurs in both the marine and freshwater ecosystems throughout Vancouver Island and the south coast. The following excerpts from a Pacific Fisheries Resource Conservation Council article provide context on this fishery:

"The recreational fishery for salmon plays an important role in the social and economic life of British Columbia...While the overall recreational share of the total salmon catch is small, at 3%, anglers catch larger proportions of chinook (35%) and coho (30%) and recreational fishing accounts for 40% of the total economic contribution of British Columbia's fishing and aquaculture sector...anglers have to recognize that much of their activity takes place in areas and at times when stocks are mixed, and their fishery can have an adverse impact on small and weak runs" (24).

Salmon aquaculture, while legally considered to be a commercial fishery in British Columbia, does not extract wild salmon from the ocean. Farm-raised salmon are not fed wild Pacific salmon (see "Chapter 7 - Caring for the Environment – Feed Sustainability") and rarely (if ever) eat wild fish that may become trapped within the sea pens (see "Chapter 6 - Caring for the Environment – Minimizing Incidental Catch").



Photo by Bill Pennell

SALMON ENHANCEMENT

DFO's website describes the purpose of [Salmon Enhancement Program](#) (SEP) (25) as follows:

"Our Salmonid Enhancement Program aims to rebuild vulnerable salmon stocks, provide harvest opportunities, work with Indigenous and coastal communities in economic development, and improve fish habitat to sustain salmon populations."

Specifically related to salmon enhancement and habitat restoration, the website states:

"Pacific salmon hatcheries play a key role in our efforts to conserve vulnerable salmon stocks; provide recreational, commercial, and Indigenous fishing opportunities; and support regional and

The Pacific Salmon Foundation recently completed an analysis of 25 hatchery experiments and found that although

international stock assessment programs."

About 300 million salmon are released each year from enhancement hatcheries in BC. Four other countries (USA, Russia, Japan and the Republic of Korea) also release fish into the North Pacific Ocean, totalling about 5 billion fish per year from all countries.

As described in "Chapter 2 - Caring for Wild Salmon - the Big Picture", hatchery fish returns have declined in BC and Japan, suggesting a declining ability of the coastal ocean to produce salmon. This is a major concern for the thousands of people working or volunteering in enhancement facilities and those relying on wild Pacific salmon.

there is some variation in trends across hatcheries, generally releasing larger smolts improved survival rates, rather than



only changing release dates (26). See their recent report, "[Review of Hatchery Release Strategies in British Columbia](#)"

(26) that identifies hatcheries with the greatest opportunities for improvement.

HELPING SALMON ENHANCEMENT

Salmon farmers grow millions of fish each year in BC. Their skills are directly transferrable to enhancement facilities. Many First Nations and community-led enhancement hatcheries have been helped by the sector by donating time, equipment, feed, and funding. Several "hatchery-in-a-box" enhancement equipment have recently been purchased and installed in local communities (Figure 5).



Figure 5. "Hatchery-in-a-box" equipment donated for community-led enhancement.

Despite the overall decline in hatchery returns in BC, some hatcheries have experienced resounding success. For example, after about 40 years of operation, the Marble River hatchery has successfully helped restore Chinook salmon to the river, from a low of about 500 spawners to 5,000 – 7,000 fish per year. For several years the hatchery has

improved early marine survival by about 3% by holding some of the smolts in a net pen, donated by salmon farmers, for their first month in the sea. Fish are fed and protected from predators, giving them a strong start before they migrate to feeding grounds. The project is supported by more than 100 volunteers and many local businesses (Figure 6).



Figure 6. Salmon babies in safe haven on Vancouver Island before hitting open ocean.

Source: [Trail Times](#) (27)

Other key enhancement projects and conservation associations that salmon farmers have supported over the years are listed in Figure 7. Veterinarians and fish health teams from individual companies have provided advice and donated their time to help ensure the success of these initiatives.



SUMMARY OF WILD SALMON CONSERVATION PROJECTS PARTNERED WITH SALMON FARMERS

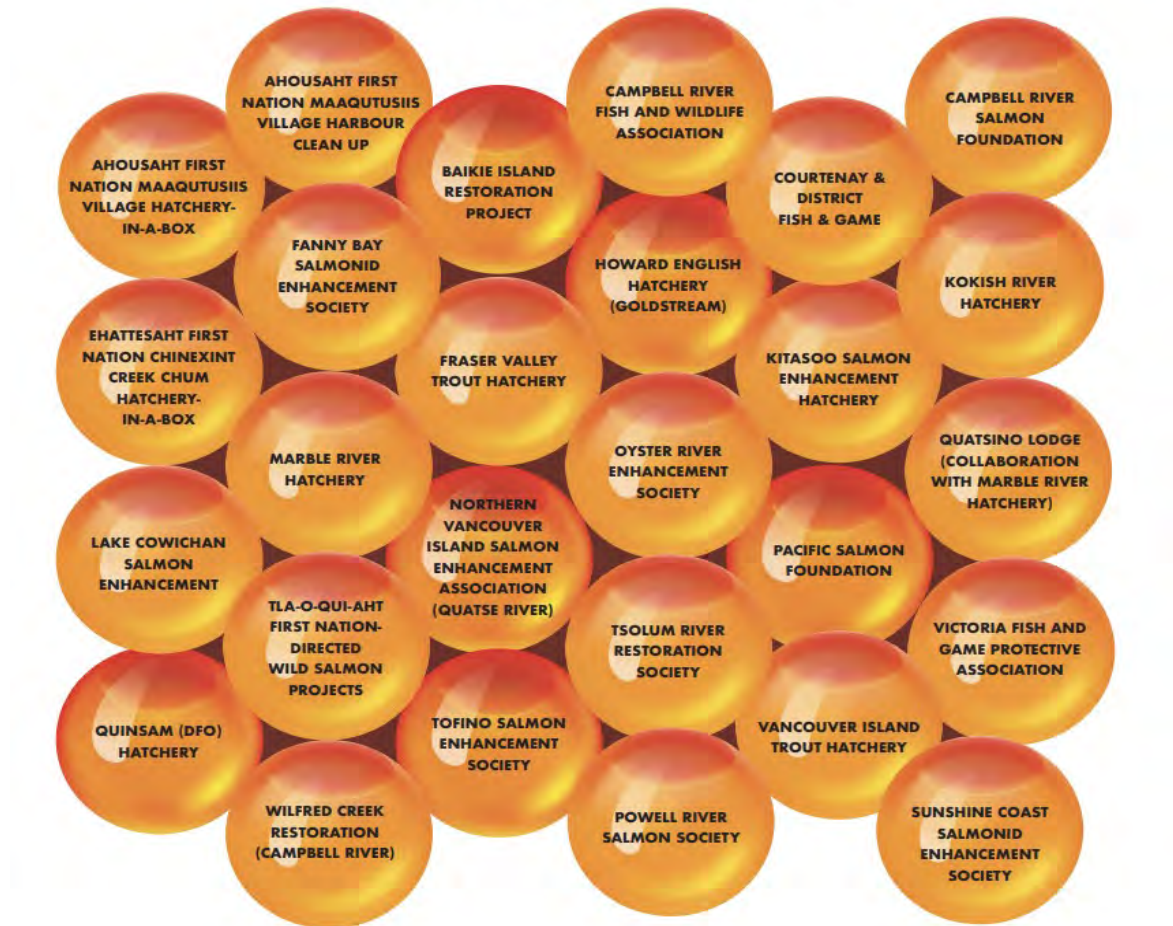


Figure 7. Key enhancement projects and conservation associations that have been supported by salmon farmers in BC.

WE CAN ALL CONTRIBUTE TO CONSERVATION



Photo by Bill Pennell

We believe everyone in British Columbia has a role in respecting, understanding, and conserving wild salmon. As salmon farmers, we have a lot to contribute, given our expertise in salmon and oceanography and year-round presence in coastal BC waters.

That is why we support past, present, and future research to understand Pacific salmon in the high seas, monitor nearshore oceanography, collaborate on mapping and restoring estuaries and watersheds and are involved in numerous enhancement projects throughout coastal BC. While this is a start, there is much more to do.

REFERENCES

1. Blewett E, Chen S, Roth M. RAS Salmon Farming in British Columbia Economic Analysis & Strategic Considerations. Prepared for Province of BC: Counterpoint Consulting; 2022. p. 48+app.https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/fisheries-and-aquaculture/aquaculture-reports/ras_salmon_farming_in_bc_-_economic_analysis_strategic_considerations.pdf
2. Campbell River City Services. 2013. Water Campbell River: City of Campbell River; [Available from: <https://campbellriver.ca/city-services/water/overview>].
3. Fisheries and Oceans Canada. Canada's Policy for Conservation of Wild Pacific Salmon. In: DFO, editor. Vancouver: Fisheries and Oceans Canada; 2005. p. 49.<https://www.pac.dfo-mpo.gc.ca/fm-gp/salmon-saumon/wsp-pss/policy-politique-eng.html#strategies>
4. Pacific Salmon Foundation. 2024. State of Pacific Salmon Vancouver: Pacific Salmon Foundation; [March 2024]. Available from: <https://psf.ca/salmon/>.
5. Canada Go. Canada's Policy for Conservation of Wild Pacific Salmon. In: Canada FaO, editor. Ottawa: Government of Canada; 2005.<https://www.pac.dfo-mpo.gc.ca/fm-gp/salmon-saumon/wsp-pss/policy-politique-eng.html>
6. International Year of the Salmon. 2022. The International Year of the Salmon Initiative [Available from: <https://yearofthesalmon.org/>].
7. Canada Go. Summary of British Columbia Salmon Restoration and Innovation Fund funding as of February 2023. In: Canada FaO, editor. Ottawa: Government of Canada; 2023.<https://www.dfo-mpo.gc.ca/about-notre-sujet/publications/infographies-infographies/fish-fund-bc-funding-financement-fonds-peche-cb-eng.html>
8. Fisheries and Oceans Canada. 2023. Pacific Salmon Strategy Initiative Ottawa: Government of Canada;; [Available from: <https://www.dfo-mpo.gc.ca/campaign-campagne/pss-ssp/index-eng.html>].
9. Government of British Columbia. 2023. Watershed Security Strategy Victoria, BC [Available from: <https://engage.gov.bc.ca/watershedsecurity>].
10. Coastal First Nations Great Bear Initiative. 2022. Connection of People, Land and Sea: Coastal First Nations; [March 2024]. Available from: <https://coastalfirstnations.ca/our-communities/place/>.
11. First Nations Fisheries Council of British Columbia. 2021. About Us Vancouver: FNFC; [Available from: <https://www.fnfisheriescouncil.ca/about-us/>].
12. Beamish R. 2022. The need to see a bigger picture to understand the ups and downs of Pacific salmon abundances. ICES Journal of Marine Science.79(4):1005-1014.10.1093/icesjms/fsac036
13. Hinch SG, Martins EG. A review of potential climate change effects on survival of Fraser River sockeye salmon and an analysis of interannual trends in en route loss and pre-spawn mortality. Cohen Commission Tech Rept 9. Vancouver: Cohen Commission; 2011. p. 134.https://epe.lac-bac.gc.ca/100/206/301/pco-bcp/commissions/cohen/cohen_commission/LOCALHOS/EN/PDF/TR/PROJECT9_REPORT.PDF

14. Mote PW, Parson EA, Hamlet AF, Keeton WS, Lettenmaier D, Mantua N, et al. 2003. Preparing for Climatic Change: The Water, Salmon, and Forests of the Pacific Northwest. *Climatic Change*.61(1):45-88.10.1023/A:1026302914358
15. Centre for Aquatic Health Sciences. 2019. Discovery Passage Plankton Monitoring Program Campbell River [Available from: <https://www.cahs-bc.ca/research/discovery-passage-plankton-monitoring-program/#:~:text=Discovery%20Passage%20Plankton%20Monitoring%20Program%20In%202007%20a,the%20monitoring%20of%20zooplankton%20productivity%20in%20Discovery%20Passage>].
16. Government of British Columbia. 2023. Harvested Areas of BC (Consolidated Cutblocks) Victoria: Forest Analysis and Inventory Branch; [Available from: <https://catalogue.data.gov.bc.ca/dataset/harvested-areas-of-bc-consolidated-cutblocks>].
17. Fisheries and Oceans Canada. 2024. NuSEDS-New Salmon Escapement Database System Ottawa: Open Government Canada; [Available from: <https://open.canada.ca/data/en/dataset/c48669a3-045b-400d-b730-48aaf8c5ee6>].
18. Anon. 2024. Demographics of British Columbia San Francisco, California: Wikipedia; [Available from: https://en.wikipedia.org/wiki/Demographics_of_British_Columbia#Population_history].
19. States B. 2021 Sub-Provincial Population Estimates Highlights. BC Stats; 2021. p. 3.https://www2.gov.bc.ca/assets/gov/data/statistics/people-population-community/population/pop_subprovincial_population_highlights.pdf
20. Lackey RT. 2003. Pacific Northwest Salmon: Forecasting Their Status in 2100. *Reviews in Fisheries Science*.11(1):35-88.10.1080/16226510390856529
21. Finn RJR, Chalifour L, Gergel SE, Hinch SG, Scott DC, Martin TG. 2021. Quantifying lost and inaccessible habitat for Pacific salmon in Canada's Lower Fraser River. *Ecosphere*.12(7):e03646.<https://doi.org/10.1002/ecs2.3646>
22. Riparian Areas Protection Act, [SBC 1997] CHAPTER 21 (1997).
23. Forest and Range Practices Act, [SBC 2002] CHAPTER 69 (2002).
24. Gerry K. 2006. The evolution of recreational salmon fisheries in British Columbia. desLibris. Report No.: 9781897110294.<https://policycommons.net/artifacts/1202313/the-evolution-of-recreational-salmon-fisheries-in-british-columbia/>
25. Fisheries and Oceans Canada. 2023. Salmonid Enhancement Program Ottawa: Government of Canada; [Available from: <https://www.pac.dfo-mpo.gc.ca/sep-pmvs/index-eng.html>].
26. Pacific Salmon Foundation. A Review of Hatchery Release Strategies. Vancouver: Pacific Salmon Foundation,; 2022. p. 10.<https://www.marinescience.ca/wp-content/uploads/2022/03/2022PDF-ReleaseStrategiesReview-Newsletter-Web.pdf>
27. Ducklow Z. VIDEO: Salmon babies in safe haven on Vancouver Island before hitting open ocean. Trail, BC: Trail Times; 2020.<https://www.trailtimes.ca/photo-galleries/video-salmon-babies-in-safe-haven-on-vancouver-island-before-hitting-open-ocean-5047809>

CHAPTER 4

CARING FOR INDIGENOUS STEWARDSHIP

CONNECTING WITH THE ORIGINAL GUARDIANS OF THE COAST



This document describes some of the history of First Nations stewardship of coastal British Columbia, and discusses how conservation and guardianship initiatives can support marine-based economic opportunities for Indigenous communities

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CHAPTER HIGHLIGHTS CARING FOR INDIGENOUS STEWARDSHIP- CONNECTING WITH THE ORIGINAL GUARDIANS OF THE COAST



Coastal First Nations have been the stewards of their lands, waters, and elements since time immemorial and are currently advancing their inherent rights to manage their territories while being active participants in Canada's economy.

This includes marine management planning that varies from Nation to Nation, but generally involves Traditional Ecological Knowledge, Western science methodology, Indigenous oversight, conservation, and economic opportunities.

Wild salmon are the lifeblood of coastal First Nations and remain top of mind when Nations build their ocean

management planning and explore new projects.

Resource sectors across British Columbia are evolving in terms of respectful partnerships with the Nations in whose territories they operate, including salmon farming.

When empowered to lead the management of their territories and the resources within them, First Nations in BC are finding exciting pathways and business opportunities that improve the human well-being of their communities.

The future of salmon farming in BC will be led by First Nations.



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CONNECTING WITH FIRST NATIONS, THE ORIGINAL STEWARDS OF THE COAST

First Nations have been the stewards of their lands, waters, and elements since time immemorial. They are the original environmentalists and have been successfully managing environmental stressors and changes to their ecosystems for thousands of years. When it comes to combatting global climate change, who better to lead the way than Indigenous peoples and their invaluable traditional knowledge?

By working alongside the First Nations in whose territories they operate, salmon farmers can apply Western science and research models with Indigenous traditional knowledge to best protect the surrounding environment and wildlife, as well as the salmon they are growing in the net pens. With Indigenous peoples guiding and overseeing salmon farming operations through initiatives like Guardian Watchmen and stewardship programs, wild and farm-raised salmon can successfully and safely co-exist and prosper in First Nations' marine spaces.



Photo by Brian Kingzett



"Indigenous Peoples have been faced with adaptation challenges for centuries and have developed strategies for resilience in changing environments that can enrich and strengthen current and future adaptation efforts." – [IPCC AR6](#)" (2)

Harmonizing Indigenous knowledge, stewardship, and Western methods is the path forward toward ecological marine health while encouraging economic growth on the coast, and will give wild salmon their best chance to survive both climate change and human impact stressors now and into the future.



INDIGENOUS OVERSIGHT, STEWARDSHIP, AND TRADITIONAL KNOWLEDGE OF THEIR MARINE SPACES

GUARDIAN WATCHMEN AND INDIGENOUS STEWARDSHIP PROGRAMS

First Nations take seriously their ancestral rights and responsibilities to take care of their lands, waters, wildlife, and food sources for future generations. Indigenous Guardians and stewardship teams are considered the “eyes and ears” for First Nations, keeping watch over the land and waters of traditional territories(3).

Guardians work in traditional areas of First Nations year-round, observing and gathering information about ongoing activities in their territories, whether on land or sea. By maintaining a presence in their territory, Guardians can help a Nation make careful decisions about resource use and continue traditional stewardship practices (Figure 1).

“Our [stewardship] obligation, how we uphold it in a modern way, is with Guardian monitoring programs and [Wei Wai Kum] participation in conducting modern, Western science, combined with our traditional knowledge, which results in, I think, the most informed decision,” says Chief Roberts, Wei Wai Kum First Nation.

Each Nation can draw upon traditional use data on archaeological sites and areas of cultural importance, guiding development away from sensitive areas (4).

Photo by Brian Kingzett





Figure 1. Members of the Tlowitsis Nation tour their traditional territory off the north-east of Vancouver Island.

Working with federal and provincial governments, Guardians also supervise companies operating in their territories and activities by the public and tourism operations to ensure compliance with environmental laws. This includes salmon farming. Some Guardian programs on the coast are already working with salmon farmers to:

- o monitor ongoing day-to-day operations of salmon farmers and their contractors,
- o conduct juvenile wild salmon sampling surrounding farm sites,
- o survey ecosystems in the area surrounding farms to monitor health of more sensitive species like kelp beds, eel grass, glass sponge reefs,
- o establish environmental baseline data of new potential sites using ROV technology,
- o identify areas suitable for marine sites for farms based on surveying, traditional knowledge, and awareness of marine conditions,
- o ensure Nation cultural sites are identified and protected from adverse impacts,
- o collect and analyze water quality and biological samples of environmental health,
- o share access to environmental data, ocean science, and traditional knowledge, and
- o assist in the careful and respectful decommission of farms being removed from the territory.



Figure 2. Wei Wai Kum First Nation's Guardians on the job in Laichkwiltach territory.

Photo by: Deirdre Leowinata / Coast Funds (4)

It is important to note that not all Nations currently have Guardian programs in place, and instead might implement other Indigenous stewardship programs or initiatives in their territories that would oversee operations in their territories. Many coastal Nations are currently working to build capacity in this arena by either growing current Guardian programs, introducing Guardian programs, or initiating stewardship programs that work for their Nation (Figure 2).



Photo by Brian Kingzett

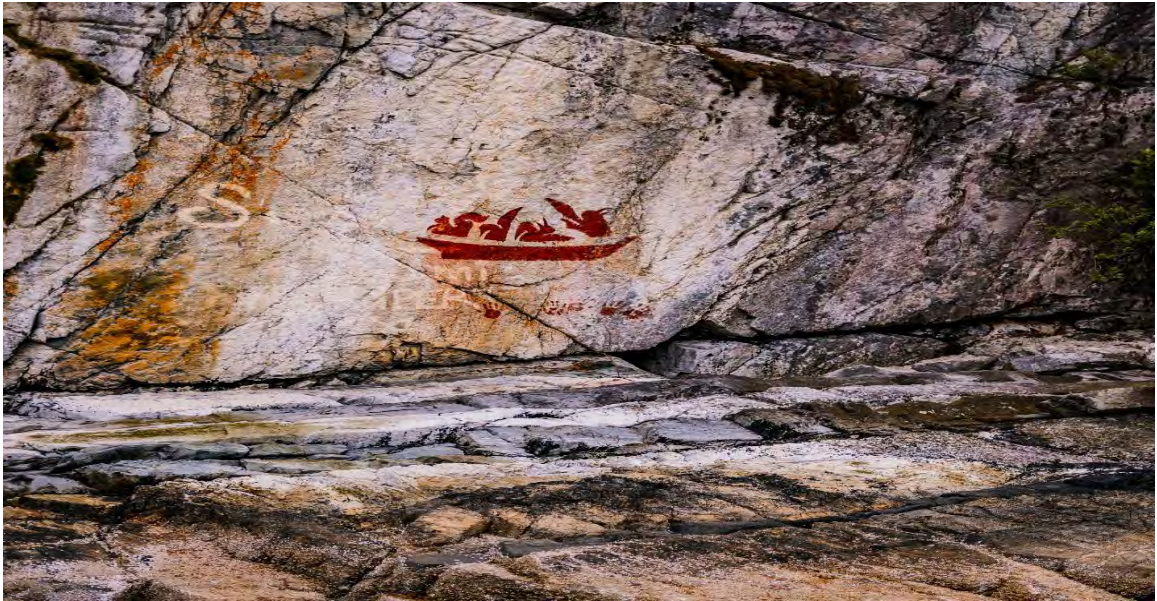


TRADITIONAL ECOLOGICAL KNOWLEDGE (TEK) AND INDIGENOUS-LED WESTERN SCIENCE

Traditional Ecological Knowledge (TEK) “represents experience acquired over thousands of years of direct human contact with the environment” however until recently, professionals in industrial development, governments, and resource management fields such as fisheries, wildlife, and forestry were slow to apply it to their existing methodologies of Western science (5). TEK was not acknowledged as credible or of utility in environmental management and was subject to who controlled the process and decision-making (6).

Today, scientists, researchers, and professionals are amongst those advocating for the rights of Indigenous people and their inclusion in land-based decision-making. Now recognizing the value of TEK, these groups are working with Indigenous peoples around the world to better understand and combat the mounting challenges and impacts of climate change on the environment.

In coastal British Columbia, Indigenous peoples have been studying, observing, and navigating their lands and waters for over 10,000 years and have been passing down that invaluable knowledge from generation to generation.





Wild salmon and their migration routes, feeding patterns, and behaviours in one area, for example, can be better understood by listening to and learning from an Indigenous person or Knowledge Keeper from that area who's been taught those characteristics (and the general history and geography of that area) by the generations before them. Both

Indigenous traditional customs and practices, as well as narrative and storytelling, were how knowledge was passed from generation to generation. As Westerners and settlers, it is important to take time to listen and hold space for these moments of knowledge sharing as an act of respect and recognition of their authority (7).

Braiding TEK and Western science can help understand, and therefore protect and revitalize, wild salmon and their surroundings in the face of warming oceans, watershed destruction, and overfishing. A growing number of universities and conservation organizations are recognizing and supporting First Nations with building on their existing capacities and adding new

By combining this rich wealth of traditional knowledge with data and methods of Western science, a more fulsome picture of a local environment can be obtained.

tools and resources to tackle the wild salmon decline on the west coast, recognizing each respective knowledge body and institution for its contribution to better environmental understanding.



Photo by Bill Pennell

The BC Centre for Aquatic Health Sciences (BC CAHS) in Campbell River, BC is an ISO-accredited lab that has recently modernized its governance system to be Indigenous led and is creating a common place for Nations to apply their knowledge and undertake research and monitoring projects to help restore wild salmon on the coast. This not-for-profit is “working with wild, enhanced, Indigenous and salmon farming communities within BC to provide relevant, timely and reliable research and diagnostic information to help make informed decisions on key issues facing salmon.” (8).

Organizations like universities and BC CAHS can help First Nation capacity and technology needs for their stewardship programs, while braiding TEK with Western science by providing training and teaching opportunities, offering workshops, and building science capacity within their communities to better maximize their conservation and oversight efforts to protect their marine environments.



Photo by Brian Kingzett

INDIGENOUS MARINE PROTECTED AREAS

Through generations of close connections with the environment, Indigenous peoples safeguard an estimated 80% of the world's remaining biodiversity. Together, the global community has an opportunity to reorient the way it interacts with nature and combat climate change through collaborating with, and learning from, Indigenous peoples, the stewards of nature and their territories (9).



Photo by Bill Pennell

On June 21, 2023, the federal government launched its United Nations Declaration Act Action Plan, a roadmap to help Canada implement the United Nations Declaration of Rights for Indigenous Peoples (10). Two measures that directly affect First Nations Marine Protected Areas (MPAs) and marine management planning are:

- o implementing Indigenous management of fisheries and fish habitats by:
 - o Amending fisheries legislation, regulations, or policies to incorporate Indigenous fishing rights, create collaborative tools for the conservation and protection of fish habitats, and enable the provision of capacity funding, and
- o maintaining Indigenous participation in climate action, sustainable development, and conservation (11).



Photo by Bill Pennell

For years, First Nations along the coast of British Columbia have been working together and with the federal and provincial governments to help establish Marine Protected Areas (MPAs). According to the Department of Fisheries and Oceans (DFO),

"Decades of scientific evidence documenting ecological, social and/or economic benefits of effectively managed MPAs demonstrates their importance as a management tool that can be applied to address multiple stressors and threats (12)."

MPAs have demonstrated positive ecological gains, while also providing a platform for First Nations to have a voice in, and lead, the ocean management of their territories.

Marine Protected Area as defined by DFO (12):

- o "A clearly defined geographical space recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values".
- o "A collection of individual marine protected areas that operates cooperatively and synergistically, at various spatial scales, and with a range of protection levels, in order to fulfill ecological aims more effectively and comprehensively than individual sites could alone."

For DFO, the establishment of a network of MPAs will serve six goals (12) (described in greater detail below):

1. To protect and maintain marine biodiversity, ecological representation and special natural features.
2. To contribute to the conservation and protection of fishery resources and their habitats.
3. To maintain and facilitate opportunities for tourism and recreation.
4. To contribute to social, community, and economic certainty and stability.
5. To conserve and protect traditional use, cultural heritage and archaeological resources.
6. To provide opportunities for scientific research, education and awareness.



Photo by Brian Kingzett



Benefits of MPAs and MPA Network (12)

Ecological Benefits

Contribute to the protection of the structure, function and integrity of ecosystems by:

- o providing harvest refugia,
- o protecting habitats critical to lifecycle stages such as spawning, juvenile rearing and feeding,
- o complementing adjacent terrestrial protected areas for anadromous species (e.g., salmon),
- o protecting spawning stocks, spawning stock biomass and spawning aggregations to enhance or maintain reproductive capacity,
- o contributing to the restoration and recovery of species, habitat and ecosystem,s
- o enhancing local and regional fish stocks through increased recruitment and spillover of adults and juveniles into adjacent areas, and
- o assisting in conservation-based fisheries management regimes.

Social and Cultural Benefits

Contribute to social and cultural benefits by:

- o encouraging expansion of our knowledge and understanding of marine systems,
- o ensuring a stable resource base for non-consumptive and sustainable consumptive activities including fishing, recreation and tourism,
- o contributing to the coordination of ecosystem-based management of marine activities, thereby ensuring long-term economic opportunities for sustainable use,
- o providing researchers, educators and policy makers with reference sites to serve as natural benchmarks,
- o increasing the quality of life in surrounding communities, and
- o protecting historical and contemporary culturally and spiritually significant sites.



Photo Credit Kitasoo Xai'xais Nation

While some First Nations are working with the provincial and federal governments to continue to identify and establish MPAs along the coast, other Nations are taking marine protection of their territories upon themselves, like the Kitasoo Xai'xais, who unilaterally declared Gitdisdzu Lugyek, also known as Kitasu Bay, to be an MPA in the summer of 2022 (1).

Alongside the declaration, the Kitasoo Xai'xais published a marine management plan defining what economic activities are and are not allowed to happen in the 33.5-acre bay.

The establishment of MPAs and marine management plans has become a key goal for many coastal First Nations who are battling climate change, overfishing, poaching, and other stressors in their waters.

For several of these Nations, aquaculture is a part of their marine management plans, and working with resource industries like salmon farming companies to maintain ecological balance and economic opportunity will become a key component of this protection process.

“We make this declaration in accordance with Kitasoo Xai'xais laws, customs, principles and values and as the holders of inherent and Aboriginal Rights and Title on our unceded territorial lands and waters...Our laws include our inherent stewardship responsibilities to act in a manner that protects this unique place on behalf of past, current and future generations of Kitasoo Xai'xais.”
(1)



WILD SALMON REVITALIZATION

Wild Pacific salmon are the cultural and community lifeblood of coastal First Nations, as well as for hundreds of Nations up major river systems (like the Skeena and Fraser Rivers) deep into the interior of British Columbia. As mentioned in “Chapter 3 – Caring for Wild Salmon – the Local Picture”, coastal and Interior First Nations are committed to wild salmon revitalization through various enhancement programs, mainly through hatchery programs, watershed restoration efforts, establishing MPAs, and fisheries closures.

Nations might prioritize different species of wild Pacific salmon from one another for varying reasons, so which species, runs, and revitalization efforts a community might focus on ranges. How they conduct these restorative efforts can also vary based on geography, capacity, current health of runs, access, infrastructure, and cultural approaches.

As mentioned above, each Nation’s capacity to revitalize wild salmon in their territory will change as well, including which tools and capacity they use or have access to (staff/volunteers, biologists/fisheries staff, Guardians, infrastructure, funding, etc.).



Photo by Steel_Snorkel



Figure 3. Early Stuart sockeye fry raised in a Hatchery-In-a-Box program in Nakadzli.

Photo by Maureen Ritter

Some additional examples of current salmon revitalization tools being used by First Nations in BC are:

- o Hatchery Programs,
 - o Nation-and-community-led flow-through hatchery projects, and
 - o “Hatchery In a Box” program: The Hatchery in a Box (HIB) is a bio-secure (and bear proof) small scale fish hatchery that can be used in remote locations. The HIB was designed to hold up to 120,000 fertilized salmon or trout eggs and produce up to 100,000 1-gram fry. The HIB is a self-contained unit with an alarm system that can be programmed to a cell phone as well as an auto start oxygenation system in case of emergency (Figure 3).
- o Cryopreservation and storage of fish sperm: gene banks are available to be used to fertilize eggs in times of low returns or when a natural (or human caused) disaster occurs,
- o Watershed and stream restoration projects,
- o Area-based fisheries closures, and
- o Indigenous protected conservation areas (similar to MPAs).

PROBLEMS, PARTNERSHIPS, AND PATHS FORWARD

When salmon farming was first introduced to BC’s coast in the 1980s, the First Nations in whose territories the farms appeared were often not approached for permission to operate, nor were there meaningful consultations on site locations of the farms.

While this unfortunately was the general approach by most resource development during that time, such as forestry and mining, this practice by these early days salmon farms initiated a poor precedent for future procedures by larger international companies that would enter the scene over the next decade.



In the early days of salmon farming in BC, the sector operated with minimal technology, safeguards, and oversight that led to ongoing environmental issues for both the farm-raised salmon and the environment around the farms. There were also few environmental regulations that applied directly to the emerging sector.

This created the view that salmon farming was not done responsibly and was harmful to the environment and wild salmon. While operations, technology, and First Nations relationships have advanced

significantly in this time, for many the negative perception from the early days has endured four decades later, and social licence has been difficult to obtain (13).

In the last decade, there's been an increased awareness and understanding of Indigenous rights and engagement by both government and industry, thanks to the Truth and Reconciliation Commission, UNDRIP, and the adoption of Declaration on the Rights of Indigenous Peoples Act (DRIPA) by the Government of British Columbia (14).

The first protocol agreement between a company and First Nation was forged in 1998 between KITASOO XAI'XAIS Nation and what is now MOWI Canada West.



Photo by Bill Pennell



While not all First Nations are fully in support of finfish net-pen aquaculture in 2023, many Nations and salmon farming companies are on a journey of reconciliation, developing a range of relationships that recognize the Rights and Title of First Nations in the coastal environment on their own terms (15).



With First Nations especially, repairing, strengthening, and advancing those relationships has moved to the forefront of priorities for the sector salmon farming companies. In the past two decades, they have formed partnerships and formal agreements in the territories where they operate to increasingly recognize Indigenous interests and needs in supporting their coastal community. These companies have taken considerable steps to ensure that the future path of the sector is created with First Nations, not apart from them.

Salmon farmers have exited territories where they are not welcomed, and as of 2023, 100% of farm-raised salmon in BC (Atlantic or Chinook salmon) was done in partnership with First Nations.

While there is still work to be done and much to learn, First Nations and the sector are feeling their way forward, and finding that by working together, transparency, shared best practices, and opportunities can be achieved – and, in turn, coastal communities and the environment will benefit.





Impact Benefit Agreements (IBAs)

Across almost all resource industries in Canada, impact benefit agreements (IBAs) with First Nations have become the standard for projects and operations that are located on or impact Indigenous peoples' traditional territories. While IBAs vary by Nation, relationship, and company, there are six areas of provision typically covered in each: labor, economic development, community wellbeing, environmental, financial and commercial arrangements (16).



Today, all BC farmed salmon is raised in partnership with First Nations, and the input, guidance, and oversight of First Nations partners in salmon farming has evolved from non-existent to expected.

Beyond the financial compensation, IBAs in the salmon farming sector can include employment, education, and training opportunities for members; first-right-of-refusal for businesses and contractors from the Nation; environmental monitoring and oversight by First Nations Guardians; regulatory and environmental thresholds set by the Nations; wild salmon revitalization projects; watershed restoration commitments; and support and donations (monetary and in-kinds) to community programs.

Although the details vary from agreement-to-agreement, IBAs with salmon farming companies help create foundations of social and economic benefits and capacity building for many Indigenous communities on the coast, as well as long-term, stable and secure coastal economic investment.

COMMUNITY AND SOCIAL BENEFITS OF PARTNERSHIPS

For many coastal Indigenous communities between mid-Vancouver Island and the Central Coast, finfish farming (ranging from Atlantic salmon, Chinook salmon, and sablefish) is the primary source of a First Nation's own-source revenue, and a major employer for their members. It is generally difficult to find other forms of year-round, well-paying employment in these communities. Furthermore, employment in salmon farming is often more than a 'job' for First Nations in these communities. Indigenous salmon farmers can have a meaningful job without leaving their remote communities, and many indicated that by working in salmon farming in their traditional territory, they are able to keep an eye on operations in

their waters and are able to maintain a marine livelihood as they have for thousands of years.

As of February 2022, the industry directly and indirectly employed over 700 Indigenous people, provided \$51 million in total annual direct economic benefit to First Nations communities, and infused \$21 million each year into Indigenous-owned businesses (15). For most of these communities, those benefits cannot be replaced, and the threat of losing them via government closures is a real threat to their social safety.





“Fifty-one per cent of our economy is fish farms. We would go back to the 70s – alcoholism, all those social issues. Hearing from other leaders about the suicides that were just rampant, I, as a young leader, do not want to go down that path”. Isaiah Robinson, Councillor, Kitsoo Xai’xais Nation

As partnerships with the sector strengthen and help diversify a Nation’s marine management planning, benefits and opportunities will advance for coastal Indigenous communities, further improving social health and wellbeing, economic independence from the government, access to improved infrastructure, and capacity building (Figure 4).

The incomes and economic benefits from salmon farming has the ability to lift entire families away from dependence on social assistance and, by providing meaningful year-round employment, helps prevent significant social issues in communities, including addiction, poverty, and suicide.



Figure 4. General elements of partnership agreements between salmon farming companies and First Nations.

DEFENDING FIRST NATIONS' DECISION-MAKING RIGHTS

Following the decision by consecutive DFO ministers to close 19 salmon farms in core Laichkwiltach territory (the "Discovery Islands") in December 2020 against the wishes of the Rightsholder First Nations, other Nations with finfish farms in their waters were suddenly faced with the reality that the precedent could apply to their territories next.

To protect their rights, title, and self-determination of their ocean management, several Rightsholder Nations met in late 2021 to share their concerns and thoughts about moving forward. They later united under a Coalition of First Nations for Finfish Stewardship in March 2022, citing that it was their **sovereign right to determine for themselves whether, if, and how salmon farms operated in their territories.**

The Coalition Nations and other Rightsholder Nations who wanted to keep salmon farms in their waters met with

several federal and provincial ministers and senior staff throughout 2022 and 2023 to assert their right to self-determination, rights to sustain their traditional marine livelihoods, and economic prosperity in their territories.

In June 2022, the licenses for all salmon farms were extended for a temporary two-year term (outside of the Discovery Islands) while an official engagement process with DFO to develop a transition plan for the sector by 2025 was put into place by the federal government beginning July 2022. All impacted First Nations, the sector, and other stakeholders have been engaging with DFO on the transition of this sector; however, the continually shifting process and its timelines were a concern for many, and asks for more time, more socio-economic analyses, and more meaningful consultation were put forward by the Coalition and other Rightsholder Nations to federal ministers and senior officials, as well as provincial leadership.



Photo Credit Gwa'sala-'Nakwaxda'xw Nations

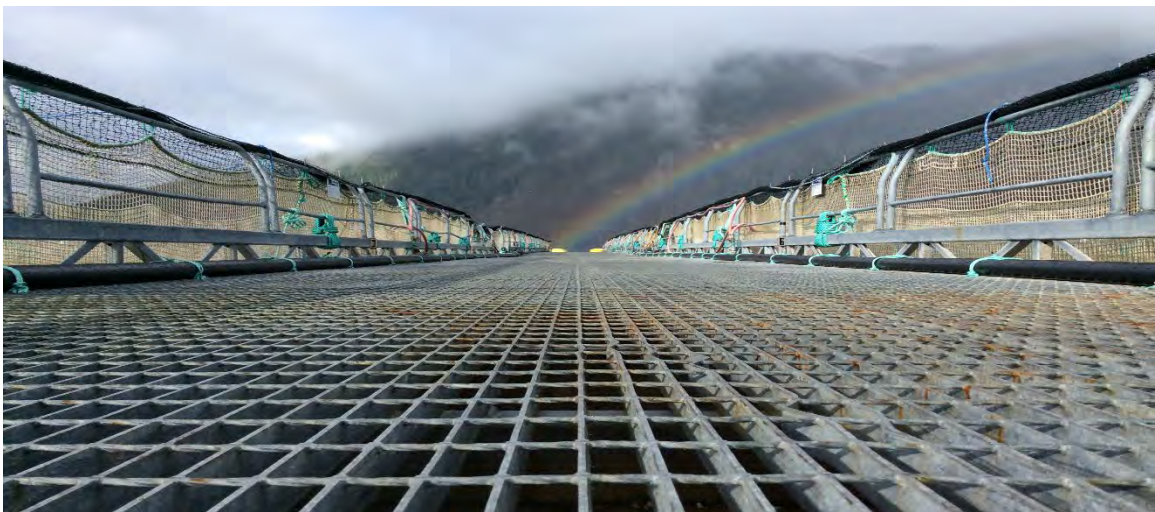


In the summer of 2023, after months of consultation, the federal government committed to conduct social and economic impact studies in all Indigenous communities that work with salmon farming to truly understand the integration of the sector. DFO also extended the Transition Plan engagement timeline by six months at the Coalition's request into January 2024 to ensure meaningful consultation was carried out in the process.



Photo by Bill Pennell

The protection of wild salmon is a priority for coastal First Nations, who would not put centuries of stewardship at risk for short-term gains.



On June 21, 2023 the Government of Canada rolled out the [UN Declaration Act Action Plan](#) – a national roadmap for implementing the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) (11). The release was announced by then Justice Minister David Lametti, alongside former Crown-Indigenous Relations Minister Marc Miller and Northern Affairs Minister Dan Vandal. The UN Declaration Act Action Plan supports and enhances decision-making rights of coastal Nations and fisheries and stewardship, particularly the measures:

- o Implementing Indigenous management of fisheries and fish habitats by:
 - o Amending fisheries legislation, regulations, or policies to incorporate Indigenous fishing rights, create collaborative tools for the conservation and protection of fish habitats, and enable the provision of capacity funding,
 - o Developing national aquaculture legislation that will support self-determination and the implementation of Aboriginal and treaty rights,
- o Maintaining Indigenous participation in climate action, sustainable development, and conservation, and
- o Strengthening Indigenous participation in decision-making over all matters that affect them (14).

This, in addition to the Province of British Columbia's commitment to the Declaration on the Rights of Indigenous Peoples Act (DRIPA), and Action #92 of the Truth and Reconciliation Commission (TRC), assist both the federal and provincial governments with their commitments to reconciliation with Indigenous peoples, while also supporting coastal First Nations to realize and execute their rights and self-determination regarding their marine management planning.

In particular, the right to free, prior, and informed consent is relevant and applicable to First Nations that both support and do not want support salmon farming.





92. We call upon the corporate sector in Canada to adopt the United Nations Declaration on the Rights of Indigenous Peoples as a reconciliation framework and to apply its principles, norms, and standards to corporate policy and core operational activities involving Indigenous peoples and their lands and resources. This would include, but not be limited to, the following:

- i. Commit to meaningful consultation, building respectful relationships, and obtaining the free, prior, and informed consent of Indigenous peoples before proceeding with economic development projects.
- ii. Ensure that Aboriginal peoples have equitable access to jobs, training, and education opportunities in the corporate sector, and that Aboriginal communities gain long-term sustainable benefits from economic development projects.
- iii. Provide education for management and staff on the history of Aboriginal peoples, including the history and legacy of residential schools, the United Nations Declaration on the Rights of Indigenous Peoples, Treaties and Aboriginal rights, Indigenous law, and Aboriginal-Crown relations. This will require skills-based training in intercultural competency, conflict resolution, human rights, and anti-racism.

As of 2023, 100 per cent of BC's farmed salmon is raised in agreement with Rights Holder First Nations. Currently First Nations, federal and provincial governments, and the salmon farming sector are working together to build a responsible, realistic, and achievable transition of net-pen aquaculture in each Nation's territory.



OPPORTUNITIES AND OUTCOMES: FIRST NATIONS' SUCCESS STORIES IN SALMON FARMING



In the spirit of reconciliation, salmon farmers are building meaningful partnerships with First Nations that may offer ownership, capacity building, as well as business and employment opportunities to their communities (Figure 5).

First Nations involved in finfish aquaculture are finding unique ways to not only benefit from the sector, but to create Indigenous-led business opportunities from their partnerships. Indigenous-led businesses include processing & value-added opportunities, (smoked and canned salmon), transport boats, crew boats, and net washing services.

In communities like Klemtu located 800km north of Vancouver, the Nation has found a way to lead and benefit from the entire farm-to-table process thanks to the installation of a smoke house by their partner, Mowi Canada West.

Figure 5. Nellie Atleo, a member of the Tla-o-qui-aht First Nation, stands on a Chinook salmon farm in her traditional territory off of Tofino, BC.

KLEMTU SPIRIT SMOKED FISH – KITASOO XAI'XAIS NATION

The Kitasoo Xai'xais began farming and processing salmon independently in their waters in the late 1980s raising coho salmon. When they struggled to be successful in their operations, they reached out to what is now Mowi Canada West, thereby forming the province's first official Nation-company partnership in 1998.

Today, Mowi operates six salmon farms in Kitasoo Xai'xais territory with an average annual harvest of 5,000 tonnes of salmon. The processing plant in Klemtu was recently converted to a smokehouse, and in December of 2021, Walmart Canada was announced as the first retailer of Klemtu Spirit Hot Smoked Atlantic Salmon, a newly launched seafood product produced by the Nation in partnership with Mowi.



Now in 2023, the product is carried in multiple grocery outlets across Canada and will soon expand to retailers in the United States.

Klemtu Spirit is an admirable example of how a First Nation can lead the success of fish farms in their water from grow-out to value-processing – or from farm to table. From farming to harvest (with Guardian oversight), to smoking, and packaging, the Kitasoo Xai'xais are involved in, and benefiting from, hosting Atlantic salmon farms in their territory. They are the first

Nation in BC to oversee almost every aspect of the sector in their territory (excluding processing, transportation of, and producing the sleeves for Klemtu Spirit).

Today over 50 per cent of the Kitasoo Xai'xais' revenue derives from their salmon farming partnership, all while conserving over 52 per cent of their territory through their Great Bear Sea and Rainforest initiatives and their recent creation of an Indigenous marine protected conservation area (IMPCA).



Fish farming and smoking is the main source of employment in Klemtu, generating more than 50 jobs for the small, remote community on the central coast of British Columbia. The Kitasoo Xai'xais pride themselves in stewarding their territory and guarding their values. For the Kitasoo Xai'xais, it is important to ensure that future generations inherit healthy lands and waters to steward for the next millennia.

“Our values ensure that the products we produce in our territory are done so in a way that minimizes the impact on the natural world and other species and does not harm the environment.” Isaiah Robinson, General Manager, Kitasoo Development Corporation



GRATITUDE SEAFOOD – NUU-CHAH-NULTH SEAFOOD LP

“When you purchase seafood from us, you join our journey and become part of the circle. Every purchase breathes new life into your community and ours.”

Gratitude Seafood, Nuu-chah-nulth Seafood LP.



Photo Credit Gratitude Seafood

The Nuu-chah-nulth-speaking people consist of 14 First Nations on the west coast of Vancouver Island, ranging from the Dididaht on the southwest coast of the Island, to the Che:k'tles7et'h' to the north.

Of these 14 communities, five partnered together to create Nuu-chah-nulth Seafood LP, “a First Nation owned seafood enterprise that operates on Vancouver Island’s pristine West Coast.

Nuu-chah-nulth Seafood offers planning and management support to our Nations

and their community members in various aspects of fisheries and aquaculture” (17).

In 2015, Nuu-chah-nulth Seafood purchased St. Jean’s Cannery and Smokehouse in Nanaimo, which enabled the partner Nations to benefit from owning Vancouver Island’s largest cannery and smokehouse.

The purchase also made it possible for the Nations to expand beyond their value-added wild-caught seafood business opportunities on Vancouver Island by working with the farmed salmon sector. Purchasing Atlantic salmon from producer companies, Nuuchahnulth Seafood began offering canned Atlantic salmon (smoked and regular) at St. Jean's under the new brand Gratitude Seafood. The canned salmon is produced "using Indigenous approved fishing and production processes" with proceeds from sales going back into the five Nuuchahnulth partner Nations.

Gratitude Seafood is "authentic aboriginal", and an example of Indigenous coastal communities benefitting from business opportunities with BC's salmon farming sector.

Three percent of annual sales of Gratitude Seafood products go directly back into Nuuchahnulth communities, with 1.5 per cent going to restoring language and identity, and the other 1.5 per cent going to creating new seafood economic opportunities for the Nations (18). Gratitude Seafood is now sold in several major grocery retailers across Canada.



Photo by Brian Kingzett



JAMES WALKUS FISHING COMPANY – GWA’SALA - ‘NAKWAXDA’XW

From humble beginnings with a single leaky boat, James Walkus of the Gwa’sala - ‘Nakwaxda’xw Nation built the multimillion-dollar fishing company, James Walkus Fishing Co. However, when wild fish stocks began to decline, the company and its employees faced a dismal future. Walkus overcame this

challenge by converting to aquaculture and forging a partnership with Mowi Canada West to provide supply and transport services. Aquaculture now accounts for 60 per cent of Walkus’ business and provides jobs for 30 people on North Vancouver Island, many of whom are First Nations (Figure 6).



Figure 6. In 2014, Walkus launched a \$9M farm-raised salmon transport boat – and added a second \$11M boat in 2018.

“The partnership has been tremendous. We have First Nations people from our reserve working on these boats. Plus, many of them are working at the processing plant. It’s absolutely great for our people.” James Walkus, James Walkus Fishing Company.

CHIEF'S PRIDE AQUACULTURE CO. – TLOWITSIS NATION

In 2021, the Tlowitsis Nation created a business called Chief's Pride Aquaculture Co. (CPAC) and signed a three-year contract with Grieg Seafood BC to provide net-washing services to its three farms in Clio Channel off Johnstone Strait – part of the Tlowitsis' traditional territory. The farms were named by the Tlowitsis and are called Noo-la, Tsa-ya- and Wa-

kwa, Kwak'wala for Big Brother, Little Sister, and Little Brother.

This contract with Grieg Seafood provides the Nation's business, CPAC, with automated net-washing equipment, a skiff, a crane barge and, most recently, an accommodation barge in Clio Channel for its all-Indigenous employees.



“As much as there seems to be controversy about the [salmon farming], we believe many First Nations should be looking at long-term relationships with salmon farming partners. There are only so many opportunities available, and most of the Nations have traditional territories adjacent to the inlet waters – it only makes sense.” Councillor Thomas Smith, Tlowitsis Nation.



For the Tlowitsis, being able to provide employment for their members through CPAC, Grieg Seafood, and other ocean-based business opportunities in their own traditional territory is invaluable. The Nation also has its own Guardian Watchmen keeping an eye on salmon farming operations, contractors, and other ongoing in its marine space (Figure 7).



Figure 7. Tlowitsis men on a canoe team, date unknown.

INDIGENOUS-LED FUTURE OF FINFISH AQUACULTURE IN BC



Photo by Brian Kingzett

For over 10,000 years, Indigenous peoples on BC's coast managed their lands, waters, and elements in a holistic way that encouraged healthy, balanced ecosystems, and plentiful resources. As discussed earlier, the traditional knowledge of coastal Indigenous peoples is proving to play a major contributor to the fights against climate change, habitat destruction, and the loss of species.

Salmon farmers have learned about the importance of relationships with First Nations, and that their operations go far beyond simply growing fish in the ocean. Working with local First Nations and their Indigenous knowledge can and will help in raising salmon successfully alongside revitalizing wild salmon stocks and protecting the environment. It will also

build stronger relationships between First Nations and the industry, encourage important work on reconciliation, and help First Nations communities reclaim their decision-making authority over their marine spaces.

Already coastal First Nations are finding increasing autonomy when it comes to marine management planning in their territories, including protection, conservation, revitalization, and economic opportunity. For several of those Nations, aquaculture (finfish, shellfish, seaweed) is a part of their ocean management planning, and by overseeing aquaculture operations with their Guardians, traditional ecological knowledge, and decision-making authority, can benefit economically and socially while protecting their territory.



First Nations are striving to reclaim their rights to manage their marine spaces as they did pre-colonization. With full support from the sector, the future of finfish farming in British Columbia will be led by the First Nations in whose territories the farms operate in.

How that will look will be different for each Nation and community and will be based on varying partnerships with salmon farming companies. This message is currently being conveyed by Rightsholder First Nations to both the provincial and federal governments, as a Transition Plan for finfish aquaculture is being developed between these three parties, the companies, and other stakeholders (19).



Photo by Brian Kingzett

By encouraging First Nations to lead this transition process, the federal and provincial governments can help advance reconciliation with coastal communities while growing Canada's Blue Economy and trusting that Indigenous traditional knowledge will do what it has for millennia – create balance.

“Salmon farming is a small drop in the bucket of the overall holistic approach we will take to managing our marine spaces. It is a part of the whole. We will be weaving Indigenous traditional ecological knowledge with western science, advancing technologies, and the oversight of our Guardian Watchmen to help lead aquaculture in Canada, all while benefitting our communities via own-source revenue.” Dallas Smith, spokesperson, Coalition of First Nations for Finfish Stewardship

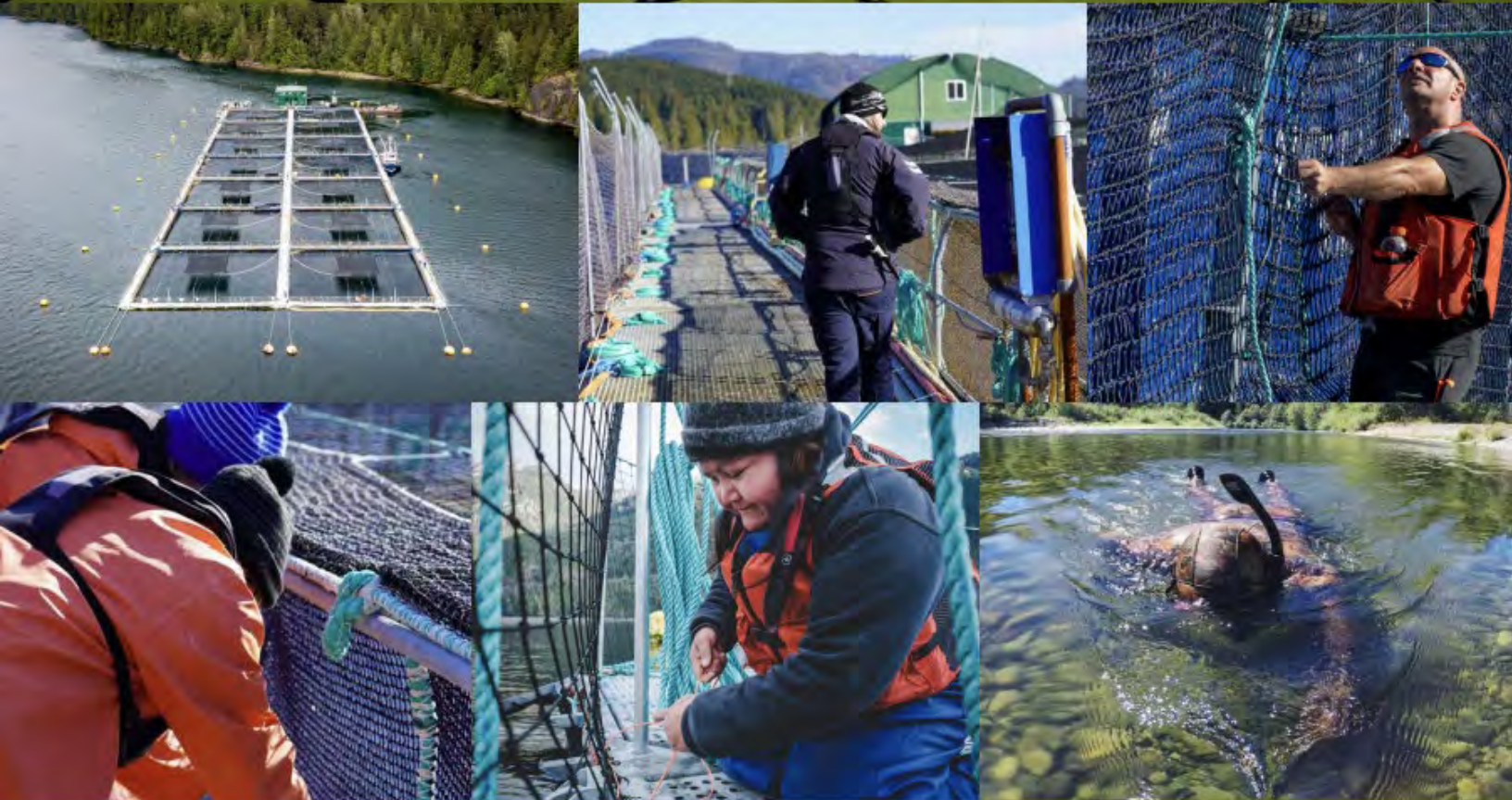
REFERENCES

1. Kitasoo Xai'xais Nation. Gitdisdzu Lugyek (Kitasu Bay) Marine Protected Area: Kitasoo Xai'xais Nation; [Available from: <https://klemtu.com/stewardship/protected-areas/gitdisdzu-lugyek-kitasu-bay-marine-protected-area/>].
2. IPCC. 2023. Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf
3. Nanwakolas Council. 2020. Ha-ma-yas Stewardship Network Campbell River, BC: Nanwakolas Council; [Available from: <https://nanwakolas.com/ha-ma-yas-stewardship-network/>].
4. Coast Funds. 2023. Wei Wai Kum Guardians: In the Steps of Our Ancestors: Coast Funds; [Available from: <https://coastfunds.ca/stories/wei-wai-kum-guardians/>].
5. Berkes F. 1993. Traditional ecological knowledge in perspective. In: Inglis JT, editor. Traditional ecological knowledge: Concepts and Cases: re, International Program on Traditional Ecological Knowledge and International Development Research Centre (Canada). p. 1-9
6. Nadasdy P. 2003. Hunters and bureaucrats: power, knowledge, and aboriginal-state relations in the southwest Yukon. Vancouver: UBC press.
7. Whyte K. 2017. What do indigenous knowledges do for indigenous peoples? In: Nelson MK, Shilling D, editors. Forthcoming in Keepers of the Green World: Traditional Ecological Knowledge and Sustainability, Edited by Melissa K Nelson and Dan Shilling. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2612715
8. BC CAHS. 2019. About BC CAHS Campbell River: BC Centre for Aquatic Health Sciences Society; [Available from: <https://www.cahs-bc.ca/about/about-bc-cahs/>].
9. UN Climate Change News. 2022. How Indigenous Peoples Enrich Climate Action March 2024. Available from: <https://unfccc.int/news/how-indigenous-peoples-enrich-climate-action>.
10. Department of Justice Canada. 2023. United Nations Declaration on the Rights of Indigenous Peoples Act Action Plan. Ottawa: Government of Canada. Available from: <https://www.justice.gc.ca/eng/declaration/ap-pa/ah/pdf/unda-action-plan-digital-eng.pdf>.
11. Department of Justice Canada. 2024. Implementing the United Nations Declaration on the Rights of Indigenous Peoples Act Ottawa: Government of Canada; [
12. Anon. 2014. Canada – British Columbia Marine Protected Area Network Strategy. Canada HMTQiRo, Ottawa. Contract No.: Fs23-585/2012E
13. Young N, Matthews R. 2010. The aquaculture controversy in Canada: activism, policy, and contested science. Vancouver: University of British Columbia Press.
14. Government of British Columbia. 2024. Declaration on the Rights of Indigenous Peoples Act Victoria, BC: Government of British Columbia; [Available from:

- <https://www2.gov.bc.ca/gov/content/governments/indigenous-people/new-relationship/united-nations-declaration-on-the-rights-of-indigenous-peoples>.
15. First Nations for Finfish Stewardship. 2022. The Reality is: Salmon Farming is a path to self determination and reconciliation for many First Nations in coastal BC. 2022.https://firstnationsforfinfish.ca/wp-content/uploads/2022/03/FNFFS_report_web.pdf
 16. Meerveld D. 2016. Assessing Value: A Comprehensive Study of Impact Benefit Agreements on Indigenous Communities of Canada. Ottawa: University of Ottawa.<https://ruor.uottawa.ca/server/api/core/bitstreams/804ccac6-b5b6-409b-b895-6b3b813b4c5b/content>
 17. 2024. Nuu-chah-nulth Seafood LP: Port Alberni, BC; [Available from: <https://www.ncnseafood.com/>].
 18. Gratitude Seafood. 2023. Gratitude Seafood 3% give back: Gratitude Seafood; [Available from: <https://gratitudeseafood.com/3percent/>].
 19. Fisheries and Oceans Canada. 2022. The future of salmon aquaculture in British Columbia - Toward an open-net pen transition plan: A framework for discussion Ottawa: Government of Canada; [updated July 29, 2022. Available from: <https://www.pac.dfo-mpo.gc.ca/consultation/aquaculture/bc-transition-cb/cadre-discussion-framework-eng.html>].

CHAPTER 5

CARING FOR THE ENVIRONMENT PREVENTING ESCAPES



This document describes important measures salmon farmers take to prevent escapes and discusses what is known about the likelihood that farm-raised salmon will establish in British Columbia

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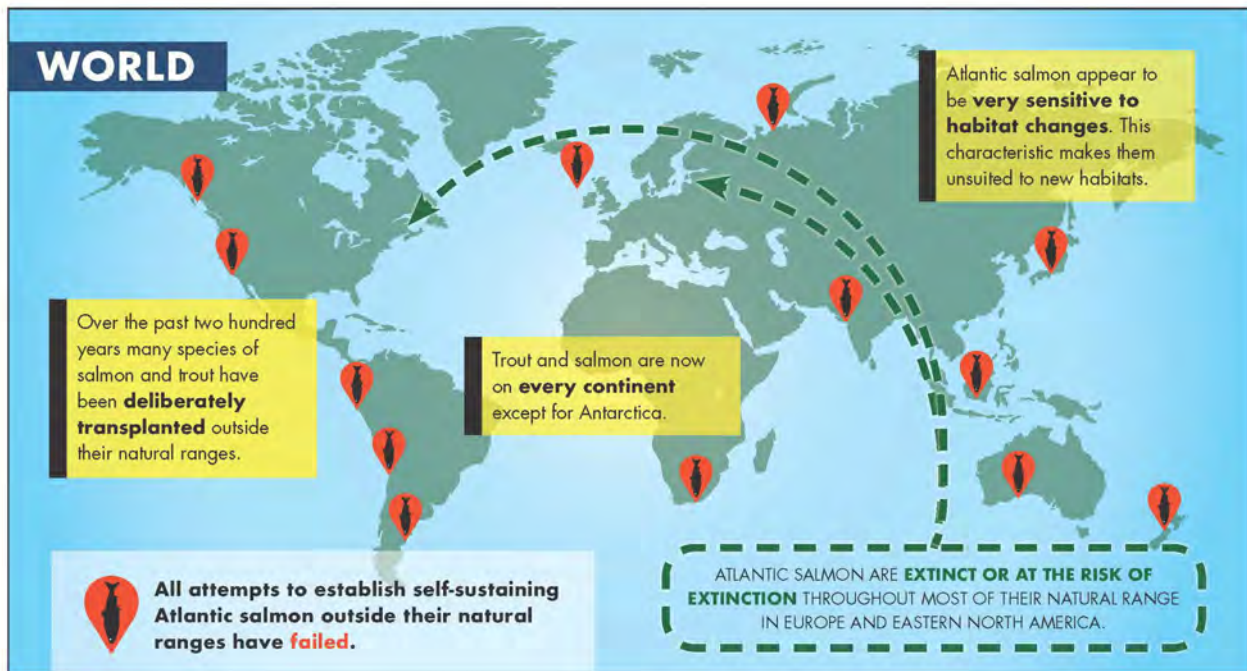
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CHAPTER HIGHLIGHTS – PREVENTING ESCAPES



BC

The **Atlantic Salmon Watch Program**, which has monitored for the presence of escaped Atlantic salmon since 1991, has reported no evidence of any self-sustaining populations in BC.

- Over the past 100 years, the government has tried about **200 times** to deliberately establish self-sustaining Atlantic salmon populations in BC.
All attempts have failed.
- Escaped farm-raised Atlantic salmon are **rarely successful** finding food, are not well suited to avoid predators, do not appear to compete well with Pacific salmon, and cannot interbreed with other salmon species.

FARM

BC Atlantic salmon farmers have **reduced fish escapes by 97%** since 2010.

- 2,998** farm-raised Pacific salmon have escaped from farms since 2012. During the same time period **2,790,629,000** Pacific salmon were released from public hatcheries in BC.
- Farms have strict cage system and net inspections and maintenance.
- Secondary predator nets, jump nets above the surface and bird nets on top of cages.
- Comprehensive employee training.**
- Escape prevention and response plans.

Salmon farmers routinely hear the concerns of First Nations and members of the general public that farm-raised salmon may escape and establish self-sustaining populations in British Columbia (BC), and accept the responsibility to keep farm-raised salmon contained and separated from wild salmon.

Over the past 200 years, many species of salmon and trout have been deliberately transplanted outside their natural ranges and have successfully established self-sustaining populations. These include brown trout, cutthroat trout, eastern speckled (Brook) trout, golden trout, rainbow trout, Chinook salmon, chum salmon, coho salmon, and pink salmon. Masu salmon is the only Pacific salmon that has not been successful in establishing self-sustaining populations beyond its natural range through artificial transplants. At least one species of trout or salmon is now present on every continent except for Antarctica.

All attempts to establish self-sustaining sea-run Atlantic salmon populations outside their natural range have ended in failure. Considered to be a superior game fish, significant efforts to establish Atlantic salmon occurred in South Africa, India, Australia, New Zealand, Argentina, Chile, Ecuador, Columbia, India, Indonesia, Japan, Faroe Islands and Western North

America. While the factors responsible for the failures of Atlantic salmon introductions are not fully understood, a narrow tolerance for habitat conditions has been suggested to play a role.

There is no evidence of any self-sustaining Atlantic salmon populations in BC, despite almost 200 purposeful attempts to create them during the past century and incidental farm escapes that have occurred from BC salmon farms during the last five decades.

The Atlantic Salmon Watch Program (ASWP) was established in 1991 to create a database of Atlantic salmon reported or observed in the BC waters. Despite numerous river systems where adults were reported—and one report of juveniles that were presumed to be a product of wild spawning—the ASWP did not identify any evidence of established feral populations of Atlantic salmon.

In collaboration with First Nation partners, government regulators and the aquaculture supply chain, BC salmon farmers have reduced fish escapes by 97% since 2010. Given the very low levels of escapes from BC salmon farms since 2010 it is highly unlikely that future escapes would occur at a level sufficient to create a risk of establishment.

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INTRODUCTION

We routinely hear that First Nations and the general public have concerns that escaped farm-raised salmon could establish self-sustaining populations and displace wild Pacific salmon. We understand the importance of preventing escapes and introducing any such risk to wild salmon. The following sections describe the history of salmon and trout movements worldwide and the actions taken by salmon farmers to prevent escapes and reach our goal of zero escapes.



CAN SALMON OR TROUT ESTABLISH OUTSIDE THEIR NATURAL RANGES?

It depends upon the species and habitat. Over the past 200 years, there have been numerous deliberate introductions of salmon and trout in many places worldwide. The efforts can be divided into two purposes:

- 1) to introduce a new self-sustaining population, or
- 2) to maintain some level of existing wild population abundance, regardless of reproductive success to support commercial or recreational fisheries (1).

Self-sustaining populations of brown trout (*Salmo trutta*), eastern speckled (Brook) trout (*Salvelinus fontinalis*), golden trout (*Oncorhynchus aguabonita*), cutthroat trout (*O. clarki*), pink salmon (*O. gorbuscha*), coho salmon (*O. kisutch*), rainbow trout (*O. mykiss*), sockeye salmon/kokanee (*O. nerka*) and Chinook salmon (*O. tshawytscha*) have been established outside their natural ranges.

Attempts to establish self-sustaining sea-run populations of Masu (cherry) salmon (*O. masou*) and Atlantic salmon (*Salmo salar*) outside their natural ranges have failed. Some of this history is explained below.

BROWN TROUT

Brown trout, natural to Europe and Western Asia, have been successfully introduced to all continents except Antarctica (2). They are found throughout Canada except for the Yukon and the Northwest Territories.



Photo by Steel_Snorkel

CUTTHROAT TROUT

Coastal cutthroat trout naturally inhabited drainages from Alaska to northern California, and inland cutthroat trout ranged from the Rocky Mountains to Hudson Bay, southward through the Mississippi River to the Rio Grande in New Mexico.



Photo by Steel_Snorkel



Cutthroat trout introductions began in the 1890s when fish from a federal hatchery in Colorado seeded fish into Lake Michigan(3). Since then, the species has been successfully introduced into eight US states, and it has hybridized with rainbow trout in Morocco (1). Attempts to seed cutthroat trout in Denmark, Sweden, and New Zealand were unsuccessful (4).

EASTERN SPECKLED (BROOK) TROUT

While natural to eastern North America, self-sustaining brook trout populations have been established in the four western Canadian provinces, fourteen US states, New Zealand, and nineteen countries in Eurasia, Central, and South America (5).



Photo by Steel_Snorkel

RAINBOW TROUT

Since 1874, the rainbow trout range has been extended, through introductions, to include eastern North America and the continents of Africa, Asia, Australia, New Zealand, Europe, and South America (1). The worldwide distribution of the rainbow trout attests to its inherent ability to adapt successfully to many environmental situations (5).



Photo by Steel_Snorkel

MASU SALMON

Naturally found in Korea, Japan, and Russia, there have been attempts to establish masu salmon in several US states, Ontario, Chile, Germany, Nepal and Thailand. None of the transplants were successful, making masu salmon the only Pacific salmon that remains exclusive to its natural range (1).



Photo by Patrick Gijbers/iStock

PACIFIC SALMON

Over a span of more than 50 years, millions of Pacific salmon eggs and fry were shipped from the Pacific Northwest to regions outside the species' natural ranges. Through these introductions, self-sustaining populations of various Pacific salmon now exist in New Zealand, Chile, Maine, New Brunswick and Ontario (5). Some Pacific salmon, such as pink salmon, have secondarily expanded their ranges in northern Europe (6); this has become a serious concern for countries such as Norway (Figure 1).



Photo by Steel_Snorkel



Figure 1. The Norwegian Minister of Climate and Environment explains the concern of pink salmon from the Pacific establishing in Norwegian rivers. June 30, 2023.
Source [The Independent Barents Observer](#) (7)



ATLANTIC SALMON

As a result of its almost mythic stature as a sports fish, many attempts have been made to establish self-sustaining sea-run populations of Atlantic salmon outside their historic range: South Africa, India, Australia, New Zealand, Argentina, Chile, Ecuador, Columbia, India, Indonesia, Japan, Faroe Islands and Western North America.

Of all these attempts, introduced Atlantic salmon are now found only in the Faroe Islands (8). The Faroe Island populations' continued existence depends on significant annual enhancements that have been ongoing since 1963 (9). In New Zealand, more than 100 years of efforts failed to develop any self-sustaining populations

of Atlantic salmon. The failures have been attributed to competition with rainbow trout and Chinook salmon. Several lakes in Oregon have been historically stocked with land-locked Atlantic salmon for recreational fishing; however, those efforts appear to have been discontinued.

All attempts to establish self-sustaining sea-run populations of Atlantic salmon (*Salmo salar*) beyond their natural ranges have failed.



Photo by Brian Kingzett

ATLANTIC SALMON IN THEIR NATURAL RANGE

The historic natural range of anadromous Atlantic salmon included every country whose rivers flowed into the North Atlantic Ocean and Baltic Sea (10). In Europe, the range of the Atlantic salmon extended southward from Iceland along the Atlantic coastal drainage to Northern Portugal, including rivers in both France and Spain (11). In North America, the Atlantic salmon range extended northward from the Hudson River drainage in New York State to outer Ungava Bay in Quebec (11).

Atlantic salmon were an important food source for human populations for thousands of years. However, as human populations grew, salmon stocks began to decline due to overfishing and habitat destruction. In the UK, salmon population declines were recognized as early as 1030 AD. And by the mid-1800s, new food preservation methods, large-scale commercial fishing, and further habitat destruction/pollution had greatly accelerated these declines (12). Atlantic salmon are now extinct in Europe in

several European countries, including Belgium, the Czech Republic, Germany, Luxembourg, and the Netherlands (11).

By the end of the 19th century, catastrophic declines and extinctions had been observed in the rivers of the UK, France, and many other European countries. Atlantic salmon populations in North America have experienced a similar fate.

Atlantic salmon populations in North America have experienced a similar fate. By the early 1800s, a significant fishing industry had developed, supporting thousands of commercial fishermen (13). Commercial overfishing, dam construction, and industrial pollution began to drive precipitous population declines, including extinctions in several rivers in Connecticut, Massachusetts, Maine, and New Hampshire.



HAVE PEOPLE TRIED TO RESTORE ATLANTIC SALMON TO THEIR NATURAL RANGE?

Yes. In Europe and North America, concern over the future of the Atlantic salmon became pronounced by the mid-19th century. Efforts to culture Atlantic salmon for restocking began as early as the 1850s in Canada, the US, and several European countries, including the UK, Norway, France, and Switzerland—with restocking activities launching in the 1870s (11).

The Government of Canada (DFO) is striving to restore and conserve wild Atlantic salmon through the Wild Atlantic Salmon Conservation Policy working with First Nations and others in eastern Canada (14, 15).

There are many organizations, researchers and volunteers actively involved in wild Atlantic salmon restoration efforts.

Salmon farmers in eastern Canada are also involved in conservation efforts. As an example, the Fundy Salmon Recovery, an association of seven partners (Parks Canada, Cooke Aquaculture, the Atlantic Canada Fish Farmers Association, the University of New Brunswick, the Province of New Brunswick, Fisheries and Oceans Canada, and Fort Folly First Nation), is working together to raise and release hundreds of wild endangered inner Bay of Fundy Atlantic salmon in hopes that these adult salmon will spawn naturally in their native rivers (16). This project is based on the hypothesis that Atlantic salmon have a better chance of survival when they are exposed to a wild environment at a young age and if they are born in the river rather than in a hatchery setting.



HISTORICALLY, WERE THERE DELIBERATE ATTEMPTS TO ESTABLISH ATLANTIC SALMON IN BC?

Yes. British Columbia appears to have been the target of one of the world's most intensive programs of Atlantic salmon introductions. Nearly 200 introduction attempts were undertaken between 1905 and 1935—with 13.9 million eggs, alevins, fry or smolts introduced into 52 different lakes and rivers (17). These introductions were supplied with eyed eggs primarily from the Miramichi River in New Brunswick and to a lesser extent, the Thurso River in Scotland. They were then shipped to several BC hatcheries where they were hatched out and liberated at various early life stages (2).



The introductions occurred primarily on Vancouver Island, the lower Fraser River and Skeena River drainages. The Cowichan River on Vancouver Island was repeatedly stocked beginning in 1905 with hundreds of thousands of Atlantic salmon in various early life stages. Despite the magnitude of these introductions, there were only three credible catches of Atlantic salmon that may have been the product of local spawning—with all three reports occurring before 1926. Juvenile fish were also released into the Coquitlam River, Lillooet River, Harrison Lake, Campbell River, Comox Lake, Horne Lake, Nanaimo Lake, Cowichan Lake and

Koksilah River. None of these introductions was successful in establishing self-sustaining runs of Atlantic salmon (2).

In the United States, there have been at least 170 attempts to establish self-sustaining Atlantic salmon populations in 34 states where Atlantic salmon were not naturally found, including Washington, Oregon, and California (17). None of these efforts were successful. In California, attempts to establish Atlantic salmon populations have been discontinued because the expectation of successful introductions is "so remote that it does not warrant the effort or expense of an attempt" (18). Even Washington State, where repeated introductions were conducted between 1904 and 1991, was unsuccessful in establishing a self-sustaining population (11). Atlantic salmon is virtually the only non-native salmonid not successfully introduced to this state (19).

One of the world's largest efforts to deliberately establish Atlantic salmon outside their natural ranges was in BC and the USA, with more than 370 unsuccessful attempts.



WHY HAVE ATLANTIC SALMON NOT ESTABLISHED SELF-SUSTAINING POPULATIONS OUTSIDE THEIR NATURAL RANGE?

The ability of an animal or plant to establish outside of its natural area will depend on the characteristics of the species as well as the suitability of the environment into which it is introduced, interspecific competition, and other ecological interactions. Several factors appear to prevent Atlantic salmon from establishing in new areas:

- o Atlantic salmon have limited tolerances to habitat changes and are known to be weak competitors with other fish species,
- o escaped farm-raised fish rarely (if ever) eat in the wild; likely due to their habituation to feed pellets,
- o increased susceptibility to predators,
- o inability to hybridize with other species, and
- o they must be successful in a series of life history stages, including freshwater and saltwater phases.

Evidence suggests that Pacific salmon are able to establish more readily than Atlantic salmon, even in areas in which Atlantic salmon are naturally found.

Limited habitat tolerances

Organisms with very specific environmental requirements are typically poor at expanding their ranges. Relative to other fish species, Atlantic salmon have limited tolerances for habitats that differ from the conditions in which they evolved (19). For example, Atlantic salmon native to Scottish rivers have different sensitivities to habitat variables than those native to England (20). We know that Atlantic salmon that have been introduced outside their natural range into areas with presumably 'ideal' conditions - areas with no competitors and ample food and space - have not been able to establish self-sustaining populations.



Photo by Bill Pennell



Photo by Steel_Snorkel

Sensitivity to habitat changes is likely one of the reasons that Atlantic salmon are extinct in 84% of the rivers in New England that historically supported salmon—with populations in the remaining 16% of New England rivers in critical condition (21). Greater sensitivity to habitat changes relative to other salmonids may also be a factor in the failure to reestablish a self-sustaining population of Atlantic salmon in Lake Ontario—while non-native coho, chum, Chinook, and steelhead have been successfully introduced (19).

Sensitivities to variations in regional environmental/habitat conditions suggest that habitat deterioration could be a critical factor challenging the restoration of Atlantic salmon to rivers within their historic range. Restocking efforts that fail to include habitat restoration have been unsuccessful—while those that seek to concurrently restore habitats achieve

greater success, for example liming in Norwegian rivers (22).

It has been suggested that the failure of early introductions of Atlantic salmon to produce self-sustaining populations within British Columbia could have been due to the rather primitive hatchery methods used in the early 1900s (23). However, the same methods that failed to establish Atlantic salmon proved remarkably successful in establishing brown trout, brook trout, and rainbow trout almost everywhere. Therefore, the success or failure of introduction can be associated with attributes inherent to each species rather than with the hatchery methods employed.

Given that many Pacific salmonid populations have experienced significant declines since the Atlantic salmon introductions of the early 1900s, Volpe et al. (23) suggested that suitable habitat is now less saturated with native residents—



and is, therefore, more available for successful Atlantic salmon establishment. However, attempts to reestablish self-sustaining Atlantic salmon populations within their natural range (e.g., New England)—as well as to introduce them to non-native ranges (e.g., Faroe Islands, New Zealand, Australia, South Africa)—have failed even though no self-sustaining populations of native or non-native salmon were present as competitors. By comparison, multiple other salmonid species have established self-sustaining populations in Washington State and BC.

Escaped Atlantic salmon from farms do not eat in the wild. Why not?

Atlantic salmon that escape from farm facilities appear to have little success or desire to prey on fish in freshwater or marine environments. Of the escaped Atlantic salmon recaptured in Washington freshwater environments, following a catastrophic escape from a farm in Puget Sound in 2017, all had empty stomachs and swollen gall bladders (swollen gall bladders are indicative of not eating). Similarly, observations of Atlantic salmon captured in marine waters of BC and Alaska indicated that only 2-4% had

herring in their stomachs, 2-4% had commercial fish food pellets, and 1-5% of the Atlantic's captured had wood chips, kelp, or other material not recognized as food (24). This indicates that the majority of escaped farm-raised Atlantic salmon, which are trained to eat feed pellets, are not successful in finding food and likely die soon after escaping.

DFO recently completed an exhaustive study to determine if farm-raised fish predate on wild salmon fry. Over 7,000 harvest-sized Atlantic salmon stomachs were analyzed at various processing plants on Vancouver Island from 2017 – 2019 (25). Of the 7,200 farm-raised salmon sampled, only seven wild fish were found in the stomachs. Four of the seven fish were identified as herring while the other three could not be fully identified but were most likely herring. No wild salmon were observed in the stomachs of farmed fish. This study found 0.08% predation prevalence, similar to past studies on this topic (26).



Increased susceptibility to predation

Solberg et al. (27) recently presented evidence that the domestication of Atlantic salmon has permitted the evolution of increased predation susceptibility. This greater susceptibility to predation is proposed to contribute to a lower survival rate of escaped farm-raised fish versus wild fish.

Limited hybridization capacity

Atlantic salmon are genetically different from Pacific salmon. Deliberate attempts to cross-breed Atlantic salmon with chum, pink and coho salmon have failed (28). Moreover, even if a successful mating was to occur and offspring were produced, the offspring would be sterile (24).



Photo by Bill Pennell



HOW DO SALMON FARMERS PREVENT ESCAPES?

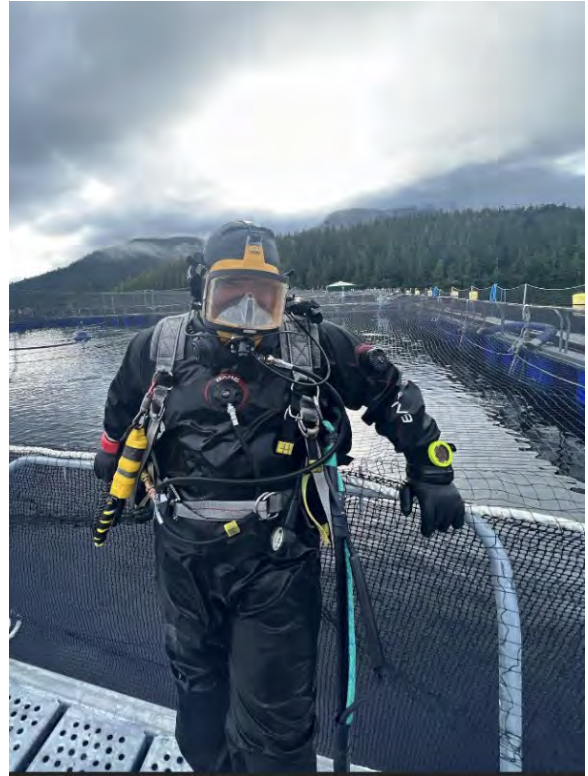
Although history has shown the risk of establishment of escaped farm-raised fish is low in BC, salmon farmers are committed to continuously analyzing and adapting policies to achieve a target of zero escapes. The current measures to prevent escapes are depicted in Figure 2 below.

All employees at salmon farms are trained to identify situations when there may be a reason to believe that one or several fish could have left the containment. This includes:

- o A sudden decrease in feed rate in a specific pen.
- o Holes large enough for a fish to escape, in both the containment net and predator net.
- o Observing farm-raised salmon outside any containment structure.

In these situations, staff inspect nets for holes with underwater cameras and site walk around and check in with other site staff to see if there was a handling error.

If a hole is identified, the escape net repair kit is deployed, the hole is covered and repaired immediately by the site staff and inspected by divers.



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- o A sudden decrease in feed rate in a specific pen.
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- o Observing farm-raised salmon outside any containment structure.
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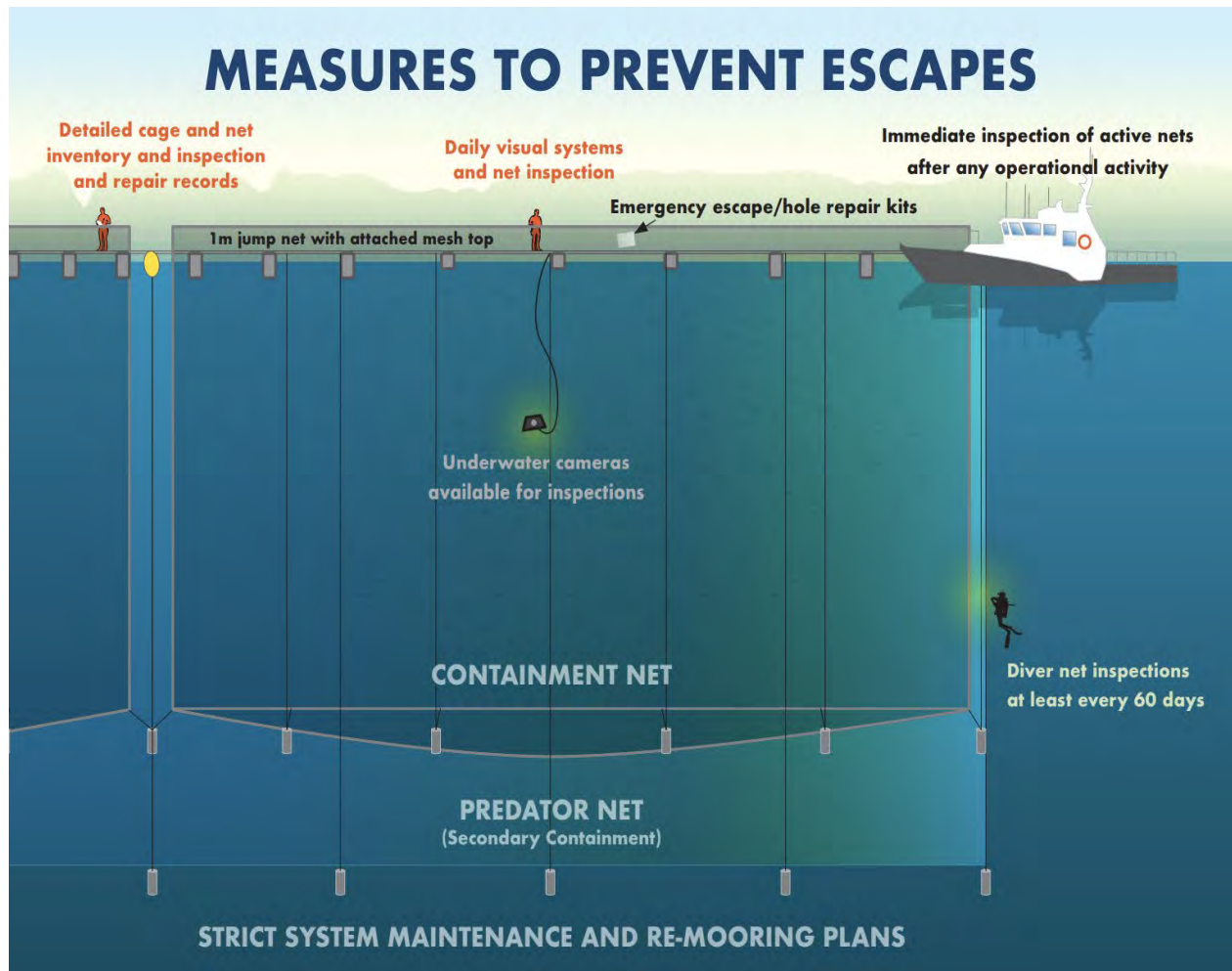


Figure 2. Current measures to prevent escapes at marine sites in British Columbia.

DOES DFO HAVE REGULATORY MEASURES IN PLACE TO PREVENT ESCAPES?

Yes. DFO requires that all finfish containment systems must be able to withstand local weather and ocean conditions. Containment systems must be regularly inspected and maintained to ensure integrity and control factors contributing to failures, including biological matter buildup, ice buildup, and marine mammal interactions (29).



WHAT HAPPENS IF AN ESCAPE OCCURS AT A SALMON FARM?

In the event of an escape, farm staff immediately implement measures to stop further loss of fish. Relevant authorities are notified within 24 hours as per license conditions, First Nation(s) territory protocols and/or agreements, and certification schemes. All events are thoroughly investigated, and reports are provided to authorities within seven days. DFO publishes detailed reports of marine finfish aquaculture escapes in BC (30).

DFO may also approve fishing to recapture escapees, where it is deemed warranted and effective.

DFO also created the Atlantic Salmon Watch Program (ASWP) to monitor for escaped Atlantic salmon in BC rivers. To

date, there is no evidence of established Atlantic salmon populations in the wild in BC.

HOW MANY ESCAPES HAVE THERE BEEN AT ATLANTIC SALMON FARMS IN BC?

During the industry's developmental phase (1991 - 2010), approximately 660,000 Atlantic salmon escaped from BC marine net pens and 60,000 juveniles escaped from freshwater facilities (12). During this same time period, over 600,000 Atlantic salmon escaped from Washington State (Puget Sound) marine net pens (12). These escapes were primarily due to infrastructure failure, human error, and natural causes (e.g., weather-related, and marine mammal damage to net pens).

From 2020 to 2022, there were 121 individual Atlantic salmon that escaped from farms. Overall, this represents a 97% reduction in escapes since 2010 when DFO assumed responsibility



By 2010, the fish containment systems had evolved into integrated, technologically sophisticated production systems strategically designed, operated, and maintained to minimize fish escapes.

As a result, from 2011 to 2018, adult Atlantic salmon escapes from BC net pens decreased dramatically, averaging 12 escaped fish/year (31). In 2019, a fire at a BC farm allowed the escape of 20,973 Atlantic salmon (32). From 2020 to 2022, there were only 121 individual Atlantic salmon that escaped from farms.



HOW MANY ESCAPES HAVE THERE BEEN AT PACIFIC SALMON FARMS IN BC?

In total, 2,748 Chinook and 250 coho salmon have escaped from salmon farms in BC since 2012. The majority of Chinook salmon escapes were from a single event in 2012, since that time only three Chinook salmon have escaped from farms. See DFO reports of marine finfish aquaculture escapes (30). By comparison, there have been 2,790,629,000 Pacific salmon

From 2020 to 2022, one individual Chinook salmon escaped from a farm. By comparison, in 2020 and 2021, public hatcheries in BC released 411,628,000 Pacific salmon.

(Chinook, coho and other) released from public hatcheries in BC from 2012 – 2021. See North Pacific Anadromous Fish Commission Statistics – NPAFC (33).



HAVE ESCAPED ATLANTIC SALMON BEEN OBSERVED IN THE WILD IN BC?

Although there have been rare observations of Atlantic salmon in the wild, no self-sustaining populations have been identified within BC.



Photo by Chris Walling aka Steel_Snorkel

SUMMARY OF OBSERVATIONS OF ESCAPED ATLANTIC SALMON IN BC STREAMS

In 1991, in response to concerns that escaped Atlantic salmon may establish in BC, DFO and the BC Ministry of Agriculture, Food and Fisheries established the Atlantic Salmon Watch Program (ASWP) to monitor the presence of Atlantic salmon in BC streams and marine waters. The initial phase of the program operated until 2003.

Additionally, in 2000, Volpe et al. (34) reported finding limited numbers of presumptive wild-spawned juvenile Atlantic salmon in the Tsitika River. These findings indicated that escapees could mature reproductively and enter coastal streams where they may produce offspring.

According to ASWP data, from 1991 – 2003 the total number of escaped Atlantic salmon recovered in BC marine waters was 18,876, with annual catches ranging from 31 fish in 1991 to 7,834 in 2000. During this period, a total of 1,079 adult and 367 juvenile Atlantic salmon were found in BC rivers and streams.

However, to establish a self-sustaining sea-run Atlantic salmon population, these offspring would themselves have to complete an ocean migration and return to spawn viable offspring.



Photo by Chris Walling aka Steel_Snorkel

The ASWP did not find any indication that first generation Atlantic salmon had completed the life cycle—and therefore stated it found no evidence of established feral populations of Atlantic salmon (35).

In December 2010, the federal government assumed primary responsibility for regulating and managing aquaculture in BC. As the lead federal agency, DFO became responsible for regulating, monitoring, and licensing all marine finfish aquaculture operations in the province. As part of the establishment of the British Columbia Aquaculture Regulatory Program, the ASWP was reestablished to monitor the presence of

Atlantic salmon in BC's marine and freshwater environments—and to undertake a focused field program to investigate whether Atlantic salmon populations had become established during the 8-year monitoring gap from 2003 to 2011.

From 2011 to 2017, the ASWP reported three confirmed Atlantic salmon caught within the BC marine environment (36). The ASWP also completed snorkel surveys of key watersheds in 2011 and 2012. The monitoring targeted water bodies in which adult Atlantic salmon (and in one instance, juveniles) had been previously identified. Snorkel survey swims of six rivers were conducted in 2011. Snorkel surveys of eight rivers considered to be of "highest risk" for the establishment of feral Atlantic salmon populations were conducted in 2012. In addition, Georgie Lake and Songhees Creek (which drains Georgie Lake) were surveyed intensely because an Atlantic salmon smolt production facility was operating on Georgie Lake—and a previous study had identified out-migrating Atlantic salmon smolts in Songhees Creek.

No Atlantic salmon of any age were identified in any of the surveys conducted as part of the ASWP field program in both 2011 and 2012. As a result of these survey efforts, it was concluded that despite the unintended introduction of both significant numbers of adult and juvenile Atlantic salmon into a number of systems in BC between 1987 and 2010, the establishment of feral populations had not occurred (37).



In 2017, the collapse of a net pen system in Washington State released between 243,000 – 263,000 Atlantic salmon into Puget Sound. In the aftermath of this escape, 43 salmon caught in BC waters were confirmed to have originated from the Washington State escape (38). The vast majority of these fish had empty stomachs and underdeveloped gonads (39).

In 2018, the ASWP confirmed that two salmon reported to their hotline were Atlantic salmon. Additionally, the ASWP conducted surveys of 14 rivers assessed to have a 'higher risk' of an establishment (including rivers where Washington State escapees had been identified in 2017 (35)). No Atlantic salmon of any age class were observed during these surveys.

SUMMARY OF OBSERVATIONS OF ESCAPED ATLANTIC SALMON IN THE PACIFIC OCEAN

Each year in spring, professional biologists have surveyed the health of thousands of juvenile wild Pacific salmon along BC's southern coastlines, with no reports of juvenile Atlantic salmon being observed in these health surveys. As detailed in "Chapter 10 - Caring for Wild Salmon – Sea Lice Management", the juvenile wild salmon sea lice monitoring program has occurred in 10 regions of coastal BC for up to 20 years in some regions (40-42).

No Atlantic salmon were captured amongst the 229,000 Pacific salmon sampled by DFO during trawl, purse, and beach seine surveys of Georgia Strait, the Discovery Islands, Desolation Sound, Sutil Channel and/or north Johnstone Strait over various years spanning 2010-2017 (43). The monitoring programs have found no evidence that Atlantic salmon are successfully reproducing in streams and migrating into the marine environment.



LISTENING AND TAKING ACTION



We understand we must operate with deep respect for wild salmon and the Pacific Ocean. We have listened to the concerns that escaped farm-raised salmon could displace wild Pacific salmon and have acted on those concerns by introducing strict practices and measures to minimize escapes. The good news is that very few farm-raised salmon escape and measures are working to continue to reduce the number of escapes. Since 2010, escapes from Atlantic salmon farms have declined by 97% (compared to 1991 – 2010).

It is very unlikely that Atlantic salmon will establish self-sustaining populations in British Columbia. In part, this is based upon the biology of Atlantic salmon. The species has a narrow tolerance to habitat changes and does not readily adapt to new environments. So much so, it has gone or is going extinct throughout much of its natural range in Europe and North America. Attempts to establish self-sustaining Atlantic salmon populations beyond their natural habitats, such as in BC, have failed. There is more than 100 years of documented history in the province, detailing hundreds of failed attempts by governments to deliberately establish the species here.

On the very rare occasion that farm-raised Atlantic salmon escape from a net pen, the likelihood of establishing a self-sustaining population is very low given:



- o Almost no farm-raised Atlantic salmon escape and the government has stopped all attempts to establish self-sustaining Atlantic salmon within BC. This means that there are no sources of Atlantic salmon to establish in BC.
- o Escaped farm-raised Atlantic salmon would need sufficient numbers to form a breeding population; their offspring would need to be successful and of a sufficient population size large enough to sustain the population through time. This means that feral Atlantic salmon would need to consistently survive in both freshwater and marine habitats in sufficient numbers to reproduce continuously and successfully.
- o Mature adult Atlantic salmon would then need to:
 - o migrate back to freshwater,
 - o find a mate of the same species,
 - o spawn and produce juveniles in sufficient numbers.
- o This cycle would need to occur repeatedly to establish a self-sustaining population.
- o Through all of these steps, the salmon would need to successfully find food, evade predators, overcome competition with Pacific salmon, and know when and where to migrate.

Collectively, these steps appear to be too much for Atlantic salmon to overcome in British Columbia.

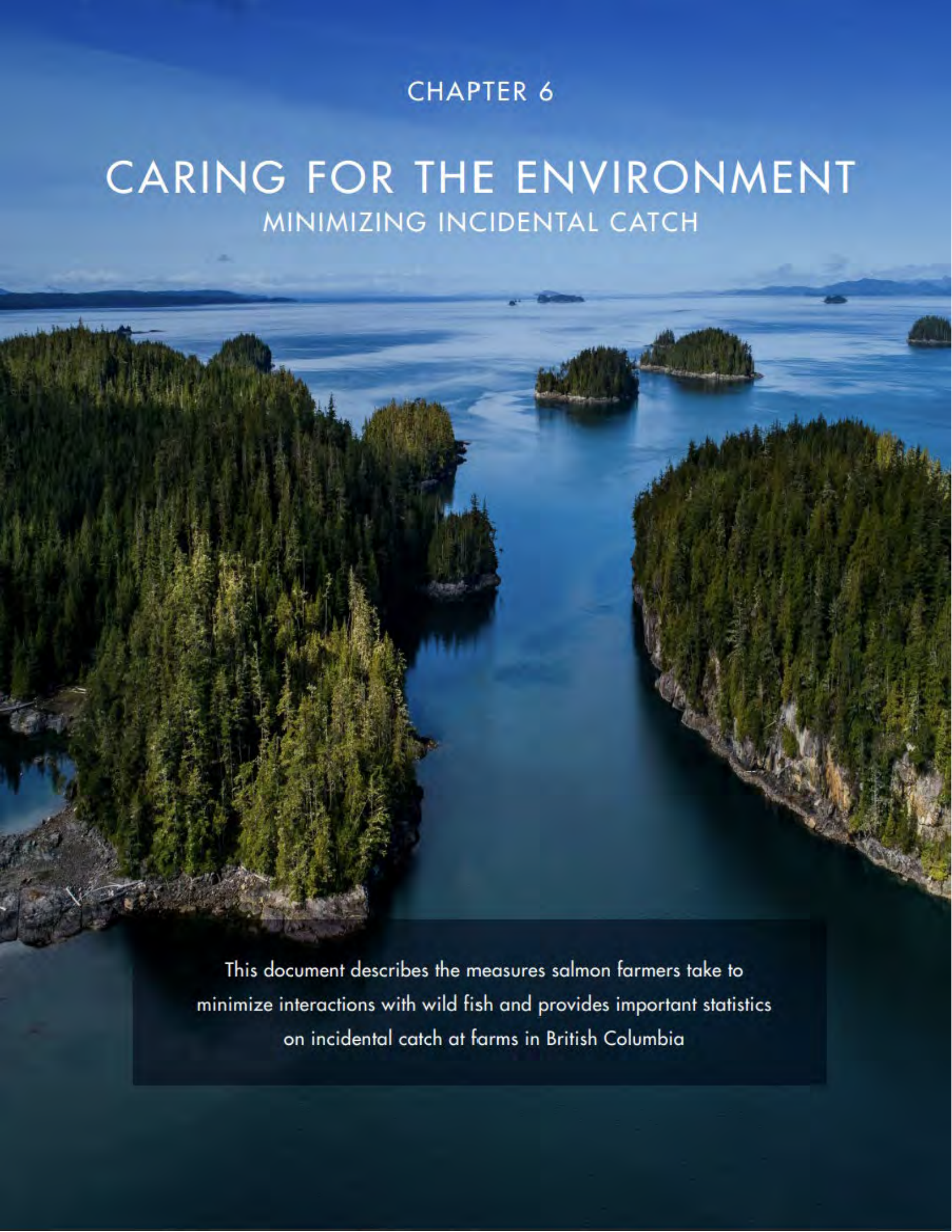
REFERENCES

1. Crawford SS, Muir AM. 2008. Global introductions of salmon and trout in the genus *Oncorhynchus*: 1870–2007. *Reviews in Fish Biology and Fisheries*.18(3):313-344.10.1007/s11160-007-9079-1
2. Ginetz RMJ. 2002. On the risk of colonization by Atlantic salmon in BC waters.: BC Salmon Farmers Association. 34
p.https://salmonfarmscience.files.wordpress.com/2012/02/escapes_2002_colonization_risk.pdf
3. Emery L. 1985. Review of fish species introduced into the Great Lakes. 1819-1974. Ann Arbor: Great Lakes Fishery Commission Technical Report. Contract No.: 45
4. Welcomme RL. 1988. International introductions of inland aquatic species. Rome: Food & Agriculture Org.
5. MacCrimmon HR, Gots BL. 1979. World Distribution of Atlantic Salmon, *Salmo solar*. *Journal of the Fisheries Research Board of Canada*.36(4):422-457.10.1139/f79-062
6. Sandlund OT, Berntsen HH, Fiske P, Kuusela J, Muladal R, Niemelä E, et al. 2019. Pink salmon in Norway: the reluctant invader. *Biological Invasions*.21(4):1033-1054.10.1007/s10530-018-1904-z
7. Vereykina E. "We have declared a war on Pink salmon" Norway fights the invasive species in the Arctic.: The Independent Barents Observer;
2023.<https://www.youtube.com/watch?v=6oCH2zvY4m0>
8. Thorstad EB, Fleming IA, McGinnity P, Soto D, Wennevik V, Whoriskey F. 2008. Incidence and impacts of escaped farmed Atlantic salmon *Salmo salar* in nature: Norwegian Institute for Nature Research (NINA). 110 p.<http://www.fao.org/3/a-aj272e.pdf>
9. NASCO. NASCO Implementation Plan for Atlantic Salmon Management in the Faroe Islands Implementation Plan Denmark (in respect of the Faroe Islands and Greenland). North Atlantic Salmon Conservation Organization.
10. COSEWIC. 2006. COSEWIC assessment and status report on the Atlantic salmon *Salmo salar* (Lake Ontario population) in Canada. Ottawa: Committee on the Status of Endangered Wildlife in Canada.https://www.registrelep-sararegistry.gc.ca/virtual_sara/files/cosewic/sr_atlantic_salmon_lake_ont_e.pdf
11. MacCrimmon HR, Gots BL. 1979. World Distribution of Atlantic Salmon, *Salmo salar*. *Journal of the Fisheries Research Board of Canada*.36(4):422-457.10.1139/f79-062
12. Piccolo J, Orlikowska EH. 2012. A biological risk assessment for an Atlantic salmon (*Salmo salar*) invasion in Alaskan waters. *Aquatic Invasions*.7(2):259-270,
13. Dunfield R. 1985. The Atlantic salmon in the history of North America.<https://waves-vagues.dfo-mpo.gc.ca/Library/28322.pdf>
14. Fisheries and Oceans Canada. 2023. Engaging on a strategy to restore and rebuild Atlantic salmon - What we Heard. Report No.: ISBN 978-0-660-49702-0.<https://www.dfo-mpo.gc.ca/about-notre-sujet/publications/fisheries-peches/atlantic-salmon-heard-saumon-atlantique-entendu-eng.html>



15. Fisheries and Oceans Canada. 2022. Canada's Wild Atlantic Salmon Conservation Policy [Available from: <https://www.dfo-mpo.gc.ca/reports-rapports/regs/wildsalmon-atl-saumonsauvage-eng.htm>].
16. Parks Canada. 2022. Recovering Inner Bay of Fundy Atlantic Salmon Ottawa: Government of Canada; [Available from: <https://parks.canada.ca/pn-np/nb/fundy/nature/conservation/saumon-salmon>].
17. OECD. 2017. Consensus Document on the Biology of Atlantic Salmon (*Salmo salar*). PARIS: Environment Directorate Organisation for Economic Co-operation and Development. 136 p.[https://one.oecd.org/document/env/jm/mono\(2017\)64/en/pdf](https://one.oecd.org/document/env/jm/mono(2017)64/en/pdf)
18. Dill WA, Cordone AJ. 1997. Fish bulletin 178. history and status of introduced fishes in California, 1871–1996.<https://escholarship.org/uc/item/5rm0h8qg>
19. Waknitz FW, Tynan TJ, Nadh CE, Iwamoto RN, Rutter LG. 2002. Review of potential impacts of Atlantic salmon culture on Puget Sound chinook salmon and Hood Canal summer-run chum salmon evolutionarily significant units NOAA. 83 p.<https://repository.library.noaa.gov/view/noaa/3331>
20. Hendry K, Cragg-Hine D. 2003. Ecology of the Atlantic Salmon. Peterborough: English Nature. Report No.: 185716 713 9 Contract No.: 7.<http://www.english-nature.org.uk/lifeinukrivers/species/salmon.pdf>
21. Smith-Tripp S. 2020. Available from: <https://food-studies.net/sustainablefish/salmon/overview-salmon/>.
22. Hesthagen T, Larsen BM, Fiske P. 2011. Liming restores Atlantic salmon (*Salmo salar*) populations in acidified Norwegian rivers. Canadian Journal of Fisheries and Aquatic Sciences.68(2):224-231.10.1139/f10-133
23. Volpe J, Anholt B, Glickman B. 2001. Competition among juvenile Atlantic salmon (*Salmo salar*) and steelhead (*Oncorhynchus mykiss*): relevance to invasion potential in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences.58.10.1139/f00-209
24. Amos KH, Appleby A. 1999. Atlantic salmon in Washington State: A fish management perspective. Washington Department of Fish and Wildlife.<https://wdfw.wa.gov/sites/default/files/publications/00922/wdfw00922.pdf>
25. Fisheries and Oceans Canada. 2018. Wild fish predation project [Available from: <https://www.dfo-mpo.gc.ca/about-notre-sujet/publications/infographies-infographies/project-predation-projet-eng.html>].
26. Blascoe N. Personal Communication. Hay et al., 2004 found 0.14% in 734 Atlantic's. Johannes and Hay, 2006 found 0.11% in 2,800 farmed chinook, coho and Atlantic salmon. As detailed by Nathan Blasco, DFO Senior Aquaculture Biologist, March 23, 2022. ed2023
27. Solberg MF, Robertsen G, Sundt-Hansen LE, Hindar K, Glover KA. 2020. Domestication leads to increased predation susceptibility. Scientific Reports.10(1):1929.10.1038/s41598-020-58661-9
28. Cubitt KF, Butterworth KG, Finstad B, Huntingford F, McKinley RS. 2006. Escaped farmed salmon: a threat to BC's wild salmon. Fraser Institute Alert Series:9, https://www.fraserinstitute.org/sites/default/files/Escaped_Farmed_Salmon.pdf

29. Fisheries and Oceans Canada. 2023. Marine finfish B.C. aquaculture licence and conditions of licence. Nanaimo: Government of Canada.<https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/licence-cond-permis-mar/index-eng.html>
30. Open Government. 2024. Escapes of cultured finfish from BC aquaculture sites Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/691dd994-4911-433d-b3b6-00349ba9f24e>.
31. Fisheries and Oceans Canada. 2020. Escapes of cultured marine finfish from BC aquaculture sites [Available from: <https://open.canada.ca/data/en/dataset/691dd994-4911-433d-b3b6-00349ba9f24e>.
32. Mowi Canada West. 2019. Available from: <https://mowi.com/caw/blog/2019/12/21/news-release-incident-at-robertson-island-causes-potential-fish-escape/>.
33. North Pacific Anadromous Fish Commission. 2023. NPAFC Statistics: Pacific Salmonid Catch and Hatchery Release Data: North Pacific Anadromous Fish Commission,; [Available from: <https://www.npafc.org/statistics/>.
34. Volpe JP, Taylor EB, Rimmer DW, Glickman BW. 2000. Evidence of Natural Reproduction of Aquaculture-Escaped Atlantic Salmon in a Coastal British Columbia River. *Conservation Biology*.14(3):899-903.<https://doi.org/10.1046/j.1523-1739.2000.99194.x>
35. Andres B. 2020. Head, Atlantic Salmon Watch Program. Personal communication.
36. Plummer E. 2017. 'Incompetent' farmed salmon remain on DFO's radar. www.hashilthsa.com [Internet]. (December 12, 2017). Available from: <https://hashilthsa.com/news/2017-12-12/incompetent-farmed-salmon-remain-dfos-radar>.
37. Andres B. 2015. Summary of reported Atlantic salmon (*salmo salar*) catches and sightings in British Columbia and results of field work conducted in 2011 and 2012. Campbell River, BC: Fisheries and Oceans Canada. Contract No.: 3061.<https://waves-vagues.dfo-mpo.gc.ca/Library/357053.pdf>
38. Fisheries and Oceans Canada. 2017. Atlantic Salmon Aquaculture Incident in Washington State [Available from: https://www.canada.ca/en/fisheries-oceans/news/2017/08/atlantic_salmon_aquacultureincidentinwashingtonstate.html.
39. Plummer E. DFO monitoring finds farmed Atlantic salmon “unlikely” to breed in B.C. waters. www.hashilthsa.com2017.<https://hashilthsa.com/news/2017-11-15/dfo-monitoring-finds-farmed-atlantic-salmon-unlikely-breed-bc-waters>
40. Grieg Seafood British Columbia. 2023. Wild Pacific salmon: Grieg Seafood ASA; [Available from: <https://griegseafood.com/bc-wild-pacific-salmon>.
41. MOWI. 2023. Juvenile Wild Salmon Sea Lice Monitoring: MOWI Canada West; [Available from: <https://mowi.com/caw/sustainability/wild-salmonid-lice-monitoring/>.
42. Cermaq Canada. 2023. Sea lice reporting: Cermaq; [Available from: <https://www.cermaq.ca/public-trust/sea-lice-reporting>.
43. Neville C, Johnson S, Beacham T, Whitehouse T, Tadey J, Trudel M. 2016. Initial estimates from an integrated study examining the residence period and migration timing of juvenile sockeye salmon from the Fraser River through coastal waters of British Columbia. 45-60 p

An aerial photograph of a coastal waterway, likely in British Columbia. The water is a deep blue, and the surrounding land is covered in dense green forest. Several small, forested islands are visible in the water. In the background, mountains are visible under a clear blue sky.

CHAPTER 6

CARING FOR THE ENVIRONMENT

MINIMIZING INCIDENTAL CATCH

This document describes the measures salmon farmers take to minimize interactions with wild fish and provides important statistics on incidental catch at farms in British Columbia

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CHAPTER HIGHLIGHTS – MINIMIZING INCIDENTAL CATCH

Over the past ten years, salmon farmers have invested in equipment, farming practices and staff training to minimize interactions with wild fish. These measures have been very effective in reducing incidental catch at farms.

INNOVATION AND TRAINING

Improved mechanization and training to prevent incidental catch and release wild fish alive to the surrounding environment

WILD FISH PREDATION

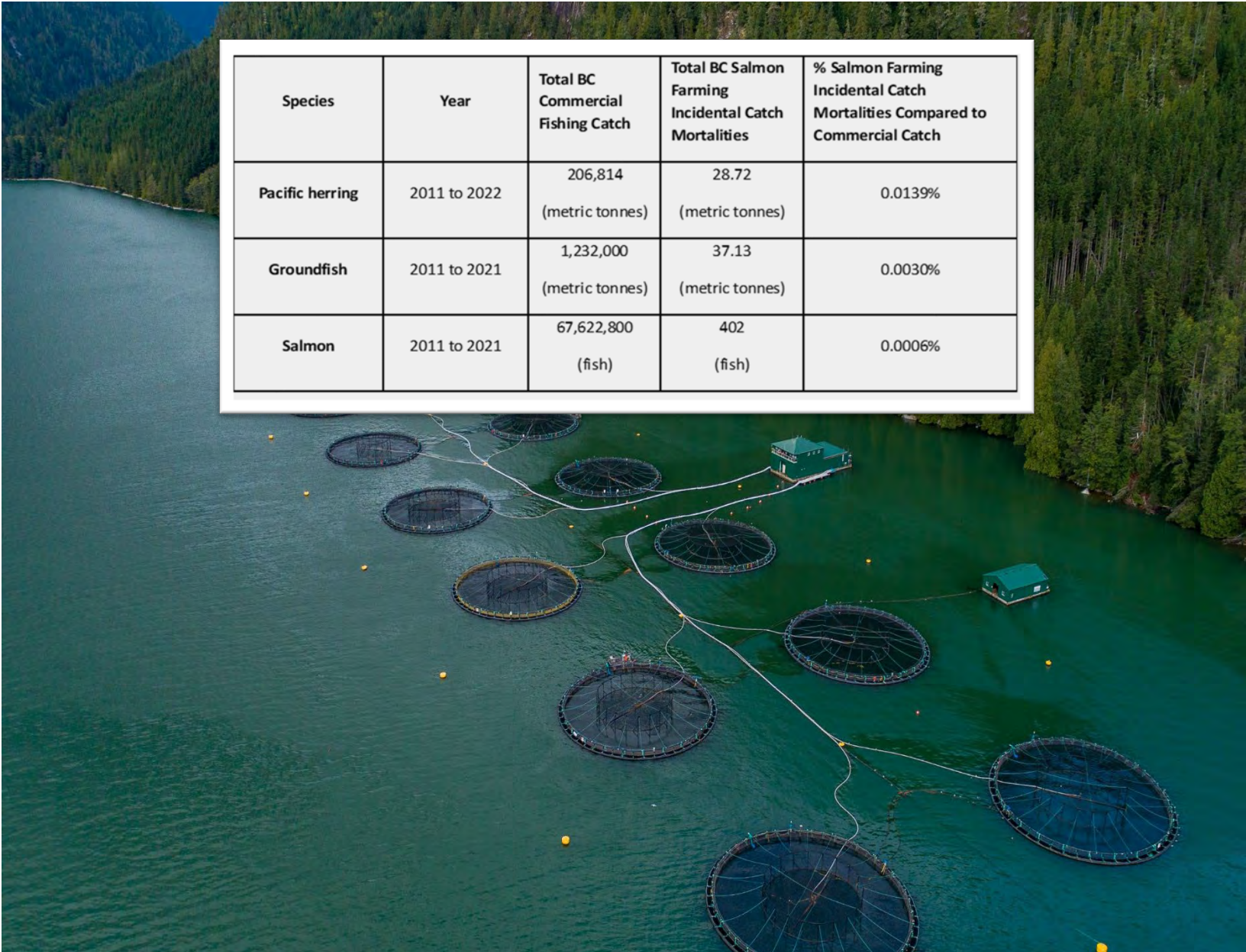
Monitoring indicates that farm-raised salmon rarely eat wild fish trapped within the pens

LIGHTING

Began switching to LED lights ten years ago to reduce fish attraction

HERRING MORTALITY

Herring (primarily juvenile) comprise 94% of the total aquaculture incidental catch mortalities (2011 to 2022)



Species	Year	Total BC Commercial Fishing Catch	Total BC Salmon Farming Incidental Catch Mortalities	% Salmon Farming Incidental Catch Mortalities Compared to Commercial Catch
Pacific herring	2011 to 2022	206,814 (metric tonnes)	28.72 (metric tonnes)	0.0139%
Groundfish	2011 to 2021	1,232,000 (metric tonnes)	37.13 (metric tonnes)	0.0030%
Salmon	2011 to 2021	67,622,800 (fish)	402 (fish)	0.0006%



Similar to the commercial capture fisheries, salmon farmers must manage incidental catch. At a farm, incidental catch is any wild finfish caught during harvest, during the movement of fish between facilities or while removing nets. It results after wild fish swim through the nets containing the farmed salmon and either choose to find refuge in the nets or grow to a size that they can no longer swim out. Fisheries and Oceans Canada (DFO) requires that farmers design all equipment and practices in manners that cause the least amount of harm to incidental catch. There are also requirements for releasing incidental catch, and reporting incidental catch mortalities. DFO publicly reports incidental catch mortalities.

Salmon farmers continually invest in equipment, farming practices and staff training to minimize interactions with wild fish. These measures have been very effective in reducing incidental catch at farms. This includes improving ways to separate and release incidental catch alive and modifying lighting systems to minimize attracting wild fish to the pens.

In total, there were 1,520,457 incidental catch mortalities from 2011 to 2022 at BC salmon farms, of which 94.4% were Pacific herring. The herring mortalities represent 0.014% of the commercial fishery herring catch during the same period (not including the roe, food, bait, and special-use fisheries). The highest number of Pacific herring incidental catch mortalities occurred in Clayoquot Sound in 2022 - the same year the West Coast Vancouver

Island herring fishing saw its largest spawn event since 2013. The total Pacific herring incidental catch mortality at all salmon farms combined for all areas was equivalent to 0.086% of the herring spawning biomass for West Coast Vancouver Island that year.

Non-herring incidental catch mortality has been low at farms. The annual groundfish incidental catch mortalities at salmon farms by weight, including rockfish and sablefish, represented 0.003% of the annual average commercial catch during 2011 to 2021. The total number of pelagic fish salmon farm mortalities, excluding herring, salmon, and eulachon, for the 2011 to 2022 period was 7,801 fish which averaged 650 fish per year. The total weight of rockfish incidental catch mortality at salmon farms during this period was 3.26 tonnes, representing 0.5% of the rockfish bycatch associated with commercial and recreational capture fisheries (650 tonnes) from 1996 to 2011. During the 2011 to 2021 period, the annual average weight of the salmon farm incidental catch mortalities of sablefish was 0.95 metric tonnes per year, representing 0.04 percent of the 2022 sablefish commercial catch allocation of 2,246 tonnes.

There were 402 Pacific salmon incidental catch mortalities at salmon farms from 2011 to 2021. During the same period, the recreational and commercial salmon fisheries captured 73,694,320 Pacific salmon. Incidental catch mortality of eulachon at salmon farms consisted of one fish from 2011 to 2022.

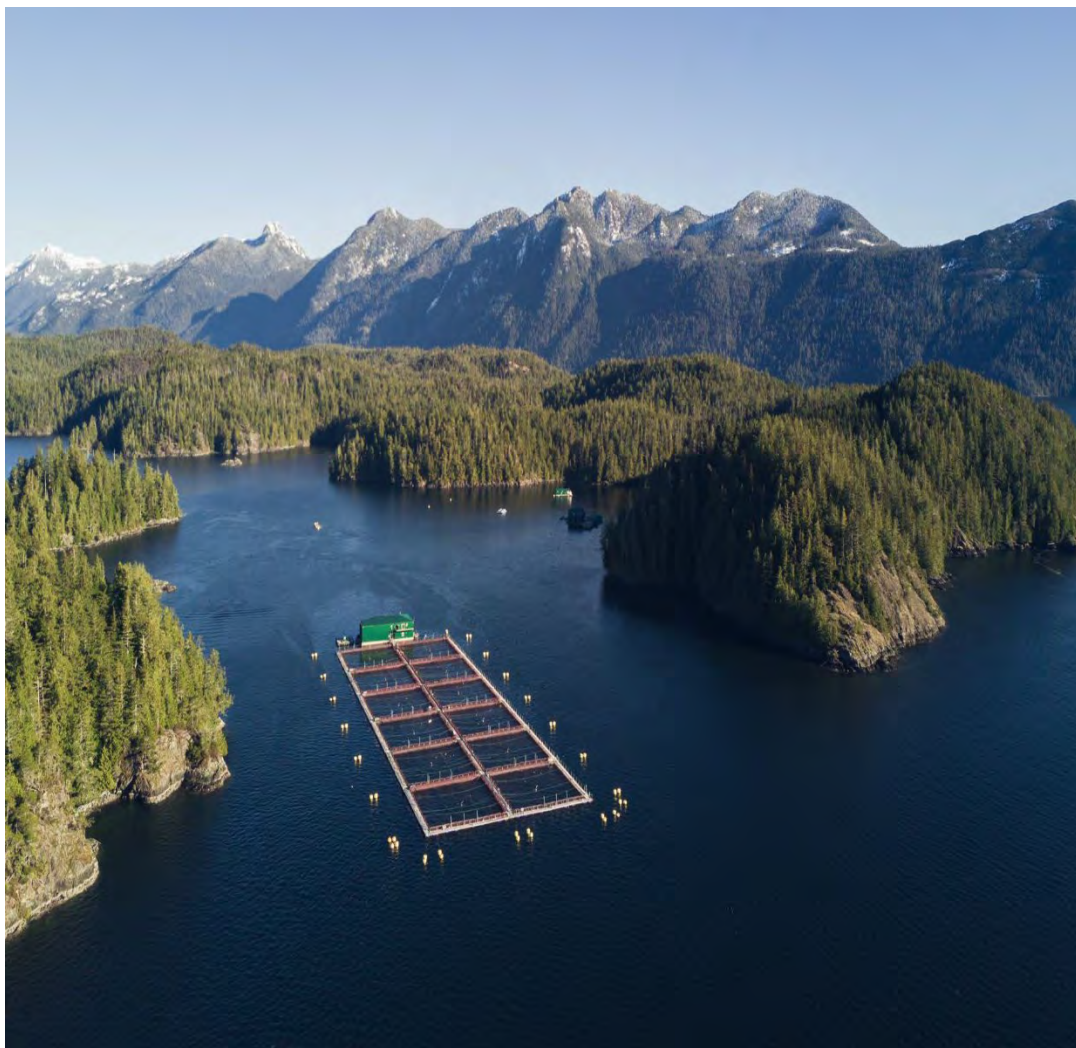
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WHAT IS INCIDENTAL CATCH?

Fish accidentally captured by commercial and recreational fisheries when fishing for other fish species has been managed for many years. Likewise, incidentally captured fish require management at marine salmon farms. At a farm, the incidental catch is defined as any wild finfish caught during fish handling events

such as sampling, treatments, harvest, fish movement between pens or facilities or during net removal. It occurs after wild fish swim through the nets containing the farmed salmon and either choose to take refuge in the nets or grow to a size that they can no longer swim out.



HOW IS INCIDENTAL CATCH REGULATED?

Each salmon farm has an aquaculture license issued by DFO. Under the Conditions of the Licence,

"the licence holder must design and use nets and equipment and conduct operations in a manner that causes the least amount of harm to incidental catch or the residence of the individuals of any species listed as threatened or endangered under the Species at Risk Act or its critical habitat and does not jeopardize the survival and recovery of these species." (1)

Farmers must have mitigations in place to sort wild fish during handling, transfer of fish between facilities, harvest and net removal, and make reasonable efforts to minimize the transfer of wild fish between facilities and processing plants. Any live wild fish must be immediately returned to waters outside the aquaculture facility in a manner that causes the least harm. All dead incidental catch must be retained and disposed of in the same manner that farmed salmon carcasses are disposed of on land. Each farm must report the incidental catch (alive and dead) to DFO each quarter according to the license conditions (Figure 1).

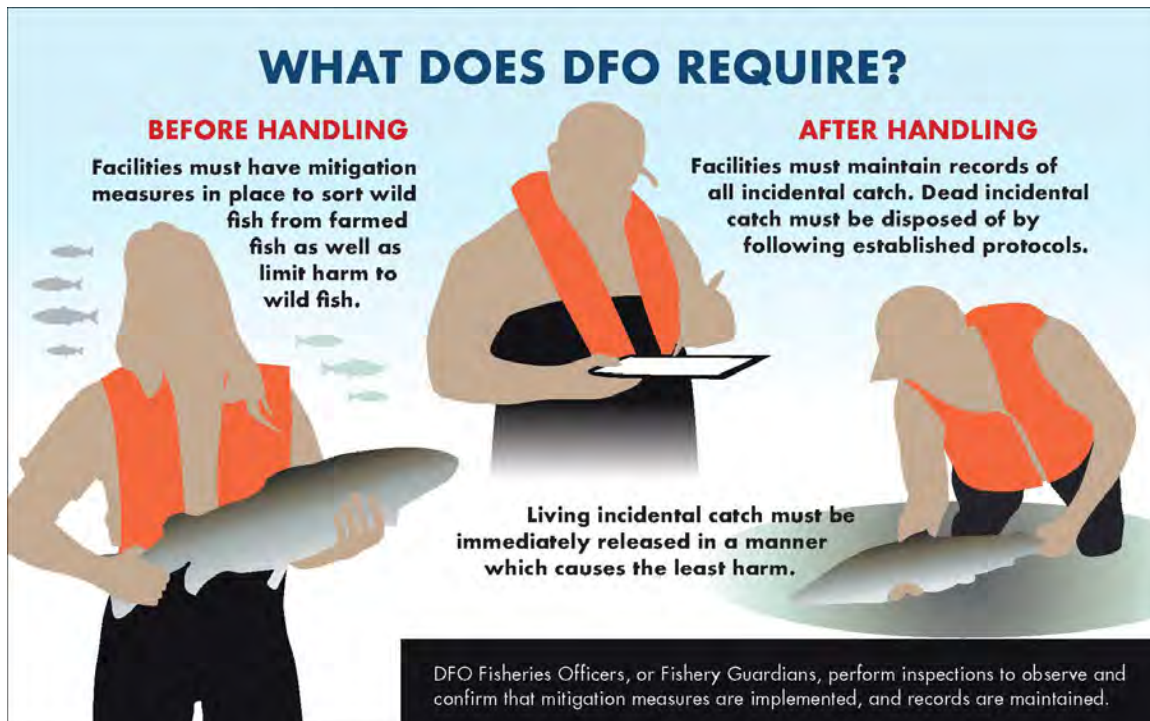


Figure 1. Regulatory requirements for minimizing incidental catch at salmon farms in BC.



IS INCIDENTAL CATCH PUBLICLY REPORTED?

Yes. Through salmon farm licence conditions, DFO requires the reporting of all wild fish releases and mortalities by species and number. This information is then made available on DFO's public website (2)

WHAT FISH SPECIES ARE POTENTIALLY CAUGHT AT SALMON FARMS?

There are several types of fish that can be captured as incidental at salmon farms. Pacific herring, cod, surfperch, and rockfish comprise most of the incidental catch at farms. Most species are caught in low numbers and are often grouped into categories by DFO:

- o groundfish (perch, cod species, sculpin, rockfish, sablefish),
- o pelagic fish (pollock, hake, northern anchovy),
- o other (example kelp greenling, flounder), and
- o salmon/trout/.



HOW DO SALMON FARMERS REDUCE POTENTIAL INCIDENTAL CATCH MORTALITY?

Staff are required to uphold the DFO licence conditions related to incidental catch. They undergo training to ensure they can correctly identify wild fish species, accurately record numbers, and report to DFO. Staff must also be familiar with in-house protocols related to the handling and operation of the equipment associated with the mitigation measures. They are encouraged to suggest improvements to existing mitigation measures as part of their work plan.

On vessels, salmon farmers often use grader systems comprised of parallel bars set a certain distance apart to separate the larger farmed fish from the much smaller wild fish (Figure 2). The distance between the bars is calibrated to the size

of the farmed fish so they cannot slip through the gaps while the smaller incidental catch can. The farmed salmon are directed to another net pen or into another vessel, depending on the purpose of the transfer. The incidental catch is directed to a sorting table where farm staff count and identify the fish before quickly returning them to a holding tank and the ocean to reduce the risk of mortality.

Prior to handling, if wild fish are observed, staff will assess the situation and monitor to ensure the placement of the seine net avoids the fish or postpone the activity. Occasionally, a dip net can be used to remove the wild fish before handling.

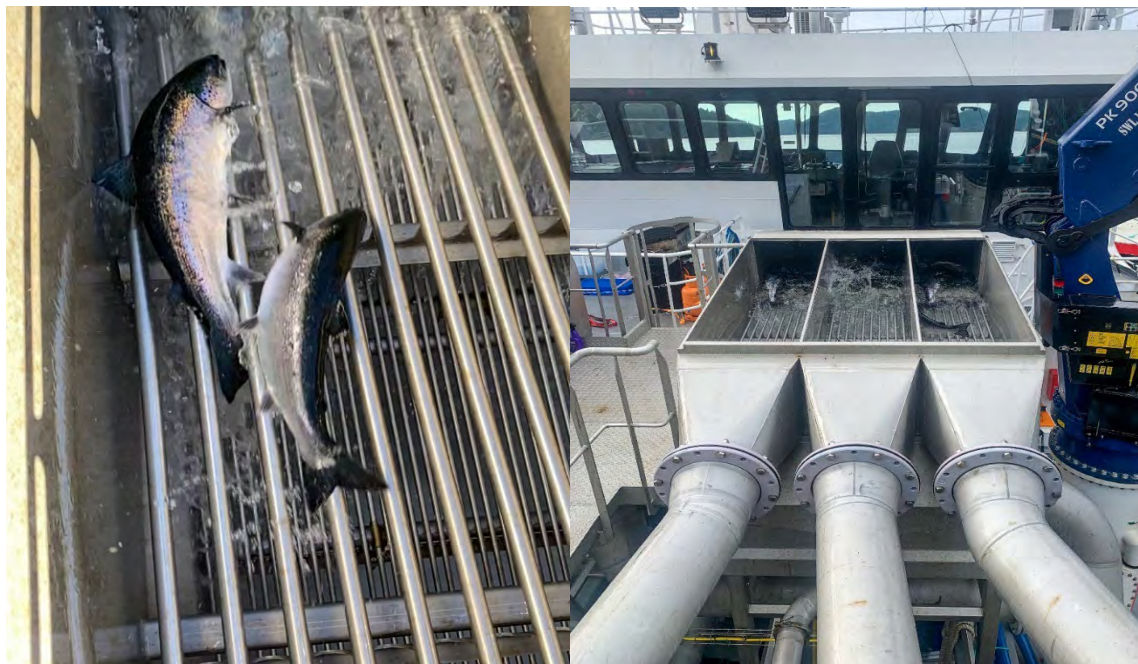


Figure 2. Example of grader bar system on a mechanical treatment vessel.



DO LIGHTS ATTRACT FISH?

Yes, some fish are likely attracted to lights; however, improved lighting technology at farms has virtually eliminated visible light beyond the edge of the net pens (Figure 3).

Atlantic salmon farms use lights during the night for a portion of the production cycle to control the salmon stock's early maturation (grilsification) during their first year at sea. Salmon (grilse) tend to be smaller, often with poorer flesh quality. Additionally, grilsification often compromises the fish's health status, making them more susceptible to disease(3).

The first lights used at BC salmon farms were high-powered incandescent or metal

halide lights that were visible to fish beyond the net pen array. Approximately ten years ago, salmon farmers began transitioning to high-efficiency-emitting diode (LED) lighting systems that use specific wavelengths to manage grilsification (Figure 4). The LED lights are installed within the net pen array at specific depths to increase the efficacy of the light on the farm-raised salmon and are directed into the net pens to reduce ambient light outside of the pens. This has resulted in about a 7-fold reduction of light penetration beyond the cages compared to incandescent lighting. The change to LED lights appears to have significantly reduced the potential of wild fish interaction.



Figure 3. Example of lights at net pens at night. Note the light penetration is focused within the cage.

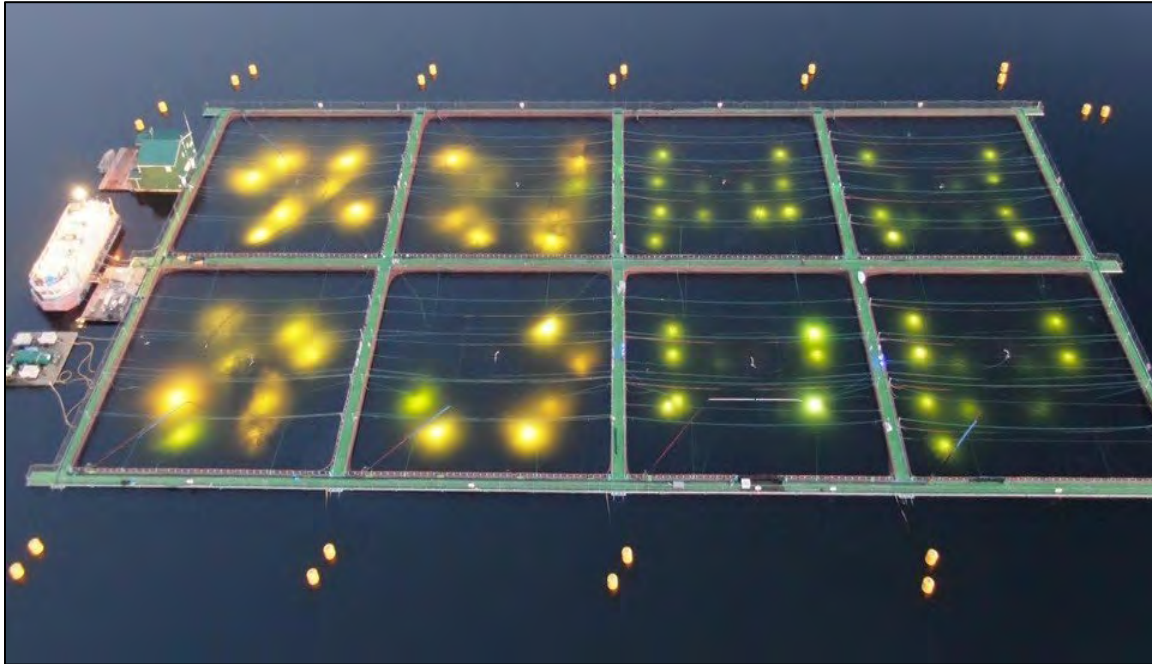


Figure 4. Metal halide lights (on the left) compared to LED lights (on the right).

HOW MUCH INCIDENTAL CATCH IS THERE AT SALMON FARMS?

In total, there were 1,520,457 incidental catch mortalities at salmon farms in British Columbia from 2011 to 2022 (Table 1). The total number of incidental catch mortalities at farms per year for each fish type is shown in Figure 5. Pacific herring were by far the most common type of incidental catch, making up 94.4% of the total mortalities during this period (4).

In total, there were 84,523 non-herring incidental catch mortalities at salmon farms in British Columbia from 2011 to

2022 (Table 1) (4). This translates to an average of 7,044 mortalities per year for the entire sector. Given that the average number of farms operating during this period was 73, this represents an average of 97 mortalities per year per farm.

While all incidental catch mortalities are unfortunate, the good news is that farming practices have been very successful at minimizing these interactions.



Table 1. Total number of incidental catch mortality by fish type for all BC salmon farms (2011 to 2022).

Source: DFO Incidental catch at BC marine finfish aquaculture sites (4, 5) Note that groundfish total excludes rockfish and sablefish, and pelagic excludes herring and salmon/trout

Fish Type	2011	2012	2013	2014	2015	2016	2017
Groundfish	358	2,161	2,023	859	13,553	2,476	16,840
Herring	7,833	11,215	23,374	24,342	28,412	45,848	75,240
Other	56	207	69	7	60	70	12
Pelagic	1,320	208	257	546	346	2,472	677
Rockfish	1,753	38	2	46	30	1,453	10,250
Sablefish	6	43	50	-	48	1,134	2,425
Salmon/Trout	58	87	43	19	58	25	6
Total	11,384	13,959	25,818	25,819	42,507	53,478	105,450

Cont'd below

Fish Type	2018	2019	2020	2021	2022	Total
Groundfish	1,493	283	425	5,657	686	46,814
Herring	15,760	4,489	28,410	154,696	1,016,315	1,435,934
Other	84	27	139	6	9	746
Pelagic	720	899	295	44	17	7,801
Rockfish	3,370	138	26	4,448	178	21,732
Sablefish	1,047	105	383	1,760	14	7,015
Salmon/Trout	11	6	50	37	15	415
Total	22,485	5,947	29,728	166,648	1,017,234	1,520,457

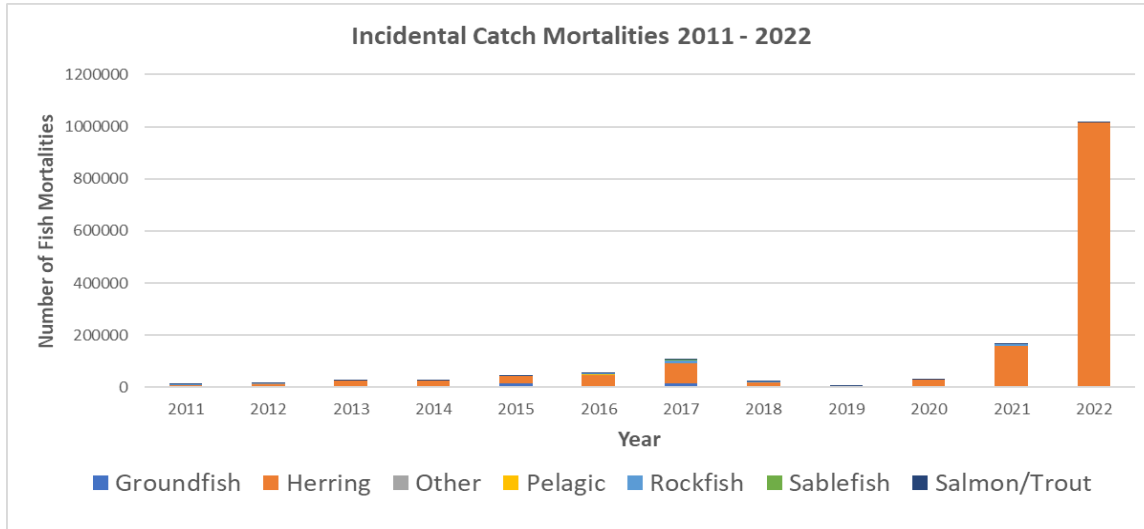


Figure 5. *Incidental catch mortalities at BC salmon farms by fish category (2011 to 2022).*

Source: [Government of Canada Open Data website](#) (4) Note that groundfish total excludes rockfish and sablefish, and pelagic excludes herring and salmon/trout.

Excluding herring mortalities, there is an average of 97 mortalities per year per farm which is less than 2 wild fish mortalities per week.

PELAGIC FISH

Pelagic fish are those that inhabit the water column (not near the bottom or the shore) of coasts, open oceans, and lakes. Many oceanic pelagic fish such as pollock, northern anchovy, herring, eulachon and salmon travel in schools and several of these species, including herring, eulachon, and salmon, have a phase of their lives when they spawn near shore (herring) or in freshwater (salmon and eulachon). Salmon farms have incidentally captured all the species listed above. Excluding herring, salmon, and eulachon incidental catch, which are discussed individually in this document, 7,801 pelagic fish were incidentally caught by salmon farms from

2011 to 2022. The annual average is 650 fish, which is less than nine fish per farm based on an average of 73 farms operating at any one time from 2011 to 2022.



Photo by Bill Pennell

**PACIFIC HERRING**

Pacific herring incidental catch mortalities at salmon farms are not consistent from year-to-year. Adult herring move around and do not always spawn at the same locations. DFO has estimated that up to 18% of BC coastline is classified as herring spawning habitat, although only 1.8% is intensively utilized by spawners in a typical season (6).

Based on an estimated average weight of Pacific herring mortalities of 20 grams per fish, the cumulative weight of all the mortalities over a 12-year period was approximately 2.39 metric tonnes per year from 2011 to 2022. For context, the Pacific herring incidental catch mortalities at salmon farms in BC is 0.014% of the commercial catch fisheries per year (Table 2).

Table 2. Pacific herring incidental catch mortalities at salmon farms in BC compared to the total commercial capture fishery (roe fisheries, food and bait and special use) from 2011 to 2022.

Source: [DFO Incidental catch at BC marine finfish aquaculture sites](#) (4, 5)

Year	Commercial Fishery (metric tonnes)	Salmon Farm Incidental Catch Mortalities (metric tonnes)	Incidental Catch Mortalities at Salmon Farms as a % of the Commercial Fishery
2011	7,275	0.16	0.002
2012	12,722	0.22	0.002
2013	18,574	0.47	0.003
2014	23,000	0.49	0.002
2015	22,757	0.57	0.003
2016	23,948	0.92	0.004
2017	28,128	1.51	0.005
2018	19,484	0.32	0.002
2019	21,419	0.09	0.0004
2020	10,439	0.57	0.005
2021	14,396	3.09	0.021
2022	4,672	20.33	0.43
Total	206,814	28.72	0.014

Pacific herring incidental catch mortalities at salmon farms in BC has been approximately 2.39 metric tonne per year. This is **0.014%** of the **average annual Pacific herring commercial catch fishery (2011 to 2022)**.

Photo by Bill Pennell

DFO has five major herring stock assessment areas along the BC coastline: Haida Gwaii, Prince Rupert District, Central Coast, Strait of Georgia and West Coast Vancouver Island (WCVI). Table 3 summarizes the cumulative spawning biomass of the five areas as well as the specific spawning biomass for WCVI for the 2013 to 2022 period.



The highest number of Pacific herring incidental catch mortality at salmon farms, primarily located on the west coast of Vancouver Island, occurred in 2022, which was associated with an extremely large 2021 spawning biomass in the WCVI stock assessment area.

By comparison, the total combined incidental catch mortality of Pacific herring at all salmon farms was a tiny fraction, less than nine-one-hundredths of a percent (0.086 %) of the surrounding Pacific herring spawning biomass associated with the WCVI area.

On average, during the 2013 to 2022 period, the percentage of Pacific herring incidental catch mortalities at salmon farms to the WCVI standing spawning biomass was less than two-one-hundredths of a percent (0.015%).

**Table 3. Cumulative spawning biomass for the five BC herring stock assessment areas**

Comparison of Pacific herring incidental catch mortalities at salmon farms with WCVI stock assessment area (PFMA 23 - 25) 2013 to 2022. Source: [Stock Status Update with Application of Management Procedures for Pacific Herring in BC](#): Status in 2022 and Forecast for 2023 (7)

Year	Province-wide Estimated Spawning Biomass (metric tonnes)	West Vancouver Island Estimated Spawning Biomass - PFMA 23 - 25, (metric tonnes)	Salmon Farm Mortality (metric tonnes)*	Incidental Catch Mortalities at Salmon Farms as a % of the spawning biomass for PFMA 23 - 25
2013	158,000	12,258	0.47	0.004
2014	175,405	13,937	0.49	0.004
2015	178,459	11,323	0.57	0.005
2016	208,411	20,528	0.92	0.005
2017	142,566	16,476	1.51	0.009
2018	151,053	28,107	0.32	0.001
2019	165,137	17,030	0.09	0.001
2020	223,893	18,761	0.57	0.003
2021	180,307	29,339	3.09	0.011
2022	172,736	23,707	20.33	0.086
Total	1,755,967	191,466	28.36	N/a

*For all calculations of incidental catch at salmon farms, Pacific herring weight was estimated as 20g.

PACIFIC SALMON

There are very few incidental catch mortalities of wild Pacific salmon at BC salmon farms. From 2011 to 2021, there were 402 wild Pacific salmon incidental catch mortalities at farms. Almost all of the salmon weighed less than 500 grams. For

context, during the same time period, commercial and recreational capture fisheries landed 73,694,320 wild Pacific salmon in BC (Table 4, note that the data does not include 2022 catch data or Indigenous fisheries).

Table 4. Comparison of the number of Pacific salmon mortalities by sector in BC, 2011 to 2021.

Source: North Pacific Anadromous Fish Commission Statistics, Incidental catch at BC marine finfish aquaculture sites - Data (4, 8)

Year	Commercial Fishery (number of fish)	Recreational Fishery (number of fish)	Salmon Farm Incidental Catch (number of fish)
2011	9,731,480	618,850	58
2012	3,012,930	408,400	87
2013	14,527,170	658,730	43
2014	14,836,650	871,180	19
2015	5,434,600	701,400	58
2016	6,848,290	425,570	25
2017	3,824,180	481,270	6
2018	5,337,840	603,520	11
2019	953,480	568,460	6
2020	2,448,090	260,660	50
2021	668,090	473,480	39
Total	67,622,800	6,071,520	402





GROUNDFISH

The groundfish category includes fish like halibut, sablefish, rockfish, cod, dogfish and perch that live near or on the seafloor. In British Columbia, the groundfish commercial fishery focuses primarily on halibut, sablefish, rockfish, lingcod, and dog fish. Since 2011, the commercial groundfish fishery has landed approximately 112,000 metric tonnes (112,000,000 kg) of fish per year (Figure 6). The figure specifies the major groundfish species that were captured including rockfish and sablefish. These two species are discussed in further detail below.

Incidental catch of groundfish at salmon farms is comprised of the same species as the commercial groundfish capture fishery, with the addition of perch and sculpin. Cod and rockfish represented 50.7% and 30.1% respectively of the groundfish incidental catch at salmon farms from 2011

to 2022. These species are discussed in more detail below.

Groundfish incidental catch mortalities at salmon farms in BC has been approximately 3.09 metric tonnes per year. This is **0.003%** of the **average annual commercial catch fishery of 112,000 metric tonnes from 2011 to 2021.**

The total number of groundfish incidental catch mortalities at salmon farms from 2011 to 2021 was 75,561 fish (Table 1). This is approximately 37.132 tonnes (based upon an average weight of 491 grams per fish) or 3.09 metric tonnes per year. Based on the average yearly catch for both sectors, the incidental catch mortalities at salmon farms was 0.003% of the annual commercial capture fishery.

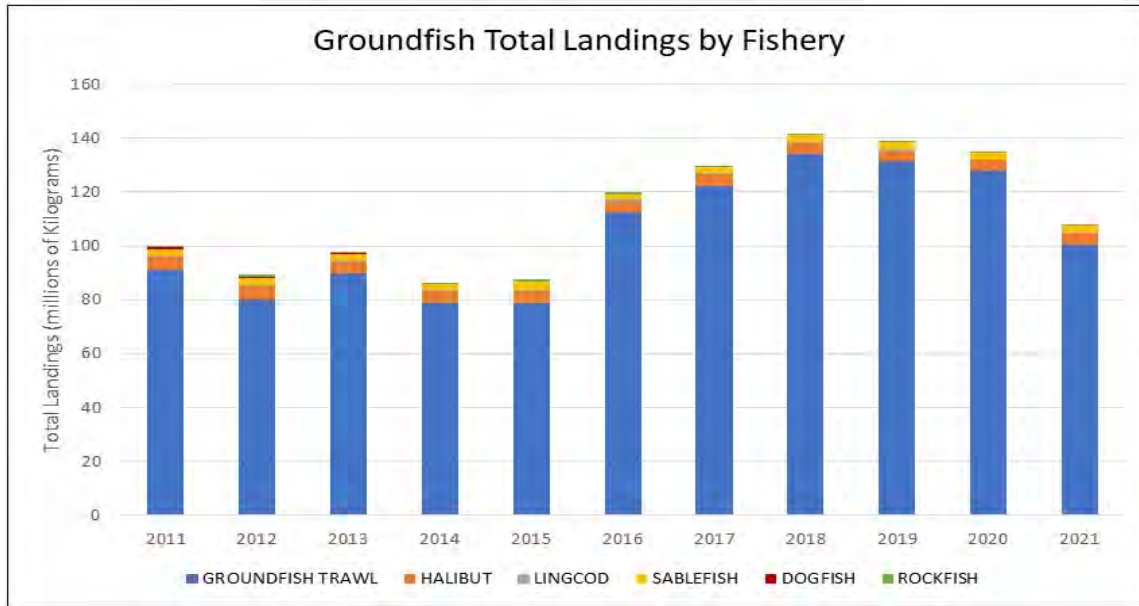


Figure 6. *Groundfish Total Landed Volume by Fishery 2011 to 2021.*

Source: The landed volume and value are calculated from the Dockside Monitoring Program landings, Groundfish Fishery Observations System and sales slip prices Reference Integrated fish (9).

ROCKFISH

Rockfish are part of the total number of salmon farm groundfish incidental catch (Table 1). The total number of rockfish incidental catch mortality from 2011 to 2022 was 21,732 fish. With the exception of 2017, rockfish mortality numbers have been generally low, averaging about 16 rockfish per farm each year. Rockfish incidental catch is predominantly juvenile fish, based on their observed average weight of 150 grams. This means that there were approximately 3.26 metric tonnes of rockfish incidental catch mortalities at BC salmon farms over the past 12 years (i.e., 21,732 rockfish X 150-gram weight).





The recreational and commercial capture fisheries in British Columbia also result in incidental rockfish catch. Recent statistics for these fisheries are not available from DFO; however, Living Oceans Society estimated mortality associated with commercial fishing bycatch to be 650 metric tonnes between 1996 to 2011 (10). By comparison, the total cumulative rockfish incidental catch mortality at salmon farms from 2011 to 2022 salmon farms was 3.26 metric tonnes, which was 0.5% of the commercial fish mortality.

The total rockfish incidental catch mortality at **salmon farms from 2011 to 2022** was **0.5% of the incidental catch mortality associated with commercial capture fisheries** in BC from 1996 to 2011.

SABLEFISH

The sablefish commercial capture fishery is highly regulated in British Columbia and few licenses are issued compared to other capture fisheries. The allowable annual catch varies from year-to-year ranging between 2,200 – 2,600 metric tonnes. In 2022, 2,246 metric tonnes were landed (not including Indigenous and recreational fisheries). By comparison, the total number of sablefish incidental catch mortalities at salmon farms from 2011 to

2022 was 7,015. Based on the average weight of 1.6 kg of an individual sablefish mortality, the total weigh of sablefish incidental catch mortalities at BC salmon farms over the past 12 years was 11.39 tonnes (i.e., 7,015 sablefish x 1.624 kg). The annual average weight of the salmon farm incidental catch mortalities of sablefish was 0.95 metric tonnes per year, which represented 0.04 percent of the 2022 sablefish commercial catch.

EULACHON

Only one individual eulachon was reported as incidental catch at salmon farms from 2011 to 2022, indicating that incidental catch in net pens is not a factor in the low level of abundance associated with this species.

DO FARMED FISH EAT WILD FISH?

From the time they are in a hatchery, farm-raised salmon are trained to eat pelleted food, which meets all their nutritional needs, growth and well-being. Farm-raised fish are closely tracked at each farm through video, feed uptake, and physical sampling during the time that they are in the net pens. Fish feed, feeding practices, fish health and growth are key topics for the farming sector and are discussed in detail in Chapters 7 and 11.

From 2017 to 2019, DFO undertook a study at all salmon farming areas to investigate whether farm-raised salmon eat wild fish in the net pens (11). DFO staff visited processing plants to observe the stomach contents of farm-raised Atlantic and Chinook salmon. The stomach contents of 14,100 farm-raised fish were examined: eleven fish were found: eight Pacific herring, a fish that was likely a sand lance and the other two were not identifiable. From this, it was calculated that 0.08% of farm-raised fish had wild fish in their stomachs (12).





RESULTS ARE ENCOURAGING

We understand that all life in the ocean is precious, and we are responsible for effectively managing and minimizing incidental catch mortalities at our farms. Over the years, we have made significant investments and steps that have significantly reduced incidental catch mortality. The results are very encouraging - incidental catch mortality is low at farms. However, we know that the work of conservation is never fully done. Respect for nature and the traditional territories within which we operate pushes us to continuously review and innovate our practices.



Photo by Bill Pennell

REFERENCES

1. Fisheries and Oceans Canada. Marine finfish B.C. aquaculture licence and conditions of licence. In: Canada FaO, editor. Nanaimo: Government of Canada; 2023.<https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/licence-cond-permis-mar/index-eng.html>
2. Canada FaO. 2023. Reporting incidental catch at BC marine finfish aquaculture sites Ottawa: Government of Canada; [Available from: <https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/incidental-catch-captures-fortuites/index-eng.html>].
3. Canada FaO. 2017. Investigation of grilsification in farmed Atlantic salmon: Causes and management solutions Ottawa: Government of Canada; [Available from: <https://www.dfo-mpo.gc.ca/aquaculture/rp-pr/acrdp-pcrda/projects-projets/MG-02-04-007-eng.html>].
4. Open Government. 2023. Incidental catch at BC marine finfish aquaculture sites Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/0bf04c4e-d2b0-4188-9053-08dc4a7a2b03>].
5. Open Government. 2023. Pacific Herring spawn index data Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/d892511c-d851-4f85-a0ec-708bc05d2810>].
6. Hay DE, McCarter PB. Spawning areas of British Columbia herring: a review, geographical analysis and classification. Revised edition: 2013. Can Manuscr Rep Fish Aquat Sci. Nanaimo, British Columbia: Fisheries and Oceans Canada; 2019. p. 17.<https://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/hertags/pdf/project-eng.pdf>
7. Canadian Science Advisory Secretariat. Stock status update with application of management procedures for Pacific Herring (*Clupea pallasii*) in British Columbia: Status in 2022 and forecast for 2023. In: Canada FaO, editor. Ottawa: Government of Canada; 2022. p. 60.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41092703.pdf>
8. North Pacific Anadromous Fish Commission. 2023. NPAFC Statistics: Pacific Salmonid Catch and Hatchery Release Data: North Pacific Anadromous Fish Commission,; [Available from: <https://www.npafc.org/statistics/>].
9. Fisheries and Oceans Canada. Integrated fisheries management plan summary: Groundfish - Pacific Region, 2024. In: Fisheries and Oceans Canada, editor. Ottawa: Government of Canada; 2024.<https://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/ground-fond-ifmp-pgip-sm-eng.html>
10. Driscoll J, Robb C, Bodtker K. Bycatch in Canada's Pacific Groundfish Bottom Trawl Fishery: Trends and Ecosystem Perspectives. A Report by Living Oceans Society. Sointula, BC: Living Oceans Society,; 2009.https://www.livingoceans.org/sites/default/files/bycatch_BC_Bottom_Trawl_Fishery_0.pdf
11. Fisheries and Oceans Canada. 2018. Wild fish predation project [Available from: <https://www.dfo-mpo.gc.ca/about-notre-sujet/publications/infographics-infographies/project-predation-projet-eng.html>].



12. Jones M. 2019. Study finds low evidence of predation by farmed salmon. Aquaculture North America [Internet]. March 2024. Available from: <https://www.aquaculturenorthamerica.com/research-finds-little-evidence-of-predation-by-farmed-fish-2374/>.



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CHAPTER 7

CARING FOR THE ENVIRONMENT

FEED SUSTAINABILITY



This document describes the feed and feeding practices at salmon farms and discusses important sustainability initiatives

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CHAPTER HIGHLIGHTS – FEED SUSTAINABILITY

Efficient – with recent gains in efficiency of feeding and growth, BC farm-raised salmon now produce more high-quality marine protein than they consume.

It takes about 1.15 to 1.2 kilograms of feed to produce 1 kilogram of farm-raised salmon.

Fish meal and oil – once the primary ingredients in Atlantic salmon feed, have been mostly replaced with plant and land-animal ingredients.

All fish trimmings used in BC for Atlantic salmon feed come from sustainably managed Alaskan pollock and Pacific hake fisheries, landed in Canada and the United States.

75-80% of the fish meal and oils used to feed farm-raised Chinook salmon are

derived from the by-products of the BC herring and hake fisheries.

Feed is formulated to optimize salmon health – there are no added steroids or hormones in farm-raised salmon feed.

Feeds are locally made in BC – with an average of about 80% of the ingredients coming from Canada and the United States. The remaining is sourced globally from sustainable sources.

Much lower carbon footprint – it requires much less feed to grow a kilogram of salmon compared to chicken, pork, and beef.

Ranks #1 for sustainability – on the Collier FAIRR Protein Producer Index compared to other farmed animal proteins.

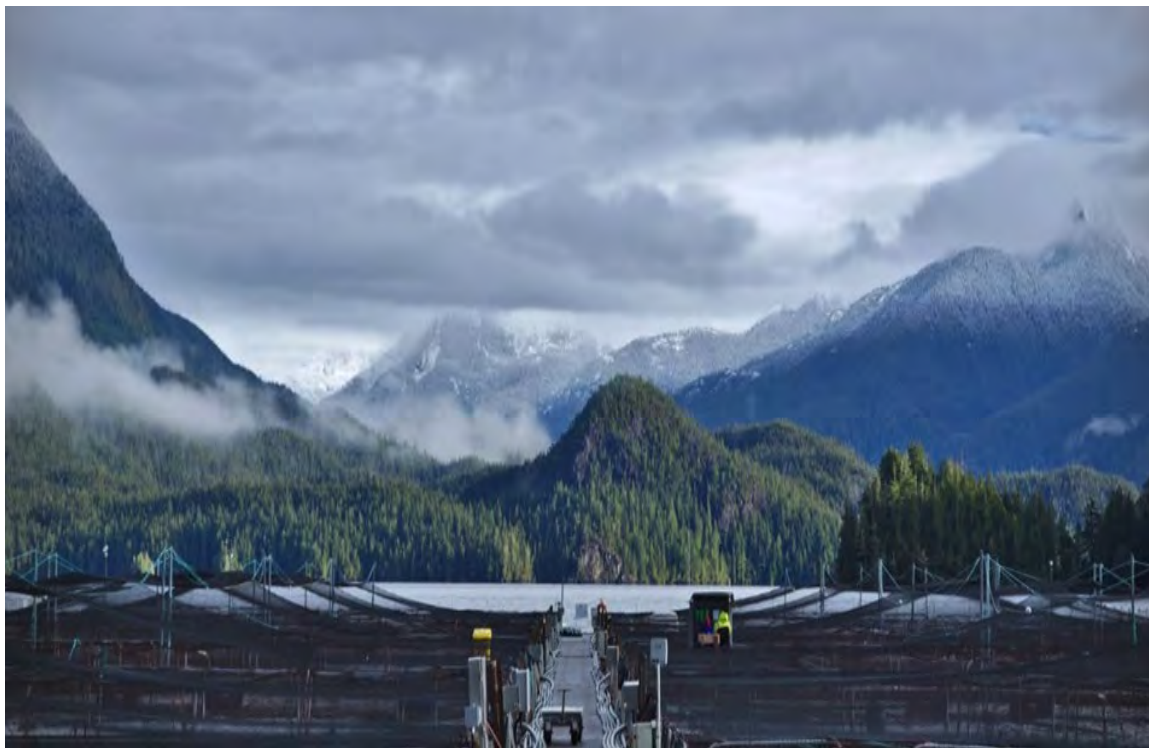
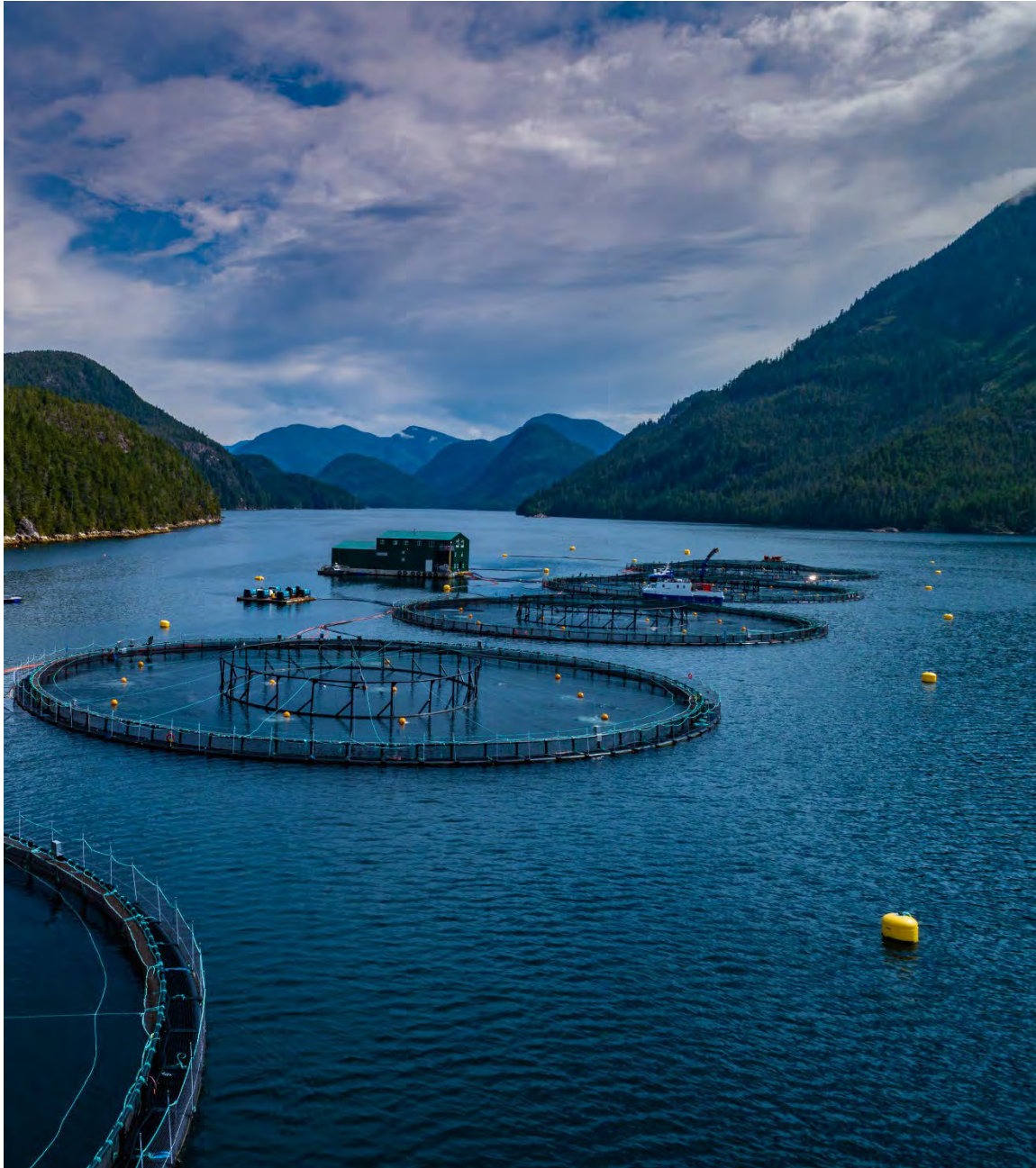




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INTRODUCTION

Salmon farmers hear the concerns of First Nations and members of the public that salmon feeds may contain high levels of marine ingredients, creating sustainability challenges. We understand the importance of ensuring that salmon farming is part of the conservation solution for the world's oceans. This includes careful and sustainable practices for sourcing and utilizing marine proteins.



WHAT DO FISH EAT?

In the wild, some fish are herbivores, eating only aquatic plants; others are carnivores, eating only other aquatic animals; and some are omnivores, consuming both plants and animals. All salmon are naturally omnivores, eating varying amounts of plants and animals at different stages of their lives. Salmon need both components to be healthy, to grow and reproduce. Farm-raised salmon are no different; they need correctly balanced, nutritious food, and this comes from both plant and animal sources.

WHAT IS IN FARM-RAISED SALMON FEED?

In British Columbia, there are three main Atlantic salmon farming companies, MOWI Canada West, Grieg Seafood BC, and Cermaq Canada; there is one Chinook salmon farming company, Creative Salmon.

Farm-raised salmon feed typically comes as an extruded pellet. Pellets are sized and formulated to meet the fish's dietary needs at various life stages and are species-specific.

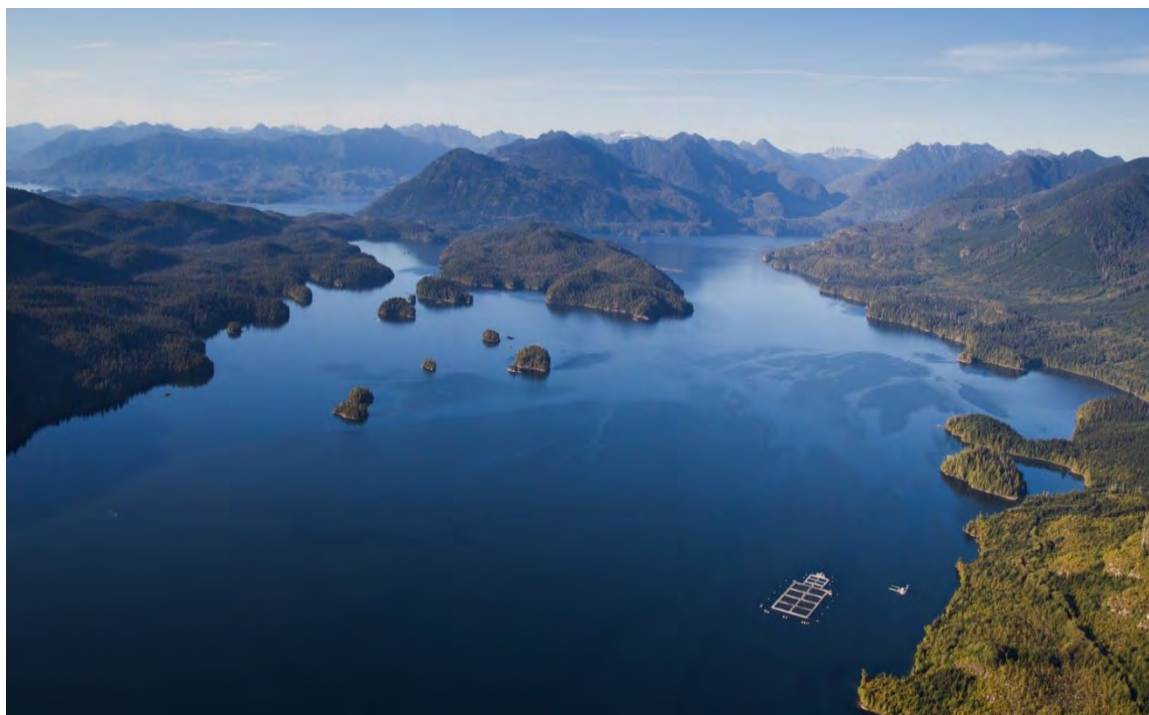
Feed components include proteins, fats, carbohydrates, vitamins, minerals, and the pigment astaxanthin. There are no added steroids or hormones in farm-raised salmon feed.

Although proportions and ingredients vary with life stage and by company, in general, **Atlantic salmon** feed is composed of (ranges provided by BC feed suppliers):

- o 30-45% alternative proteins (e.g., plants, poultry)
- o 12-20% alternative oils (e.g., flax, canola)
- o 2-16% fish meal
- o 10-15% binders and carbohydrates
- o 10-15% fish oil
- o 2-5% water
- o 4-6% micronutrients (e.g., vitamins and minerals)

Salmon feeds are nutritionally dense and highly digestible to meet the needs of this high-efficiency, cold-blooded fish and reduce the amount of waste as much as possible.





WHERE IS SALMON FEED MADE?

All salmon feeds used in British Columbia are locally made in BC. Two companies in BC supply Atlantic salmon farms, Cargill Aqua Nutrition Canada/EWOS feeds in Surrey and Skretting in Vancouver. Taplow Feeds in Chilliwack supplies feed to steelhead, arctic charr and Chinook salmon.

Each salmon farming company has its feed formulated to its own specifications. The ingredients and proportions are not the same for each company. For example, Creative Salmon has organic certified feed produced by both Taplow Feeds and Cargill Aqua Nutrition Canada/EWOS Feeds.

WHERE DO FEED INGREDIENTS COME FROM?

BC feed companies estimate that on average, about 80% of raw sourced materials for Atlantic salmon feeds come from Canada and the United States; this percentage varies between companies, availability and quality of ingredients. The remaining 20% is sourced globally from sustainable sources.

Farm-raised Atlantic salmon feed ingredients are sourced from terrestrial and aquatic plants and animals. Common plant-based protein sources include, but are not exclusive to, wheat and corn gluten, and sunflower. Plant-based oils are mainly from canola and flax. Plant-derived carbohydrates are typically from wheat, beans, and pea flour. Some feeds may contain oil derived from algae.

According to BC feed suppliers, many of the animal-derived ingredients are by-products from fish and poultry processing. Atlantic salmon feeds commonly contain poultry meal and oil, feather meal and blood meal by-products.

Fish and crustacean meal are a common by-product from wild fisheries used in farm-raised salmon feeds to provide high-quality protein and oil.

All of the fish trimmings used in BC for Atlantic salmon come from Alaskan pollock and Pacific hake fisheries landed in Canada and USA.



Using fish trimmings and other by-products maximizes the use of these species for human consumption instead of going to waste.

As in all domesticated animal production, salmon farmers must ensure that the feed meets the nutritional and welfare needs of the fish under their care. Feed companies have nutritionists on staff to strive to understand the needs of the fish and develop optimal diet recipes. Diets are continuously updated as new ingredients become available and nutritional requirements change.

Farm-raised organically certified Chinook salmon feeds do not contain the same ingredients or proportions as Atlantic salmon feeds because of the fish's dietary needs and the product's organic status. For organically certified Chinook salmon, feed must be as close to that found in nature as possible. As such, they contain a higher proportion of marine products than Atlantic salmon feeds, and these products are sourced as locally as possible.



According to feed suppliers, currently, 75-80% of marine meals and oils in organically certified Chinook salmon feed are derived from the by-products of the

BC herring and hake fisheries, with smaller amounts from other BC fisheries.

Substitutions of marine meals and oils are difficult for organically certified Chinook salmon can't tolerate alternative ingredients such as soy or pea protein.



Photo by Brian Kingzett

DO FEED COMPANIES CARE WHERE THEIR INGREDIENTS COME FROM?

Yes. Modern feed companies have policies and principles they follow to ensure feed ingredients are responsibly sourced. Companies have criteria for sourcing marine-derived ingredients such as meals and oils, and many follow the [FAO Code of Conduct for Responsible Fisheries](#). (1)

Companies have their own policies and guidelines for ingredient sourcing. All BC Atlantic salmon farms require proof of relevant certification for all raw ingredients. Feed companies also have their own guidelines for ingredients to ensure they are sourced responsibly. For example, Nutreco/Skretting and Cargill have developed marine and soy and palm oil sourcing guidelines. Both

Cargill/EWOS and Skretting/Nutreco feed companies are committed to responsible sourcing of raw ingredients used in their feeds.

Detailed descriptions of these goals and policies are publicly available on their respective websites and in key documents such as the [Cargill Aqua Nutrition Sustainability Report](#) (2) and [Skretting/Nutreco Responsible Sourcing](#) (3) as well as [Skretting/Nutreco Sustainability Report](#) (4).

Taplow feed ingredient sourcing adheres to the Canadian Organic Aquaculture Standard and requirements for good manufacturing practices.



HOW IS IT SUSTAINABLE TO FEED WILD FISH TO FARMED FISH?

Salmon farmers are keenly aware that both the amount of feed ingredients used, and the sources of proteins and oils must be sustainable. As such, the Atlantic salmon farming sector has and continues to invest in research to decrease the amount of marine-derived ingredients, maintain fish health, and utilize ingredients (both marine and terrestrial) from ethical sources.

The good news is that even with a growing global Atlantic salmon farming sector, the amount of wild-sourced proteins and oils has decreased in recent

years. This reduction in wild-sourced fish meal and oil has been possible by substituting and adding new ingredients, including oils from algae or marine microbes and plant-derived ingredients such as yeast, rice, and peas (e.g. Skretting responsible sourcing) (3).

Based on information from BC feed suppliers, over the last few decades, the composition of Atlantic salmon feed has changed from one primarily based on fish meal and oil to one with a major composition of plant ingredients.



In BC, Atlantic salmon feed suppliers have reduced the amount of fish meal used to approximately 15% and fish oil to 11%. Some companies have proportions as low as 2.3% fish meal and 7% fish oil.

ARE WILD FISH CAUGHT TO MAKE SALMON FEED?

Yes. Fish meal and fish oil are sourced from both wild-caught fisheries and by-products from these fisheries. Wild sources of fish meal and oil are typically fish species that are short-lived and exceptionally oily. Examples of these species include sardines, menhaden, herring, pilchard, and mackerel.

BC farm-raised salmon are highly efficient. They now produce more marine protein than they consume.

According to BC feed suppliers, fish meal and oil are also derived from seafood processing by-products. Over 40% of fish meal and more than 50-72% of fish oil in Atlantic salmon feed is now sourced from trimmings and by-products of wild capture fisheries.

DOES FARMING ATLANTIC SALMON USE MORE WILD FISH THAN THEY PRODUCE?

No. Farmed Atlantic salmon are efficient at converting food to body mass. On average, BC farm-raised Atlantic salmon need 1.15 to 1.2 Kg of food, all ingredients combined, to gain 1 Kg of body mass. Farm-raised Atlantic salmon are now net producers of marine proteins. That is, they create more marine protein than they consume.



Although highly efficient, farm-raised Atlantic salmon do need to eat some fish and fish components to be healthy. The amount needed has decreased dramatically by substituting other ingredients such as land plant and animal products and incorporating trimmings from wild-caught fish. Fish trimmings are not used to feed the same species (i.e., salmon are not fed to salmon).

It is important to fish health that the amount of omega-3s, especially EPA and DHA, are at optimal levels in salmon feed to meet the requirements of the fish.

WHY DO YOU HAVE TO USE WILD FISH TO FEED FARMED FISH?

Salmon need fish meal and oil components to grow and develop properly. These products contain about 40 essential nutrients, and they provide essential amino acids and fatty acids that salmon require. Fish oil is particularly important in providing healthy omega-3 fatty acids for both the salmon and the humans that eat them. These fatty acids are essential, and salmon cannot make it themselves.

To maintain a sustainable and growing global Atlantic salmon farming industry, researchers have been working to reduce the reliance on wild-sourced fish meals and oils by finding healthy alternatives, including plants and potentially insects. For example, Skretting is working with a seed development company, Nuseed, in the production of [Aquaterra Advantage Omega-3](#), a canola-based source of DHA and EPA to aid in reducing the amount of wild source omega-3 oil (5).



IS HARVESTING FISH FOR AQUACULTURE FEED SUSTAINABLE?



Yes, wild fish products used to produce salmon feed come from sustainably managed stocks. There are two general types of fisheries from which these ingredients are sourced, targeted pelagic fisheries and by-products of wild capture fisheries.

Targeted fisheries are directed fisheries for small pelagic species such as herring, sardine, and menhaden. They are highly valuable sources of oil and meal and have many uses, including baitfish for commercial fisheries, human nutritional supplements, pet food ingredients, and terrestrial livestock diets. The largest end

user, however, remains the aquaculture industry, with shrimp culture taking 25% of aquaculture fishmeal use and salmonids approximately 14% (6).

These fisheries are considered successfully managed as they can be fished without long-term depletion of stocks. An outcome of this successful management is that the world harvest of pelagic species has remained relatively constant over the last 20 years. Additionally, 30% of the world's fish meal and 51% of total fish oil production comes from fishery by-products (7).



Salmon feeds also incorporate by-products from sustainable wild capture fisheries, and in BC, these are typically Pacific hake and pollock by-products. There is a directed fishery for Pacific hake and pollock for human consumption, by-products from these fisheries not destined for direct human consumption are used in salmon feeds.

Feed suppliers are working hard to reduce reliance on targeted pelagic fisheries by sourcing by-products from capture fisheries and increasing the use of terrestrial ingredients when possible.



WHY CAN'T YOU SUBSTITUTE ALL FISH OIL AND FISH MEAL IN SALMON DIETS?



The Atlantic salmon farming sector has come a long way in reducing the amount of fish oil and fish meal in salmon diets and will continue to source novel ingredients to reduce it even more. There are several considerations when developing new formulas, even if a substitute ingredient is a good replacement on paper. Ingredients must be palatable to the salmon. If they don't taste good, the fish will not eat it. If the fish do eat it, the new ingredient must be digestible, or the fish won't utilize the nutritional benefits.

In Canada, all ingredients must meet the health and safety requirements of the Canadian Food Inspection Agency. We must also consider if the new ingredient is sustainable and if it can be produced in large enough volume and quality to be a viable substitute. For example, some plant

ingredients may not be able to be sustainably grown or have a large carbon footprint. Ingredients such as insect meals may not be available in large enough quantities to readily be incorporated into feeds.

Another consideration is whether the new ingredient causes any other negative effects, such as increased waste production or the need for increased feed consumption to produce the same amount of fish.

Finally, before an ingredient can be substituted in a feed formulation, the quality and availability at a reasonable price must be ensured. Supply chain reliability and global inflation have become significant concerns for all feed ingredients.



WHY ARE FARM-RAISED SALMON PINK?

Wild and farm-raised salmon have pink flesh because of their food. Salmon, both in the wild and those farm-raised, consume foods with carotenoids. Carotenoids are pigments, as well as antioxidants (8). Many carotenoids have been shown to directly improve the immune system aiding in disease resistance and improved growth, survival, and egg quality.

Wild salmon consume species such as krill, which are high in carotenoids, particularly astaxanthin and canthaxanthin. Farmed Atlantic salmon fish pellets are supplemented with naturally sourced and synthetic astaxanthin. Certified organic farmed Chinook salmon feed is supplemented with a natural astaxanthin pigment to maintain compliance with the certification. All salmon flesh is pigmented pink as a result of consuming carotenoids.



IS THERE A LOT OF FOOD AND FISH FECES ROTTING UNDER SEA CAGES?

No. There are many reasons why uneaten food and fish feces is not building up under salmon farms. Regulations limit the amount of organic waste, either uneaten food or fish feces, that can accumulate under salmon farms.

In BC, sea floor monitoring of salmon farms is regulated federally by Fisheries and Oceans Canada (DFO) through the [Aquaculture Activities Regulations](#) (AAR) (9). Monitoring requirements are available in the [monitoring standard](#) (10). Under the AAR, salmon farm companies must submit sea floor monitoring reports to DFO at their production peak when the biomass is highest. If fish are on-site continuously, monitoring must occur every 2 years.

Farms cannot be restocked until they meet the sea floor requirements in the monitoring standard. Results of sea floor monitoring are publicly available. Image below was captured during benthic monitoring as required by AAR. See “Chapter 8 – Caring for the Environment – Protecting Biodiversity” for more information.

Salmon feed is the most expensive part of growing farm-raised salmon. No company wants to waste feed. If the fish do not eat the food, they won't grow, and the money spent on feed is wasted. Much research and technology goes into feeding fish - the right type and amount of food at the right time to minimize waste in terms of uneaten food, feces, and money.





Feeds are specially sized, highly digestible and formulated for the life stage of the fish, as well as how fast or slow the pellets will fall through the water column. Feed quality is tightly monitored and traced to ensure freshness and palatability.

Technology is used to deliver the feed to the fish, including automatic feeders and underwater cameras to monitor consumption. Companies have feeding regimes to ensure all fish in a cage have access to feed to minimize competition. Underwater cameras allow farmers to see if the fish are full and food is unwanted so that feeding can be stopped.

- o BC Atlantic salmon farms use automatic feed delivery systems to distribute feed evenly throughout the sea cage at specified times.
- o Overfeeding is unlikely to occur as feeding is monitored via underwater video, in real-time. At some farms, the video is analyzed by pellet detection software and the feed operator is

notified if too many pellets have fallen past the camera.

- o Underwater video is also used to monitor feeding behaviour and measure biomass. These data can be utilized to inform machine learning models, artificial intelligence (AI), and deep learning to integrate feeding information with environmental monitoring sensors. This allows farmers to decide how to optimize feeding given farm conditions and fish behaviour.

Companies are beginning to invest in remote feeding centres. MOWI Canada West has developed two such centres, one in Port Hardy and another in Klemtu. These centres allow fish on multiple farms to be fed from a centralized on-land location. Three main reasons for this are to enhance on-farm staff safety in highly exposed areas, 2) to allow new training opportunities for staff who are good at feeding, and 3) to provide employment opportunities for residents who can't travel to the farm.

HOW SUSTAINABLE BY COMPARISON?

For 2021, MOWI and Grieg Seafood, two international companies operating most of BC's Atlantic salmon farms, ranked number 1 and 2, respectively, on the [Coller Fairr Protein Producer Index](#), which ranks publicly traded companies (11). These companies are the only publicly traded Atlantic salmon farming companies in BC. This index measures 10 environmental, social and governance risk and opportunity factors aligned with the Sustainable Development Goals (Figure 1).

The index assessed 60 of the world's largest protein-producing companies, including meat, dairy and aquaculture companies. Seven of the top ten companies ranked for 2021 were aquaculture companies MOWI and Grieg Seafood rated the top 2 with overall "Low Risk" scores. Salmon farming companies performed better than animal protein producers on all risk factors, particularly deforestation, biodiversity, and antibiotics.



Figure 1. List of metrics evaluated by Coller Fairr Protein Producer Index to compare the world's top listed animal protein producers.

WHAT IS THE CARBON FOOTPRINT OF SALMON FEED AND FARMED SALMON?

Carbon footprint can be calculated in many different ways. It is typically defined as the total greenhouse gas emissions caused directly and indirectly by the production of a product. Carbon footprint is calculated and publicly reported for Atlantic salmon feed and farmed salmon compared to other animal proteins.

For example, feeds produced by Skretting in Canada have, compared to Chile and Norway, shown to have a lower carbon footprint (12). Cradle-to-gate calculations, that is ingredient production (including land use change), transportation to feed facility, feed manufacturing, packaging and packaging end of life is 1.6 kg CO₂e/

kg feed in Canada compared to approximately 2.2 in Norway and 2.4 in Chile. This lower footprint for feeds produced in Canada is because many of the main ingredients are sourced locally. Protein sources are to a large extent from animal by-products with low raw material footprint, and vegetable-based proteins and oil ingredients are locally sourced.

When comparing the carbon footprint of BC farm-raised salmon to other agricultural proteins, farm-raised salmon (all species) have the lowest average [carbon footprint](#) compared to chicken, pork and beef as measured as kilograms of CO₂ per typical 40g serving (Figure 2) (13).

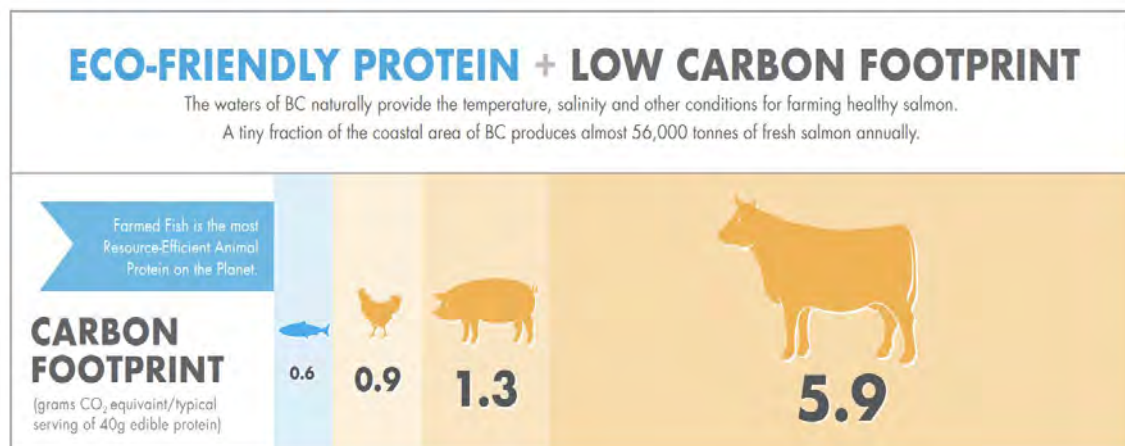


Figure 2. Comparison of the carbon footprint of farm-raised salmon to chicken, pork and beef.





CERTIFICATION PROGRAMS

There are many certification programs relevant to fish feeds and farm-raised salmon. In general, they endeavour to ensure that raw feed ingredients are sourced from environmentally and socially sustainable sources and that farm-raised salmon are reared in a similarly social and environmentally sustainable manner.



In terms of certifying Atlantic salmon farms in BC, there are two main standards, [Aquaculture Stewardship Council](#) (ASC) and [Best Aquaculture Practices](#) (BAP) (14, 15). All Atlantic salmon farms are currently BAP certified; some are also ASC certified. Creative Salmon's Chinook salmon farms are all organically certified according to the Canadian Organic Aquaculture Standard (16).

Part of BAP certification of Atlantic salmon includes compliance to feed standards. BAP Mill Standards encourage feed mills to actively favour responsibly managed and independently assessed marine ingredients. They also state that when available, terrestrial ingredients such as soy and palm oil are from certified sources, including any ingredients containing protein from the same genus as the species which will consume the feed. So, by-products of Atlantic salmon processing such as trimmings in Atlantic salmon feed is prohibited.

Farms that are ASC certified, among other things, source their feed from ASC certified feed mills. The ASC Feed Standard ensures that all feed ingredients are sustainably sourced. The Standard requires that ingredients that make up more than 1% of the feed (including fish meal and fish oil) must be traceable and responsibly sourced, that is

environmentally sustainable as well as socially responsible.

All companies work with their feed suppliers to ensure that the company standards and certification standards are met for all feed ingredients.

WHAT'S NEXT FOR FEED SUSTAINABILITY?

BC salmon farmers will continue to improve feed sustainability by:

- o working together with feed suppliers to optimize the use of sustainable raw ingredients,
- o increasing efficiency in feed production (decreasing carbon footprint), and
- o continuing to innovate feed delivery systems.

Companies continue to research new, more sustainable ingredients that can meet the needs of the fish, including their health and wellbeing, are available on a commercial scale, and are economical. We recognize the importance of and responsibility to strive to reduce our reliance on marine products.





REFERENCES

1. FAO. Code of Conduct for Responsible Fisheries. Rome: Food and Agriculture Association of the United Nations; 1995. p. 41.<https://www.fao.org/3/v9878e/v9878e.pdf>
2. Cargill Aqua Nutrition. 2022. Sustainability Report 2022. Minneapolis, MN <https://www.cargill.com/doc/1432219325606/cargill-aqua-nutrition-sustainability-report-2022.pdf>
3. Skretting. 2024. Responsible sourcing Stavanger, Norway: Nutreco; [Available from: <https://www.skretting.com/en/sustainability/responsible-sourcing/>].
4. Skretting. 2022. Sustainability report. Stavanger, Norway.<https://www.skretting.com/siteassets/global/sustainability/pdfs/skretting-sustainability-report-2022.pdf?v=4a9c6a>
5. Nuseed. 2023. Friend of the Sea Certifies Aquaterra® for Sustainable Omega-3 Oil: Nuseed Global; [Available from: <https://nuseed.com/aquaterra-certified-as-sustainable-omega-3-oil/>].
6. Glencross BD. 2022. Changing demands to global fishmeal use March 2024]. Available from: <https://www.iffco.com/changing-demands-global-fishmeal-use>.
7. IFFO. 2024. The sources of marine ingredients: Whole fish & by-products London. United Kingdom: IFFO – The Marine Ingredients Organisation [Available from: <https://www.iffco.com/sources-marine-ingredients-whole-fish-products>].
8. Colombo S. The colour of farmed salmon comes from adding an antioxidant to their feed, with benefits for everyone. The Conversation 2023.<https://theconversation.com/the-colour-of-farmed-salmon-comes-from-adding-an-antioxidant-to-their-feed-with-benefits-for-everyone-201344>
9. Fisheries and Oceans Canada. Aquaculture Activities Regulations guidance document. Ottawa: Government of Canada; 2018.<https://www.dfo-mpo.gc.ca/aquaculture/management-gestion/aar-raa-gd-eng.htm> - purpose
10. Canada FaO. Aquaculture Monitoring Standard - 2018. In: Aquaculture, editor. Ottawa: Government of Canada; 2018. p. 12.<https://www.dfo-mpo.gc.ca/aquaculture/management-gestion/aar-raa-ann7-eng.htm>
11. FAIRR. 2023. Coller FAIRR Protein Producer Index: FAIRR Initiative; [Available from: <https://www.fairr.org/tools/protein-producer-index>].
12. Skretting. Skretting sustainability report. Skretting; 2022. p. 94.<https://indd.adobe.com/view/3d322c33-3e34-40df-88d1-ae1210fedd36>
13. Global Salmon Initiative. 2022. Sustainability Report: Global Salmon Initiative;; [Available from: <https://globalsalmoninitiative.org/en/sustainability-report/>].
14. ASC. 2024. Setting The Standard for Seafood Utrecht The Netherlands: Aquaculture Stewardship Council; [Available from: <https://asc-aqua.org/>].
15. Best Aquaculture Practices. 2024. Keeping Fish in Our Future Portsmouth, NH, USA Global Seafood Alliance; [Available from: <https://www.bapcertification.org/>].

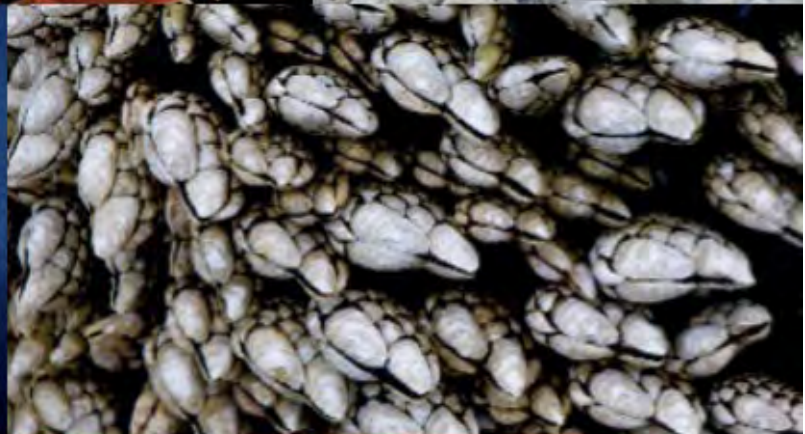
16. Canadian General Standards Board. 2018. Organic production systems, Aquaculture – General principles, management standards and permitted substances lists. Gatineau: Government of Canada. 33 p. https://publications.gc.ca/collections/collection_2018/ongc-cgsb/P29-32-312-2018-eng.pdf



CHAPTER 8

CARING FOR THE ENVIRONMENT

PROTECTING BIODIVERSITY



This chapter describes important measures salmon farmers take to protect biodiversity and discusses what is known about effects to the sea floor beneath the cages and along the shoreline

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CHAPTER HIGHLIGHTS – PROTECTING BIODIVERSITY

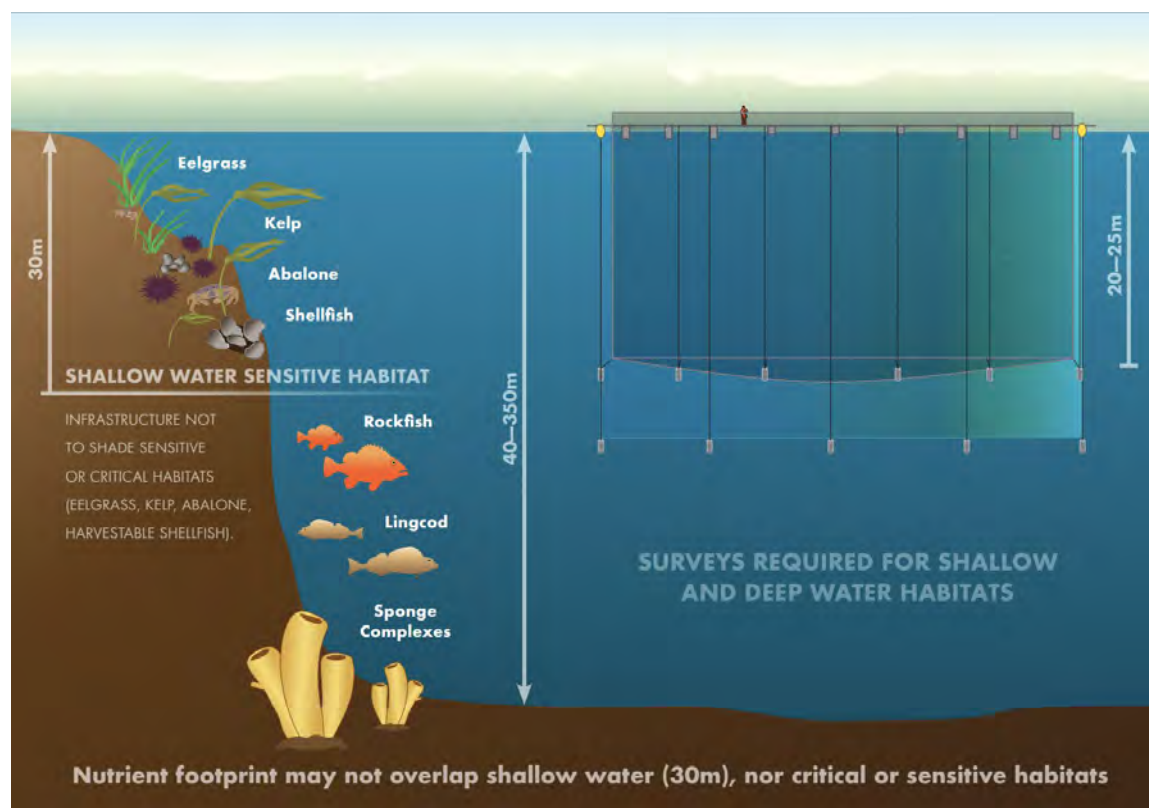
Protecting biodiversity is at the core of sustainable development. 100% of farm-raised salmon in BC is raised in partnership with local First Nations, who provide oversight and guidance on farm locations and operations.

Finding suitable places for salmon farms is a complex process that takes years. Federal, provincial and local governments have legislation and processes that protect wildlife and biodiversity. Farms must meet all of the criteria in order to be approved.

Once operational, farms must follow all laws to protect fish, fish habitat and wildlife. In particular, each farm must

demonstrate that its operations meet the requirements of the Aquaculture Activities Regulation. This includes monitoring the footprint beneath farms.

The nutrient footprint is one of the primary drivers determining how many fish can be grown at a site and when a site can be used. On average, 86% of farms in BC met seafloor thresholds each year from 2011 – 2022 and required no additional monitoring prior to restocking. Farms typically recover within a three-month fallow. About 1 to 1.5 million pounds of salmon per hectare are grown in each crop, which is an incredibly efficient and sustainable way to grow food.





The use of medicines at sea sites is strictly controlled in BC. Only products that are registered under the Pest Control Products Act (regulated by the Pest Management Regulatory Agency) and the Food and Drugs Act (regulated by the Veterinary Drugs Directorate of Health Canada) can be used and only under the authority and supervision of a licensed veterinarian. See “Chapter 11 – Caring for Fish Health” for more information.

Medicines prescribed by licensed veterinarians might deposit in the near field of farms, typically within the nutrient footprint (with the feed). On average, between 2016 to 2021, florfenicol was used at 47.8% of active sites each year, primarily to treat yellow mouth infections in newly smolted Atlantic salmon. This antimicrobial is water soluble and was not detected in a recent survey of farms across Canada.

Oxytetracycline was administered (on average) 9.7% at active salmon farms between 2016 to 2021. It has been found in low concentrations in sediments at several farms in BC; however, it is considered to have low toxicity to crustaceans (for example, it can be safely

used to treat bacterial infections in lobsters).

On average, 52% of BC Atlantic salmon farms were treated with the sea lice medicine, emamectin benzoate (SLICE®), each year between 2016 and 2021. It is administered via medicated feed pellets on average about 1.2 times per growing cycle. Ultra-low concentrations of emamectin benzoate have been detected at sea sites for more than a year; however, the concentrations have been below levels known to be harmful to BC crustaceans tested in laboratory exposure trials.

Hydrogen peroxide (Interlox®Paramove®50) baths were applied to an average of 22% of active Atlantic salmon farms from 2016 to 2021. Hydrogen peroxide is water soluble and rapidly degrades to its components of water and oxygen following release from well boats.

No farm-raised Chinook salmon were treated for sea lice from 2016 to 2021 in BC. Creative Salmon, who specialize in raising organic Chinook salmon, have never treated for sea lice in the 34 years they have grown Chinook salmon in BC.

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HOW DO WE ENSURE ECOSYSTEMS ARE HEALTHY?



The North Pacific Ocean is home to a spectacular assemblage of more than 10,000 species of marine life. Respecting and protecting this biodiversity is the responsibility of all coastal people, including salmon farmers.

This chapter describes how salmon farm locations are sited and operated in order to minimize potential effects on marine biodiversity arising from the presence of the farm infrastructure, feeding practices and from applying veterinary treatments to farm-raised salmon.

Salmon farmers, with guidance from First Nation advisors, have adopted a four-step approach to minimizing effects on biodiversity:

1. **Respect for First Nations Rightsholders** – input and guidance on how to protect biodiversity,
2. **Prevention - selecting suitability locations for salmon aquaculture** – selecting locations with environmental conditions suitable for growing healthy salmon; and careful siting to avoid sensitive and critical habitats,
3. **Monitoring** – routinely monitor farm footprints for potential impacts to biodiversity, and
4. **Mitigation** – careful operating practices and alignment of fish production to the capacity of the surrounding environment.

Each of these steps is described in detail in the following sections.

PROTECTING BIODIVERSITY STARTS WITH FARM SITING. HOW ARE FARMS SITED?



IT BEGINS WITH FIRST NATIONS APPROVAL

Today, 100% of farm-raised salmon in BC is grown in partnership with local First Nations (Figure 1). The continued operation of existing sites, and applications to change existing sites or apply for new sites occur through permissions and partnership agreements with Nations. Recognition of Indigenous

rights and their holistic use and occupation of their lands is at the forefront of all data collection and siting considerations. Please see Chapter 4 “Caring for Indigenous Stewardship - Connecting with the Original Guardians of the Coast” for more information.



Figure 1. Celebratory speeches given during the opening of Klemtu Spirit Hot Smoked Atlantic Salmon facility
[Klemtu Spirit \(klemtuspiritsmokedsalmon.com\)](http://klemtuspiritsmokedsalmon.com). (4)

ONLY A FRACTION OF THE COAST IS SUITABLE FOR FARMING SALMON

While BC has a large coastline, a relatively small proportion of the nearshore waters are suitable for growing salmon year-round in net pens. This is because salmon are sensitive to changes in water quality and thrive within narrow ranges of temperature and oxygen. Many of the initial farms in BC were located in shallow, protected bays that had limited water mixing and not well suited to growing salmon.

Today, First Nations Rightsholders and salmon farmers discuss where potential farms may be located. Then, oceanographic conditions at potential farm locations are investigated for months or years before advancing an application

to develop or modify a site. Information on water temperature, salinity, current speeds, water exchange rates, wave and wind exposure, plankton, and oxygen profiles is collected and assessed to determine if a location is suitable for growing salmon. The goal is to find optimal conditions to grow healthy salmon.

Farm-raised Atlantic salmon grow best in sites where water temperature ranges from 6-16 °C, salinities are close to oceanic levels (33-34‰), and water flows need to be sufficient to supply well oxygenated water (ideally 7 – 10 parts per million oxygen) (5). Farm-raised Chinook salmon have similar requirements.

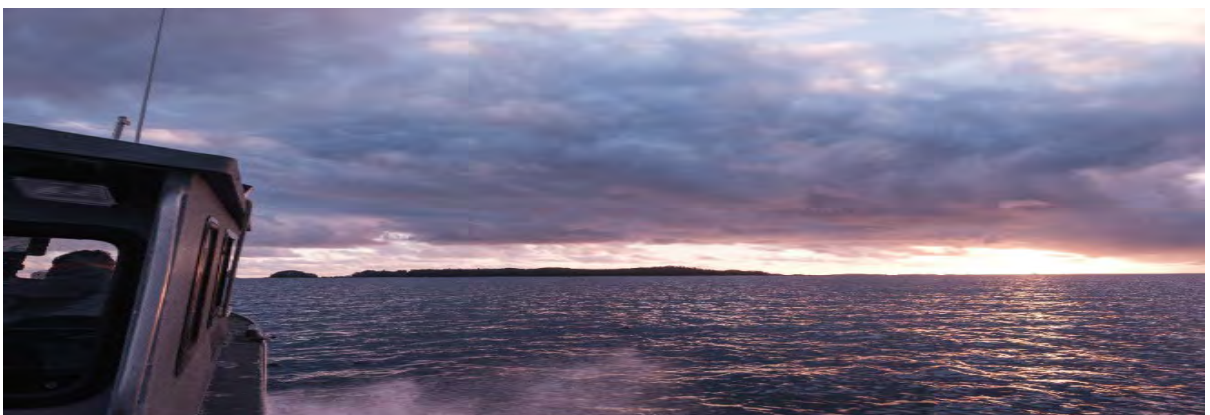




In BC, ocean currents and winds are arguably the most important physical criteria for site selection to ensure there is adequate water mixing to moderate temperature, provide continual oxygen to the fish in the pens, and prevent water stratification, which can lead to plankton blooms. During summer months, in the presence of plankton blooms, oxygen levels may drop below 5 parts per million and cause extreme stress to salmon in the net pens. This is the leading cause of mortality for farm-raised salmon in BC (see “Chapter 11 – Caring for Fish Health” for more information). These variables are constantly monitored at every salmon farm in BC (Figure 2).



Figure 2. Water quality and plankton monitoring are essential for understanding growing conditions for salmon



MEETING REGULATORY CONDITIONS FOR NEW SITES

There are many regulations that protect fish, fish habitat and wildlife in BC (see Appendix A). The Department of Fisheries and Oceans (DFO) has specific siting guidelines for marine finfish farms to avoid critical and sensitive habitats and protect biodiversity (see Table 1). Salmon farmers must demonstrate how they meet all of these requirements for any new site application.

All new site applications and amendments in BC require formal applications through Front Counter BC following the Pacific Region Marine Finfish Aquaculture Application guidebook (6). There are three lead government agencies within the application:

- o **Ministry of Water, Land and Resource Stewardship** - responsible for managing Crown land, including the issuance of land tenures. This includes tenures for aquaculture facilities and ancillary uses on land covered by water, upland and foreshore.
- o **DFO** - responsibility includes most aspects of the aquaculture industry including, but not limited to: species cultured, production practices and volumes, fish containment, fish health, sea lice levels, marine mammal and escape mitigation, and fish habitat protection measures.
- o **Transport Canada** - responsible for reviewing and approving applications for the placement of aquaculture containment and/or structures within the navigable waters of Canada.



Table 1. DFO siting guidelines for marine finfish aquaculture in British Columbia. (7)

General Siting Considerations

Management Objective – farms must respect First Nations Rights and Title and have the required permits, tenures and authorizations

- o Siting must be consistent with all legislation and agreements governing Indigenous relations
- o Provincial land tenure and Navigable Waters Permit
- o No siting within Marine Protected Areas, unless exempted within regulations

Potential fish, fish habitat and environmental impacts

Management Objective - farmers must minimize potential impacts to the environment (e.g., seabed) that might result in a negative impact on existing commercial, recreational or aboriginal (CRA) fisheries or important/valued ecosystem components

- o Farms should be capable of meeting performance measures for benthic conditions, as identified in the Aquaculture Activities Regulations
- o Predicted footprint of increased deposition should be located in water depth of greater than 30 m to mitigate potential impacts to shallow water habitats
- o A minimum distance of 10m should be maintained between the bottom of the facility infrastructure (i.e., netting, predator nets etc.) and the seabed to mitigate potential impacts from direct contact
- o Placement and operation of the proposed aquaculture facility should not impact Species at Risk Act (SARA) listed species

Potential impacts to existing fishery activities

Management Objective - minimize and/or mitigate potential impacts on existing fisheries. Within this objective, Aboriginal Rights to fish for Food, Social and Ceremonial (FSC) purposes have priority, after conservation, over other uses of the aquatic resource

- o Placement and operation of the proposed facility in relation to First Nations' ability to access fish for Food, Social and Ceremonial (FSC) purposes will be evaluated
- o Placement and operation of the proposed aquaculture facility in relation to existing commercial, recreational or aboriginal (CRA) fisheries will be evaluated

Fish health and wild-farmed interactions

Management Objective - Minimize and/or mitigate potential risks to the health of wild and farmed stocks resulting from interactions between wild and farmed fish

- o Siting of aquaculture facilities will take into consideration potential impacts to the health of wild migratory salmon and other fish stocks
- o Aquaculture facilities should be located at least three kilometers from an existing marine finfish facility or operate under coordinated Health Management Plans

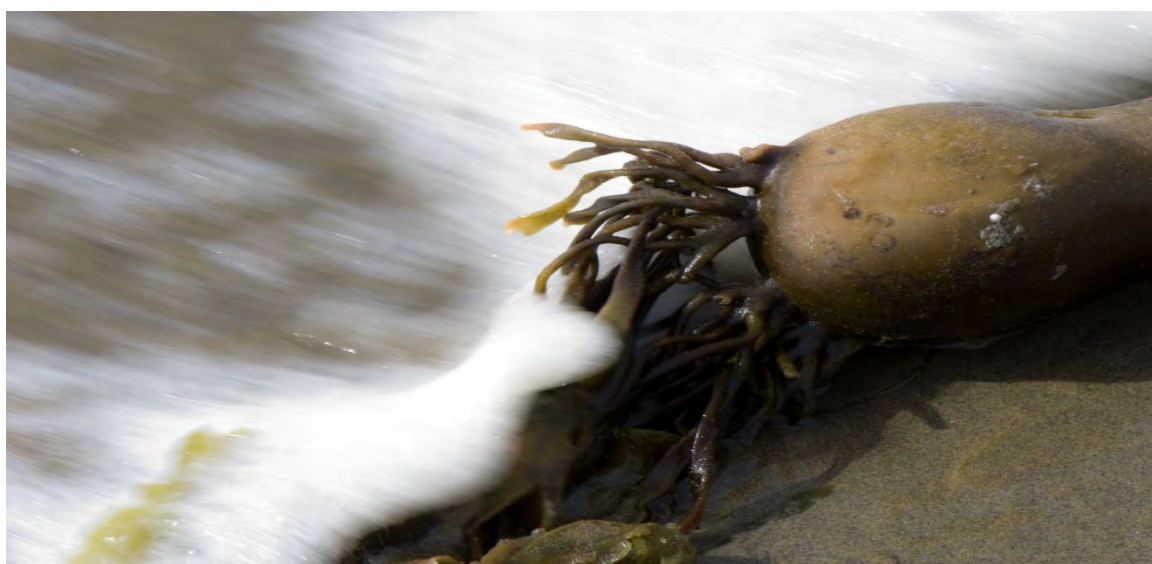


Photo by Brian Kingzett

COLLECTING BASELINE INFORMATION

Detailed environmental information is required for each site application, according to:

- o Agreements with First Nations Rightsholders,
- o the Guide to the Pacific Marine Finfish Aquaculture Application (6), and
- o the Baseline Fish and Fish Habitat of the Aquaculture Activities Regulation (8).

It can take several years to collect all of the necessary baseline information. This includes physical information about the geography of the site and water movements (ocean current flow measurements, bathymetry and seabed habitat mapping).

Comprehensive information is collected to understand the size, location and magnitude of the potential nutrient footprint:

- o Water movement data is used to program DEPOMOD, a footprint



- simulation model, to predict the location and intensity of the depositional footprint beneath the cages,
- o Underwater video of the seafloor within the proposed tenure and along the shoreline is collected and BC Registered Professional Biologists identify organisms and any sensitive or critical habitats encountered,
 - o Seafloor sediments are collected and analyzed, and
 - o Ultimately, this information is used to demonstrate that the predicted farm nutrient footprint will meet benthic management performance measures set out in the Aquaculture Activities Regulations (9).

Shoreline surveys within the proposed tenure area are completed by BC

Registered Professional Biologists.

This includes assessments of potential sensitive and critical habitats.

Depending upon site conditions, this may include monitoring for northern abalone, eelgrass beds, kelp beds, intertidal clam beds, subtidal clam beds, rockfish and ling cod habitats, and mapping of any high concentrations of glass sponges or complexes within the proposed tenure rearing areas.

The proposed farm infrastructure and anticipated nutrient footprint must be sited to avoid overlapping with sensitive and critical habitats (Figure 3). Additional monitoring may be required if the feature is within the tenure but not within the nutrient footprint.



Photo by Brian Kingzett

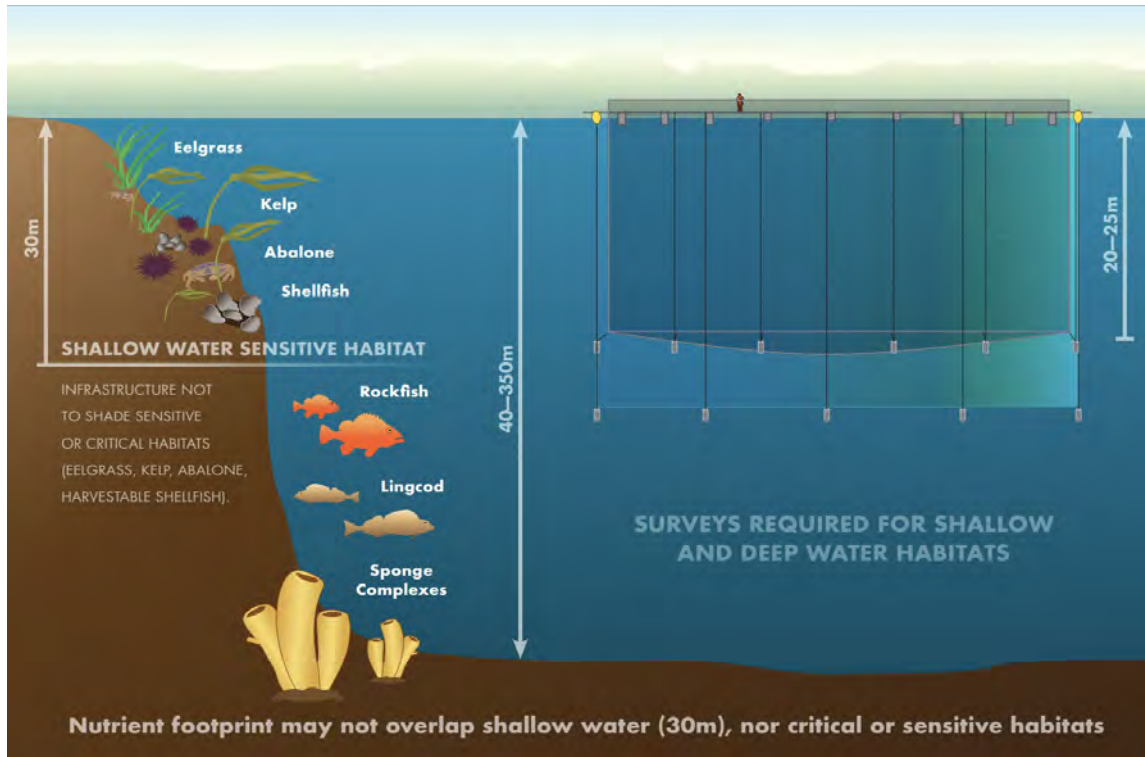


Figure 3. *Schematic of potential critical and sensitive habitats and required baseline surveys and siting restrictions.*

Information on wild fish and marine mammals must also be provided. This includes:

- o Mapping historical Pacific herring spawn and completing standard stream assessments for wild salmonids within a five-kilometer radius of the proposed site (10),
- o The application review process considers known salmon migratory routes, holding/rearing/resting areas for salmon, the status of the local Pacific Salmon Conservation Unit, and the location of anadromous salmonid spawning habitat,
- o Marine mammal usage of the proposed area must be provided,
- o Detailed maps are developed to show the potential placement of farm infrastructure along the seafloor and shoreline, information collected in the environmental surveys, and the results of the DEPOMOD simulations (Figures 4 and 5), and
- o Management plans for fish production, fish health, escape prevention and response, and marine mammal interactions are also required in the initial submission to Front Counter BC.

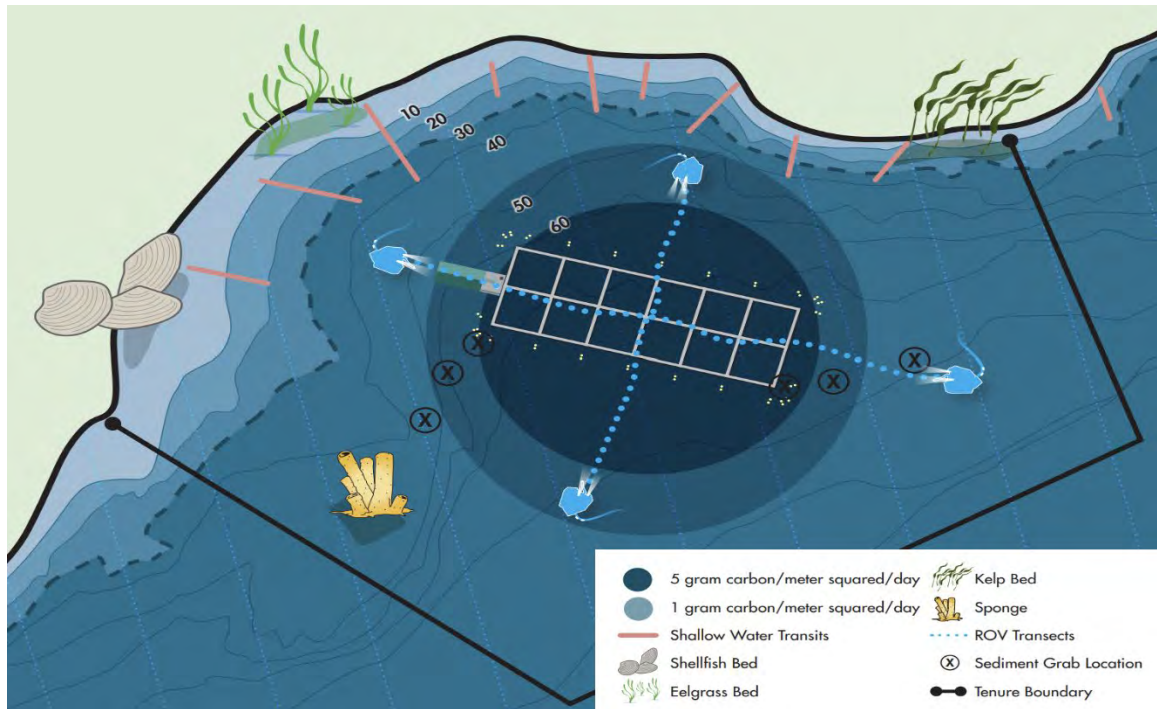


Figure 4. Depiction of proposed cage array, seafloor surveys and predicted nutrient footprint as estimated by the footprint simulation model DEPOMOD.

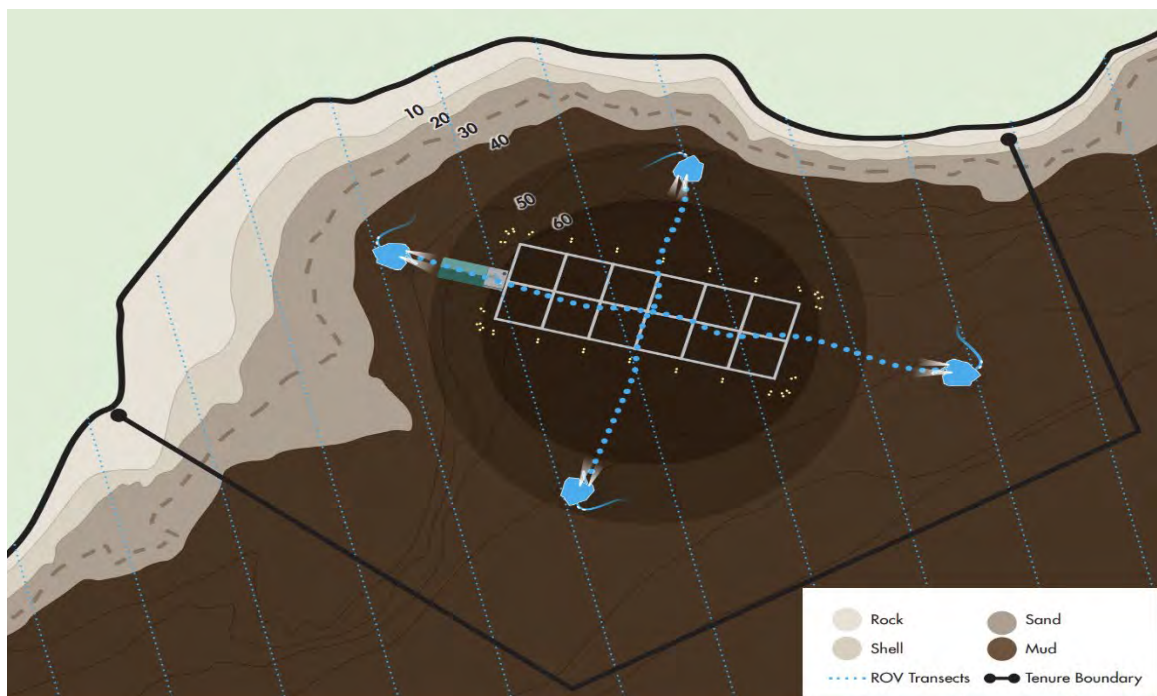


Figure 5. Depiction of seafloor habitats.

WHAT IS THE FOOTPRINT SIMULATION MODEL DEPOMOD?

DFO has management thresholds limiting both the size and intensity of the nutrient footprint of farms (9). Since 2004, DFO has required that all farmers use the simulation model DEPOMOD to estimate the dimensions of the nutrient footprint when the farm is using the maximum amount of feed during a production cycle (typically just before harvest) (11). The model is also used to predict the 'average' footprint for the entire production cycle.

The DEPOMOD model uses inputs on the size of the operation, location, feed inputs, and environmental data like current speed and direction and bathymetry, to track particles and predict

the deposition of carbon and total solids and the impacts of that deposition on the benthic environment.

DFO considers a deposition rate of 5 grams of carbon/ meter²/day of seafloor to be a threshold of significant impact. For any new farm or significant amendment, DFO will not allow the 5-gram carbon contour to overlap shallow water (less than 30 meters depth) (Figure 6). A carbon flux less than 1-gram of carbon has been shown to indicate a healthy and diverse benthic community (11); however, shoreline surveys are required if it overlaps with shallow water.

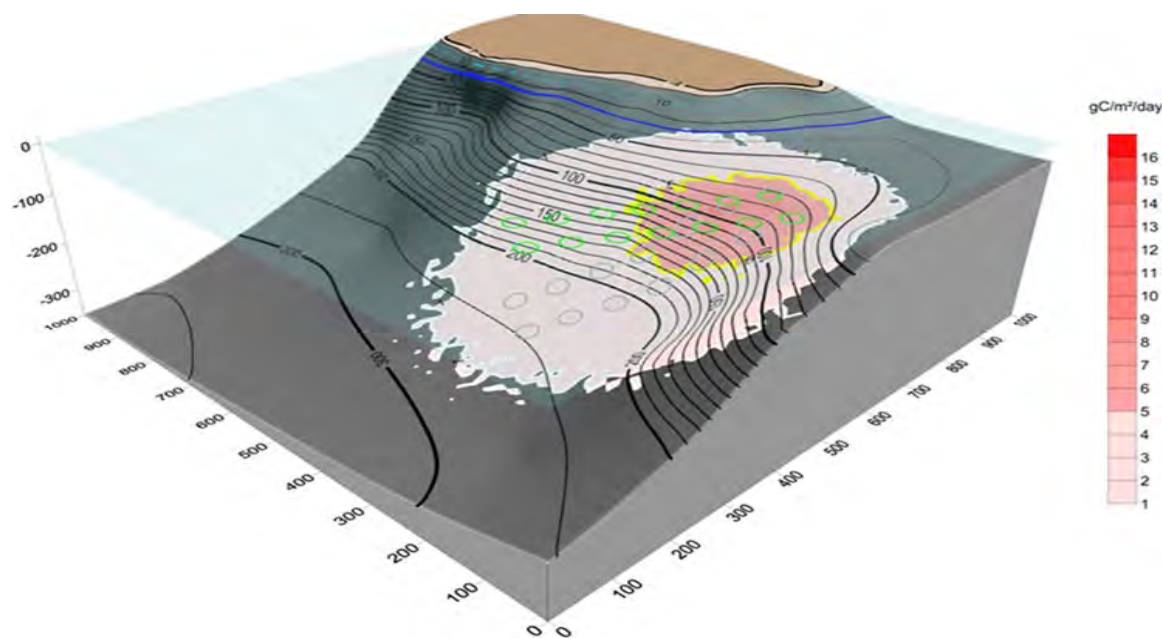


Figure 6. *Example of DEPOMOD footprint simulation model.*

Note: Farm cages shown as green circles. The shore is shown as brown. Black contours depict depth in meters. The predicted deposition of carbon (grams/m²/day) is shown in the colored footprint, according to the legend bar on the right of the figure. The 5 gram carbon/m²/day contour is outlined in yellow. The sensitive shallow water 30m depth contour is shown in dark blue. Note that the 5 gram carbon/m²/day contour does not overlap shallow water. The majority of the footprint is closer to 1 gram carbon/m²/day, indicating a minimally impacted benthic environment.



EVALUATING A NEW SITE APPLICATION



The three agencies evaluate each application according to their mandates.

- o DFO assesses each application according to the siting guideline themes, acts and regulations, and their Pathway of Effects for Finfish and Shellfish Aquaculture with consideration for mitigation measures (Appendix B) (12). If DFO considers the potential impacts to be unacceptable, the application may be declined.
- o Transport Canada reviews infrastructure and locational details according to Navigation Protection Act rules. They also review

environmental assessment information.

- o The BC government assesses the infrastructure and intended use of the site for consistency with local land use bylaws and zoning, land use plans and marine plans, and checks for potential conflicts with the riparian rights of other upland owners and eelgrass meadows and kelp beds. They also have set back distances from First Nations reserves, parks and conservancies and salmon-bearing streams.
- o All three agencies consult with local First Nations.

PROTECTING BIODIVERSITY - WHAT IS IN THE FARM FOOTPRINT?

The farm 'footprint' consists of three classes of substances managed under the Aquaculture Activities Regulation(9):

1. Biochemical oxygen-demanding matter (BOD) – nutrients released by uneaten feed and fish fecal material, and fouling debris that is removed from nets to maintain water flow,
2. Medicines – antimicrobials that are prescribed by licensed veterinarians, and
3. Pesticides – sea lice medicines that are prescribed by licensed veterinarians (Figure 7).

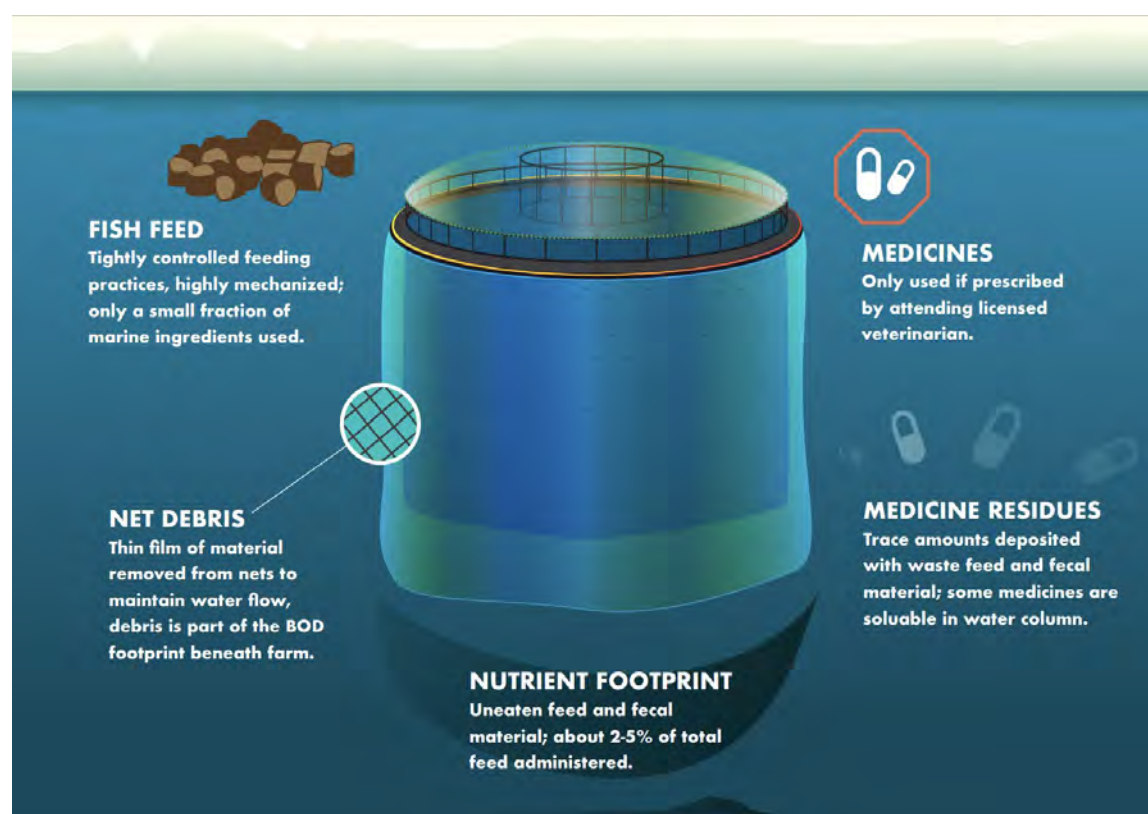


Figure 7. Schematic of inputs and outputs from cages at salmon farms in BC. See "Chapter 7 – Caring for the Environment – Feed Sustainability", "Chapter 10 – Caring for Wild Salmon – Sea Lice Management", and "Chapter 11 – Caring for Fish Health" for more information on feeding practices and the use of medicines at sea sites.



WHAT IS IN THE NUTRIENT FOOTPRINT?



The nutrient footprint at a farm is created by the deposition of fish feces, minor amounts of fish feed, and biofouling material from net cleaning on the seafloor directly beneath and adjacent to the farms. This “BOD benthic footprint” is unique to each farm as it is dependent upon local currents, water depth, prevailing winds, bottom substrate, and farming practices.

The size, location and intensity of the “BOD benthic footprint” has been regulated in British Columbia since 2002 (initially the BC Waste Management Act, Finfish Aquaculture Waste Control Regulation) (13); and subsequently through DFO site aquaculture license

conditions and the Aquaculture Activities Regulation.

Nets are maintained with small cleaning units that routinely remove thin skins of growth off the fibers to maintain water flow for the salmon (Figure 8). Any nutrients that fall to the seafloor are included in the thresholds administered in the Aquaculture Activities Regulation.

Trace elements such as copper and zinc are also found in uneaten feed and feces. At some farms, copper is used as a net antifoulant, although the majority of the BC sector has discontinued this practice.

The nutrient footprint (i.e., BOD benthic footprint) is *one of the primary drivers* determining where farms can be located, how many fish can be grown, and the length of the fallow period between crops. Individual farms and company fish production schedules rely on sustainable seafloor performance.



Figure 8. *View of net scrubber in pen.*
Routine net cleaning prevents biofilm build up on nets and maintains water flow for salmon.



WHAT HAPPENS TO MEDICINES USED ON SITES?

Veterinarians may prescribe treatments for fish. The use of antimicrobials (antibiotics) at BC salmon farms is strictly controlled in BC:

- o Only products that are registered under the Pest Control Products Act (regulated by the Pest Management Regulatory Agency) and the Food and Drugs Act (regulated by the Veterinary Drugs Directorate of Health Canada) can be used (14), and only under the authority and supervision of a licensed veterinarian (Figure 9).
- o The Aquaculture Activities Regulations requires that veterinarians consider using other non-chemical viable alternative measures. Where no alternative measures would be effective, the use of chemical products may be approved.
- o Licensed veterinarians consider a variety of information, including fish behaviour, environmental conditions, laboratory tests, site records and information from monthly site visits and from an ongoing dialogue with site managers, to determine the appropriate prescription for maintaining the health of farmed fish (see “Chapter 11 – Caring for Fish Health” for more information).
- o Unlike other agri-food sectors, antimicrobial use in salmon farming is only for clinical disease, there are no prophylactic treatments, and usage is tracked and publicly reported (15).
- o All medications used at sites must be reported through the Aquaculture Activities Regulation(16).
- o The two main antimicrobials used in BC are florfenicol and oxytetracycline. Both are broad-spectrum (effective against a variety of organisms) and administered as medicated feeds for short periods of time (example, 10 days).
- o Florfenicol is primarily used to treat “yellow mouth” (also known as “mouth rot”) infections caused by *Tenacibaculum maritimum* at sites with newly stocked Atlantic salmon (see “Chapter 11 – Caring for Fish Health” for more information). Once fish are larger than 500 grams, they are not generally susceptible to yellow mouth; therefore, florfenicol is typically administered for several weeks every two to three years at Atlantic salmon farm sites depending upon production cycles. On average, florfenicol was administered at 47.8% of marine sites each year from 2016 to 2021 (Figure 10).

Only products that are registered under the Pest Control Products Act (regulated by the Pest Management Regulatory Agency) and the Food and Drugs Act (regulated by the Veterinary Drugs Directorate of Health Canada) can be used at BC salmon farms, and only under the authority and supervision of a licensed veterinarian.

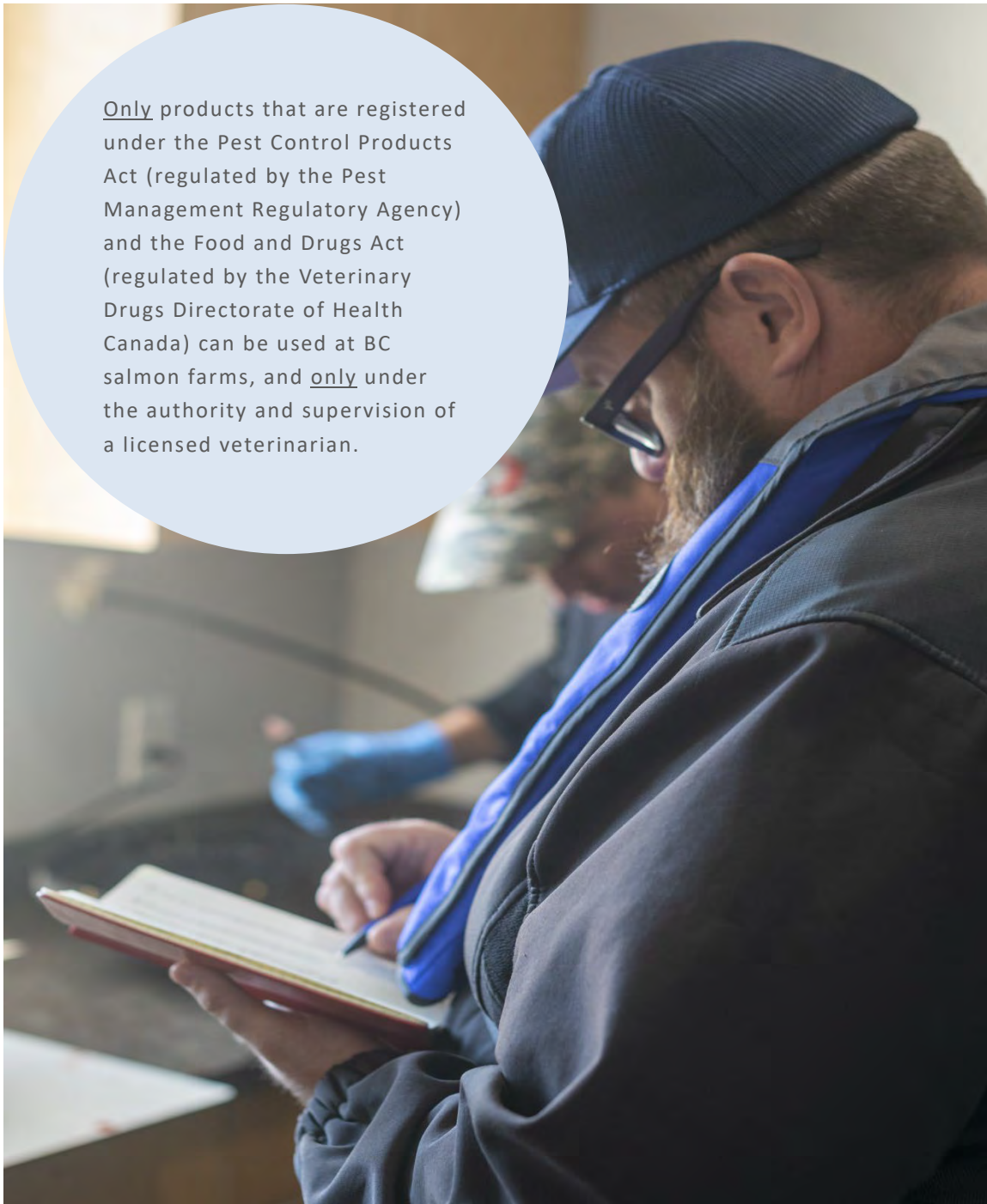


Figure 9. Licensed veterinarian completing a fish health check at a newly stocked Atlantic salmon farm.

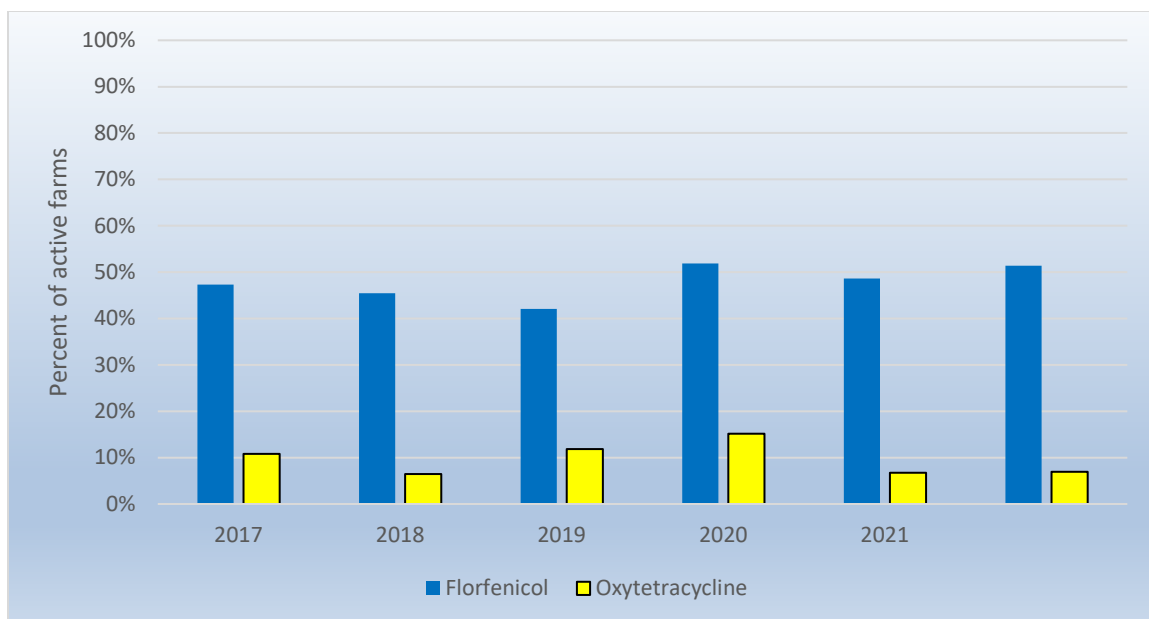


Figure 10. Percentage of active salmon farms in BC where florfenicol and oxytetracycline antimicrobial treatments were administered 2016 to 2021.

Data source: [National Aquaculture Public Reporting Data](#) (16)

Oxytetracycline is used to control certain gram-negative bacteria that cause infections in salmonids (e.g., furunculosis, *Vibrio*, salmonid piscirickettsiosis (SRS), and bacterial kidney disease (BKD)). On average, from 2016 to 2021, oxytetracycline was administered at 9.7% of the sea sites (Figure 10). Erythromycin, an injectable antimicrobial, is rarely used in BC – it was used twice from 2016 to 2021, to treat bacterial kidney disease in broodstock fish not destined for consumption by consumers.

Very few farms used more than one antimicrobial in the same year (one to four farms/year out of an average of 75 operating farms/year) between 2016 and 2021. Vaccination of fish in freshwater, and improved vaccine efficacy have greatly reduced the need for antimicrobial treatments for several diseases (*Aeromonas salmonicida* (Furunculosis), *Vibrio anguillarum*, and *Moritella viscosa* (winter ulcer)).

Fate in the Environment

The antimicrobials are delivered to salmon via food pellets. Residues may be released into the environment as either: dissolved within the water column, or within fish waste, or uneaten feed pellets.



Florfenicol is water soluble and breaks down in the presence of water (hydrolysis) and light (photolysis) thus limiting its persistence in the environment. Florfenicol is estimated to have a half-life (the time it takes to decrease to 50% of the original concentration) of 4.5 days in the sediment beneath farms (17), while oxytetracycline is around 150 days (18). Although

oxytetracycline persists longer in the environment, it is considered to degrade rapidly in seawater (19), and its antimicrobial activity decreases once bound to the sediments (14).

Oxytetracycline has low toxicity to crustaceans as it can be used to safely treat bacterial infections in crustaceans such as lobsters (20).

In a recent study of ten salmon farms in Canada, florfenicol was not detected in the sediments at any site, confirming that the antimicrobial disperses rapidly and is not readily absorbed into the seafloor, while oxytetracycline was detected within the enriched organic footprint of the farms (3).

Between 2019 and 2022 additional monitoring for florfenicol was completed for Aquaculture Stewardship Council certification in British Columbia. Samples during this monitoring were taken at stations 25m outside the 1g C/day DEPOMOD contour and at two reference stations. In all cases samples have been below the laboratory's detectable limit (2.0 -5.0 ppb). A key describing chemical concentrations is presented in Table 2. See Appendix C for descriptions of exposure and ecotoxicity in the marine environment.

*Table 2. Description of chemical concentrations.*

Solutions (mass per volume)		Solids (mass per mass)		Parts per notation	Example
g/L	mg/mL	g/Kg	mg/g	Parts per thousand; ‰	1 second in 17 minutes
mg/L	µg/mL	mg/Kg	µg/g	Parts per million; ppm	1 second in 11.5 days
µg/L	ng/mL	µg/Kg	ng/g	Parts per billion; ppb	1 second in 32 years
ng/L	pg/mL	ng/Kg	pg/g	Parts per trillion; ppt	1 second in 31,700 years

Both florfenicol (21, 22) and oxytetracycline have low toxicity (20), however rather than toxicity, most of the concern around the use antimicrobials is the potential for the development of antimicrobial resistance in fish, non-target organisms, the bacterial community, and even humans. The development of antimicrobial resistance is complex and depends on numerous factors such as:

- o the type of bacteria present,
- o the environmental conditions (ocean currents, seafloor bottom type) (Figure 11),
- o the concentration of exposure to antimicrobials, and
- o the duration of exposure to antimicrobials (in BC, fish receive medicated feed for short durations, typically ten days).

Researchers found that concentrations of oxytetracycline used within many aquaculture operations do not pose a high risk of causing major changes in sediment bacterial community structures, however the influence of local, site specific conditions warrants further investigation (23).

There are no environmental quality standards or threshold values for oxytetracycline deposition in Canada. Studies have developed Predicted No Effect Concentrations (PNEC) based on development of antibacterial resistance (which is more sensitive than traditional toxicity-based results). However, these values have either been derived for water or freshwater sediment exposures, and may not be appropriate for marine sediments, especially given the influence of sediment type and characteristics on the fate of oxytetracycline.

Currently there is no known evidence of harm to the surrounding marine environment due to the use of antimicrobials in salmon farming in BC. While antibiotic resistant genes (ARGs) have been detected in the vicinity of aquaculture sites in eastern Canada, the impact of these genes, which are found naturally throughout the marine environment, remains unknown.

A suggested Predicted No Effect Concentration (PNEC) for development of antimicrobial resistance is 10,000 ppb dry weight (2), which is ~100 times greater than the available measured concentrations in sediment in BC (3).

Recent data have shown that Atlantic salmon farms in the Bay of Fundy are host to vibrant microbial communities, and that these communities differ in structure depending on their distance from farm sites (24). Within these communities, as well as in microbial communities from reference sites and sites near wastewater treatment outflows, there was detection of ARGs.

These results highlight that ARGs are common in the marine environment, and that their concentrations in microbial communities can vary widely, over a million times (six orders of magnitude). However, the patterns and association of ARGs with antimicrobial drugs (e.g., florfenicol and oxytetracycline) were not consistent, and the implications for potential transmission to other organisms is yet unknown. Further research into this topic is ongoing.



Figure 11. Underwater view of monitoring transect crossing into shallower nearshore water.

Note: Many salmon farms in BC have rocky bottoms with fast currents and little evidence of nutrient accumulation.



WHAT HAPPENS TO SEA LICE TREATMENT MEDICINES IN THE ENVIRONMENT?

Sea lice treatments generally occur at Atlantic salmon farms during the spring juvenile wild salmon outmigration window (March 1 – June 30). There are four methods veterinarians can prescribe to remove sea lice in BC: water jets (mechanical delousers), freshwater baths (Figure 12), emamectin benzoate (SLICE® - classified as an in-feed drug) and hydrogen peroxide (Interlox®/Paramove®50 – classified as a pesticide).



Figure 12. Sea lice are routinely removed in freshwater baths within the hold of the AquaTromØy vessel.

Note: The vessel has onboard reverse osmosis equipment that generates freshwater from seawater.



The use of chemical medicines to manage sea lice is strictly controlled in BC:

- o Only products that are registered under the Pest Control Products Act (regulated by the Pest Management Regulatory Agency) and the Food and Drugs Act (regulated by the Veterinary Drugs Directorate of Health Canada) can be used (14), and only under the authority and supervision of a licensed veterinarian.
- o Before the use of pest control products, the Aquaculture Activities Regulations requires that other non-chemical viable alternative measures be considered. Where no alternative measures would be effective, the use of chemical products may be approved.
- o These products may only be used under the authority and supervision of a registered veterinarian, and their usage must be reported through the Aquaculture Activities Regulation (Source: Government of Canada, [National Aquaculture Public Reporting Data](#)) (16).

- o The use of pesticides must follow the application details within the registered product label, while the determination of the appropriate prescription for the use of drugs is determined by the veterinarian.
- o The prescribing veterinarian's decision is informed by trends in sea lice counts and site-specific aspects (i.e., life stage of farmed fish, environmental conditions, prior treatments, and conditions of license), and dialogue with site managers.
- o The use of hydrogen peroxide in BC also requires a Pesticide Use Permit regulated by BC Integrated Pest Management Act (Source: [Integrated Pest Management Act](#)) (25).

Medicinal chemical treatments of sea lice at BC salmon farms are summarized in Figure 13. On average, SLICE® was administered to fish at 52% of sites and 22% of the sites administered Interlox®Paramove®50 hydrogen peroxide treatments. No farm-raised Chinook salmon were treated for sea lice.

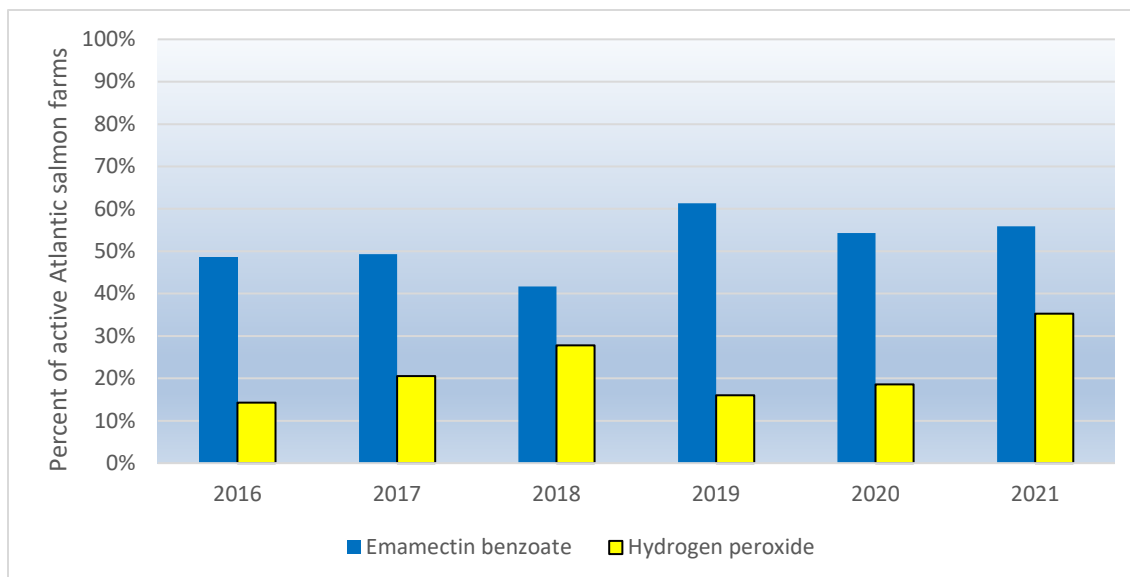


Figure 13. *Percentage of active salmon farms in BC where sea lice treatments, Emamectin benzoate (SLICE®) and hydrogen peroxide (Interlox Paramove® 50), were administered 2016 to 2021.*

Data source: [National Aquaculture Public Reporting Data](#) (16)

EMAMECTIN BENZOATE (SLICE®)

Emamectin benzoate, also known as SLICE®, is added to fish feed for a short duration (typically seven days) to control all stages of sea-lice (motile and non-motile). SLICE® can offer protection against sea lice infestation for up to 60 days because it is slowly metabolized and excreted by treated fish. It is administered at ultralow doses (50 ppb), totaling on average 26 kg of active ingredient used for the entire BC salmon farming sector from 2016 - 2021 (16).

On average, BC Atlantic salmon farms treat 1.2 times per crop of fish (i.e., it is administered for about 1 week of the typical 72 to 96 week production cycle). The concentration of emamectin benzoate in medicated feed pellets ranges from 1 to

25 ppm; the most common dosage is 10 ppm (26).

SLICE® can enter the environment through fish waste and uneaten medicated feed. It has low water solubility (does not dissolve readily in seawater) and binds tightly with seafloor sediments (27) and is considered to be an immobile chemical that will not readily move into the environment (28). SLICE® has a reported environmental half-life (time it takes to reduce to 50% of the original concentration) between 100 and >400 days (29) (30).

The environmental concern with the use of SLICE® centers around the potential exposure to sea floor organisms including non-target crustaceans (e.g., crabs, shrimp

and prawns) (31). Once SLICE® enters the environment there are three potential avenues of exposure for marine organisms:

- o the dissolved fraction in the water column,
- o direct consumption of medicated feed pellets or fish waste, or
- o exposure to what is bound to the sediments.

Researchers have reported that American lobsters (32, 33), BC spot prawns (26), and BC Dungeness crab (34) avoid feed pellets that contain SLICE®. Given the general avoidance for feed pellets and preference for other food items, it is unlikely that the wild lobsters would ingest a sufficient amount of medicated pellets to cause the adverse effects observed in these laboratory studies which utilize force-feeding (31).



Photo by Brian Kingzett

For toxicity to be realized:

- o an **organism has to be exposed** to the potential toxicant in its habitat, **AND**
- o the potential toxicant has to be in a form that is **available for uptake**, **AND**
- o the uptake (dose) of the contaminant has to be **at a level that causes toxicity** to the particular organism.



Photo by Brian Kingzett

Researchers have reported that American lobsters, BC spot prawns, and BC Dungeness crab avoid feed pellets that contain SLICE®.

In BC, a researcher found that BC spot prawns were able to detect and avoid medicated pellets containing low concentrations of emamectin benzoate (i.e., concentrations at the lowest range of doses used in feed pellets, and about one tenth the dose typically used in feed pellets) (26). No increased mortality or molting was observed with feeding spot prawns, even with feed pellets containing 4X the maximum potential dose used at salmon farms (26).

Given that SLICE® has low water solubility and binds tightly with seafloor sediments, the likelihood that the therapeutic would be found in the water column around farm sites is very low (35). In 2011, an assessment of the fate of SLICE® near salmon farms in BC completed for the

Canadian Science Advisory Secretariat (CSAS) reported ultra-low water column concentrations of 0.0006 parts per billion (ppb) emamectin benzoate within 50 meters of net pens one day after a SLICE® treatment, falling to below the method limit of quantification of the laboratory equipment for measuring water concentrations (0.000006 ppb) at a distance of 150 meters (36).

In a laboratory trial, BC spot prawns did not exhibit increased molting or mortality when directly fed pellets containing 4X the maximum medicated dose in feed pellets used at salmon farms.

The main exposure pathway for organisms to SLICE® released in the environment appears to be through contact with sediments. Three studies in BC found low concentrations of emamectin benzoate in sediments near salmon farms, ranging from 0.07 to 35 ppb, with the majority below 1 ppb (3, 26, 36).



Figure 14. Deepwater video transect within farm nutrient footprint, food and fecal material are rarely seen in abundance.

In BC, reported concentrations of emamectin benzoate in sediments near salmon farms range from less than 0.07 ppb to 35 ppb, with the majority below 1 ppb. In laboratory trials, BC spot prawns have exhibited negative effects when exposed to sediments containing higher concentrations than what has been found near salmon farms in BC.

A laboratory-based examination of BC spot prawns reported negative effects following an 8-day exposure to sediment containing more than 100 ppb (wet weight) emamectin benzoate (37), however increased mortality was not observed at much higher sediment concentrations (1,200 and 4,800 ppb) (38). A second laboratory study found elevated mortality after thirty days of exposure to sediments containing 735 ppb (26). Molting was not affected in either study. These concentrations are higher than anything reported in sediments at salmon farms in BC (36).

With respect to crustaceans dwelling *within* the sediments beneath farms, in 2010, a laboratory-based examination of the Canadian west coast crustacean *Eohaustorius estuarius* reported that sediment concentrations of 185 ppb emamectin benzoate (wet weight of sediments) were toxic after 10 days of exposure (39). This sediment concentration is 5X higher than what has been observed in sediments near salmon farms in BC.



Toxicological studies examining the impact of emamectin benzoate on species other than the ones described above have been completed by researchers from other parts of the world; however, these might not be of direct relevance to resident species found in the coastal areas of Canada.

HYDROGEN PEROXIDE (INTEROX® PARAMOVE®50)



Figure 15. View of specialty vessel equipped with live wells in the hull where Interlox®Paramove®50 treatments are performed.

Farm-raised fish are pumped into and out of the vessel for treatment.

Hydrogen peroxide (Interlox®, Paramove®50) is used in sea lice treatment baths to cause pre-adult and mature lice to detach from the host fish. Atlantic salmon farmers have vessels with live wells that are designed to administer the treatment (Figure 15). Due to the capacity of the vessels, it takes multiple days to treat all the pens.

As hydrogen peroxide is water soluble and administered in the upper water-column it does not tend to be detectable in the sediment (40, 41). It is expected to remain in the water column for a short time following release and will rapidly disperse and degrade into its components of water

and oxygen (42), and it is considered as non-persistent in the environment (14).

Hydrogen peroxide has a registered dosage of 1.2 – 1.8 g/L (42), and studies with tracker dyes have shown that concentrations of dye are reduced by a thousand times (three orders of magnitude) within 3 to 5 hours post release from a treatment tarp by dilution alone (43), suggesting that the combined actions of dilution and degradation of released hydrogen peroxide will quickly diminish concentrations.

The Pest Management Regulatory Agency (PMRA) has assessed potential impacts of

the use of hydrogen peroxide on non-target species and concluded that “the long-term use of hydrogen peroxide, taking cumulative impacts into consideration, is expected to not pose risks of concern to non-target marine organisms such as mammals, crustaceans,

birds, adult lobsters, lobster larvae, copepods or fish.” (42).

For more information, please see the Registration Decision [RD2016-18](#), Hydrogen Peroxide (44).

MEETING REGULATORY CONDITIONS FOR THE NUTRIENT FOOTPRINT

Seafloor monitoring occurs within 30 days of maximum fish tonnage at each site, in order to monitor the maximum nutrient footprint at each farm. Third-party BC Registered professional biologists are retained to complete the monitoring according to the requirements of the Aquaculture Activities Regulation (9). The type of survey depends upon the seafloor characteristics; defined as either “soft bottom” (where a sediment grab can be used) or “hard bottom” (where an underwater camera must be used).



In 2002, the BC Ministry of Environment set environmental thresholds for the farm nutrient footprint at “soft bottom” sites and prescribed underwater video

monitoring methods for “hard bottom” sites where sediment grab samples were not obtainable (13). The thresholds were developed by studying thousands of



organisms that live on the sea floor and their response to organic deposition from farms (45, 46). Two relatively easily measured chemical indicators, total free sulfides and oxygen reduction potential, were linked to enrichment responses of organisms within the nutrient footprint (47). The utility of using total free sulfide sediment concentrations as a proxy for environmental health was evaluated and

reconfirmed by DFO in 2005 (48). In the case of “hard-bottom sites” which are monitored by underwater video, only minimal amounts of nutrient-enrichment-indicating worms and bacteria can be present. In 2010, DFO adopted the standards during the development of the British Columbia Aquaculture Regulatory Program and subsequent development of the Aquaculture Activities Regulations.

SOFT BOTTOM SEAFLOOR MONITORING

Based upon detailed environmental studies, a near-field threshold was set 30 meters from the cages for farms with “soft bottom” seafloors to ensure that nutrients released from farms would not significantly impact the variety of organisms associated with the sea floor habitat.

The threshold was set at the boundary between when sediments are well oxygenated (i.e., oxic) and the beginning of conditions when oxygen is less available (i.e., hypoxia) as defined by benthic scientists (45). A second threshold, about 125 meters from the cages, ensures that oxygen levels are near background conditions (i.e., oxic).

Soft bottom monitoring requires the collection of sediment from the ocean floor using a grab sampler at a distance

30m from the pen system and 125m from the pen system (Figures 16 and 17).

Sediment is collected from these locations on transects that follow the dominant and sub-dominant currents and consider the predicted nutrient footprint from DEPOMOD simulations, which is where the nutrients would most likely be deposited. Cage arrays longer than 200 meters that are perpendicular to the ocean currents require additional transects. Multiple grabs are collected from each station and tested for total free sulfide concentration and oxidation-reduction potential.

DFO will not permit farmers to restock the site unless total free sulfide concentrations are below 1,300 μM 30-meters from the cage array, and below 700 μM at 125 meters from the cages.



Figure 16. View of grab sampler and seafloor sediments.



Figure 17. A typical two-transect monitoring survey design for a soft-bottomed site. Grab samples are collected at cage edge, 30 meters and 125 meters from the array along dominant and sub-dominant current directions. Note that cage arrays longer than 200 meters require more than two transects if perpendicular to the current flow.



HARD BOTTOM SEAFLOOR MONITORING

Hard bottom monitoring requires the collection video of the ocean floor from the edge of the pen system out to a distance that is 140 m from the pen system. Video is collected using a remotely operated underwater vehicle (ROV) (Figures 18 and 19) along two to four individual transects depending on the orientation and length of the pen array (Figure 20).

Each transect video is divided into 4-meter-long segments. Organisms in each segment along with the substrate type in each segment are identified and counted by biologists. The amount of substrate

covered by nutrient enrichment indicators (worm complexes and indicator bacteria) is estimated for each video segment.

DFO will not allow farmers to restock the site with fish until the amount of indicator worm and bacteria complexes are not greater than 10% in at least three of the six video segments between 100 and 124 meters from the containment array.

Additional monitoring may occur if requested by First Nations partners, DFO, or if companies are seeking a deeper understanding of the seafloor performance.



Figure 18. View of remotely operated underwater vehicle camera used to monitor “hard bottom” sites.



Figure 19. View of rocky habitat beneath a salmon farm. Image captured by underwater ROV.



Figure 20. A typical two-transect underwater video survey design for monitoring a hard-bottomed site.

Note that cage arrays longer than 200 meters require additional transects.

Benthic monitoring results are very encouraging, with 86% of the sites over the last decade demonstrating a limited nutrient footprint on the seafloor that does not accumulate and is quick to recover.

DO FARMS MEET REGULATORY REQUIREMENTS?

The nutrient footprint has been monitored for more than 20 years in British Columbia. A summary of operational monitoring results is available online through DFO (49).

From 2011 to 2022 there were 592 regulatory surveys at salmon farms in British Columbia (Figure 21). The majority of surveys (86%) met the seafloor compliance thresholds, and no additional monitoring has been required prior to fish re-entry into the site. Sites that exceeded performance thresholds were required to complete an additional survey, after a

fallow period, showing the site met the fish entry criteria before fish could be re-entered at the site.

To ensure the accuracy of the industry provided monitoring reports DFO completes random audits of the conditions of the ocean bottom at finfish aquaculture sites during the required peak biomass sampling window (30 days before or after peak biomass). Between 2011 and 2022 DFO completed 138 audits of industry monitoring and found similar results during 93% of those audits (50).



Photo by Brian Kingzett

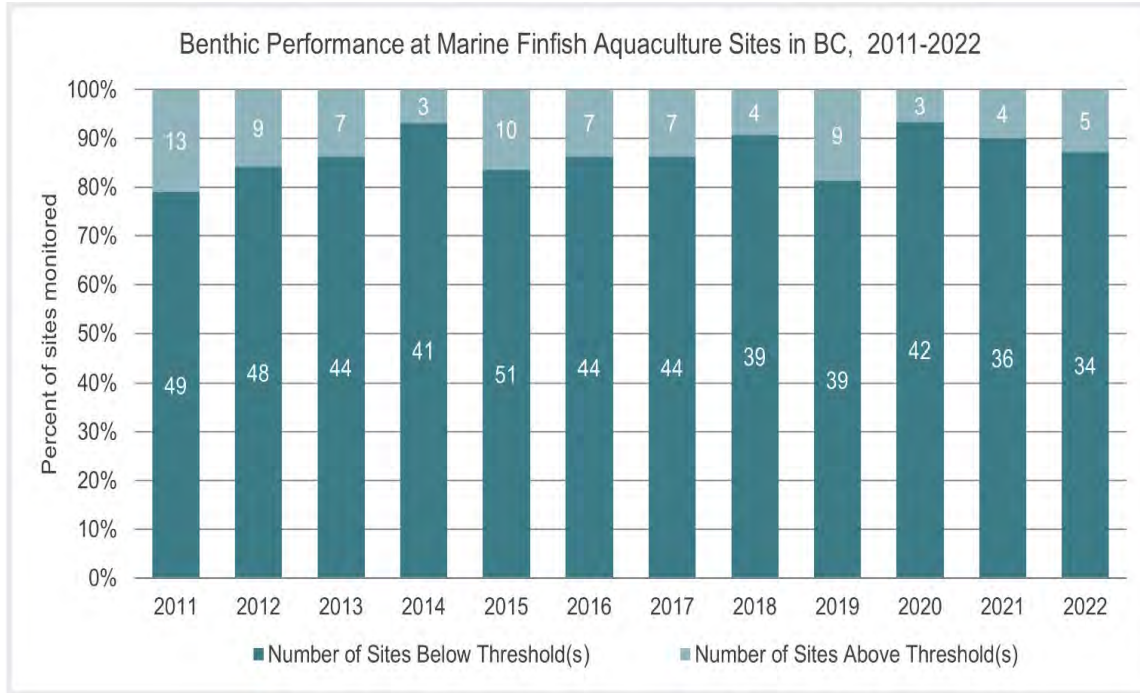


Figure 21. Benthic monitoring results at BC finfish aquaculture sites (2011 to 2022).

Data Source: [Benthic performance at marine finfish aquaculture sites in BC](#)

WHAT HAPPENS IF A FARM NUTRIENT FOOTPRINT EXCEEDS FEDERAL REGULATIONS?

If a threshold(s) is not met the farm must be left fallow until another survey is completed to ensure the thresholds are met. The benthic performance thresholds (soft or hard bottom) have been designed to limit the size and intensity of the BOD footprint, and make sure the seafloor recovers between crops.

The Aquaculture Activities Regulation encourages farmers to have as light a footprint as possible; farms that have a heavier footprint will have a slower recovery timeline and cannot be restocked until sustainability thresholds have been met.



THIRD-PARTY AUDITS AND TRANSPARENCY

Seafloor monitoring results are available on the DFO website (49) and company websites with Aquaculture Stewardship Council (ASC) certification (51).

MITIGATION: HOW DO SALMON FARMERS MINIMIZE THE NUTRIENT FOOTPRINT?

Two decades of sea floor monitoring have helped farmers adapt production to optimize benthic performance and maintain the best growing conditions for fish. The deposition of nutrients and organic matter, as fish fecal matter and uneaten feed is now about 5% of the administered feed. (52). Further advancements in camera assisted feeding control and acoustic registration of lost feed pellets have likely reduced feed loss to about 3% (53) (11) (Figure 22).

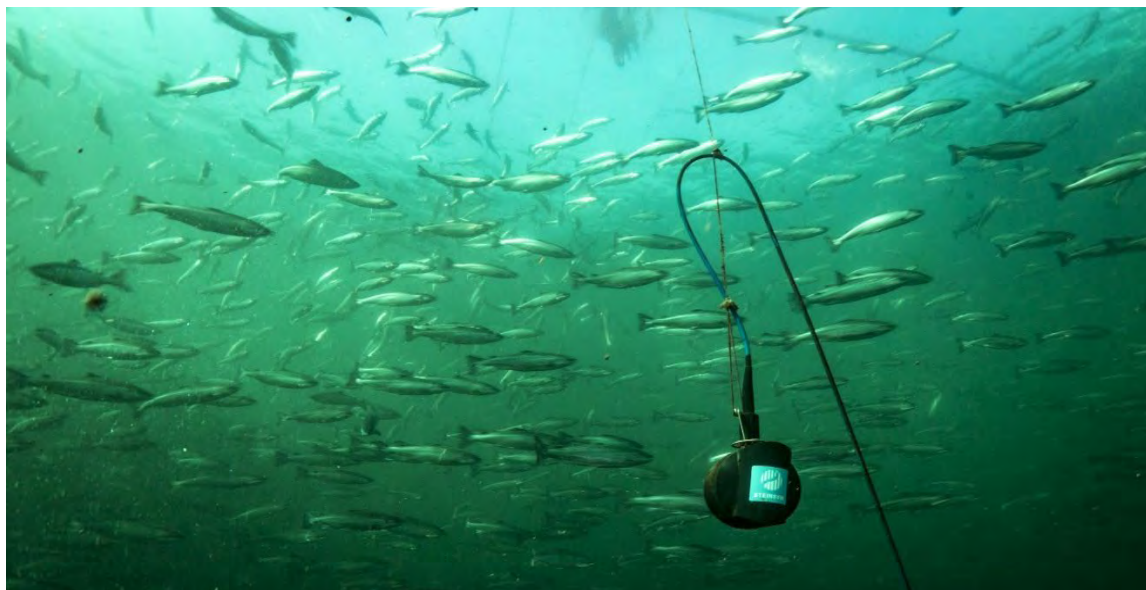


Figure 22. View of feed camera within fish pen.

The regulatory framework has been effective to limit the size and location of the BOD benthic footprint, as well as make certain that sea floor recovery occurs between crop cycles. Companies have restructured to improve benthic performance, including:

- o Reducing production at low-capacity sites,
- o Repositioning cages to improve flushing,
- o Closing non-sustainable sites,
- o Improving fish feeding strategies (see “Chapter 7 – Caring for the Environment – Feed Sustainability”), and
- o Shifting production to sites with higher capacity to assimilate nutrients (54).

HOW BIG ARE THE NUTRIENT FOOTPRINTS?

The “BOD nutrient footprints” typically center around the cage arrays and can be detectable about 30 – 300 meters from the cages (55). The majority of nutrients fall within 150 meters of the cages (56) and changes in organisms within the footprint are mainly found in this area. Based upon modeling estimates, a small amount (about 3%) of the particulate organic material is dispersed by currents more

than 2 km away from the cages (57). This reflects the patchiness of the seafloor, which is often comprised of a complex mixture of rocky outcrops, mud, sand, cobbles, and broken shell (Figure 23). Tidal currents and local bathymetry affect how far nutrients may be transported. In general, feed is heavier than fecal material and tends to settle closer to the pens.

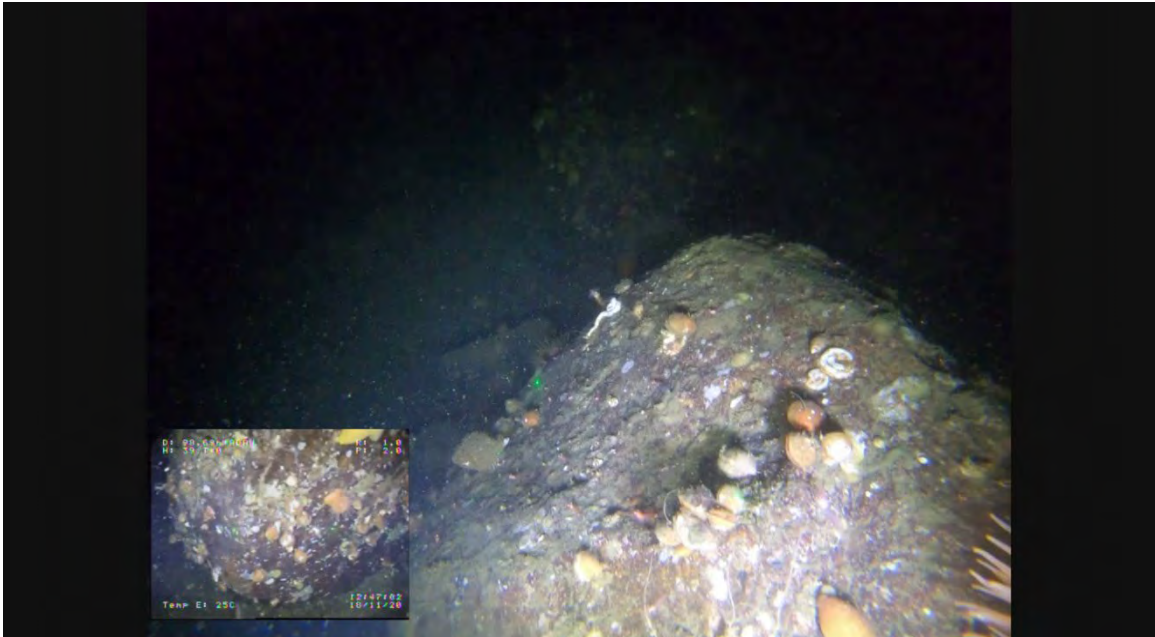


Figure 23. *View of rocky habitat within the farm nutrient footprint.*

Image captured by underwater ROV at peak biomass (maximum fish tonnage and maximum feeding).

A typical salmon farm produces 1 to 1.5 million pounds of salmon per hectare every two years in a cage array that is about 4 hectares in size. This is an incredibly efficient method of animal farming. Consider Canadian beef, which produces between 236 – 600 pounds per hectare per year (1).

IS THERE STILL LIFE UNDERNEATH A FARM?

Yes, it is generally accepted in the scientific community that low levels of organic enrichment can enhance benthic communities, while higher levels lead to negative community level impacts either directly from increased toxic sulfide concentrations, or through a reduction in dissolved oxygen levels (58). Regulated thresholds consider both sulfide and oxygen concentrations along the seafloor.

Undisturbed seafloor areas in coastal British Columbia have on average about 52 species of organisms that live in the sediments; the 30-meter near-field threshold of 1,300 μM total free sulfide has about 50% of that diversity (59). This means that farmers must ensure that the

nutrient footprint is close to the farm with a high enough diversity to recover very quickly (Figure 24).

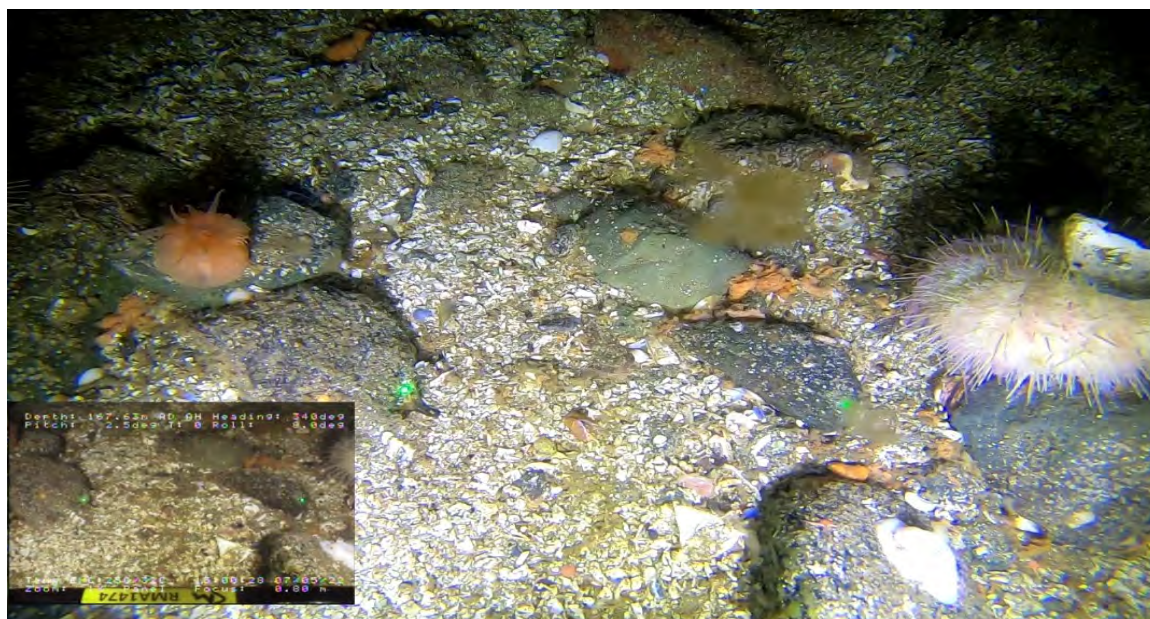


Figure 24. View of patchy seafloor habitat consisting of cobble, gravel and broken shell within the farm nutrient footprint.

Image captured by underwater ROV at peak biomass (maximum fish tonnage and maximum feeding).

HOW LONG DOES IT TAKE THE SEAFLOOR TO RECOVER FROM A FARM?

Nutrients are released from farms in “pulses” following the stocking-growing-harvesting-fallow cycle of each site. While variable, recovery generally occurs in two overlapping steps:

- o Chemical recovery - aided by opportunistic organisms that consume the excess feed and fecal material, and
- o Biological recovery – organisms that naturally lived within the footprint area begin to return as chemical recovery occurs; this follows the natural spawning cycle of the organisms (60). At some farms, biological recovery

begins as soon as harvesting begins (60).

Some of the first salmon farms in British Columbia were located in areas with slow current speeds and highly depositional environments not well suited to farming. The worst-case scenario, Centre Cove, Kyuquot Sound, was estimated to require a 15-year recovery (61). Sites with high impact and long recovery timelines are clearly not environmentally nor economically sustainable. Over the years all farms with slow recovery have been phased out of production.



Today, most sites take less than three months of fallow to meet re-stocking thresholds and 86% of sites do not require additional surveys prior to re-stocking. The farm fallow period is an important

part of taking care of the sea floor. It ensures that the benthic habitat can rest and recover between crops and gives farm staff time to get the site ready for the next fish.



DO FARMS IMPACT WATER QUALITY?

BC waters are naturally rich in nutrients (62) originating from the many rivers and streams that flow to the ocean. Additionally, there is frequent nutrient upwelling, bringing nutrient-rich deep waters towards the near-shore surface (62). Warm, sunny summers with low winds can create the ideal conditions for plankton blooms in BC.

The promotion of a harmful algal blooms by the addition of nutrients discharged

from salmon farms is feasible but unlikely to occur in the Pacific Northwest because the natural nutrient load is already very high. This is similar to other salmon farming regions in the world. For example, a 2012 study quantified the loading of nitrate from Norwegian salmon farms and found that it was <15% of the natural loading rate from deep water upwelling, suggesting the contribution from aquaculture is within safe limits (53).

Estimates for the amount of dissolved N that are predicted to be released from aquaculture vary between 35 – 120 kg of dissolved nitrogen per metric tonne of salmon produced (53), however this value has continually been decreased owing to improvements in feeding and reduction in food conversion ratios (ratio of the weight of feed added to the weight of fish produced, see “Chapter 7 – Caring for the Environment – Feed Sustainability”.

Another approach to limit nutrient loading into the environment that is actively being

explored is integrated multitrophic aquaculture (IMTA). IMTA is seen as a means of making aquaculture more sustainable and profitable, as the integration of other aquatic species from different, lower trophic levels (e.g., seaweed, sea cucumbers, mussels) may reduce the waste generated (as these species use waste as their source of nutrients), while providing ecosystem services (e.g., filtration, oxygen production) in addition to being harvested themselves. Further research into the best IMTA practices may lead to increased sustainability in salmon aquaculture.



Photo by Cascadia Seaweed



FUTURE GOALS

Salmon farming, with guidance from First Nations advisors, will continue to minimize potential impacts to biodiversity through prevention, monitoring, and mitigation. This includes adherence to the many federal and provincial laws and regulations that protect fish, fish habitat and wildlife in BC. In addition, ongoing and future research into additional vaccines and veterinary tools to support fish health programs, and continued innovations in feed and feeding practices may further improve the sustainability of the sector.



REFERENCES

1. Canadian Roundtable for Sustainable Beef (CRSB). 2016. National Beef Sustainability Assessment and Strategy summary report. Calgary, AB: : Canadian Roundtable for Sustainable Beef https://crsb.ca/wp-content/uploads/2021/12/Assessment-and-Strategy_summary_report_2016.pdf
2. O'Reilly A, Smith P. 2001. Use of indirect conductimetry to establish predictive no effect concentrations of oxytetracycline and oxolinic acid in aquatic sediments. *Aquaculture*.196(1):13-26.[https://doi.org/10.1016/S0044-8486\(00\)00569-X](https://doi.org/10.1016/S0044-8486(00)00569-X)
3. Kingsbury MV, Hamoutene D, Kraska P, Lacoursière-Roussel A, Page F, Coyle T, et al. 2023. Relationship between in feed drugs, antibiotics and organic enrichment in marine sediments at Canadian Atlantic salmon aquaculture sites. *Marine Pollution Bulletin*.188:114654.<https://doi.org/10.1016/j.marpolbul.2023.114654>
4. Kitasoo Xai'xais Nation. 2023. Klemtu Spirit: Kitasoo/Xai'Xais First Nation; [Available from: <https://klemtuspiritsmokedsalmon.com/>].
5. FAO. 2009. *Salmo salar*. Text by Text by Jones MEacbVCaMN: FAO.https://www.fao.org/fishery/docs/DOCUMENT/aquaculture/CulturedSpecies/file/en/en_atlanticsalmon.htm
6. Anon. 2017. Guide to the Pacific Marine Finfish Aquaculture Application. Government of British Columbia and Canada.https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-resource-use/land-water-use/crown-land/pacific_marine_finfish_aquaculture_application_guide.pdf
7. Fisheries and Oceans Canada. 2016. DFO siting guidelines for marine finfish aquaculture in British Columbia Ottawa: Government of Canada; [Available from: <https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/site-guide-direct-eng.html>].
8. Canada FaO. 2018. Aquaculture Monitoring Standard - 2018. Ottawa: Government of Canada.<https://www.dfo-mpo.gc.ca/aquaculture/management-gestion/aar-raa-ann7-eng.htm>
9. Fisheries and Oceans Canada. 2018. Aquaculture Activities Regulations guidance document. Ottawa: Government of Canada; Sept. 9, 2018. Contract No.: March 2024.<https://www.dfo-mpo.gc.ca/aquaculture/management-gestion/aar-raa-gd-eng.htm#purpose>
10. BC Fisheries Information Services Branch. 2001. Reconnaissance (1:20 000) Fish and Fish Habitat Inventory: Standards and Procedures. Victoria, BC: Resources Inventory Committee, Province of British Columbia.<https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/recce2c.pdf#:~:text=The%20reconnaissance%20is%20a%20sample-based%20survey%20covering%20whole,of%20habitat%20sensitivity%20and%20capability%20for%20fish%20production.>
11. Chamberlain J, Stucchi D, Lu L, Levings C. 2005. The suitability of DEPOMOD for use in the management of finfish aquaculture sites, with particular reference to Pacific Region. Fisheries & Oceans Canada, Science, Canadian Science Advisory Secretariat. Report No.: 1499-3848.<https://www.researchgate.net/profile/Lin-Lu->



- [17/publication/280091630 The suitability of DEPOMOD for use in the management of finfish aquaculture sites with particular reference to Pacific Region/links/55a7f38008ae481aa7f56437/The-suitability-of-DEPOMOD-for-use-in-the-management-of-finish-aquaculture-sites-with-particular-reference-to-Pacific-Region.pdf](https://www2.gov.bc.ca/gov2/pub/pub_280091630/The-suitability-of-DEPOMOD-for-use-in-the-management-of-finish-aquaculture-sites-with-particular-reference-to-Pacific-Region/links/55a7f38008ae481aa7f56437/The-suitability-of-DEPOMOD-for-use-in-the-management-of-finish-aquaculture-sites-with-particular-reference-to-Pacific-Region.pdf)
12. Fisheries and Oceans Canada. 2019. Framework for Aquaculture Risk Management (FARM). Ottawa: Government of Canada. 23 p.<https://www.dfo-mpo.gc.ca/aquaculture/consultations/farm-cgra/farm-cgra-eng.html>
 13. "Point in Time" Regulation Content Environmental Management Act Finfish Aquaculture Waste Control Regulation, (2012).
 14. Fisheries and Oceans Canada. 2021. Advice to inform the development of a drug and pesticide post-deposit marine finfish aquaculture monitoring program in support of the Aquaculture Activities Regulations. Ottawa, Ont.: Fisheries and Oceans Canada, Ecosystems and Ocean Science. Report No.: 978-0-660-38356-9.https://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2021/2021_013-eng.html
 15. Morrison DB, Saksida S. 2013. Trends in antimicrobial use in Marine Harvest Canada farmed salmon production in British Columbia (2003-2011). Can Vet J.54(12):1160-1163,
 16. Open Government. 2024. National Aquaculture Public Reporting Data Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/288b6dc4-16dc-43cc-80a4-2a45b1f93383>].
 17. Armstrong SM, Hargrave BT, Haya K. 2005. Antibiotic Use in Finfish Aquaculture: Modes of Action, Environmental Fate, and Microbial Resistance. In: Hargrave BT, editor. Environmental Effects of Marine Finfish Aquaculture. Berlin, Heidelberg: Springer Berlin Heidelberg. p. 341-357.<https://doi.org/10.1007/b136017>
 18. Brooks B, Maul J, Belden J. 2008. Antibiotics in aquatic and terrestrial ecosystems. Encyclopedia of Ecology:210-217,
 19. Samuelsen OB. 1989. Degradation of oxytetracycline in seawater at two different temperatures and light intensities, and the persistence of oxytetracycline in the sediment from a fish farm. Aquaculture.83(1):7-16.[https://doi.org/10.1016/0044-8486\(89\)90056-2](https://doi.org/10.1016/0044-8486(89)90056-2)
 20. Bayer RC, Daniel PC. 1987. Safety and efficacy of oxytetracycline for control of gaffkemia in the American lobster (*Homarus americanus*). Fisheries Research.5(1):71-81.[https://doi.org/10.1016/0165-7836\(87\)90016-6](https://doi.org/10.1016/0165-7836(87)90016-6)
 21. Florencio T, Carraschi SP, Cruz Cd, da Silva AF, Marques AM, Pitelli RA. 2014. Neotropical bioindicators of ecotoxicity and environmental risk of drugs with aquaculture interest. Boletim do Instituto de Pesca.40(4):569-576,
 22. Basti D, Bouchard D, Lichtenwalner A. 2011. Safety of Florfenicol in the Adult Lobster (*Homarus americanus*). Journal of Zoo and Wildlife Medicine.42(1):131-133, 3, <https://doi.org/10.1638/2010-0023.1>
 23. Suga N, Ogo M, Suzuki S. 2013. Risk assessment of oxytetracycline in water phase to major sediment bacterial community: A water-sediment microcosm study. Environmental Toxicology and Pharmacology.36(1):142-148.<https://doi.org/10.1016/j.etap.2013.03.013>
 24. Murphy GM, Robinson SMC. 2022. Review of Antibiotic Resistance Genes (ARGs) in Salmon Aquaculture and Empirical Data on Spatial and Seasonal Trends in the Bay of

Fundy. Ottawa ON Fisheries and Oceans Canada. Available from:

https://publications.gc.ca/collections/collection_2023/mpo-dfo/fs70-5/Fs70-5-2022-061-eng.pdf.

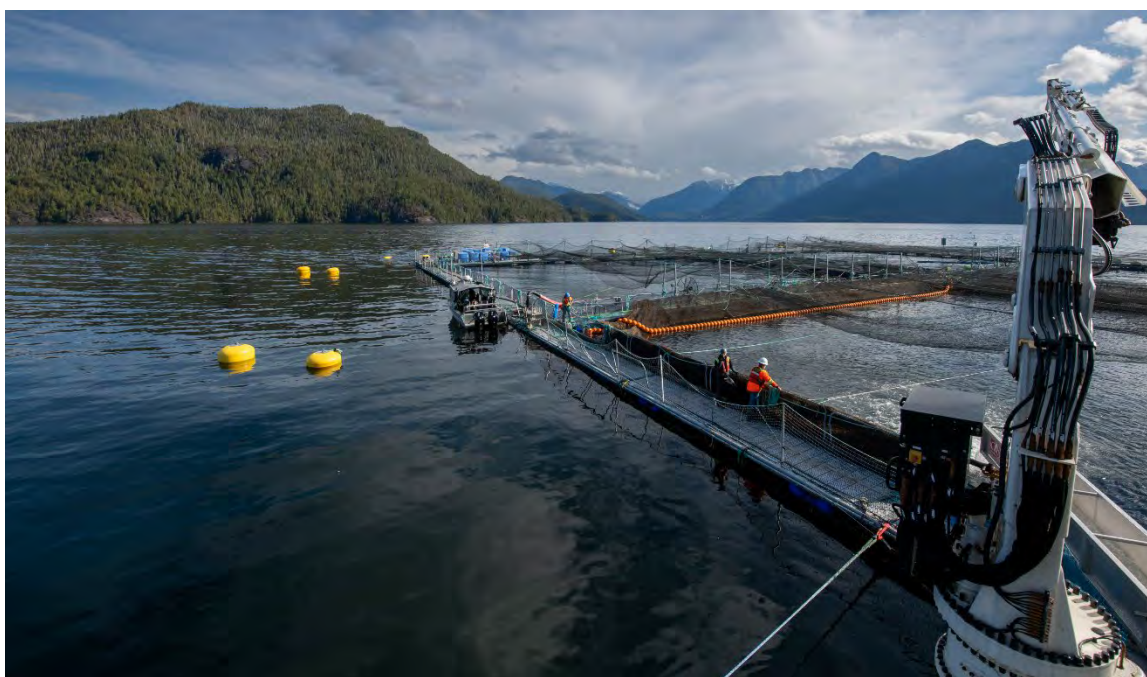
25. Integrated Pest Management Act, [SBC 2003] CHAPTER 58 (2003).
26. Park A. 2013. The biological effects of emamectin benzoate (SLICE®) on spot prawn (*Pandalus platyceros*). University of Victoria. http://dspace.library.uvic.ca/bitstream/handle/1828/4530/Park_Ashley_MSc_2013.pdf
27. Bright D, Dionne S. 2004. Use of emamectin benzoate in the Canadian finfish aquaculture industry: a review of environmental fate and effects. UMA Engineering, <https://www.watershed-watch.org/publications/files/EnvCan-ReviewofSlice.pdf>
28. Mushtaq M, Feely WF, Syintsakos LR, Wislocki PG. 1996. Immobility of Emamectin Benzoate in Soils. *Journal of Agricultural and Food Chemistry*.44(3):940-944.10.1021/jf950474v
29. Benskin JP, Ikonomou MG, Surridge BD, Dubetz C, Klaassen E. 2016. Biodegradation potential of aquaculture chemotherapeutants in marine sediments. *Aquaculture Research*.47(2):482-497. <https://doi.org/10.1111/are.12509>
30. Strachan F, Kennedy CJ. 2021. The environmental fate and effects of anti-sea lice chemotherapeutants used in salmon aquaculture. *Aquaculture*.544:737079. <https://doi.org/10.1016/j.aquaculture.2021.737079>
31. Waddy SL, Mercer SM, Hamilton-Gibson MN, Aiken DE, Burrridge LE. 2007. Feeding response of female American lobsters, *Homarus americanus*, to SLICE®-medicated salmon feed. *Aquaculture*.269(1):123-129. <https://doi.org/10.1016/j.aquaculture.2007.04.060>
32. Burrridge LE, Hamilton N, Waddy SL, Haya K, Mercer SM, Greenhalgh R, et al. 2004. Acute toxicity of emamectin benzoate (SLICE™) in fish feed to American lobster, *Homarus americanus*. *Aquaculture Research*.35(8):713-722. <https://doi.org/10.1111/j.1365-2109.2004.01093.x>
33. Waddy SL, Merritt VA, Hamilton-Gibson MN, Aiken DE. 2010. Effect of emamectin benzoate on the molt cycle of ovigerous American lobsters *Homarus americanus* is influenced by the dosing regimen. *Aquatic Biology*.11(1):47-52, <https://www.int-res.com/abstracts/ab/v11/n1/p47-52>
34. Aggelen GCv, Linssen M, Endris R, editors. 2003. Toxicity of emamectin benzoate in commercial fish feed to adults of the spot prawn and dungeness crab. *Oceans 2003 Celebrating the Past Teaming Toward the Future* (IEEE Cat No03CH37492); 2003 22-26 Sept. 2003
35. Fish Farm Advisory Group. 1999. Emamectin Benzoate, An Environmental Risk Assessment. Scottish Environment Protection Agency,.
36. DFO. 2012. Assessment of the Fate of Emamectin Benzoate, the Active Ingredient in SLICE®, near Aquaculture Facilities in British Columbia and its Effect on Spot Prawns (*Pandalus platyceros*). Nanaimo, BC: Centre for Science Advice (CSA) Pacific Region Fisheries and



- Oceans Canada. Report No.: 1919-5087 <https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/346389.pdf>
37. Veldhoen N, Ikononou MG, Buday C, Jordan J, Rehaume V, Cabecinha M, et al. 2012. Biological effects of the anti-parasitic chemotherapeutant emamectin benzoate on a non-target crustacean, the spot prawn (*Pandalus platyceros* Brandt, 1851) under laboratory conditions. *Aquatic Toxicology*.108:94-105.<https://doi.org/10.1016/j.aquatox.2011.10.015>
 38. DFO. 2015. Proceedings of the Pacific regional peer review on the assessment of the fate of emamectin benzoate, the active ingredient in SLICE®, near aquaculture facilities in British Columbia and its effect on the Pacific Spot Prawn (*Pandalus platyceros*); October 18-19, 2011.https://publications.gc.ca/collections/collection_2016/mpo-dfo/Fs70-4-2015-057-eng.pdf
 39. Kuo J-n, Buday C, van Aggelen G, Ikononou MG, Pasternak J. 2010. Acute toxicity of emamectin benzoate and its desmethyl metabolite to *Eohaustorius estuarius*. *Environmental Toxicology and Chemistry*.29(8):1816-1820.<https://doi.org/10.1002/etc.209>
 40. Burridge L, Weis JS, Cabello F, Pizarro J, Bostick K. 2010. Chemical use in salmon aquaculture: A review of current practices and possible environmental effects. *Aquaculture*.306(1):7-23.<https://doi.org/10.1016/j.aquaculture.2010.05.020>
 41. Munn S, Allanou R, Aschberger K, Berthault F, De Bruijn J, Musset C, et al. 2003. European Union Risk Assessment Report. Hydrogen Peroxide. Luxembourg:: European Chemicals Bureau Institute for Health and Consumer Protection.<https://publications.jrc.ec.europa.eu/repository/handle/JRC26024>
 42. Pest Management Regulatory Agency (PMRA). 2016. Registration decision RD2016-18 : Hydrogen peroxide. Ottawa, ON: Pest Management Regulatory Agency. Report No.: 1925-0940.https://publications.gc.ca/collections/collection_2016/sc-hc/H113-25-2016-18-eng.pdf
 43. Ernst W, Jackman P, Doe K, Page F, Julien G, MacKay K, Sutherland T. 2001. Dispersion and Toxicity to Non-target Aquatic Organisms of Pesticides Used to Treat Sea Lice on Salmon in Net Pen Enclosures. *Marine Pollution Bulletin*.42(6):432-443.[https://doi.org/10.1016/S0025-326X\(00\)00177-6](https://doi.org/10.1016/S0025-326X(00)00177-6)
 44. Canada H. 2016. PMRA (RD2016-18) Hydrogen Peroxide Ottawa: Government of Canada; [Available from: [https://www.canada.ca/en/health-canada/corporate/request-publication-form.html?title=PMRA%20\(RD2016-18\)%20Hydrogen%20Peroxide](https://www.canada.ca/en/health-canada/corporate/request-publication-form.html?title=PMRA%20(RD2016-18)%20Hydrogen%20Peroxide)].
 45. Wildish D, Pohle G, Hargrave B, Sutherland T, Anderson R. 2005. Benthic monitoring methods for habitat management of finfish mariculture in Canada. Fisheries and Oceans Canada Canadian Science Advisory Secretariat. Report No.: 1499-3848.<https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=810eb2096ed2244edcd79359083bf5a033cd9325>
 46. DFO. 2014. Potential impacts of finfish aquaculture on hard bottom substrates and development of a standardized monitoring protocol. St. John's, NL: Canadian Science Advisory Secretariat. Report No.: 1919-5087.<https://publications.gc.ca/site/eng/474009/publication.html>
 47. Brooks KM. 2001. An evaluation of the relationship between salmon farm biomass, organic inputs to sediments, physicochemical changes associated with those inputs and the

- infaunal response—with emphasis on total sediment sulfides, total volatile solids, and oxidation-reduction potential as surrogate endpoints for biological monitoring Final Report. BC Ministry of Environment.
48. DFO. 2005. Assessment of Finfish Cage Aquaculture in the Marine Environment. Ottawa, Ont. Report No.: 1480-4913
 49. Fisheries and Oceans Canada. 2023. Benthic performance at marine finfish aquaculture sites in BC. Ottawa: Government of Canada. <https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/benth/index-eng.html>
 50. Open Government. 2023. Results of DFO benthic audits of British Columbia marine finfish aquaculture sites Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/c1a54a0c-4eb0-4b50-be1f-01aee632527e>.
 51. Grieg Seafood British Columbia. 2024. Reporting & Compliance: Greig Seafood ASA; [Available from: <https://griegseafood.com/gsf-british-columbia-reporting>.
 52. Folkedal O, Macaulay G, Fosseidengen JE, Mikkelsen G, Myrland J, Sjøvegjarto B, et al. 2022. Deployment of hydroacoustic feeding control in salmon sea-cages; biological and technical considerations. Aquaculture.561:738700. <https://doi.org/10.1016/j.aquaculture.2022.738700>
 53. Wang X, Olsen LM, Reitan KI, Olsen Y. 2012. Discharge of nutrient wastes from salmon farms: environmental effects, and potential for integrated multi-trophic aquaculture. Aquaculture Environment Interactions.2(3):267-283,
 54. Backman DC, DeDominicis SL, Johnstone R. 2009. Operational decisions in response to a performance-based regulation to reduce organic waste impacts near Atlantic salmon farms in British Columbia, Canada. Journal of Cleaner Production.17(3):374-379. <https://doi.org/10.1016/j.jclepro.2008.08.019>
 55. Hamoutene D, Hua K, Lacoursière-Roussel A, Page F, Baillie SM, Brager L, et al. 2021. Assessing trace-elements as indicators of marine finfish aquaculture across three distinct Canadian coastal regions. Marine Pollution Bulletin.169:112557. <https://doi.org/10.1016/j.marpolbul.2021.112557>
 56. Chamberlain J, Stucchi D. 2007. Simulating the effects of parameter uncertainty on waste model predictions of marine finfish aquaculture. Aquaculture.272(1):296-311. <https://doi.org/10.1016/j.aquaculture.2007.08.051>
 57. Bannister RJ, Johnsen IA, Hansen PK, Kutti T, Asplin L. 2016. Near- and far-field dispersal modelling of organic waste from Atlantic salmon aquaculture in fjord systems. ICES Journal of Marine Science.73(9):2408-2419.10.1093/icesjms/fsw027
 58. Hargrave BT, Holmer M, Newcombe CP. 2008. Towards a classification of organic enrichment in marine sediments based on biogeochemical indicators. Marine Pollution Bulletin.56(5):810-824. <https://doi.org/10.1016/j.marpolbul.2008.02.006>
 59. Hargrave B. 2010. Empirical relationships describing benthic impacts of salmon aquaculture. Aquaculture Environment Interactions.1(1):33-46,
 60. Brooks KM, Stierns AR, Mahnken CVW, Blackburn DB. 2003. Chemical and biological remediation of the benthos near Atlantic salmon farms. Aquaculture.219(1):355-377. [https://doi.org/10.1016/S0044-8486\(02\)00528-8](https://doi.org/10.1016/S0044-8486(02)00528-8)

61. Obee N. 2009. Chemical and Biological Remediation of Marine Sediments at a Fallowed Salmon Farm, Centre Cove, Kyuquot Sound, . B.C. Environmental Protection, BC Ministry of Environment. https://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/aquaculture/remediation_aquaculture.pdf
62. Peña MA, Fine I, Callendar W. 2019. Interannual variability in primary production and shelf-offshore transport of nutrients along the northeast Pacific Ocean margin. Deep Sea Research Part II: Topical Studies in Oceanography.169-170:104637. <https://doi.org/10.1016/j.dsr2.2019.104637>
63. Ianni C, Bignasca A, Magi E, Rivaro P. 2010. Metal bioavailability in marine sediments measured by chemical extraction and enzymatic mobilization. Microchemical Journal.96(2):308-316. <https://doi.org/10.1016/j.microc.2010.05.003>



APPENDICES

APPENDIX A. ACTS AND REGULATIONS PROTECTING FISH, FISH HABITAT AND WILDLIFE IN BC

Fisheries Act <https://laws-lois.justice.gc.ca/eng/acts/F-14/>

Pacific Aquaculture Regulation
<https://laws.justice.gc.ca/eng/regulations/SOR-2010-270/FullText.html>

Aquaculture Activities Regulation
<https://laws.justice.gc.ca/eng/regulations/SOR-2015-177/page-1.html>

Species at Risk Act
<https://laws.justice.gc.ca/eng/acts/S-15.3/page-1.html>

Coastal Fisheries Protection Act
<https://laws.justice.gc.ca/eng/acts/C-33/index.html>

Canada National Marine Conservation Areas
Act [Canada National Marine Conservation
Areas Act \(justice.gc.ca\)](#)

Canada National Parks Act [Canada National Parks Act \(justice.gc.ca\)](#)

Canada Wildlife Act & Regulations [Canada Wildlife Act \(justice.gc.ca\)](#)

Park Act & Regulations [Parks Canada](#)
[Agency's Forward Regulatory Plan: April 1, 2022 – March 31, 2024](#)

Migratory Birds Convention Act [Birds
protected under the Migratory Birds
Convention Act - Canada.ca](#)

Oceans Act
<https://laws.justice.gc.ca/eng/acts/O-2.4/rpdc.html>

Health of Animals Act <https://laws-lois.justice.gc.ca/eng/acts/H-3.3/>

Food and Drugs Act <https://laws-lois.justice.gc.ca/eng/acts/F-27/page-2.html#h-234115>

Pest Control Products Act <https://laws-lois.justice.gc.ca/eng/acts/P-9.01/>

Navigation Protection Act
<https://tc.canada.ca/en/corporate-services/acts-regulations/navigation-protection-act-rs-1985-c-n-22>

BC Land Act
https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/96245_01

BC Environmental Management Act
https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/03053_01

BC Fisheries Act
https://www.bclaws.gov.bc.ca/civix/document/id/consol26/consol26/00_96149_01

Protected Areas of British Columbia Act
[Protected Areas of British Columbia Act](#)
(gov.bc.ca)

Ecological Reserve Act & Regulation
Ecological Reserve Act (gov.bc.ca)

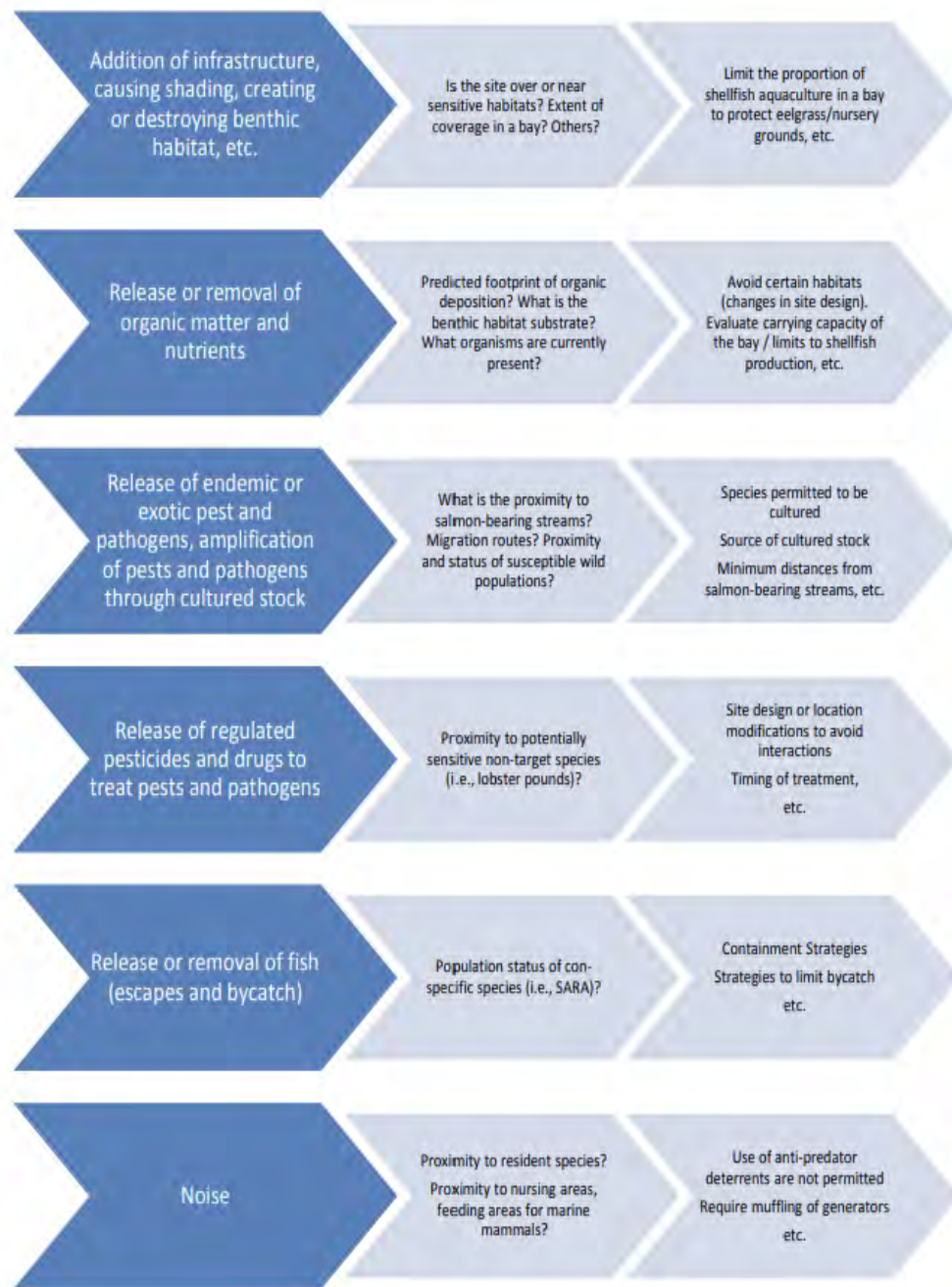
BC Wildlife Act & Regulations [Wildlife Act](http://www.gov.bc.ca/wildlife)
(gov.bc.ca)

BC Integrated Pest Management Act
https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/00_03058_01

Veterinary Drugs Act [Veterinary Drugs Act
\(gov.bc.ca\)](http://www.gov.bc.ca)



APPENDIX B. DFO AQUACULTURE PATHWAY OF EFFECTS



Key considerations and examples of potential stressors and risk mitigation options to avoid or limit effects on fish, fish populations and habitat. DFO source, Framework for Aquaculture Risk Management (12).

APPENDIX C. UNDERSTANDING CHEMICAL EXPOSURE AND ECOTOXICITY

Exposure

Once a chemical is in the environment, it has the potential to interact with organisms that live in that environment, this is termed exposure. The degree of exposure is often determined by the route through which the contaminant enters the organism. The route of uptake is important for determining whether adverse effects are likely to occur. With respect to exposure to aquaculture associated chemicals, two potential routes of exposure may occur. These include direct consumption of salmon feed and or contaminated sediments, or through passive contact with sediment and water.

Exposure via the water is unlikely given the rapid dissipation by ocean currents and the soluble nature of the antimicrobials florfenicol and oxytetracycline, and the sea lice treatment medicine Interlox®Paramove®50. Conversely, the sea lice treatment medicine SLICE®, which is administered in the feed, has low water solubility meaning it will stay bound to particles. Dietary ingestion of fish feed has been shown to be limited in many species, especially when other food sources are available. Studies have repeatedly shown that lobsters, BC spot prawns and Dungeness crabs avoid eating feed pellets containing SLICE®. Uneaten pellets are likely to be incorporated into the sediments, making sediment exposures particularly relevant.

The bulk measurement of a contaminant in a sediment is not always a good predictor of potential effects. This is because the bulk measurement does not reflect the 'bioavailability' of that contaminant within the sediment. Bioavailability may be defined as the maximum amount of a contaminant which is available in the gut environment of an organism(63). Chemicals that have strong binding affinity for sediments like SLICE®, have lower bioavailability to organisms. Bioavailability in sediments is very complex, and is specific to the species, chemical, and environment. The bioavailability reflects the actual exposure of an organism and will dictate whether adverse impacts are observed.

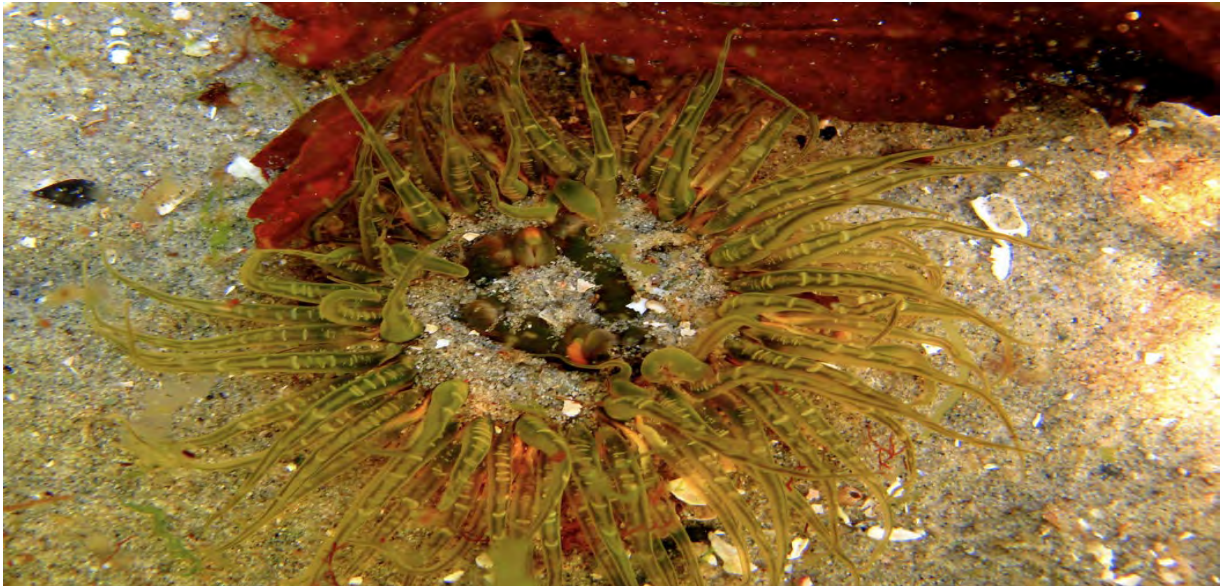
Toxicity

For toxicity to be realized:

- o an **organism has to be exposed** to the potential toxicant in its habitat, AND
- o the potential toxicant has to be in a form that is **available for uptake**, AND
- o the uptake (dose) of the contaminant has to be **at a level that causes toxicity** to the particular organism.



Understanding the toxicity of a compound to an organism in a laboratory test helps to understand the hazard associated with that compound and can inform risk assessments.



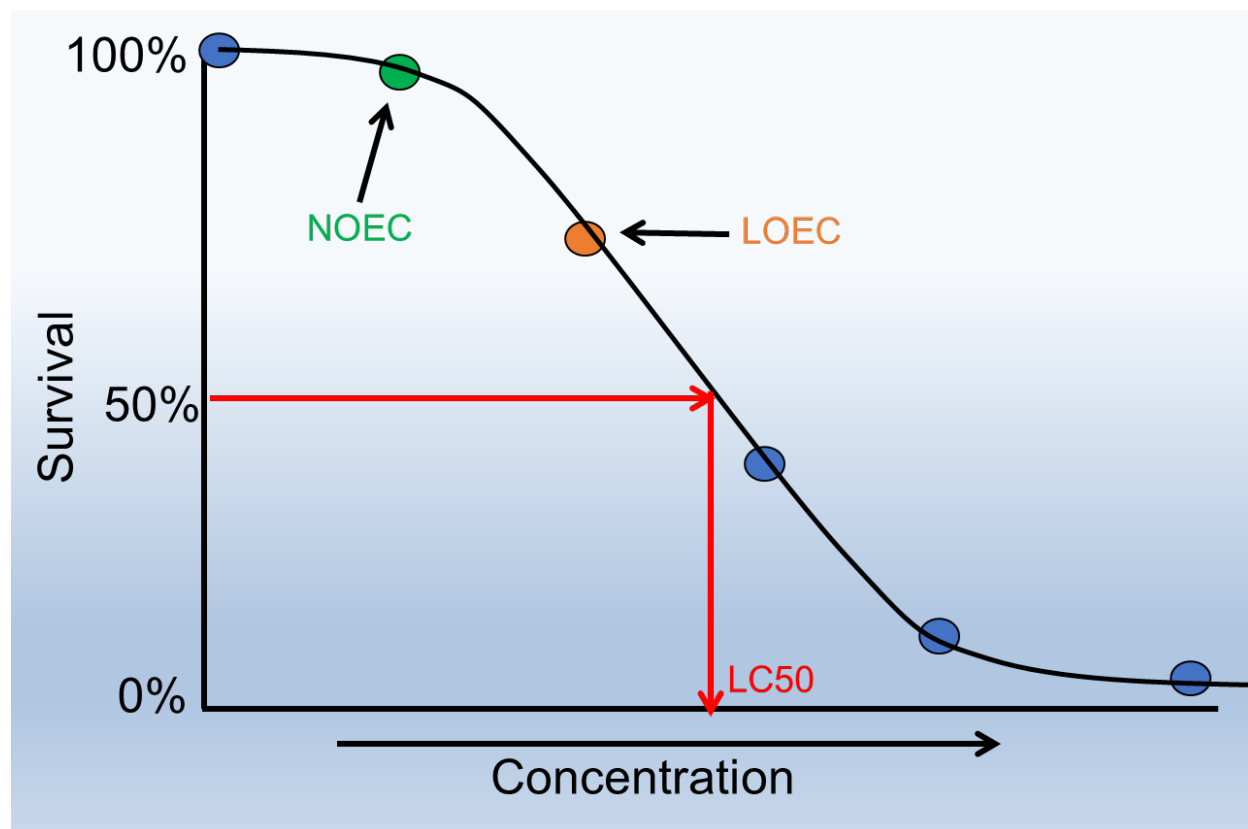
Many laboratory toxicity tests are designed to determine the hazard a specific toxicant has on a specific organism – that is to determine how much exposure is required (both the concentration and duration) in order for the organism to begin experiencing harmful effects. The toxicity tests may be:

- o acute (high range of concentrations, short duration) or
- o chronic (low range of concentration, long duration) in design, and
- o tend to employ the early, most vulnerable life stage of an organism.

Depending on the biology and traits of the test organism, the toxicity test may be conducted in the water or sediment phase. The choice of exposure matrix (e.g., water or sediment) is also informed by the usage patterns and environmental fate of the test chemical. For example, for a chemical like emamectin benzoate a sediment toxicity test would be most appropriate because that chemical partitions to and persists in sediments. On the other hand, hydrogen peroxide does not reach or persist in sediments, and as such a water born exposure would be most appropriate.

Sediments are spiked with known concentrations of chemicals, either alone or in combination, to establish definitive cause-and-effect relationships between chemicals and biological responses.

At the end of the test period, the response of the test organism is examined in relation to a biological end point (e.g., survival, reproduction, growth). An example of the results from a typical toxicity study is shown in the figure below.



Example of a typical result from a toxicity test. The figure shows with increasing concentration (moving left to right), there is a decrease in survival. Each point along the curve represents a different concentration that was tested. The green circle is the last treatment concentration that has a response that is not statistically different from the control, this is termed the No Observed Effect Concentration (NOEC). The orange point is the lowest concentration that is significantly different from the control, this is termed the Lowest Observed Effect Concentration (LOEC). From the relationship between the concentration and the response, the concentration which is lethal to 50% of the population (LC50) can be mathematically determined.

These laboratory tests are very useful for generating data that can be used to compare the sensitivity of different organisms or comparing the response of the same species to different toxicants. However, it can be difficult to compare between different studies owing to differences in methodology (e.g., different sediment types, exposure durations), and especially if analytical determination of the test concentrations was not performed. Because of this, the results from each study must be considered within the context of their own objective, and in order to be used for other objectives, such as developing regulatory



thresholds, their **reliability** (e.g., Did the study measure its concentrations? Did it employ appropriate experimental controls?) and **relevance** (e.g., Was the study performed with a species and life stage likely to be found in the area of interest? Was the exposure duration appropriate based on the environmental fate of the compound) must be evaluated. Differences in the reliability and relevance of studies are considered through a weight of evidence approach, where more reliable and relevant studies are given more weight when considering all available data.

Laboratory tests have limitations, in particular they cannot recreate everything that happens in the field environment. In the field there are numerous interactions and processes that act together to change the exposure and the response of organisms. In laboratory tests, these variables are tightly controlled, and the exposures are generally constant. As such, results from laboratory tests tend to be conservative compared to what would be observed in the field.

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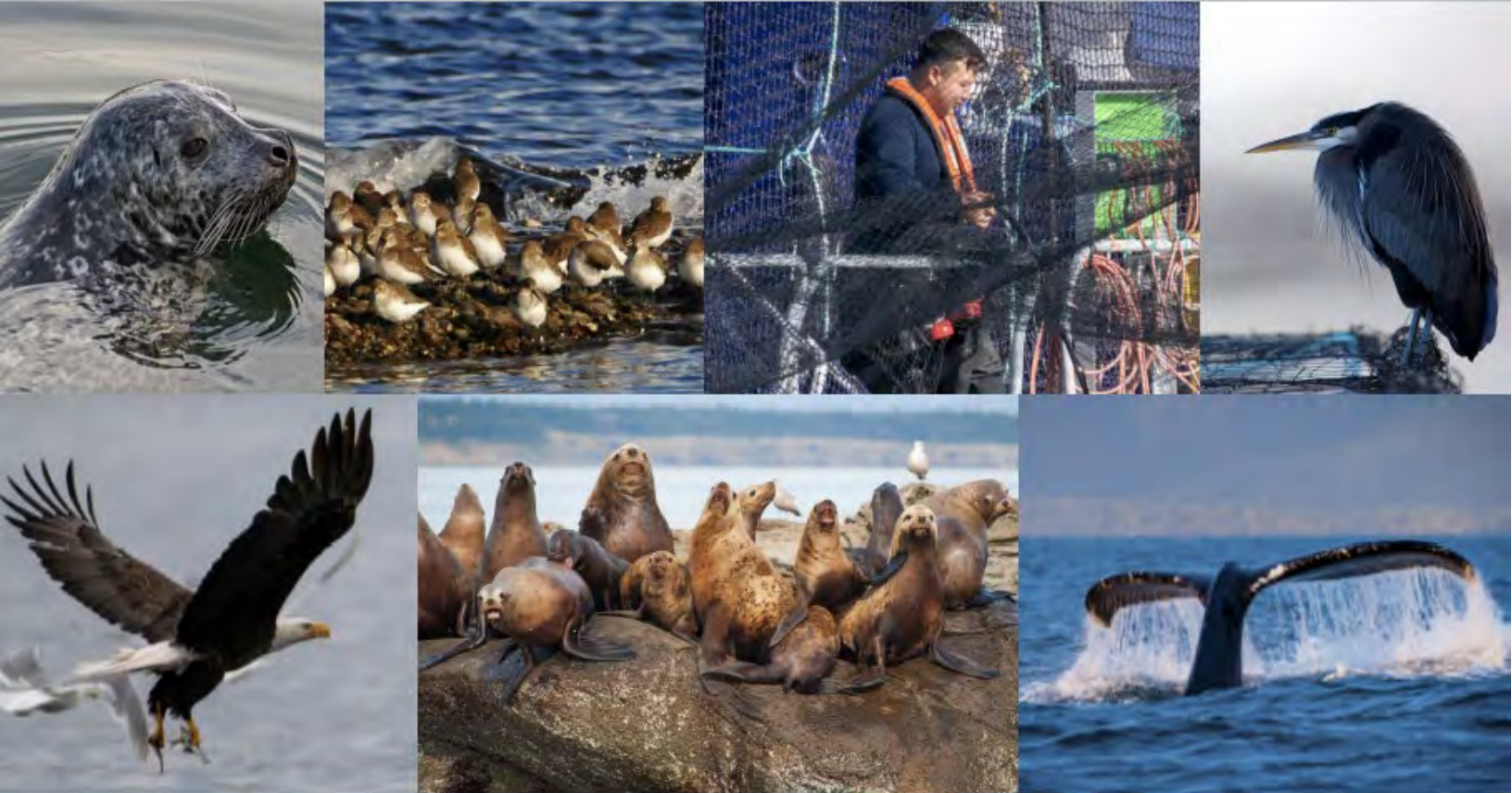
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CHAPTER 9

CARING FOR THE ENVIRONMENT

MINIMIZING WILDLIFE INTERACTIONS



This document describes measures salmon farmers take to minimize interactions with wildlife and provides important statistics on wildlife interactions at farms in British Columbia

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CHAPTER HIGHLIGHTS - MINIMIZING WILDLIFE INTERACTIONS

Interactions between wildlife and salmon farms occur in a variety of ways. The majority of these interactions are harmonious, consisting of viewing each other from a safe distance. On occasion, wildlife comes into close proximity to farms. Care must be taken to ensure wildlife, people and infrastructure are not harmed during these events.

Farmers focus on preventing interactions by minimizing both attractants and the ability for wildlife to access farm infrastructure. If these measures do not work, non-lethal deterrents (authorized by DFO) may be used to encourage wildlife to avoid the farm. Underwater acoustical deterrents are not permitted in BC.





From 2011 to 2022, there were 431 megafauna mortalities at salmon farms in BC. Almost all (98%) were California sea lions and harbour seals, reflecting increasing population growth in both species. In 2012, BC salmon farmers implemented a sector-wide management policy for seals and sea lions that included the implementation of mandatory prevention measures and a “no-kill” policy. Innovations in infrastructure and staff training have significantly reduced mortalities at farms. From 2013 to 2022, there were, on average, 10 mortalities per year at salmon farms in BC, which is approximately one mortality per seven operating farms yearly.

Sea lion and seal population growth will continue to challenge salmon farmers, given that salmon is naturally a part of the diet of these very intelligent animals. Salmon farmers are working with seal/sea lion biologists to further develop non-harmful deterrents and exclusionary infrastructure.

Six humpback whales interacted with salmon farms in BC from 2011 to 2022. An additional two interactions occurred with farms: one in 2008 and another 2009. Of the eight entangled humpback whales over the thirteen year period (2008 to 2022), five were successfully released unharmed (24). Unfortunately, the other three did not survive. The entanglements accounted for less than six per cent of all entanglements in B.C.

These events were related to mooring lines or nets located under farms. Operational changes to mooring lines were made after 2018 to reduce these interactions. DFO whale experts and regulatory personnel provide guidance/instruction to farmers in the event of an entanglement.

There have been no reported mortalities of sharks, turtles, otters, porpoises or dolphins at BC salmon farming operations.



Photo by Brian Kingzett

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INTRODUCTION

British Columbia is home to vast tracts of wilderness, majestic inlets and island archipelagos that support a rich and diverse array of wildlife species, from sharks and crustaceans to seabirds and marine mammals. Salmon farmers acknowledge the significance of operating in these coastal waters, recognizing the deep cultural and public value attributed to the wildlife in their environments by First Nations and the public. We have developed effective infrastructure and processes to protect wildlife, with a primary focus on preventing harm. This chapter describes how salmon farmers minimize interactions with wildlife to keep both farmers and wildlife safe and provides important statistics on wildlife interactions at farms in British Columbia.



WHAT IS CONSIDERED AN INTERACTION?

Salmon farms are located in wilderness areas of coastal BC. Interactions between wildlife and salmon farms occur in a variety of ways. The majority of these interactions are harmonious, consisting of viewing each other from a safe distance. On occasion, wildlife comes into close

proximity to farms. Care must be taken to ensure wildlife and people are not harmed during these events. Infrastructure innovations, farm practices and regulatory frameworks have been successful at reducing both the frequency and consequences of close interactions.

REGULATIONS TO PROTECT WILDLIFE

The conservation and protection of wildlife is regulated on global, federal, provincial, and municipal levels.

- o Internationally, Canada regulates the international trade in animals and plants in adherence to the Convention on International Trade in Endangered Species of Wild Fauna and Flora ([CITES](#)), 1975(2).
- o Federally, the government's jurisdiction with respect to the conservation of wildlife, habitat and the recovery of species at risk is established by the Species at Risk Act ([SARA](#)), 2002, (3) the [Fisheries Act](#), 1985, (4) and the [Migratory Birds Convention Act](#), 1994 (5), including their associated Regulations and Orders.
- o Through amendments to the Fisheries Act and associated regulations, Canada also adheres with the international requirements of the [US Marine Mammal Protection](#)

[Act](#), 1972, which prohibits the lethal removal of nuisance mammals for the protection of fishing equipment (6).

- o Provincially, the [Wildlife Act](#), 1996, (7) with associated regulations, protects wildlife from harm.
- o Municipalities can incorporate wildlife protection objectives through several measures, including by enacting local bylaws.

In addition to these protections, there are specific requirements for wildlife interactions at farms prescribed in the Marine Finfish Aquaculture License under the [Fisheries Act](#) (4). License requirements are described in the following sections.

See "Chapter 6 – Caring for the Environment – Minimizing Incidental Catch" and "Chapter 8 – Caring for the Environment – Protecting Biodiversity", for more information on how incidental catch and biodiversity are protected near salmon farms.

DFO REQUIREMENTS

Salmon farmers are required to provide information to DFO on how they will minimize interactions with megafauna at each site, as well as report any entanglements or entrapments (Figure 1). The term "megafauna" refers to marine

mammals (whales, dolphins, porpoises, seals, sea lions, sea otters), turtles, and sharks. Considerations for basking sharks and turtles came into effect in 2020, in alignment with the Species at Risk Act.

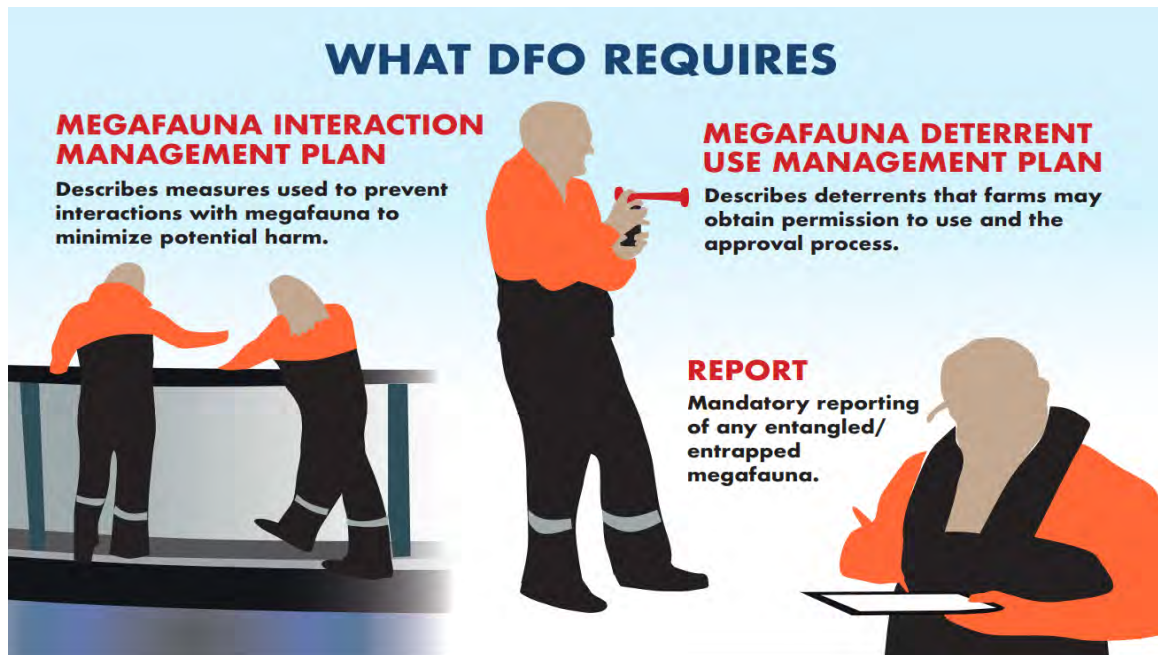


Figure 1. The current requirements under the Marine Finfish Aquaculture License under the Fisheries Act.

Source DFO Marine finfish B.C. [aquaculture licence and conditions of licence](#) (8)

Requirements include:

- o **Megafauna Interactions Management Plan** - describes how the site will minimize conflicts with megafauna.
- o **Megafauna Deterrent Use Management Plan** – describes non-harmful deterrents the site may need to use in the unlikely event there is a threat to human safety or to the integrity of the farm system. These measures can only be used if approved by DFO.
- o **Reporting** – mandatory for any entangled or entrapped megafauna.

MEGAFAUNA INTERACTIONS MANAGEMENT PLAN REQUIREMENTS

Salmon farmers are required to submit a Megafauna Interaction Management Plan (MIMP) each year to DFO. The plan must describe policies, procedures, infrastructure, and measures each site has implemented to minimize conflicts with megafauna (Figure 2). This must include procedures to address issues related to entanglements and entrapments.

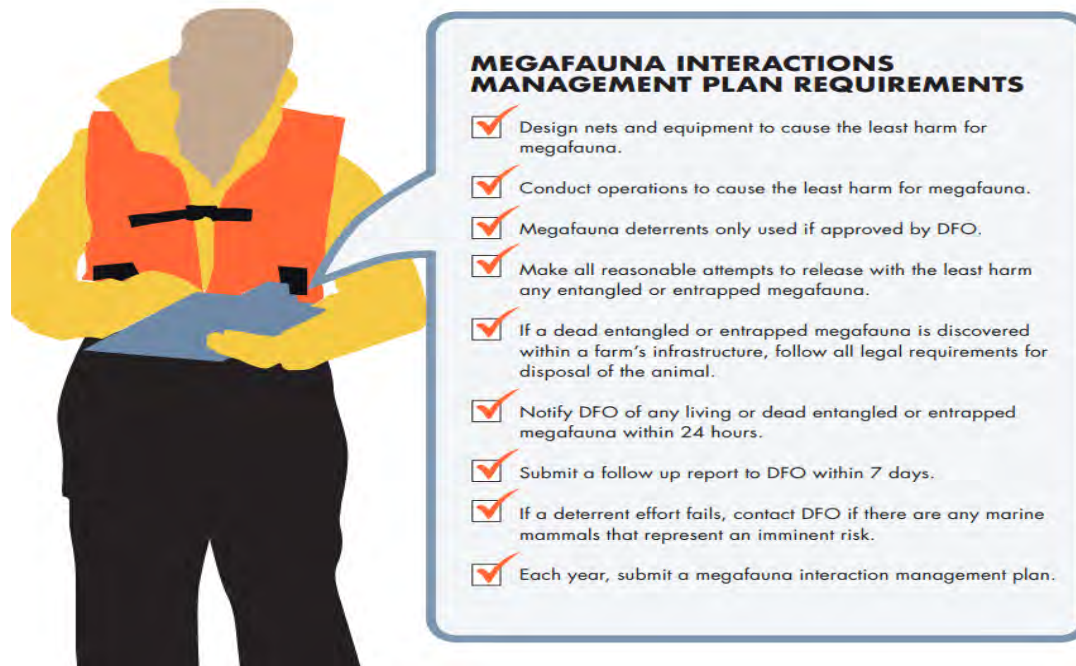


Figure 2. List of requirements for Megafauna Interactions Management Plans, as a condition of licensing for salmon farms in BC.

Source DFO Marine finfish B.C. [aquaculture licence and conditions of licence](#) (8)

MEGAFAUNA DETERRENT USE MANAGEMENT PLAN REQUIREMENTS

As of March 2023, salmon farmers may provide a Megafauna Deterrent Use Management Plan (MDUMP) describing the non-harmful deterrents a farm site may use to manage challenging mammal interactions that threaten the safety of the salmon farmers and the integrity of the farm systems. The submission of an MDUMP is voluntary and will only be approved if the licence holder has demonstrated that all available exclusion devices and other preventative measures have been ineffective. This proactive approach aims

to pre-authorize what can be used at a salmon farm, in order to maximize planning and safety for all.

REPORTING

All reports related to entanglements and entrapments are made publicly available on the Government of Canada Open Data website (9). If a salmon farm is certified to the Aquaculture Stewardship Council (ASC) Salmon Standards, marine mammal and bird interaction information is publicly available on the company's website.



DFO uses the term “megafauna” to describe marine mammals (whales, dolphins, porpoises, seals, sea lions, sea otters), turtles and sharks.



Photo by Britan Kingzett

HOW MANY WILDLIFE INTERACTIONS ARE THERE AT SALMON FARMS?

Wildlife that interacts with salmon farms in BC typically consists of fish-eating animals. This includes the California sea lion (*Zalophus californianus*), the harbour seal (*Phoca vitulina*) and, less commonly, the Steller sea lion (*Eumatopias jubatus*). River otters (*Lutra*

canadensis) have also been known to directly interact with the farms. Birds may be attracted to the feed or the farm infrastructure as a resting space (10). The most common birds that interact with farms include crows (*Corvus* spp.) and seagulls (*Larus* spp.).

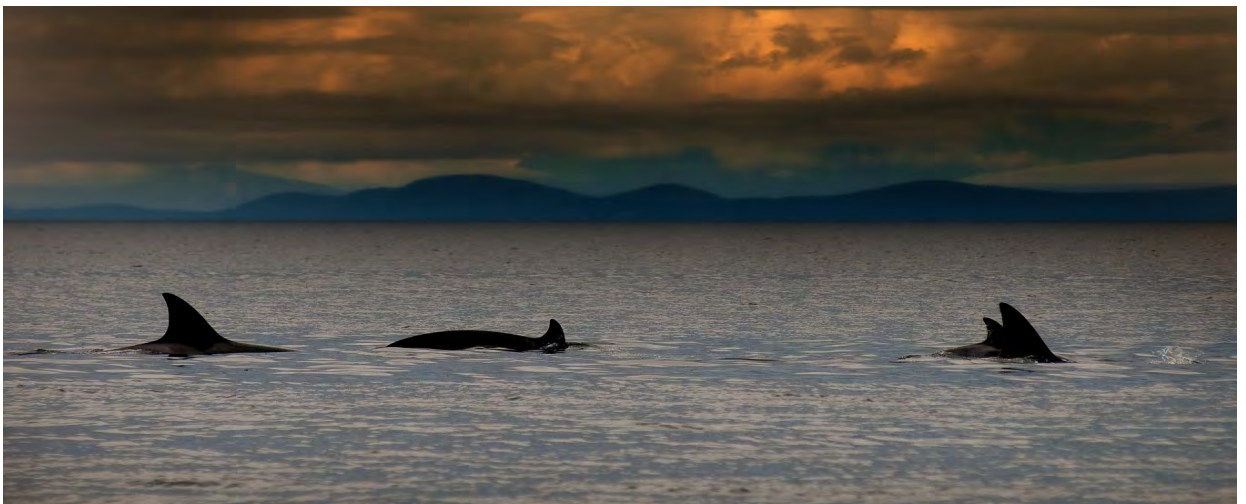


Photo by Britan Kingzett

*Photo by Bill Pennell*

MEGAFAUNA INTERACTIONS

In total, there were 431 megafauna mortalities at salmon farms in British Columbia from 2011 to 2022 (Table 1). California sea lions accounted for 68% and seals

There have been no reported mortalities of sharks, turtles, otters, porpoises or dolphin at BC salmon farming operations.

accounted for 30% of the mortalities from 2011 to 2022. In 2012, BC salmon farmers implemented a sector-wide management policy for seals and sea lions that included the implementation of mandatory prevention measures and a “no-kill” policy. Innovations in infrastructure and staff training have significantly reduced mortalities at farms. From 2013 to 2022, there were, on average, 10 mortalities per year at salmon farms in BC, which is approximately one mortality per seven operating farms yearly.

Table 1. Megafauna interactions at BC salmon farms 2011 to 2022.

Source [DFO Open Data](#) (11).

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
California Sea Lion	232	9	4*	6	25	5	0	2	0	2	2	6
Accidental drowning	4	7	0	6	10	4	0	2	0	2	2	4
Permitted Euthanasia	228	2	1	0	15	1	0	0	0	0	0	0
Harbour Seal	70	18	3	9	17	1	2	1	0	3	4	0
Accidental drowning	4	13	1	7	14	1	2	1	0	3	4	
Permitted Euthanasia	66	5	2	2	3	0	0	0	0	0	0	0
Northern Fur Seal	0	0	0	0	0	0	0	0	0	0	1	0
Accidental drowning	0	0	0	0	0	0	0	0	0	0	1	0
Steller Sea Lion	2	0	0	0	0	0	0	0	0	0	0	1
Permitted Euthanasia	2	0	0	0	0	0	0	0	0	0	0	0
Under Investigation	0	0	0	0	0	0	0	0	0	0	0	1
Humpback Whale	0	0	1*	0	0	3	0	1	0	0	1	0
Accidental drowning	0	0	0	0	0	2	0	0	0	0	0	0
Live release	0	0	0	0	0	1	0	1	0	0	1	0
Porpoises, Dolphins, Other Whales	0	0	0	0	0	0	0	0	0	0	0	0
Species at Risk (Turtles, Sharks) **	N/a	N/a	N/a	N/a	N/a	N/a	N/a	N/a	N/a	0	0	0
Total mortalities	304	27	8	15	42	9	2	4	0	5	8	7

* Three California sea lions and one humpback whale were discovered deceased, cause unknown.

** New reporting requirements to align with the Species at Risk Act.

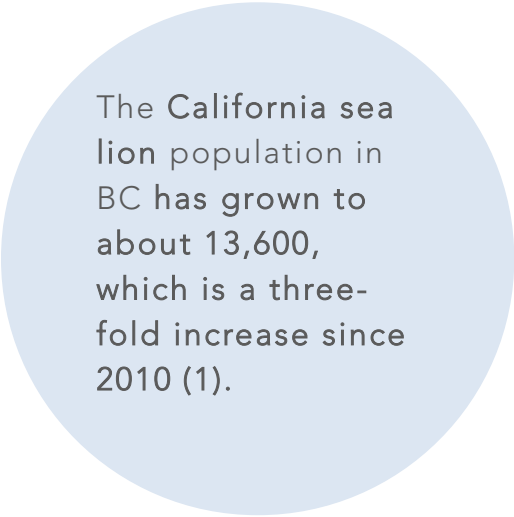


SEA LIONS

There are two types of sea lions in BC: the California sea lion and the Steller sea lion.

Both have exhibited exponential population growth over the past 20 years (1, 12, 13). California sea lions, which breed in California, have stabilized, but the proportion that overwinter in BC has increased in recent years, raising concerns about impacts on local ecosystems, including competition for prey resources and local fisheries (1). The number of rookeries and year-round haul-out sites of Steller sea lions is also increasing (13).

Population increases in sea lions increase competition for resources in the sea. Sea



The California sea lion population in BC has grown to about 13,600, which is a three-fold increase since 2010 (1).

lions eat a variety of fish and shellfish, including salmon. Sea lions are very effective predators with excellent abilities

for sound detection, learning potential and memory (14). This has brought additional pressure to salmon farmers as some sea lions strive to enter pens to consume the farm-raised salmon.

Before 2012, salmon farmers retained qualified contractors to undertake DFO-authorized euthanasia as a management tool for sea lions that were hazardous or could not be deterred from the pens. Out of concern for wildlife, the sector collaborated and developed preventative measures to keep sea lions away from the pens and instituted a “no-kill” policy (Figure 3). In 2016, in response to the US Marine Mammal Protection Act, DFO also no longer permitted authorized euthanasia as a management tool (15).

Recognizing that populations are growing, salmon farmers have invested in infrastructure and staff training to stay one step ahead of the growing populations and keep sea lions safe. For most farms, exclusion devices effectively deter sea lions from accessing the farms. Unfortunately, there are instances where determined sea lions continue to pursue entry into farms aggressively. This can lead to accidental drowning if they are caught between the primary containment and predator nets.

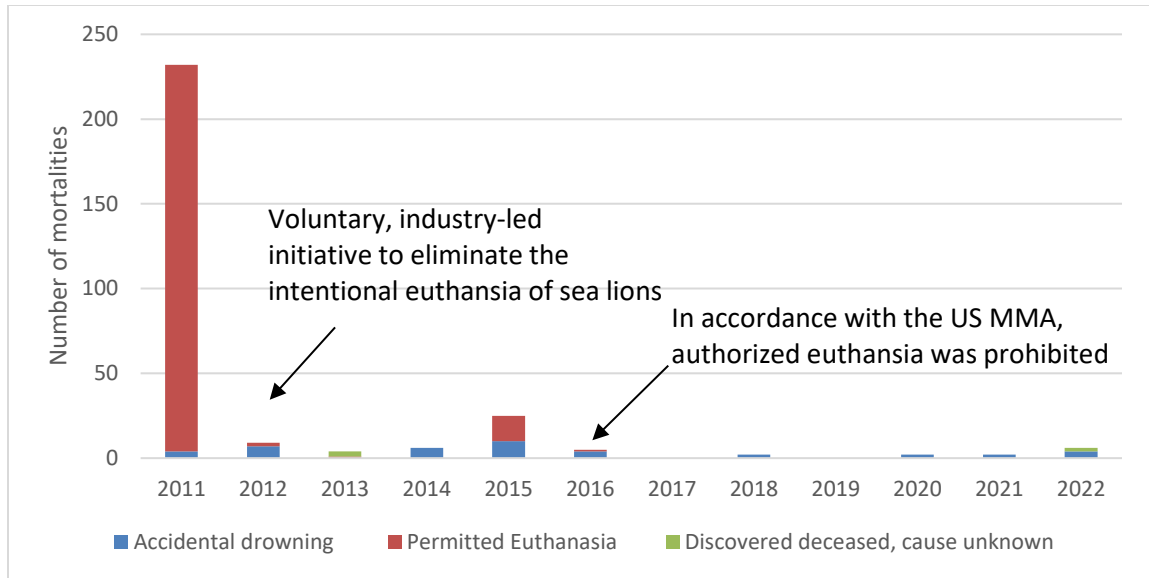


Figure 3. *California sea lion mortalities at BC salmon farms from 2011 to 2012.*
Source [DFO Open Data](#) (11).



Photo by Brian Kingzett



Photo by Bill Pennell

HARBOUR SEALS

Populations of harbour seals in BC have been slowly increasing since the 1960s when hunting ended. DFO now estimates that the population has fully recovered in BC, with the majority of the population residing in the Strait of Georgia (16).

BC harbour seal populations have increased from about 10,000 seals in the 1960s to over 100,000 seals in the early 2000s (DFO 2023).

Similar to sea lions, after the industry implemented a voluntary “no-kill” policy in 2012, there was a dramatic reduction in the authorized euthanasia of seals at salmon farms (Figure 4). Salmon farms have also entirely phased out the use of shark guards at the bottom of containment nets that had been a source of entanglement for seals and sea lions.

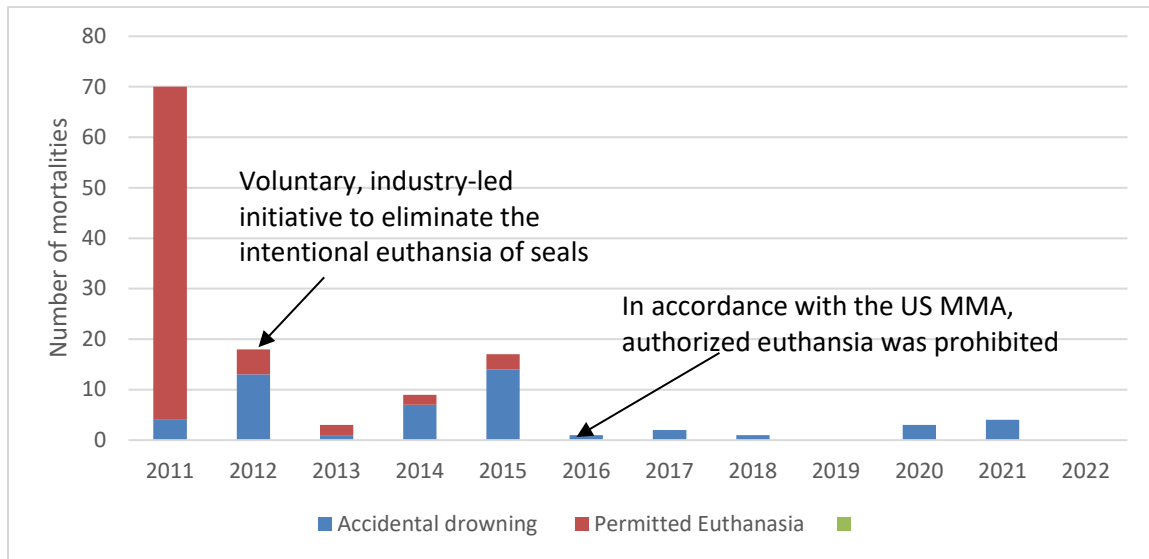


Figure 4. Harbour seal reported mortalities from 2011 to 2012.

Source: [DFO Open Data](#) (11).

DOLPHINS, PORPOISES, ORCAS AND OTHER WHALES

From 2011 to 2022, there were no lethal interactions with orcas, dolphins or porpoises at BC salmon farms. Orca, grey, minke and humpback whales are seen in the vicinity of farms. Salmon farmers have participated in cetacean (whales, dolphins, and porpoises) sighting programs and specific research programs.

To date, there have been no mortalities of cetaceans at farms, with the exception of three humpback whales, as described below.

Humpback whales

Humpback whale populations are increasing in BC. In the 1800's and early 1900's they were a targeted species for whaling and the population declined by 90% (17). In 1982, the North Pacific population of humpback whales was designated as "Threatened" by the Committee on the Status of Endangered Species in Canada (18). This was re-

examined and reconfirmed in May 2003(19). In May 2011, reflecting increasing populations of humpback whales in the north Pacific Ocean, the designation was lowered to "Special Concern"(20). As of 2018, there were an estimated 12,460 humpback whales in BC waters, with an estimated annual population growth between 4 to 8% (21).

The increase in humpback whales in BC coastal waters has resulted in increasing interactions with human activities. Blunt force trauma and serious injury from ship strikes have been identified, on an international scale, as major causes of mortality for whales (22). As vessel traffic volume increases, whale strikes in high vessel traffic areas is on the rise. However, in BC the estimated probability of a ship strike is less than a 1%, even in the areas of highest predicted risk for whale-ship strikes (22).

Humpback whales may be more prone to becoming entangled in fishing gear than toothed whales because they do not use echolocation for navigation. A preliminary research study reported nearly 50% of sampled BC humpback whales had scarring that could be an indication of entanglement with commercial fishing gear (23).

Six humpback whales interacted with salmon farms in BC from 2011 to 2022. Prior to the development of the DFO database (Table 1), an additional two interactions occurred with farms: one in 2008 and another 2009. Of the eight entangled humpback whales over the thirteen year period (2008 to 2022), five were successfully released unharmed (24). Unfortunately, the other three did not survive.

These events were related to mooring lines or nets located under farms. Contributing factors to entanglement included facility design, anatomy and age: all whales entangled were young (24). The authors of the study concluded that this could be due to naivety and inexperience, as well as developing new feeding methods compared with adults. The entanglements accounted for less than six per cent of all entanglements in B.C.

Operational changes to mooring lines were made after 2018 to reduce these interactions. DFO whale experts and regulatory personnel provide guidance/instruction to farmers in the event of an entanglement.



Photo by Brian Kingzett



BIRDS

Most wildlife interactions at salmon farms are with birds. Birds will perch on farm infrastructure for a reprieve from travelling at sea while other birds are in search of food. Bird nets and shade nets placed on pens deter most birds. Farm staff receive instruction on minimizing bird interactions, identifying bird species (especially any species at risk), and what to do if they encounter an entangled bird. On the rare occasion a bird finds its way through the mesh (typically a crow or gull), farmers will try to coax the bird outside the net.

Since companies started tracking bird interactions and mortalities, there has been, on average, zero to two bird mortalities on a farm in a 2-year period.



DFO does not request bird mortality data but, if a salmon farm is certified to the Aquaculture Stewardship Council (ASC) Salmon Standards, the information is publicly available on the company's website.



SEA OTTERS AND RIVER OTTERS

River otters and sea otters are often seen near salmon farms. River otters try to slip through small openings in nets to eat fish. Electric fences and leap fences help deter river otters from getting onto farms and into sea pens. Sea otters are commonly seen floating past farms; however, they generally avoid interacting with farms.



Photo by Brian Kingzett

HOW DO SALMON FARMERS MINIMIZE INTERACTIONS AT FARMS?

STAFF TRAINING

All site staff are trained on how to inspect and maintain the equipment that is used to minimize wildlife interactions. Training incorporates regulatory requirements including reporting, safety considerations, boating distance buffers for marine mammals and wildlife identification guides.

PREVENTION

Farmers focus on preventing interactions by minimizing both attractants and the ability for wildlife to access farm infrastructure. Over the past 20 years, farm infrastructure, including nets, anchoring, lighting, fencing, feed storage, fish mortality storage and disposal have been redesigned to minimize wildlife interactions.



MINIMIZING ATTRACTANTS

Feed use and storage

Salmon feed pellets contain ingredients and odors that can attract wildlife. To reduce the amount of uneaten feed that enters the environment, advanced feeding systems have been developed to optimize feed intake (see “Chapter 7 – Caring for the Environment – Feed Sustainability” and “Chapter 8 – Caring for the Environment – Protecting Biodiversity”). Feed is distributed to the farmed-raised salmon in the pens either by hand (for smaller fish) or by using a floating spreader on the surface of the water (Figure 5), or through a slightly submerged “snorkel feeder”. Bird nets are attached to the top of pens to prevent birds from accessing feed as it spreads from the feeder in the center of the pen.

Feed is stored securely within the floating barges to prevent wildlife from accessing the feed (Figure 6).



Photo by Brian Kingzett



Figure 5. A feed spreader is positioned at the center of the circular pen, equipped with protective netting to prevent bird interactions.



Figure 6. Feed being stored within a floating barge.



Use of lights

Atlantic salmon farms use lights during the night for a portion of the production cycle to control the salmon stock's early maturation (grilsification) during their first year at sea. The use of lights and the availability of refuge at the farms may draw wild fish to the area, and this, in turn, may attract marine mammals (25). Conversely, the structure and lights, as well as vessel traffic and other farm disturbances can also deter marine wildlife (26).

About ten years ago, salmon farmers began transitioning from high-powered incandescent or metal halide lights to high-efficiency-emitting diode (LED) lighting systems. This has resulted in about a 7-fold reduction of light penetration beyond the cages, which appears to have significantly reduced the potential of wild fish interaction (see "Chapter 6 Caring for the Environment - Minimizing Incidental Catch") (Figure 7).



Figure 7. View of LED lights at night within a salmon pen. Note the minimal light penetration beyond the edge of the cage.

Energy use and sound

Energy is required to operate the feeding and environmental mitigation systems at farms, as well as the accommodations for staff. Given that hydro power is not currently accessible at any of the salmon farms operating on the BC coast, farmers rely on diesel powered generators and air

compressors that produce noise. This noise can attract curious seals and sea lions (14). There are several trials underway to incorporate the use of alternate technologies to reduce dependence on diesel fuelled systems on the farms (see "Chapter 1 – Caring for Coastal British Columbia"). These alternatives include the use of hybrid battery systems that can

reduce generator run times on the feed and accommodation barges and the installation of efficient air compressors(27, 28).

Carcass handling

Despite the sometimes challenging conditions of the marine environment, on average Atlantic salmon growing in ocean pens have an 80% survival rate, and Pacific salmon have an 87% survival rate (see "Chapter 11 – Caring for Fish Health"). Carcasses from farm-raised salmon that have not survived are routinely collected by in pen retrieval systems and are transferred into containers. These containers are generally stored on floats away from the cage arrays. The containers

are secured to prevent wildlife access until they are transported to licensed facilities on land for disposal (Figure 8).

An ensilage system is an alternate way to store fish carcasses on the farms (Figure 9). An ensilage system uses a low concentration of formic acid to break down the fish carcasses. An inert, odorless, liquid results. The liquid is stored within a double walled tank, generally on floats alongside the accommodation barges in order to access the power required to operate the ensilage system.



Figure 8. Sealed mortality totes shown on a smaller utility float.



Figure 9. Ensilage system.

Fish carcasses are put through a grinder before entering the steel mixing container. An automated system adds formic acid into container and thoroughly mixes the contents into a liquid slurry. The liquid is considered inert and is stored in a double walled container until it is transported to a licenced disposal facility on land.



Photo by Brian Kingzett

EXCLUDING ACCESS

Excluding wildlife from accessing the farm infrastructure is an effective way to minimize wildlife interactions. This includes the use of physical barriers, like nets and perimeter fences, and active deterrents like electric fences (Figure 10). Note that the type of exclusion devices used at each farm is site-specific and determined by the type of wildlife present in the vicinity. For example, sea lions do not interact with all farms.

JUMP NETS AND PERIMETER FENCES

As part of the DFO Marine Finfish Aquaculture license for each site, all sea pens must have jump nets that rim the

outside of the cage and extend at least one meter above the surface of the water to contain any salmon that may jump out of the water. These jump nets also help prevent small marine mammals such as seals and otters from accessing the fish; however, they are not effective to deter sea lions.

In areas with high sea lion populations, many farms are using taller perimeter fences to prevent access into the pens (Figure 11). As seals and sea lions have adapted over time, so have these nets; some are now taller than seven feet.

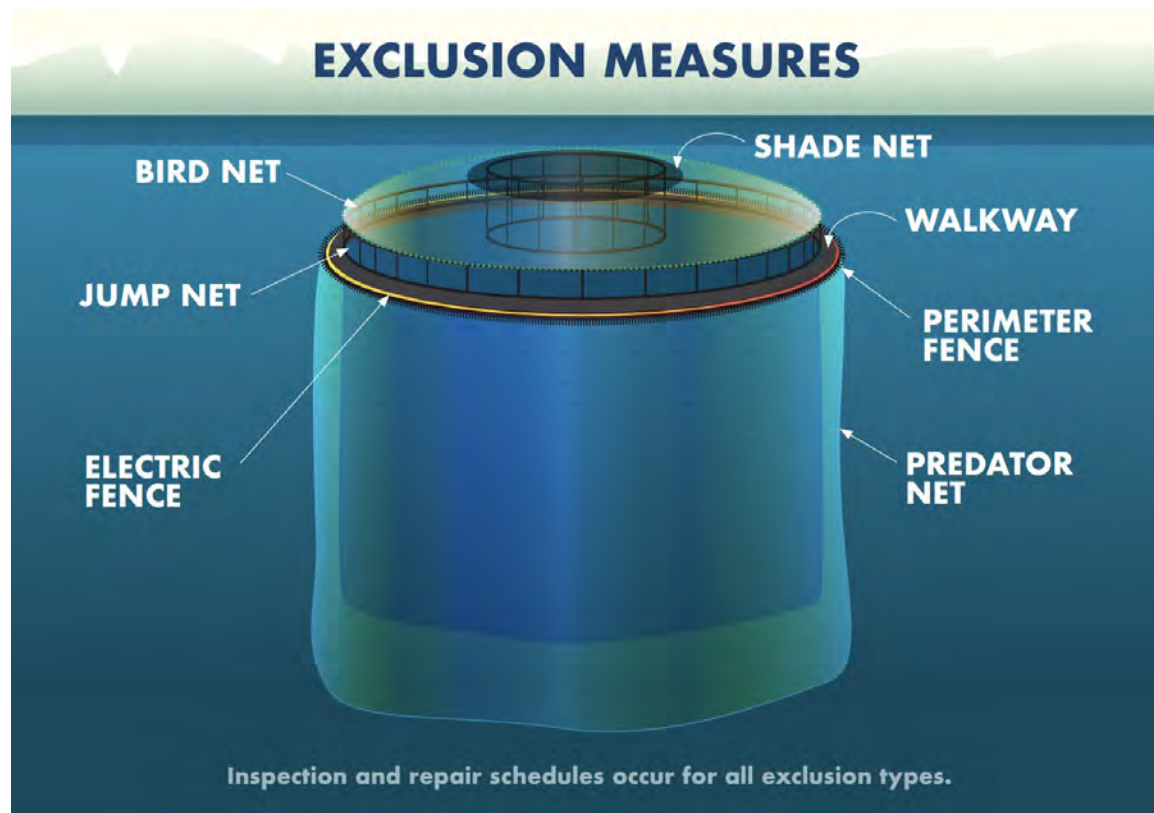


Figure 10. Illustration of the potential exclusion devices to deter wildlife that may be used in any combination at farms, depending upon the wildlife in the vicinity.

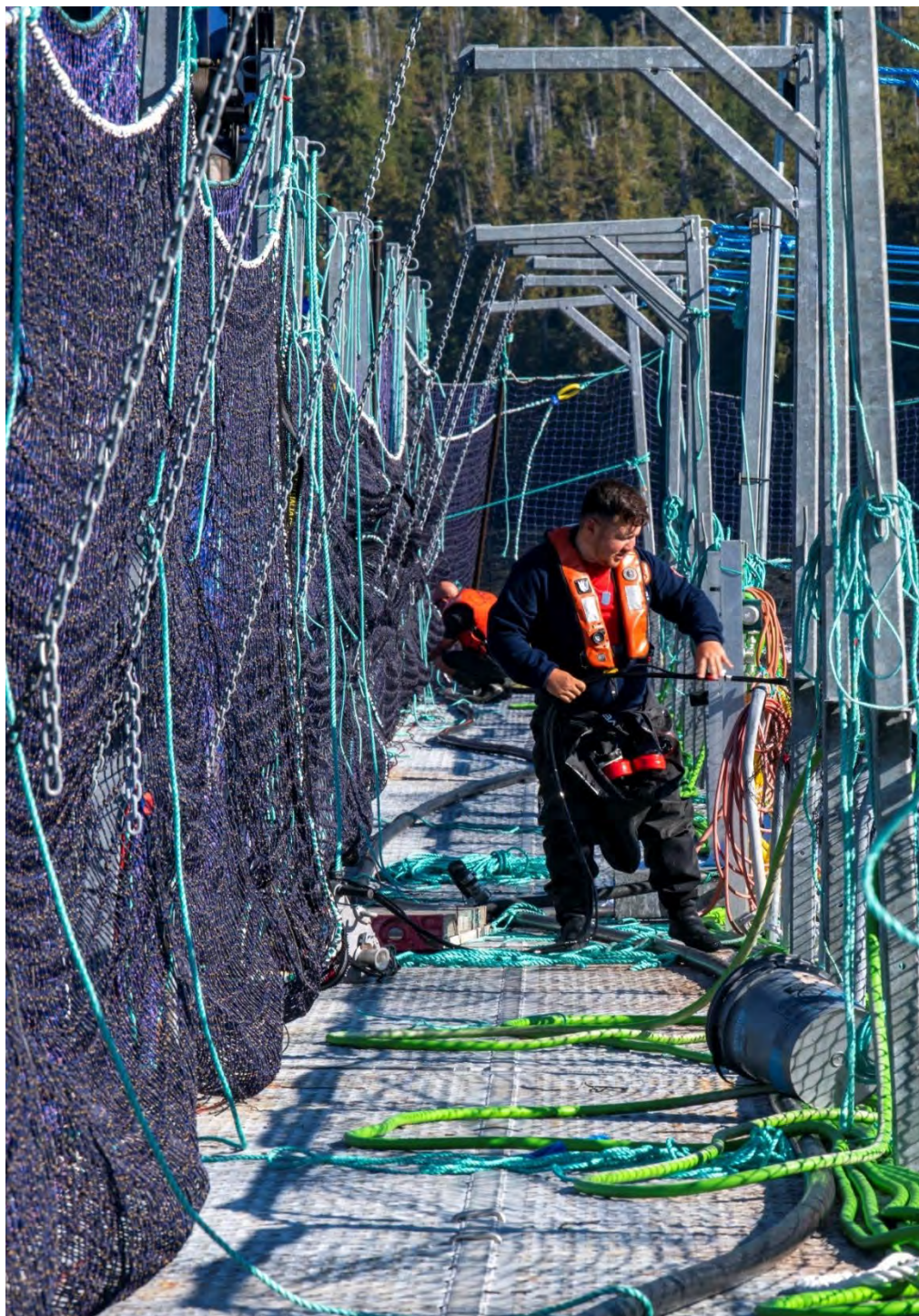


Figure 11. View of perimeter fence on a farm in an area with a dense sea lion population.

ELECTRIC FENCES

Electric fences are exclusion devices that require electricity and are considered to be an “active deterrent”. Electric fences are used along the perimeter of the farm structures and can be tied into perimeter fences (Figure 12). Electric fences can also be used on floats that mammals may rest on. This exclusion device is commonly found on farms and can be effective in preventing access to the containment nets.

Improvements to electrical fence systems include:

- o Redesigning and increasing the size of the power boxes, suitable for the marine environment, to ensure the charge in the lines is powered consistently at a charge that deters wildlife.
- o Double running lines or using larger wires with multiple disconnection points to isolate parts of the system where the fence must be shut off for operational activities, without compromising the entire line.



Figure 12. Electric line along outside of perimeter fencing.

BIRD NETS AND SHADES

All farms use bird nets to prevent birds from entering the pens in search of food. Bird nets are secured to the top of the primary containment net and are held up by poles or large plastic structures in the middle of the pen (Figure 13). These structures prevent the net from draping down into the water. Bird nets have been effective for excluding birds.

Bird shades may also be used in combination with bird nets over top of the feed spreaders. They are similar to a tarp, but allow light to penetrate into the pen. Shades prevent birds from accessing feed directly above the spreaders.



*Figure 13. Jump net being lowered to allow diver to exist the primary containment net of the fish pen.
The bird net is visible above the diver. The perimeter fence is visible in the background behind the farm staff.*

PREDATOR NETS

Salmon farmers commonly install underwater secondary predator nets around the outside of the primary containment nets that keep the salmon in the pens. Predator nets add an additional layer of underwater protection to exclude marine mammals from accessing the salmon in the pens. There have been continual improvements in the way these nets are secured and weighted to keep them taut to make it very difficult for sea lions to chew the netting material. Since 2008, there has been a shift to high density polyethylene (HDPE) netting which is more difficult for sea lions to tear. Some farms

have added metal threading to make nets even more difficult to chew or tear.

Net and infrastructure inspections

Sea cages and exclusion devices are inspected daily to ensure integrity. This includes:

- o Electric fences are operational, and charge is being consistently delivered throughout the entire line as applicable to the schedule of use developed for each site,
- o Above water perimeter fences, perimeter nets and bird nets are

- taut and do not have any gaps or holes,
- o Any damage to the system that would indicate that a mammal was attempting to access the system is reported to a supervisor and documented,
- o Underwater net pen cages are visually inspected every 30 – 60 days subject to wildlife activity, and
- o Underwater predator nets are inspected at minimum every 60 days unless there has been an increase in predator related fish mortality or a facility breach by a marine mammal.

Note that the type of exclusion devices used at each farm is site-specific and determined by the type of wildlife present in the vicinity. For example, sea lions do not interact with all farms.



Photo by Brian Kingzett

USE OF AUTHORIZED DETERRENTS

For most farms, exclusion devices are effective in preventing wildlife from interacting with farms. Unfortunately, there are instances where determined sea lions continue to aggressively pursue entry into sea pens. This can create a dangerous situation for both the sea lions and farm staff, as well as risk damage to

infrastructure. In situations where all feasible exclusion devices have failed, DFO may authorize the use of deterrents. Authorization is given through the approval of the Megafauna Deterrent Use Management Plan.



Photo by Brian Kingzett

BEHAVIOURAL DETERRENTS

Farmers will try to encourage smaller marine mammals, like seals, to leave by banging pipes, shouting, or waving arms. If this is not effective or for larger marine mammals such as sea lions, startle devices like bear bangers may be approved for use. These devices are intended to change the behavior of the marine mammal and do not cause any physical harm.

AGGRESSIVE DETERRENTS

Non-lethal aggressive deterrents may be used at a farm to deter California sea lions if authorized by DFO through the Megafauna Deterrent Use Management Plan (MDUMP) process. Deterrents can only be used from the farm infrastructure by qualified individuals approved in the MDUMP.

Aggressive deterrents that may be approved include:

- o chemical irritants used for animal control (e.g., nontoxic pepper spray),
- o projectiles (e.g., non-toxic, water-soluble paint ball or rubber pellets), and
- o electrified implements (e.g., cattle prods).

If the aggressive deterrent includes a firearm to shoot projectiles (rubber bullets) the qualified individual must be licenced, use factory projectiles and be trained on where to target the area of least impact on the sea lion. Prior to using an aggressive deterrent, the salmon farmers must:

- o provide a synopsis of the situation that warrants the use of the aggressive deterrent,
- o proposed timing of deterrent use, and
- o identify the qualified individual and their contact information.

Within seven days after the last use of the aggressive deterrent, the licence holder must provide DFO a detailed account of the deterrent usage.

ACOUSTICAL DETERRENTS

Underwater acoustical deterrents are not permitted and are not used at any salmon farm in BC. DFO defines acoustical deterrents as “a device that is used underwater and is intended to generate an aversive response in marine mammals and could cause harm, which includes but is not limited to: explosives, incendiary devices, and electronic sound recordings” (8).



Photo by Brian Kingzett

RESULTS ARE ENCOURAGING

We understand that farming within the wilderness of BC is both a privilege and a responsibility. Over the years, we have made significant investments to significantly reduce wildlife interactions at salmon farms. Our approach has been to minimize attractants at farms, prevent wildlife from accessing fish, and only, when necessary (and authorized by DFO), use deterrents to encourage wildlife to leave. The results are very encouraging – very few animals are harmed at farms.

We know many marine mammal populations are increasing in BC and there will be continued pressure to breach farm infrastructure. For this reason, we continue to support research and new technology. For example, bubble curtains used for sea lice (see “Chapter 10 – Caring for the Wild Salmon- Sea Lice Management”) may be effective in reducing interactions as the fish will not be visible to the mammals from underwater. New cage systems that sit higher above the water surface to prevent access are being trialed in BC. We are confident that continued innovation will keep both wildlife and people safe at salmon farms.



REFERENCES

1. Fisheries and Oceans Canada. California Sea Lion abundance estimation in Canada 2020-21. DFO Can Sci Advis Sec Sci Advis Rep2023.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/40951753.pdf>
2. Environment and Climate Change Canada. Convention on International Trade in Endangered Species Ottawa: Government of Canada; [Available from: <https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-organizations/convention-trade-endangered-species-summary.html>].
3. Species at Risk Act, (S.C. 2002, c. 29) (2002).
4. Fisheries Act, (R.S.C., 1985, c. F-14) (1985).
5. Migratory Birds Convention Act, 1994, S.C. 1994, c. 22 (1994).
6. The Marine Mammal Protection Act of 1972 as amended through 2018, 16 U.S.C. 1361 (1972).
7. Wildlife Act, [RSBC 1996] CHAPTER 488 (1996).
8. Fisheries and Oceans Canada. Marine finfish B.C. aquaculture licence and conditions of licence. In: Canada FaO, editor. Nanaimo: Government of Canada; 2023.<https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/licence-cond-permis-mar/index-eng.html>
9. Open Government. 2024. Escapes of cultured finfish from BC aquaculture sites Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/691dd994-4911-433d-b3b6-00349ba9f24e>].
10. Forrest B, Keeley N, Gillespie P, Hopkins G, Knight B, Govier D. 2007. Review of the ecological effects of marine finfish aquaculture: final report. Prepared for Ministry of Fisheries. Nelson, New Zealand: Cawthron Institute. Contract No.: 1285.<https://www.mpi.govt.nz/dmsdocument/15865-Review-of-the-Ecological-Effects-of-Marine-Finfish-Aquaculture-Final-Report>
11. Open Government. 2023. Marine mammal interactions at British Columbia marine finfish aquaculture sites Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/a7b3fdfb-5917-4ca6-b29c-093e3f65d6ba>].
12. Fisheries and Oceans Canada. Status of Steller Sea Lions (*Eumetopias jubatus*) in Canada. DFO Can Sci Advis Sec Sci Advis Rep2020.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/40951753.pdf>
13. Fisheries and Oceans Canada. Trends in abundance and distribution of Stellar Sea Lions (*Eumetopias jubatus*) in Canada. DFO Can Sci Advis Sec Sci Advis Rep2021. p. 8.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41003925.pdf>
14. Schusterman RJ. 1981. Behavioral Capabilities of Seals and Sea Lions: A Review of Their Hearing, Visual, Learning and Diving Skills. *The Psychological Record*.31(2):125-143.10.1007/BF03394729
15. National Oceanic and Atmospheric Administration. Fish and Fish Product Import Provisions of the Marine Mammal Protection Act. In: National Marine Fisheries Service (NMFS)

- NOaAAN, Commerce, editor.: Federal Register, US Government; 2016. p. 31.<https://www.federalregister.gov/documents/2016/08/15/2016-19158/fish-and-fish-product-import-provisions-of-the-marine-mammal-protection-act>
16. Fisheries and Oceans Canada. Stock Assessment of Pacific Harbour Seals (*Phoca vitulina richardsi*) in Canada 2019. In: Branch EaO, editor. Ottawa, Ont: Canadian Science Advisory Secretaria; 2022. p. 10.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41073654.pdf>
 17. Canada FaO. 2020. Special Projects - Structure of Populations Levels of Abundance, and Status of Humpbacks Ottawa: Government of Canada; [Available from: <https://www.dfo-mpo.gc.ca/science/mammals-mammiferes/structure/index-eng.html>].
 18. COSEWIC. Canadian wildlife species at risk. Ottawa: Committee on the Status of Endangered Wildlife in Canada; 2022. p. 136.https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/species/CSAR%20EN%202022.pdf
 19. Baird R. 2003. Update COSEWIC status report on the humpback whale *Megaptera novaeangliae* in Canada. COSEWIC Assessment and Update Status Report on the Humpback Whale *Megaptera Novaeangliae* in Canada, https://www.researchgate.net/profile/Robin-Baird/publication/288950602_Update_COSEWIC_status_report_on_the_humpback_whale_Megaptera_novaeangliae_in_Canada/links/631154c4acd814437ff7878d/Update-COSEWIC-status-report-on-the-humpback-whale-Megaptera-novaeangliae-in-Canada.pdf?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19
 20. COSEWIC. 2003. COSEWIC assessment and status report on the Humpback Whale *Megaptera novaeangliae*, North Pacific population in Canada. Ottawa: Committee on the Status of Endangered Wildlife in Canada. Available from: https://publications.gc.ca/collections/collection_2012/ec/CW69-14-233-2011-eng.pdf.
 21. COSEWIC. 2022. COSEWIC assessment and status report on the Humpback Whale *Megaptera novaeangliae* kuzira, North Pacific population in Canada. Ottawa: Committee on the Status of Endangered Wildlife in Canada. Available from: <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/humpback-whale-2022.html>.
 22. Canadian Science Advisory Secretariat. 2017. Assessing the risk of lethal ship strikes to humpback (*Megaptera novaeangliae*) and fin (*Balaenoptera physalus*) whales off the west coast of Vancouver Island, Canada. Ottawa: Fisheries and Oceans Canada. 10 p.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/40619709.pdf>
 23. Fisheries and Oceans Canada. 2020. Keeping whales free from fishing gear Ottawa: Government of Canada; [Available from: <https://www.pac.dfo-mpo.gc.ca/fm-gp/mammals-mammiferes/whales-baleines/docs/entanglements-empetirements-pub-eng.html>].
 24. Storlund RL, Cottrell PE, Cottrell B, Roth M, Lehnhart T, Snyman H, et al. 2024. Aquaculture related humpback whale entanglements in coastal waters of British Columbia from 2008–2021. *PLOS ONE*.19(3):e0297768.10.1371/journal.pone.0297768
 25. Callier MD, Byron CJ, Bengtson DA, Cranford PJ, Cross SF, Focken U, et al. 2018. Attraction and repulsion of mobile wild organisms to finfish and shellfish aquaculture: a review. *Reviews in Aquaculture*.10(4):924-949.<https://doi.org/10.1111/raq.12208>

26. Quinones R, Fuentes M, Montes R, Soto D, León-Muñoz J. 2019. Environmental issues in Chilean salmon farming: a review. *Reviews in Aquaculture*.11.10.1111/raq.12337
27. Fjord Maritime. 2023. Cermaq Canada with first hybrid in BC [Available from: <https://fjordmaritime.co.uk/cermaq-canada-with-first-hybrid-in-bc/>].
28. Poseidon Ocean Systems. 2024. Flowpressor Campbell River: Poseidon Ocean Systems,; [Available from: <https://poseidonos.com/life-support/#flowpressor>].



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CHAPTER 10

CARING FOR WILD SALMON

SEA LICE MANAGEMENT



This document describes sea lice management at salmon farms and discusses important results from juvenile wild salmon feedback loops

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CHAPTER HIGHLIGHTS – CARING FOR WILD SALMON – SEA LICE MANAGEMENT

SEA LICE NATURALLY EVOLVED ALONGSIDE PACIFIC SALMON

Sea lice occur on all species of wild Pacific salmon and are called *k̓at̓a'yat'si* by coastal Kwak'waka peoples, and *daaga* by Hlgaagilda Xaayda Kil (Haida) peoples.

Two main species of sea lice are in BC: the "salmon louse" (*Lepeophtheirus salmonis* *oncorhynchi*), which mainly infests salmon; and the "herring louse" (*Caligus clemensi*), which infests at least 12 fish species besides Pacific herring. The salmon louse is the larger and more harmful species and the subject of regulatory management programs.

Susceptibility to sea lice and the ability to reject sea lice vary considerably among species of salmon.

Atlantic salmon appear to be the most susceptible salmon species to sea lice in BC. Chum and sockeye salmon are the next most susceptible to sea lice followed by Chinook, pink, and coho salmon. Coho salmon skin mucus can engulf and disintegrate sea lice.

In controlled laboratory experiments, sockeye salmon at 40 grams can host 19 attached "salmon lice" with no significant harm. By about 90 grams, sockeye salmon appear to become more vulnerable to the "salmon louse", similar to Atlantic salmon.

Pink salmon develop the ability to shed sea lice within a few weeks after entering seawater. Based on laboratory trials, it takes an average of seven or more "salmon lice" to kill a 0.7-gram pink salmon. All researchers have reported that rapid shedding of sea lice makes it challenging to study sea lice effects on pink salmon in controlled laboratory and field settings.

Newly emergent pink salmon can swim well above the typical cruising speed of one body length per second while infested with three pre-adult "salmon lice." It takes two or more pre-adult/adult louse to compromise maximum swimming speed in small pink salmon 0.5 – 0.7 grams in size.



SEA LICE ON FARMS ARE MANAGED PRIMARILY AS A MEASURE TO PROTECT JUVENILE WILD PACIFIC SALMON

Farm-raised salmon are sea lice-free when they are stocked in ocean pens. Although Atlantic salmon are the salmon species most sensitive to sea lice, observations of significant harm to farm stock caused by sea lice have been extremely rare. Farm-raised Pacific salmon are robust against sea lice infestation and almost never require treatment. For example, there were no sea lice treatments for farm-raised Chinook salmon between 2016 and 2021.

Farmers have treated for sea lice infestations on farm-raised Atlantic salmon in British Columbia since at least 1991. In 2003, the BC government instituted a precautionary management threshold for sea lice that was twice as stringent as Norway at that time. The regulatory sea lice management threshold has been in place for 20 years.

Farmers have progressed to sophisticated and effective measures to minimize sea lice transmission from farm-raised salmon to wild salmon. These measures focus on integrated pest management using a suite of prevention and treatment tools as well as an industry agreement to cooperate, innovate, and improve.

Salmon farmers are successfully managing sea lice populations at Atlantic salmon farms during the juvenile wild salmon out-migration window, with very few exceptions. Sea lice levels at most farms have been below the regulated management threshold; all farms that exceeded the threshold initiated management measures to reduce sea lice.



PUBLICLY AVAILABLE DATA FROM FIRST NATIONS, NGOS, DFO, RESEARCHERS AND INDEPENDENT THIRD-PARTY PROFESSIONAL BIOLOGISTS DOCUMENTS THAT MOST BC WILD JUVENILE SALMON HAVE NO OR FEW SEA LICE

Sea lice levels on juvenile wild salmon are monitored in every salmon farming region in BC as a condition of federal licensing for Atlantic salmon farms. Sea lice are also monitored by other organizations. We compiled a dataset from this monitoring that includes 320,177 juvenile wild salmon that were examined for sea lice (2001 – 2022). Pink and chum salmon comprised 96% of the fish examined; coho (2%), Chinook (1%) and sockeye salmon (<1%).

- o Over a two-decade period, 86.0% of wild salmon had zero or one sea louse.
- o Sockeye salmon were the most infested species; however, the majority of sea lice were “herring louse”; only 1% of sockeye salmon had pre-adult/adult “salmon lice”.
- o Among pink salmon larger than 0.7 grams, 99% had no adult “salmon lice”.

Pink salmon grow rapidly, doubling their body size in 2 – 4 weeks. As they grow, so does their ability to shed sea lice. Most of the “salmon lice” that successfully infect a pink salmon are shed before the sea lice reach pre-adult and reproductive stages.

Comparing the dataset to published laboratory-derived thresholds of harm for juvenile pink salmon revealed:

- o sea lice might have impeded the natural cruising speed of 0.17% of the wild salmon
- o sea lice might have impeded the maximum swimming speed of 5.1% of the wild salmon

It is not known what proportion of sea lice originated from farms versus natural hosts. Also, it is not known if pink salmon that were harmed by sea lice would have otherwise survived to adulthood.

Salmon species	Number of fish sampled	% juvenile wild salmon with sea lice (any species or life stage)						
		0 lice	1 louse	2 lice	3 lice	4 lice	5 lice	>5 lice
Chinook	4,353	89.8	4.5	2.1	0.9	0.9	0.5	1.4
Chum	168,832	72.4	12.4	5.7	2.9	1.8	1.1	4.0
Coho	6,112	71.8	7.5	6.6	2.5	3.0	1.7	7.0
Pink	138,970	73.0	15.1	5.9	2.4	1.3	0.7	1.6
Sockeye	1,910	53.7	13.9	8.0	4.8	3.8	2.9	12.9
Total	320,177	72.6	13.4	5.8	2.7	1.6	0.9	3.0



SEA LICE DO NOT IMPACT CHUM SALMON POPULATIONS

Chum salmon are common in all monitoring regions. They have consistent yearly out-migration patterns in all regions (as opposed to the strong odd-year pink spawning cycle), and the species is more vulnerable to sea lice than Chinook, pink and coho salmon.

Most juvenile chum salmon do not have sea lice (any species or life stage). The highest prevalence of chum salmon with no sea lice on is in Muchalat Inlet (94.5%);

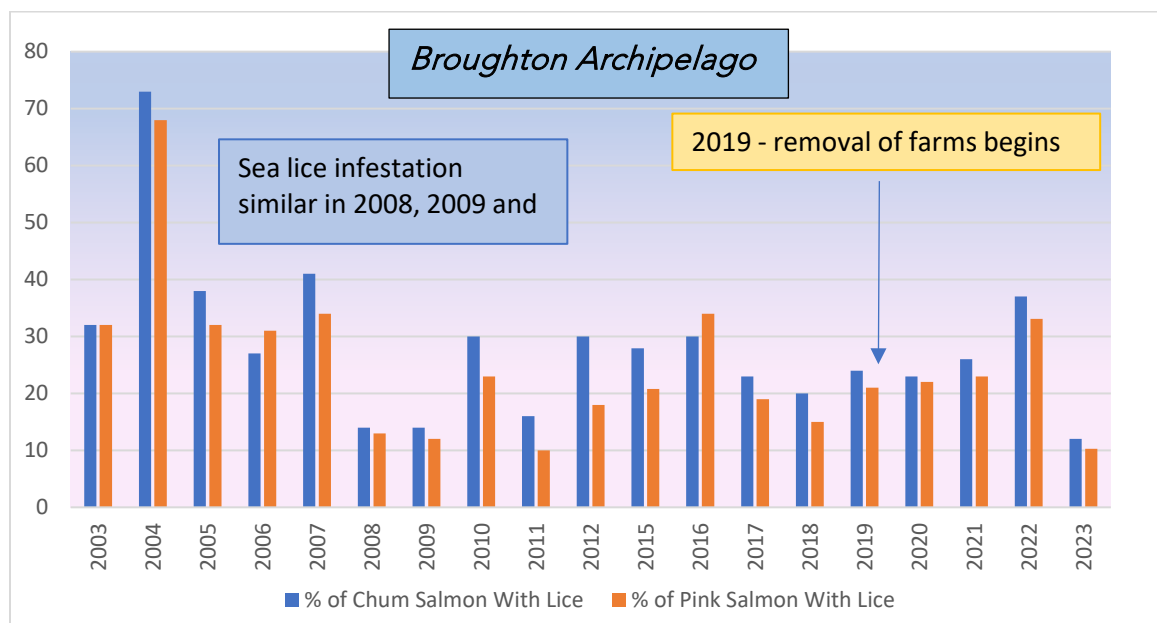
the lowest is in the Broughton Archipelago (63.5%).

Researchers focusing on the Broughton Archipelago conclude that despite higher infestation rates in chum salmon compared to pink salmon, there is no evidence of reduced productivity on chum salmon populations with either the expansion of salmon farming in the 1990s or sea louse infestations on farm-raised salmon.

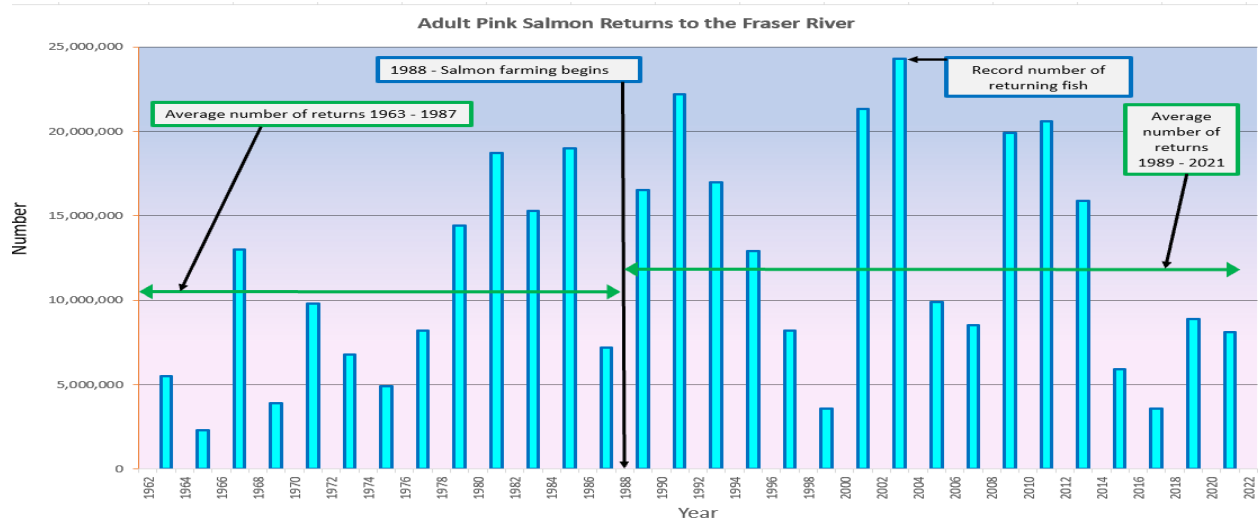
ICONIC SALMON POPULATIONS DID NOT DECLINE DURING THE SALMON FARMING YEARS

Researchers from the Broughton Archipelago Monitoring Plan (BAMP), a collaboration between DFO, environmental groups, academic researchers and salmon farmers report that sea lice treatments at salmon farms prior to the out-migration of wild juvenile salmon successfully reduce infestations on juvenile pink salmon in the Broughton Archipelago.

Sea lice infestations of pink and chum salmon in the Broughton Archipelago and Discovery Islands appear to be unchanged with the removal of salmon farms.



The Fraser River supports the largest pink salmon population in the northeast Pacific basin south of Alaska. Large pink salmon returns have occurred more often during salmon farming years in the Broughton Archipelago and Discovery Islands than in years without salmon farming. Similar patterns also occurred with sockeye salmon in the Fraser River.



In conclusion, wild salmon returns were highly variable both before and after the introduction of salmon farms. Removal of salmon farms in one area had no immediate impact on salmon returns, suggesting an independence. Wild salmon returns will continue to fluctuate with or without salmon farms. Farm management measures are effective at controlling sea lice.





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INTRODUCTION

Salmon farmers routinely hear that First Nations and other members of the public are concerned that sea lice from salmon farms harm wild salmon. For example, sea lice might become resistant to treatment methods and farmers might not be able to manage lice loads, a situation that could be exacerbated by the warming waters of climate change. It is important that salmon

farmers demonstrate that management measures are effective at reducing sea lice on farm-raised salmon now and into the future. The following sections describe the actions taken by salmon farmers to ensure that wild salmon are protected from sea lice from farms and the results of those measures.

WHAT ARE SEA LICE?

Sea lice is a common name for external parasitic copepods, a type of crustacean related to shrimp and crabs. Sea lice infest many species of fish, and they are common on salmon in both the Pacific and Atlantic oceans. In the northern Pacific Ocean along the BC coastline, all five anadromous Pacific salmon species are natural hosts for primarily two species of lice, the "salmon louse" (*Lepeophtheirus salmonis oncorhynchi*) and the "herring louse" (*Caligus clemensi*). Sea lice have a complicated life cycle (Figure 1).

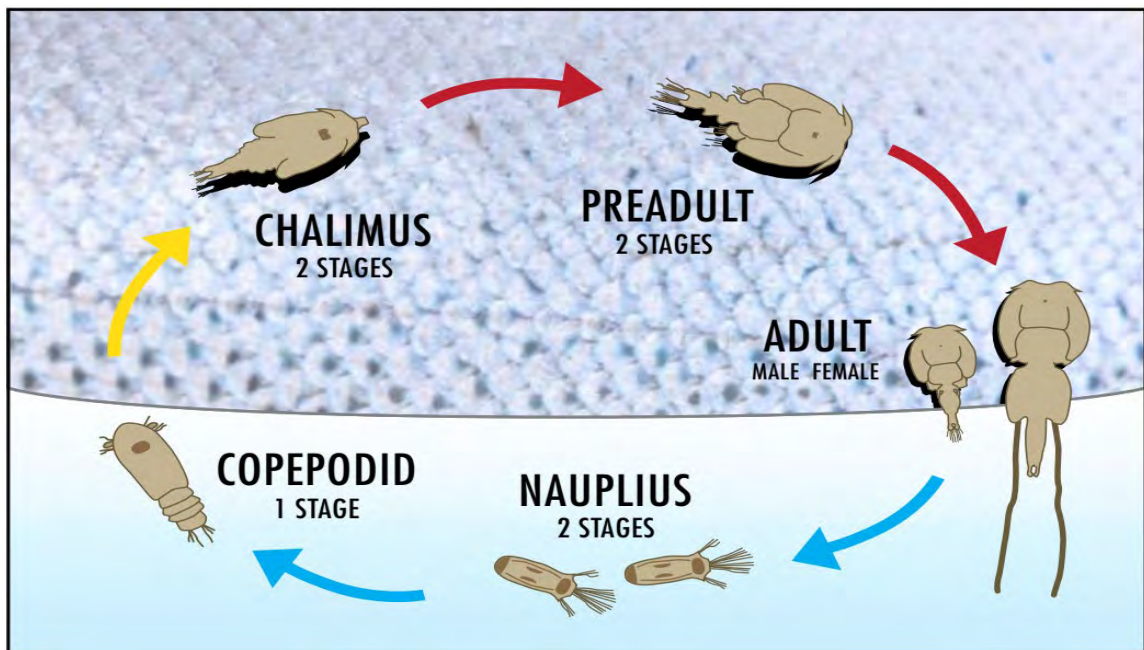


Figure 1. Life cycle of the salmon louse (*Lepeophtheirus salmonis*).

Blue arrow represents free floating stage, yellow arrow indicates the attachment stage, and red arrows represent the motile stages. Figure adapted from Thorstad et al (6)

Both species are naturally occurring parasites that attach to the outside of fish (on skin, fins, and gills) and feed on the mucus and skin. Farm-raised Atlantic salmon in the Pacific Ocean are susceptible to both species of lice, as are farm-raised Pacific salmon; however, sea lice infestation on farm-raised Pacific salmon is generally low and the fish almost never require treatments to remove sea lice (7). A third louse species, *Lepeophtheirus cuneifer*, also occasionally infests wild and farm-raised salmon in BC.

Atlantic salmon in the Atlantic Ocean are susceptible to infestations by *Lepeophtheirus salmonis salmonis* and *Caligus elongatus*, a louse species not found in the Pacific Ocean. The Atlantic form of *L. salmonis* causes more physical harm than the Pacific form (*L. salmonis oncorhynchi*). Unless otherwise noted, the Pacific form of *L. salmonis oncorhynchi* will be referred to as *L. salmonis* for the remainder of this chapter.

WHAT IS THE NATURAL SEA LICE CYCLE IN BC?

In general, large salmon are more heavily infested than smaller fish. The natural spread and infestation of *L. salmonis* on salmon occurs over time and as fish grow in the high seas (8) and when adult salmon return towards their natal rivers (9).

freshwater. Juvenile salmon that remain in nearshore habitats, after adult salmon enter freshwater, may help to carry the infections over the winter and into the following year (11).

Sea lice have naturally evolved alongside Pacific salmon. They occur on all species of wild Pacific salmon and are called *k̓at̓a'yat'si* by coastal Kwak'waka peoples, and *daaga* by Hlgaagilda X̱aayda Kil (Haida) peoples. (3)

Source: <https://www.firstvoices.com/explore/FV/s>

Infested mature salmon returning to natal rivers to spawn, can infest out-migrating juvenile Pacific salmon (10) and also resident salmon, trout and charr that spend most of their lives in coastal BC (Figure 2). All sea lice on mature salmon die in

Salmon are only one of the hosts for sea lice. Other marine host fish species include herring, threespine stickleback, rockfish, greenling, ratfish, and pollock.

These other hosts might be a source of sea lice infesting wild salmon.

The salmon louse, *L. salmonis*, is host specific, with pink and chum salmon the main natural hosts (8). *L. salmonis* is found on all Pacific salmonids and threespine stickleback (Figure 3), but it rarely matures on threespine stickleback (12). Thus, threespine stickleback, which commonly cohabit with juvenile salmon in the Broughton Archipelago, may act as temporary hosts for sea lice until a salmonid host is encountered (13).

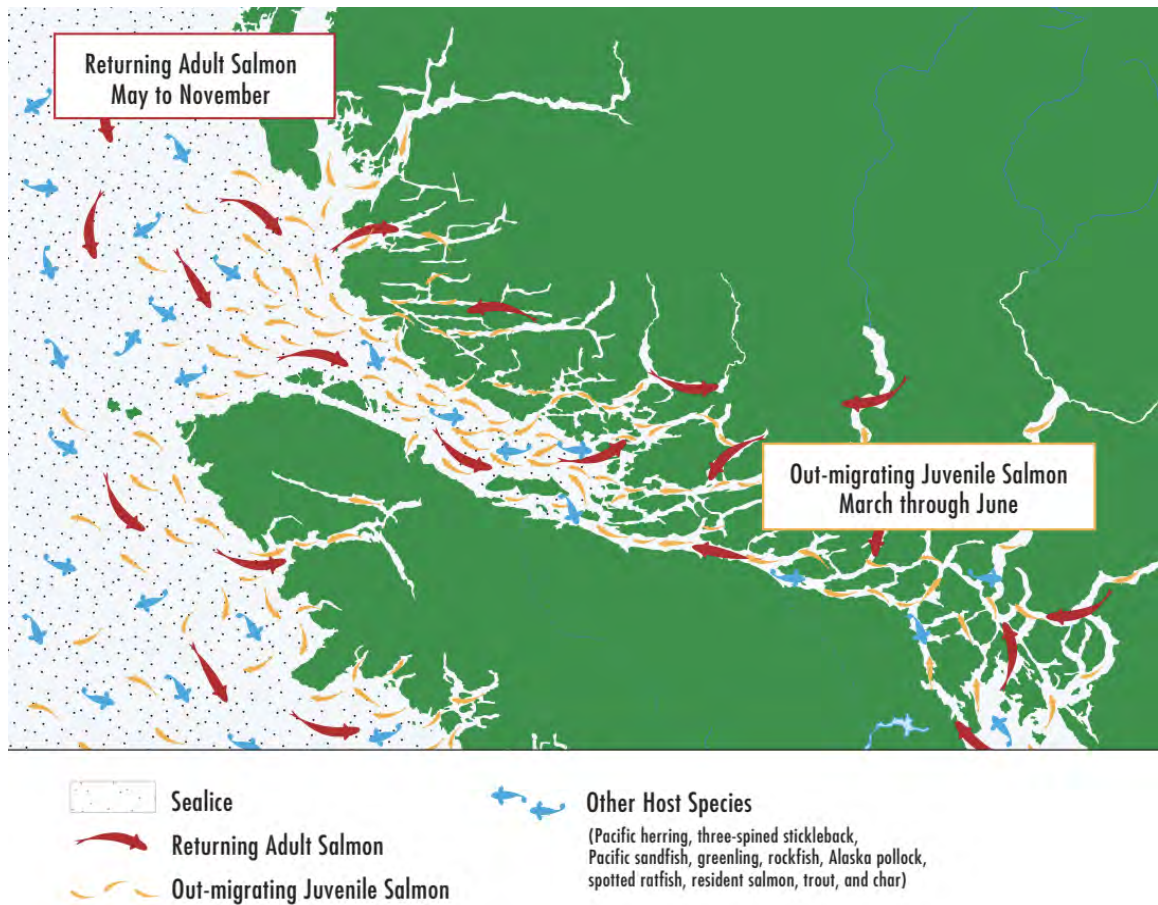


Figure 2. Schematic of natural sea lice transmission in BC without salmon farms.



Figure 3. Threespine stickleback, one of the many hosts for sea lice in BC.

Photo by Bill Pennell

In contrast, the herring louse, *C. clemensi*, infests at least 13 host species (14) and appears to favour specific environmental conditions rather than any specific fish species (7). Caligus do infest salmon and have highly mobile pre-adult and adult phases, moving between fish hosts. Infestations by the herring louse are complicated by the large number of hosts in the ocean, including Pacific herring

(Figure 4), and their ability to move from fish to fish. It is the most common louse species found on wild salmon in the north coast of BC, the Discovery Islands area, and on juvenile sockeye salmon (15). Compared to the salmon louse (*L. salmonis*), the herring louse is not likely to cause direct mortality of juvenile sockeye salmon (15).



Figure 4. *The largest population of Pacific herring in BC occurs in the Discovery Islands. The herring louse, C. clemensi, is the most common louse species in the Discovery Islands and north coast.*

HOW DO SEA LICE TRANSFER BETWEEN FISH?

Sea lice infestation can happen in two ways:

- o Most commonly as copepodids that develop from the hatched eggs of sea lice (produced by mature egg-bearing female lice), or
- o Sometimes as pre-adult or adult (motile or 'mobile' lice that can move across the surface of the fish) being transferred from one fish to another (Figure 1).

It takes about three to four weeks in BC waters for eggs produced by female lice to develop into infective copepodids in the environment, which then have about a week to find a host; otherwise, they die (5). Copepodids firmly anchor themselves to a host with a 'stalk'. Typically, another four weeks of growth on a host is needed for a copepod to mature into a reproductive adult (5). However, development is greatly affected by temperature (16). For example, the generation time from



copepodid to adult for L. salmonis is eight to nine weeks at 6 °C but only four weeks at 18 °C (17). This has implications for where the offspring of farm-source lice become infective, based upon ocean currents. There is currently no reliable method to trace the origin of a sea louse infestation.

The copepodid stage is the most common stage for *L. salmonis* to infest salmon, where they develop and stay on their original host. *Caligus* species are different;

motile *Caligus* stages commonly change hosts and, therefore, *Caligus* infestation can be from copepodids, pre-adults, or adults.

Regulatory farm sea lice treatment thresholds aim to minimize sea lice spreading their offspring to other fish. Monitoring programs evaluate the stages of lice development and are essential to determine when treatments are necessary. Farm treatments work on all species of sea lice.

At typical spring water temperatures in BC, it takes about four to six weeks for an attached salmon louse (*L. salmonis*) to mature on a salmon host. During this time, it takes a newly emerged 0.2 – 0.3 gram pink salmon about 14 – 30 days to reach 0.5 grams in size based upon an estimated growth of 3–7% body mass/ day. Thus, a juvenile pink salmon might double its size while a louse is maturing from the pin-head size infective stage to a mature adult stage (1, 2).

HOW MANY SEA LICE ARE NATURALLY FOUND ON WILD SALMON IN BC?

Adult pink salmon are often the most heavily infested wild salmon species, sometimes with more than 50 sea lice per fish (8, 9). Adult chum salmon have the second highest infestation rates in the high seas (8) and nearshore (18), ranging from 2 to 43 *L. salmonis* per fish.

13% of juvenile chum salmon had sea lice (21-29).

About 15 to 30% of juvenile chum salmon south of the Discovery Island fish farming area had sea lice (in years 2007, 2008, 2017-2023) (22, 30-37).

For wild juvenile salmon in areas without salmon farms, such as the Skeena watershed, scientists reported that about 10-23% had one or more sea lice (salmon and/or herring louse) (19). Other researchers found that 18% of juvenile pink salmon in the central coast had at least one louse of either species (20). In Holberg Inlet, from 2015 – 2023, about

Background levels of sea lice on juvenile pink salmon south of the Discovery Islands varied from 19 – 33% in years 2007, 2008, and 2017-2023 (22, 30-36).

Areas with low salinity brackish water, such as the headwaters of Knight Inlet, have few sea lice. This is to be expected, given

that sea lice cannot tolerate freshwater or brackish water.

As detailed in Table 1, these numbers are comparable to those for juvenile wild salmon sampled in salmon farming areas. For example, 27% of juvenile pink salmon and 28% of juvenile chum salmon have sea lice.

HOW DOES THE ENVIRONMENT AFFECT SEA LICE?

Water temperature, salinity, and water movement are major factors influencing the prevalence of sea lice on salmon, as is the number of returning wild fish in the area as they are natural hosts for sea lice. Warmer, saltier seawater favors the survival of lice. As an example, the warm waters associated with the El Niño in 2015 resulted in higher than typical sea lice levels on farm-raised salmon. In areas, such as the Broughton Archipelago, abundant adult pink salmon returns in

2014 likely also increased sea lice levels in spring 2015. Spring freshets reduce sea lice numbers. Consequently, sea lice distribution varies seasonally, annually, and regionally on both farm-raised and wild salmon. The abundance (the average number of sea lice per fish), prevalence (the proportion of fish with one or more sea lice) and intensity of infestations (the average number of lice per infested fish) vary by species, location, and year.

HOW DO DIFFERENT SALMON SPECIES RESPOND TO SEA LICE?

Species of salmon react differently to sea lice because they vary in their ability to reject sea lice (Figure 5). Atlantic salmon appear unable to mount a vigorous skin inflammatory response to reject sea lice (38), possibly because salivary secretions from sea lice suppress the inflammatory response in Atlantic salmon (39).

Some Pacific salmon species can resist sea lice by creating a rapid skin and systemic inflammatory response following exposure

(39-41). Coho salmon are highly resistant to sea lice and reject lice by engulfing the sea lice with a mucus layer on their skin(42), indicating that coho salmon would not likely be negatively impacted when preying on other juvenile salmon carrying lice as suggested in one scientific paper (43). This aligns with the very low sea lice observed on farm-raised coho salmon in BC (44). There are, however, currently no active coho farms in BC.

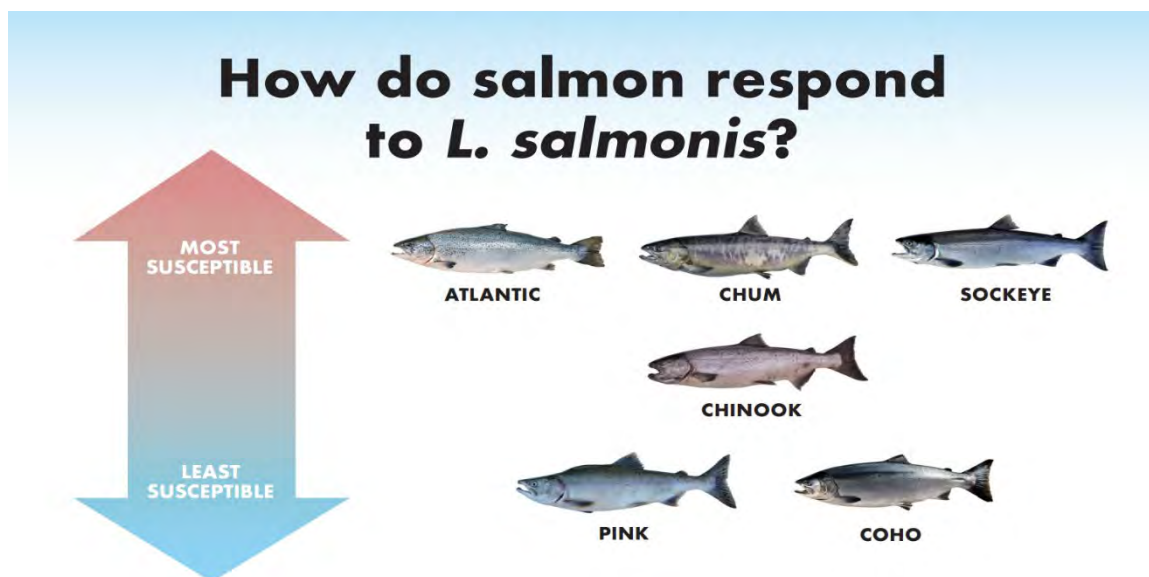


Figure 5. Response to *Lepeophtheirus salmonis* infestation by salmon species.

Juvenile pink and coho salmon can reject sea lice at higher rates than chum, Atlantic, and sockeye salmon (45). Chinook salmon tolerance to *L. salmonis* is somewhere between these two groups. Indeed, sea lice numbers on farm-raised Chinook and coho salmon are generally low, and when they do occur, they are typically below one motile *L. salmonis* per fish (44).

Susceptibility to sea lice varies by the size of salmon. For example, at 90 grams, sockeye salmon appear to have similar susceptibility as Atlantic salmon (46). Juvenile sockeye salmon migrating past salmon farms range from about three to 32 grams (47) with an average abundance of up to one *L. salmonis* per fish after a potential exposure to salmon aquaculture (48, 49). Sockeye salmon as small as 40 grams are robust against *L. salmonis* infestation in controlled laboratory experiments (45). In one laboratory experiment, sockeye salmon exposed to

100 copepodids per fish were not impaired until 21 days after initial exposure. Significant impacts to blood physiology required about 14 pre-adult sea lice per fish, but by 34 days, when infestation levels had naturally declined to only three pre-adult/adult lice per fish, blood physiology was back to normal. No fish died in the experiment. *This work clearly demonstrated that the stage at which sea lice infests the fish matters, where only larger pre-adult sea lice appeared to harm the sockeye and sockeye can reject attached sea lice.* For completeness, additional controlled exposure data is needed to clarify whether smaller (~12 g) sockeye salmon are also robust against sea lice.

Controlled laboratory experiments have reported that chum salmon are consistently more susceptible to sea lice than pink salmon (40, 50). One large data analysis, using BC data from 1970 – 2003, reported that population declines in BC

wild salmon were significantly correlated with salmon aquaculture in the case of pink salmon, but not chum salmon or coho salmon (51). This population-level correlation, however, predates much of our subsequent empirical findings, such as:

- o how many sea lice it takes to harm different species of wild salmon, and
- o the natural defense mechanisms that Pacific salmon can mount to combat sea lice, e.g., the ability to shed sea lice by a juvenile pink salmon and the ability of coho salmon skin to engulf and disintegrate sea lice.

These empirical findings provide evidence that sea lice are not the cause of the correlation of salmon aquaculture with pink salmon but not chum salmon. This is a good example of how new scientific discoveries have informed and changed our understanding of the risks of sea lice to wild salmon. In 2014, another analysis of chum salmon populations in the Broughton Archipelago, using data from 1980 – 2005, reported no effect of sea lice on wild chum productivity (52). This is good news, considering the highest prevalence of sea lice in chum salmon in BC is in the Broughton Archipelago, suggesting that effects to chum salmon in all other areas would also be minimal.



Photo by Steel_Snorkel



THE CHALLENGE OF INVESTIGATING THE CONSEQUENCES AND HARMFUL EFFECTS OF SEA LICE INFESTATIONS ON SALMON

All *L. salmonis* infection studies in laboratories or field have struggled to maintain infection levels because pink salmon shed sea lice during the trials. “Collectively, these findings of high rates of shedding of attached lice suggest that the majority of the salmon lice that successfully infect a pink salmon will be shed before they reach motile and reproductive stages.” (Brauner et al 2012) (5)

A classic empirical approach to investigating consequences of an infection is to compare uninfected animals (i.e., control animals) with infected animals. In a lab environment the louse stage and number of lice per fish can be carefully controlled and studied, but only up to a point:

- o A significant challenge is that all *L. salmonis* infection studies in laboratories or the field have struggled to maintain infection levels because salmon shed sea lice (40, 53, 54). For example, one study reported “a large group of artificially infected pink salmon were able to shed 75–80% of the initial number of attached lice after 14 days, while some individuals shed four or more salmon lice.” (54).

- o Salmon grow rapidly and, for species such as pink salmon, the ability to shed sea lice increases as they grow. Therefore, as the experiments progress, the fish grow and more readily reject sea lice.
- o Not all laboratory experiments have mimicked natural *L. salmonis* infections. It is critical that naïve, uninfected fish are the starting point. Some studies have placed adult lice on fish, but this is not the biologically typical method of infection because a) copepodids are the infective life stage, b) a fish can grow as the louse develops, and c) *L. salmonis* typically stay on their host once attached. A better infection approach to generate an infected cohort is to co-habitat salmon with either gravid female lice or copepodids harvested from them.
- o Because pink salmon shed sea lice, it is not possible to know how many sea lice they have encountered (and shed) prior to being collected as specimens from the wild. One mechanism used by salmon to shed lice is to ascend in the water column and enter diluted surface seawater that is lethal to sea lice. Juvenile pink salmon in the Broughton Archipelago performed a “significant diel migration pattern ..., which involved a preference for the surface at night-time, compared with daytime” (55). In fact, the number of live sea lice placed into the large (9 m) experimental plankton column could not be accounted for at the end of this experiment, suggesting that they had died or been eaten by fish (55).

Regardless of these challenges, statistically significant differences between a control and lice-infected groups of fish can be used to empirically identify a harmful effect or consequence of that

DO SEA LICE AFFECT SWIMMING PERFORMANCE?

One would naturally expect that adult sea lice would have the largest effects due to their larger size and that the impact would increase with the number of sea lice on a fish. For example, if a sea louse on the surface of a juvenile salmon creates a drag effect while swimming (much like pulling a parachute), then two lice might double this drag effect.



Photo by Steel_Snorkel

Thresholds for 'harmful' effects on juvenile pink salmon (0.3 to 1.5 grams) were studied in a Broughton Archipelago field laboratory using naïve salmon that had been collected from Glendale River. The salmon were infected by bath immersion with copepodids to create different levels of lice infection (54). Control and infected salmon were periodically tested over a month while the fish grew and the lice developed into pre-adults.

specific lice load. For example, laboratory trials can be used to measure the effects of sea lice on the swimming performance of juvenile salmon.

No effect levels for harm to maximum swimming performance and body ion balance were identified:

- o Fish with three pre-adult lice could still swim well above (3 BL/s) the typical cruising speed (1 BL/s), (5, 56)
- o It takes two or more pre-adult or adult *L. salmonis* to impair maximum test swimming speed in 0.5-gram pink salmon (56).
- o By about 1 gram in size, there was no measurable difference in maximum test swimming speed or in the body ions for pink salmon that were captured in seawater with one existing sea louse compared to control pink salmon (56, 57).

Combining all of the datasets together, researchers concluded that size-related tolerance to sea lice is associated with physiological adaptations that pink salmon endure while transitioning from freshwater to seawater, as well as the development of their skin/scales and immune systems. They concluded that small pink salmon (0.5 grams) are not impacted when infected with one pre-adult (chalimus-4) louse (57).



Describing Fish Swimming Performance (4)

A characteristic of locomotion in all animals is that the faster the speed the shorter the endurance time. For example, a horse cannot gallop for as long as it can canter. This characteristic is simply a consequence of the physiology of skeletal muscles.

Fish physiologists typically characterize fish swimming with three primary modes (or gaits):

1. **Cruise swimming can be maintained for days** and in natural a swimming speed (U) commonly used for fish migration is 1 body length per second, i.e., the fish moves the equivalent of its body length (BL) every second, which means that while a longer fish is moving faster than smaller fish, they are moving at the same relative speed.
2. **Prolonged swimming speeds can be maintained for up to 1 hour.** Treadmill tests that increment swimming speed every 15-60 min up to a fatigue velocity (termed U_{crit}), typically 2-4 times faster than a cruising speed.
3. **Maximum swimming speeds can be maintained for just seconds** (termed U_{max}). This is the fastest velocities used by a fish, perhaps 10-times faster than a cruising speed, are typically used for capturing prey, escaping predators and negotiating fast rapids.

A BRIEF HISTORY OF FARM-RAISED SALMON AND SEA LICE IN BC

Salmon farms have operated in British Columbia since the late 1980s. From the 1980s to 2003, veterinarians occasionally prescribed treatments to remove sea lice on farm-raised Atlantic salmon (58) (Figures 6 and 7). The earliest public records of sea lice infestations are from an August 1991 BC government survey; Atlantic salmon stocked in 1991 into the Discovery Islands area had “heavy infestations of sea lice (*Caligus* sp. and *Lepeophtheirus salmonis*)” and, “fish in affected pens were undergoing oral treatment with ivermectin to control the sea lice infestation” (59).

Sea lice numbers on farm-raised Pacific salmon are consistently low, so farm-raised Pacific salmon are rarely, if ever, treated for sea lice. For example, there were no sea lice treatments for farm-raised Chinook salmon between 2016 – 2021 (60).

Sea lice infestations of farm-raised Atlantic salmon do not cause the same health issues in Pacific Ocean farms as they do in Atlantic Ocean farms (61). These differences were initially difficult to explain

because identical-looking Atlantic and Pacific *L. salmonis* were believed to be the same species. However, genetic research eventually found significant differences between *L. salmonis* subspecies in the different oceans (62). Therefore, there is a need to use BC-based Pacific science rather than extrapolations from the Atlantic Ocean when discussing the effects of *L. salmonis* on salmon.

In 2001, a high prevalence of sea lice on sick juvenile wild pink salmon was reported in the Broughton Archipelago, leading to the hypothesis that sea lice from salmon farms were the cause of the population collapse in 2002 (63). No other diagnostic investigation was done to rule out other potential causes of mortality. The researchers did not have access to farm sea lice records, and their estimate of harm to the pink salmon caused by sea lice was based upon studies with the European subspecies of *L. salmonis*, where young salmonids can tolerate only one louse per gram of body weight (64, 65).



Figure 6. Sea louse on farm-raised Atlantic salmon..



Figure 7. Routine sea lice check on salmon farm.

Veterinarians have prescribed treatments for sea lice on Atlantic salmon farms since at least 1991.

Pink salmon have the simplest life cycle of all the Pacific salmon species. Adults spawn one year in freshwater in the fall (e.g., 2000), juveniles then migrate into saltwater the next spring (e.g., 2001), and these fish return as adults in the fall of the next year (e.g., 2002). Pink salmon have odd and even-year runs that never mix.

In contrast, farm sea lice records do not support sea lice as the cause of the population collapse in 2002 (Figure 8). The total number of adult female sea lice on all farm-raised salmon in the Broughton Archipelago was estimated to be greater in March 2000 (9.1 million) than in March 2001 (7.5 million), but adult returns of the March 2000 cohort (in 2001) were the second highest ever for the odd year run (Figure 8). It is important to note that high numbers of sea lice on farm-raised salmon in 2000 were reported by an independent assessment of escaped farm salmon; the study found an average total of 25.8 sea

lice per Atlantic salmon in August 2000 (66).

In 1999 and 2000, juvenile pink salmon out-migrated past the salmon farms and returned in 2000 and 2001 to spawn in record high numbers (67). The record returns in pink salmon were followed by population declines of 97% in 2002 and 88% in 2003 (67). Although the population declines of 2002 and 2003 generated widespread attention, the total number of adult returns each year exceeded 100,000, which is greater than adult returns in 1950 and 1953 (Figure 8).

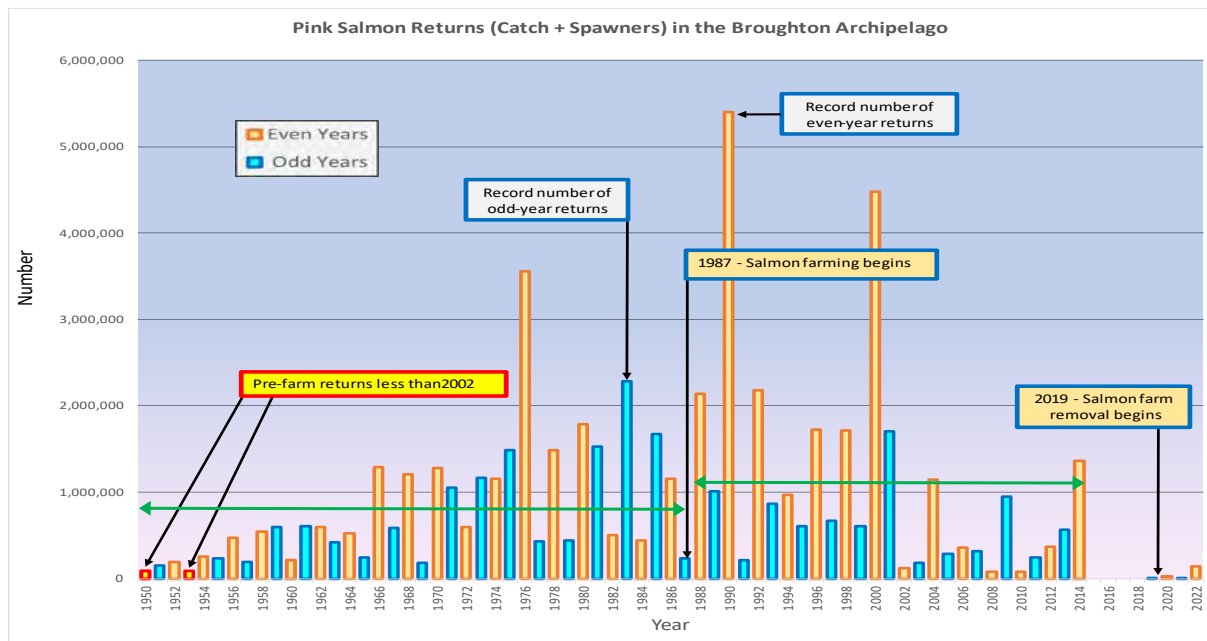


Figure 8. Number of pink salmon adults returning to the Broughton Archipelago (commercial catch plus spawners).

Note: Green lines are averages over time; data from Fisheries and Oceans Canada are incomplete after 2014 (68).

Despite the continued presence of sea lice on pink salmon at levels similar to 2007 or higher through 2014; in 2014, eight years after the prediction of 99% collapse, pink salmon returns were 14% greater than the historic average for the even year run in the Broughton Archipelago (Figure 8).

Sea lice infestations on wild juvenile pink salmon continued at 2007 levels or above through 2014 (69). During the salmon farming years 1988 to 2014, the population sometimes rebounded substantially from one generation to the next: up to an eight-fold increase from 2002 to 2004.

Modeling studies that reported a significant effect of sea lice on wild pink salmon either assumed that Broughton farm-raised Atlantic salmon had no lice in 2000 (70) or only 50,000 lice (71). This is contrary to information from the farms (67) and to the independent assessment of sea lice on escaped farm-raised Atlantic salmon in 2000 in the Broughton Archipelago by Morton and Volpe (66).

The assumption that Broughton farms had no sea lice, or not more than 50,000 lice in 2000 is implausible; therefore, the conclusions that sea lice caused the population decline in 2002 derived from mathematical models that are based upon this assumption by Krkošek et al. (2007, 2011) are also implausible. Further, early models did not account for the ability of pink salmon to shed sea lice. The incorporation of realistic shedding rates reduces the predicted mortality of pink salmon owing to salmon louse infection by 95% (5).

Scientific studies have since established that pink salmon in British Columbia are resilient to the Pacific subspecies of sea lice, and it takes 7.5 sea lice per 0.7-gram pink salmon to cause direct mortality from *L. salmonis* (72). This is vastly different from European studies that found young salmonids can tolerate about one louse per gram of body weight of the European subspecies of *L. salmonis* (64, 65).

The susceptibility of different species of salmon to the different *L. salmonis* subspecies has become increasingly relevant within Europe. Pink salmon have successfully established in northern

Europe following releases from Russian hatcheries since the 1950s (73). In June 2023, the Minister of Climate and Environment in Norway declared a “war on pink salmon” to combat their expansion into the country ([see video](#) in “Chapter 5 – Caring for the Environment – Preventing Escapes”). **Pink salmon are expanding in Norway even though the country produces approximately 25X more farm-raised Atlantic salmon than in BC (74), and the Norwegian farm salmon are infested with the European subspecies of *L. salmonis*. These facts demonstrate the robust nature of pink salmon populations exposed to sea lice.**



INITIATION OF REGULATORY THRESHOLDS FOR SEA LICE MANAGEMENT IN BC

Although the pink salmon population collapse predicted by modelers did not occur in the Broughton Archipelago, the statements were alarming for British Columbians. In 2003, in response to public concerns, the provincial government instituted stringent sea lice monitoring programs and a management action threshold of three motile *L. salmonis* from March through June, during the out-migration period of juvenile wild salmon (75), to minimize sea lice reproduction on farm-raised salmon and the potential infestation of wild hosts. At that time, the management threshold was half of the prescribed six-motile threshold in Norway and low enough to be considered at the no - or minimal - effect level for the protection of juvenile salmon (44). Norway has since updated their thresholds to a standard comparable to BC.

In 2003, the BC government instituted a precautionary treatment threshold for sea lice that was twice as stringent as Norway at that time. It is low enough to be considered effective for the protection of juvenile wild salmon. The threshold has been in place for 20 years.

Less stringent reporting and assessment requirements were established for Chinook and coho salmon farms, reflecting the low incidence of sea lice on these stocks (44).

KEY SCIENTIFIC ADVANCEMENTS IN UNDERSTANDING SEA LICE IN BC

The mandated sea lice threshold and monitoring requirements have now been in place for 20 years. Over this time, significant advances in both the management and understanding of sea lice in BC have occurred, supported by tens of millions of dollars of research funding.

The “salmon louse” in the Pacific and Atlantic oceans are genetically different subspecies. This explains the differences observed in farmed Atlantic salmon in the two oceans.



Key findings include:

- o The “salmon louse” in the Pacific and Atlantic oceans are genetically different (76, 77) subspecies (62). This helps explain differences in pathogenicity and virulence observed on farm-raised fish between the two oceans.
- o The “salmon louse” is the species of sea louse most reported on wild (9, 78, 79) and farm-raised salmonids in coastal BC (80). It is also the largest and most aggressive species affecting wild salmon and is, therefore, the target of management and treatment (81).
- o The “herring louse” infests both wild and farm-raised salmon and in particular wild sockeye salmon (15); however, the species appears to be more transient, jumping on and off fish, and it is most often associated with Pacific herring (82).
- o Sea lice have been reported on all returning Pacific salmon species, with pink and chum salmon often being the most heavily infested (18). Large infestations of the “salmon louse” on adult Pacific salmon have occurred without lesions or any evidence of detrimental effects (9, 83-85). The intensity of the infestations indicates that the natural production of sea lice could be significant during the coastal migration of adult Pacific salmon (7). The presence of early sea lice life stages on adult salmon returning to their natal rivers suggests that transmission also occurs in coastal waters (9).
- o For wild juvenile Pacific salmon, sea lice have been reported on all species. Levels vary among species (fish and louse species), by geographic location, environment (sea temperature and salinity), length of time in seawater and annually (18, 86).
- o Sea lice on farm-raised and wild salmon can come from a number of sources (9). With few exceptions, “salmon louse” abundances increase on farm-raised Atlantic salmon in BC in the autumn when adult Pacific salmon return to their natal rivers (67).
- o There is a wide range of susceptibility to sea lice infestations among Pacific and Atlantic salmon species (Figure 5). It is evident that resistance among some Pacific salmon species is associated with the ability to mount a rapid skin and systemic inflammatory response following exposure (39-41).

Conversely, Atlantic salmon appear unable to mount a vigorous cutaneous inflammatory response, possibly because they are sensitive to immunosuppressive factors present in salivary secretions of the sea lice (39).

- o Controlled “salmon louse” infection studies in the laboratory and field have struggled to maintain the infection level because salmon can shed sea lice. (40, 53, 54)



Photo by Bill Pennell



WHAT HAS BEEN LEARNED AT THE POPULATION LEVEL FROM WILD SALMON SEA LICE MONITORING PROGRAMS?

Since 2001, juvenile wild salmon in BC have been monitored for sea lice by various organizations including First Nations, DFO, researchers, non-governmental organizations (NGOs) and independent third-party professional biological consultants. These sampling programs have generated a large data set collected by a diverse group of organizations over a wide area of the BC coast that has been divided up into 10 monitoring areas based upon salmon farm production (Figure 9).

Although surveillance programs began much earlier, monitoring sea lice on wild salmon has been a mandatory requirement of the Aquaculture Stewardship Council certification program since 2012, and of the DFO Marine Finfish Aquaculture Conditions of License since 2020. Monitoring data from various NGOs (87, 88) and contracted independent professional biologists (89-91) are publicly available.

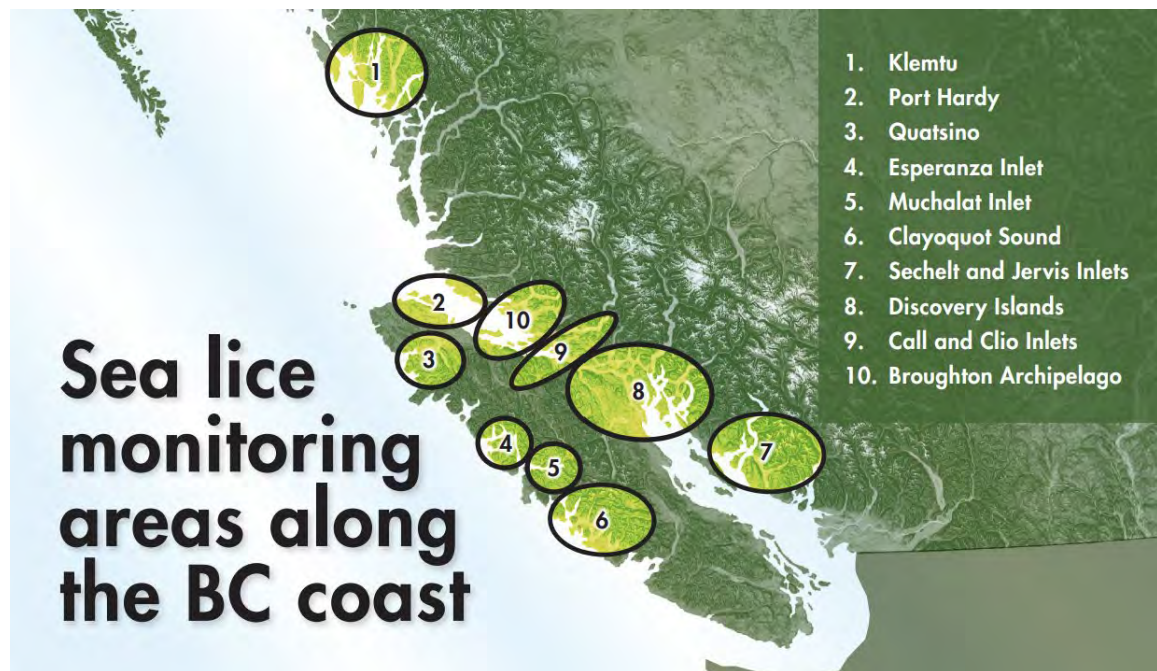


Figure 9. Map depicting sea lice monitoring areas along the BC coast.



For this report, we compiled the publicly available dataset (as of December 2022) from Non-Governmental Organizations (87, 88), independent third-party professional biologists available on company websites (89-91), and First Nations; and, we included data on both species of lice and all stages of development. Data from a joint research program between NGOs, DFO, university researchers and salmon farmers in the Broughton Archipelago (the Broughton Archipelago Monitoring Program) has also been included. After combining all the data from all available sources, the dataset was screened for quality control; duplicate and incomplete entries were removed.

Overall results from the combined data set are shown in Table 1 and Figure 10. Regardless of species, 72.6% of juvenile salmon in this combined dataset were lice-free. Furthermore, 86.0% of all sampled juvenile salmon had none or just one sea louse.

In interpreting these data, we acknowledge that the combined data set includes samples that were not collected or examined similarly. For example, fish collection methods (beach seine, purse seine etc.), time of year, fish handling procedures, and sea lice identification methods (fish examined live in the field, dead in the field, or by microscope in a laboratory) varied between and sometimes within data sets. All these variables can influence the results.

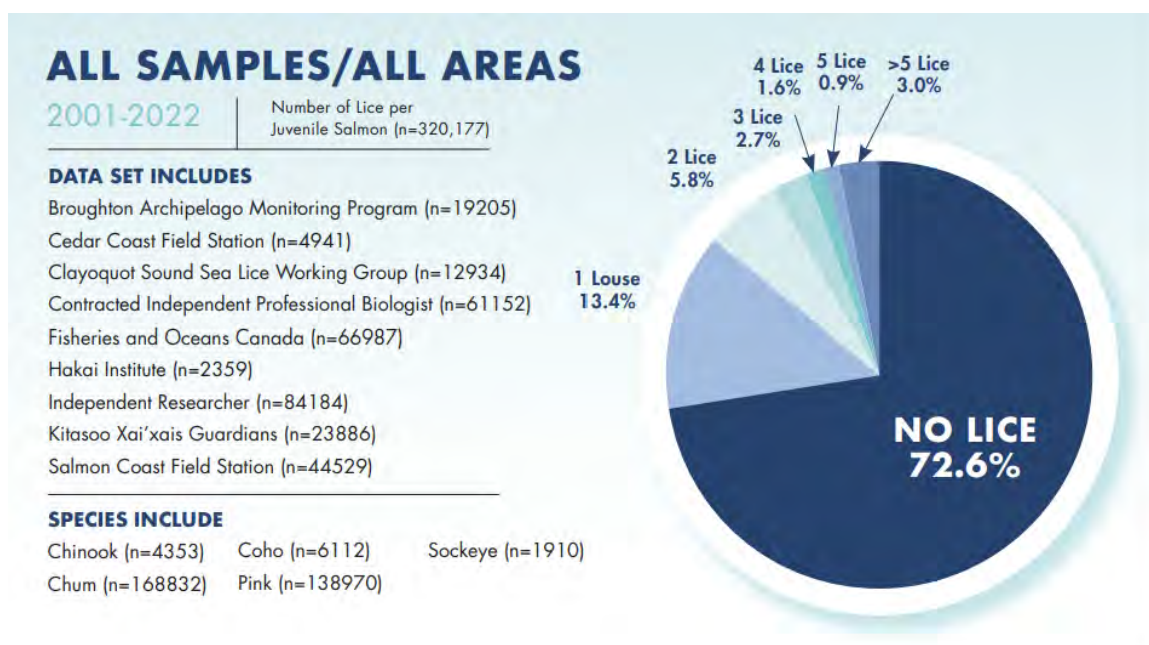


Figure 10. The number of sea lice (all stages) per fish on the 320,177 juvenile salmon sampled in the combined data set (2001 to 2022).

320,177 juvenile wild salmon have been examined for sea lice, and 96% of the fish examined were pink and chum salmon. Other species comprised a small amount of the samples collected: coho (2%), chinook (1%) and sockeye salmon (<1%). **72.6% of the of all sampled wild salmon in the data set had no sea lice at all and 86.0% had none or just one sea louse.**

Table 1. Percentage of fish by species with varying numbers of sea lice (all stages, all lice species) from the combined dataset (2011-2022)

Salmon species	Number sampled	% fish						
		0 lice	1 louse	2 lice	3 lice	4 lice	5 lice	>5 lice
Chinook	4,353	89.8	4.5	2.1	0.9	0.9	0.5	1.4
Chum	168,832	72.4	12.4	5.7	2.9	1.8	1.1	4.0
Coho	6,112	71.8	7.5	6.6	2.5	3.0	1.7	7.0
Pink	138,970	73.0	15.1	5.9	2.4	1.3	0.7	1.6
Sockeye	1,910	53.7	13.9	8.0	4.8	3.8	2.9	12.9
Total	320,177	72.6	13.4	5.8	2.7	1.6	0.9	3.0

WHAT DOES THE COMBINED DATASET SAY ABOUT DIFFERENT SPECIES OF JUVENILE SALMON?

The number of lice per fish on pink, Chinook, chum, and coho salmon are shown in Figures 11 and 12.

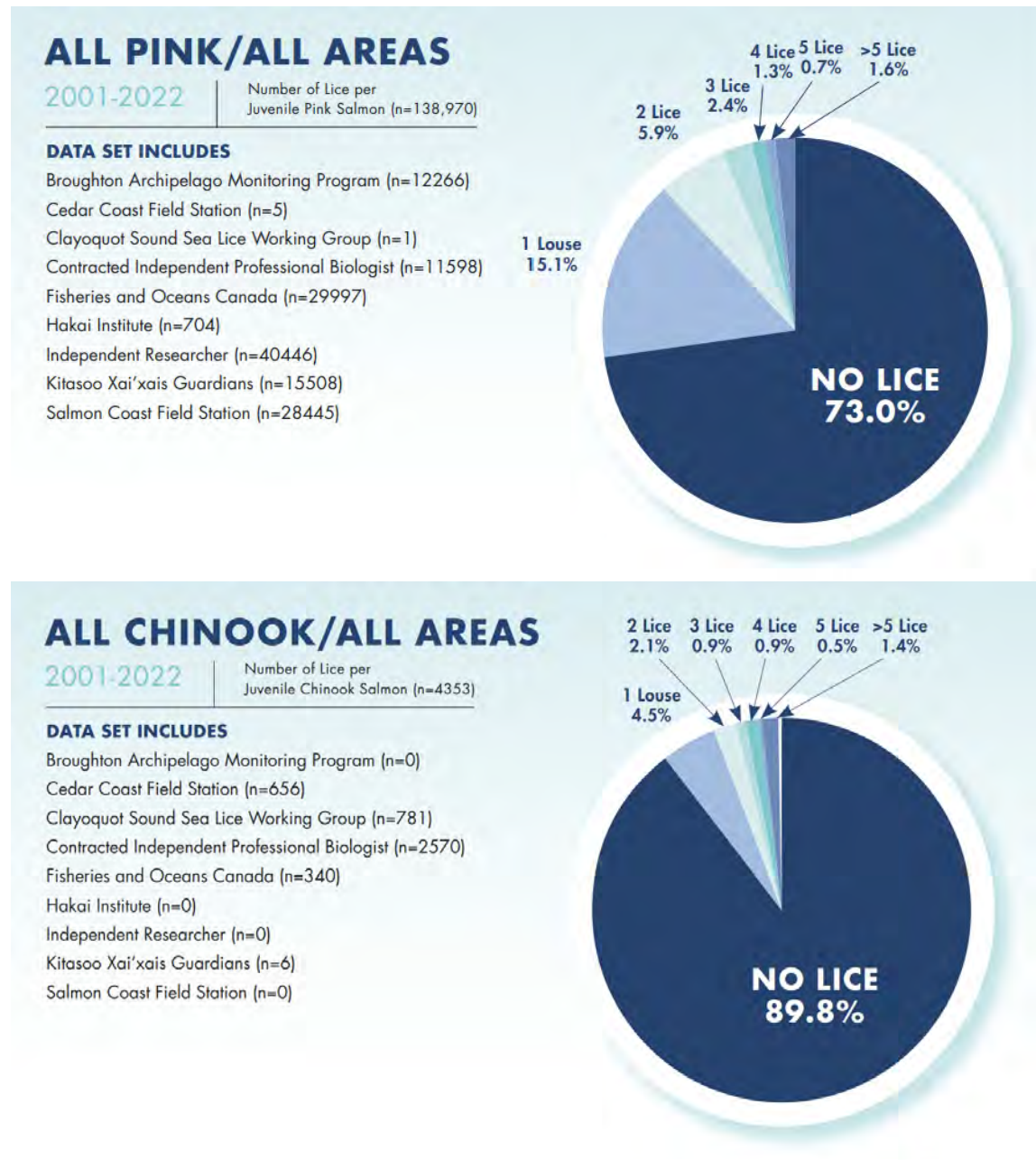


Figure 11. Sea lice prevalence (all stages, all species) on pink and Chinook salmon in all areas from the combined dataset (2011-2022).

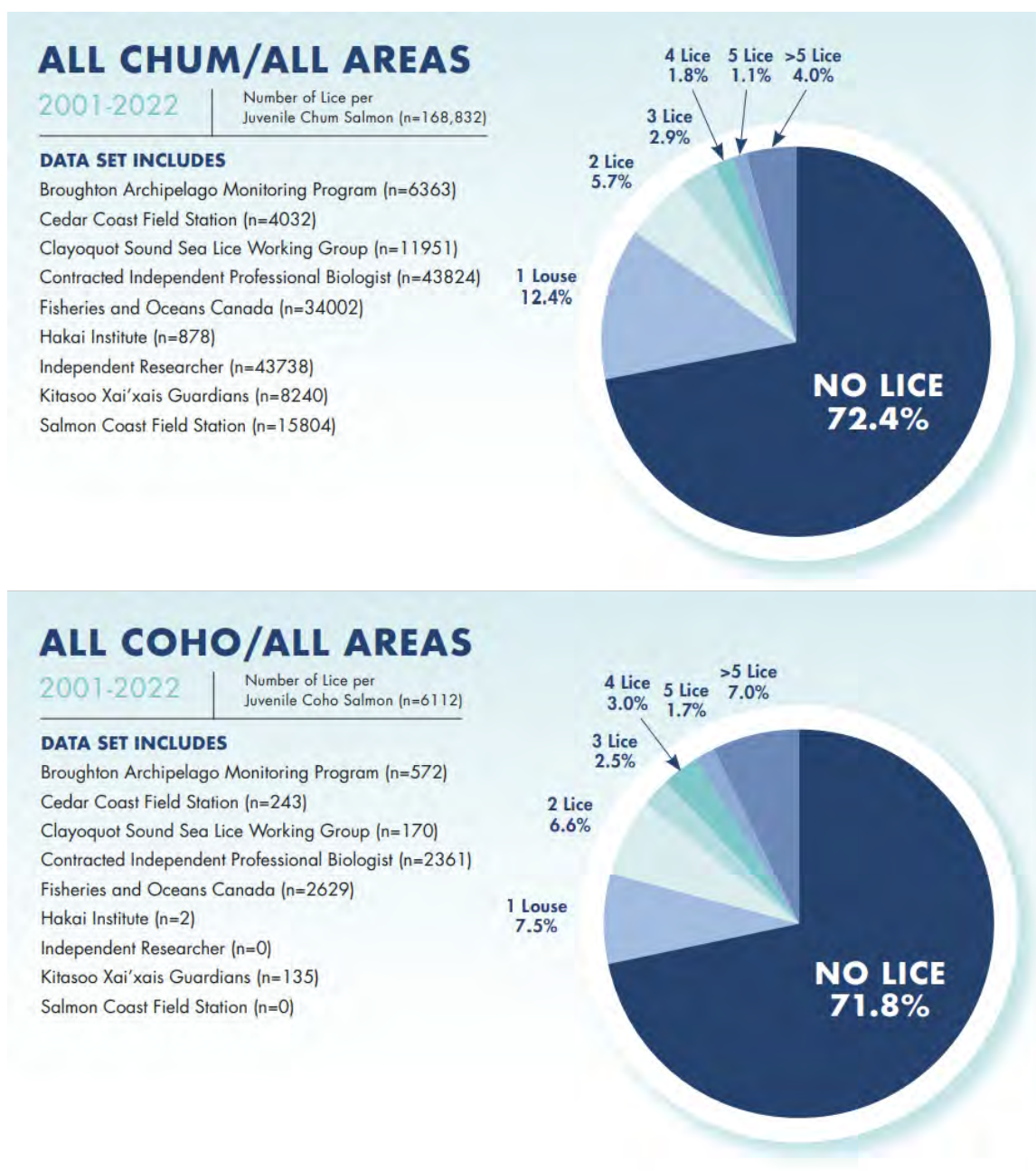


Figure 12. Sea lice prevalence (all stages, all species) on chum and coho salmon in all areas from the combined dataset (2011-2022).



Photo by Centre for Aquatic Health Sciences



FEW PINK SALMON JUVENILES ARE HARMED BY SEA LICE

Researchers have assessed the potential effects of sea lice on swimming performance and mortality in BC pink salmon in controlled laboratory experiments. Based on these experiments, juvenile pink salmon rapidly gain resistance to sea lice:

- o Sea lice shedding – Pink salmon grow very rapidly, likely doubling their body mass each month (54). As pink salmon grow from 0.3 to 0.7 grams, they develop an innate ability to shed sea lice (92). When the fish reach 0.7 grams, which occurs within weeks of entering seawater, they are highly resistant to sea lice and readily shed lice (92). The resistance to infestation appears to diminish as pink salmon reach sexual maturity (38), likely explaining the large numbers of lice on returning adults. Note that there is no evidence that the reduced resistance causes any increase in sea-lice induced mortality in adult pink salmon.
- o Swimming performance - Juvenile pink salmon migrate from fresh water to the ocean when their yolk stores are depleted, which occurs when they are about 0.2 - 0.3 grams. These newly emergent pink salmon (about 0.3

grams) can still swim well above the typical cruising speed of one body length per second with three pre-adult lice (5, 56). Maximum swimming performance can be compromised in juvenile pink salmon less than 0.34 grams that are infested with one or more subadult/adult *L. salmonis* (56). When the fish reach 0.5 grams, two or more *L. salmonis* per fish are required to affect the maximum swimming performance (54, 56, 93). Once pink salmon are larger than one gram, sea lice do not have a significant effect on maximum swimming performance (54, 56, 93).

- o Lethal threshold - It has been estimated that it takes 7.5 *L. salmonis* to kill a juvenile pink salmon weighing less than 0.7 grams (72).

Using these data to assess the potential impact of sea lice on wild pink salmon, very few juvenile pink salmon were likely harmed by sea lice infestation (Table 2 and Figure 13). Of the total 138,970 pink salmon in the combined database, 27,107 have the required level of detail (weight and life-stage identification of sea lice for each species) to assess potential swimming-performance effects.

Table 2. Comparison of pink salmon sea lice data and published harm thresholds for *L. salmonis*.

Published harm threshold	What did we find?	What does this mean according to published scientific studies that have directly estimated harm to pink salmon from <i>L. salmonis</i> ?
Swimming performance – natural cruising speed	Of the 9,950 pink salmon in the database at 0.5g or less, 17 (0.17%) were infested with 4 or more pre-adult stage <i>L. salmonis</i> (Chalimus 2 or later stage).	Sea lice might have impeded the natural cruising speed in these 0.17%. Natural cruising speed for the remaining 99.8% was not likely impacted.
Swimming performance – maximum speed	Of the 9,950 pink salmon in the database 0.5g or less, 177 (1.8%) were infested with 1 or more pre-adult stage <i>L. salmonis</i> (Chalimus 2 or later stage).	Sea lice might have impeded maximum swimming speed in these 1.8%. The remaining 98.2% were not likely impacted.
	Of the 17,157 pink salmon in the database between 0.5g and 0.7g, 571 (3.3%) were infested with 2 or more pre-adult stage <i>L. salmonis</i> (Chalimus 2 or later stage).	Sea lice might have impeded maximum swimming speed in these 3.3%. The remaining 96.7% were not likely impacted.
Lethal threshold	Of the 29,092 pink salmon in the database 0.7g or smaller, 42 (0.1%) had 7.5 sea lice or more.	Sea lice might have killed these 0.1%.
Innate resistance (shedding) of sea lice is well developed	Of the 40,228 pink salmon in the database larger than 0.7g, 362 (0.89%) had one or more adult stage <i>L. salmonis</i> .	Adult sea lice were not observed in 99.1% of pink salmon larger than 0.7 grams.

It is not known if the pink salmon that were potentially harmed by sea lice would have otherwise survived to adulthood. Typically, about 5 % of pink salmon survive to spawn in BC. **It is also not known what proportion of sea lice originated from farms versus natural hosts.** While it is possible that sea lice killed some pink salmon before they could be sampled, similar numbers of pink salmon adult returns before and during salmon farming supports the hypothesis that sea lice had no population-level impact on pink salmon in the Broughton Archipelago (see Figure 8).

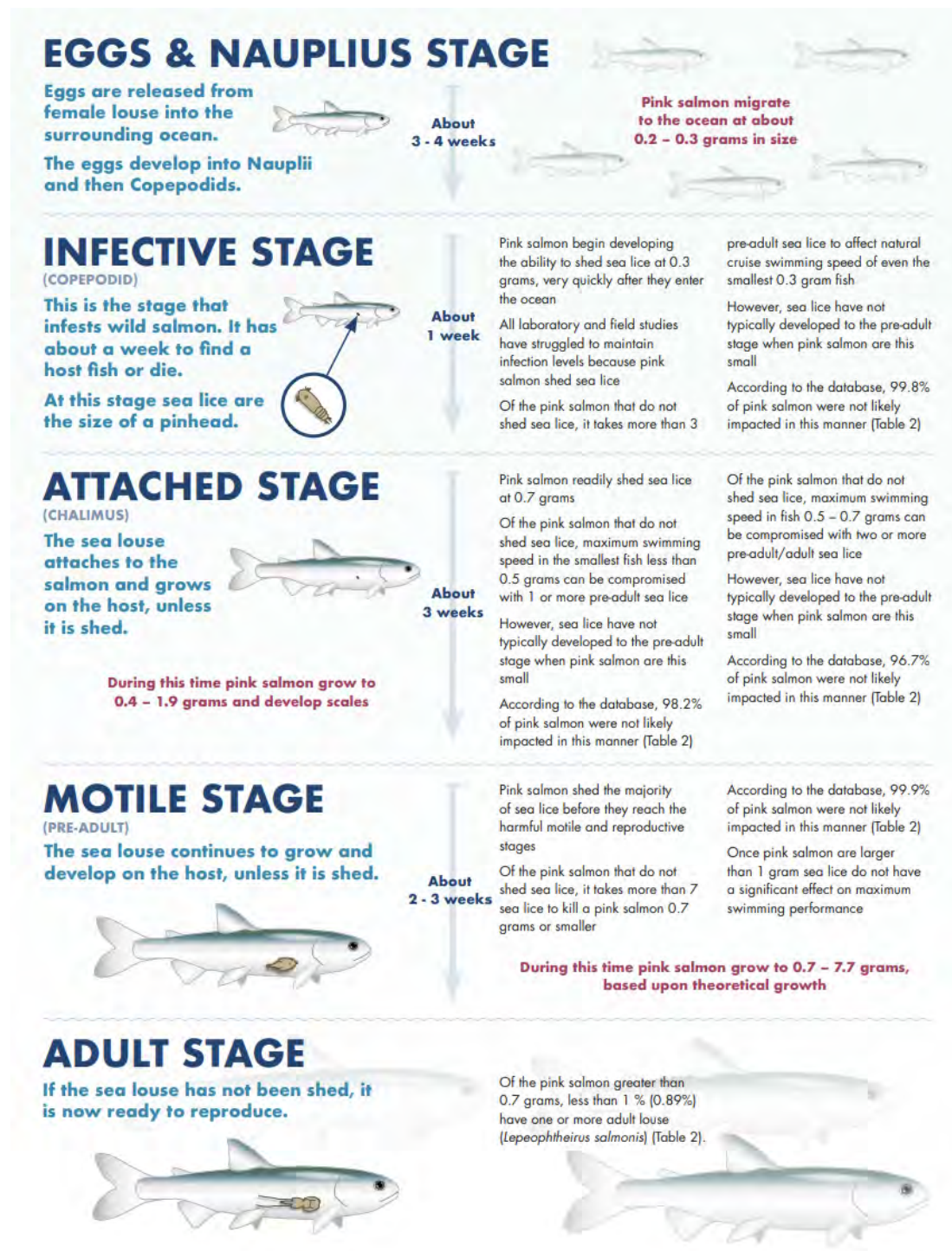


Figure 13. Relationship between pink salmon growth, sea lice development and published thresholds of harm.

Note: Although development is highly dependent upon water temperature, it takes several weeks for a *L. salmonis* to develop into the harmful pre-adult/adult stages on a host fish. By that time, most pink salmon are large enough to defend themselves from sea lice. Pink salmon growth is estimated at 3 - 7% body weight per day (2).

FEW SOCKEYE SALMON JUVENILES ARE HARMED BY SEA LICE

In total, 1,910 sockeye salmon examined for sea lice are included in the coastwide juvenile wild salmon database; fish were captured in the Broughton Archipelago, Discovery Islands, Sunshine Coast, Muchalat Inlet, Port Hardy, and Quatsino Sound. The capture method varied between purse and beach seines. Sea lice are more common on sockeye salmon (54 % infested) than any other species in the database, and the proportion of fish with more than five lice (13 %) is more than double most other species (Table 1).



Only 567 fish in the juvenile wild salmon database, all captured by beach seine, had sea lice identified to louse species and development stage. The average weight of these fish was 6.4 grams, ranging from 0.7g to 63.0 g (Figure 14). *L. salmonis* are uncommon on juvenile sockeye salmon exposed to BC salmon aquaculture, and most infestations are less than the 14 motile *L. salmonis* levels

demonstrated to be harmful under controlled laboratory conditions. Among the 567 juvenile sockeye salmon in the combined data set (in this report) that were assessed for sea lice species and developmental stage, 27 fish (4.8%) have any stage of *L. salmonis*, but only two fish (0.4%) have more than three *L. salmonis* (one with four lice and one with six lice) (Figure 15). Only eight fish (1.4%) have adult or pre-adult (motile) *L. salmonis*, and all but one of these fish have only one motile louse (one fish has 3 motile lice). The average weight of the eight fish with motile *L. salmonis* is 11.3g.

Newly published research not yet included in the coastwide database reports similar results. Among 104 sockeye salmon sampled in 2020 in the Discovery Islands region, 31 fish (30%) have any stage of *L. salmonis*, but only one fish (1.0%) has more than three *L. salmonis*. Ten fish (10%) have motile *L. salmonis*, and all but two of these fish have only one motile louse (one fish with two motile lice; the other fish, three motile lice) (94).

Average adult returns of key sockeye salmon and pink salmon populations were similar before and during the salmon farming years.

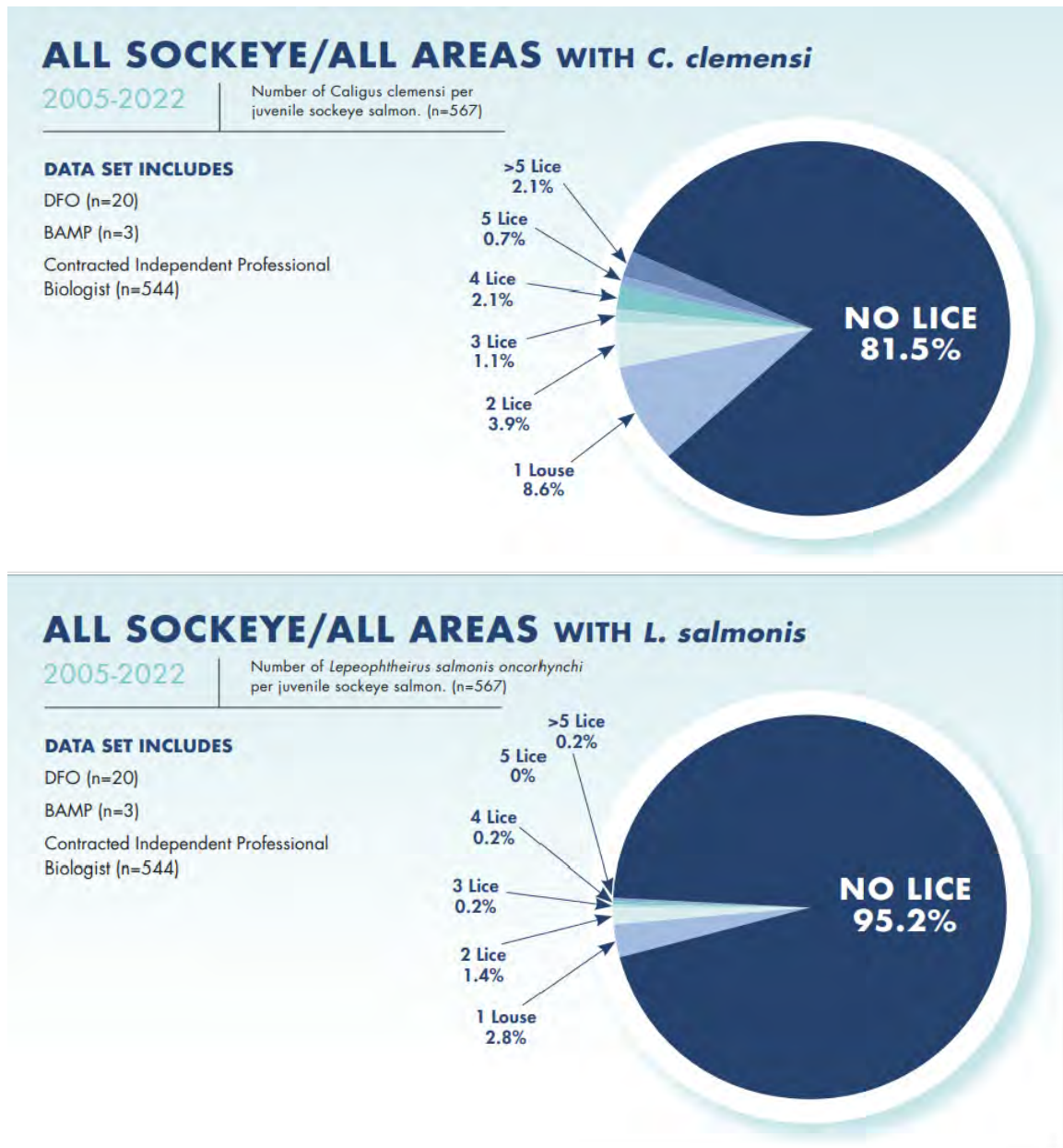


Figure 14. Sea lice prevalence by species (*Caligus clemensi* and *Lepeophtheirus salmonis*) (all stages) on sockeye salmon in all areas from the combined data set (2005-2022) that had sufficient detail to differentiate by species.

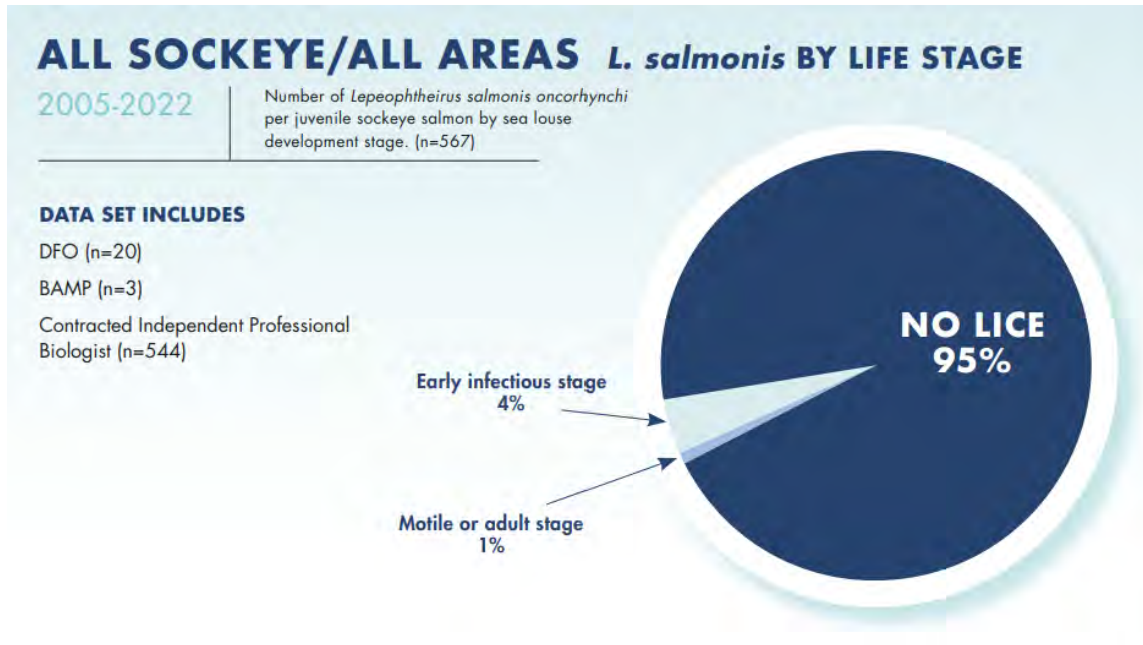


Figure 15. Sea lice prevalence of *Lepeophtheirus salmonis* by louse stage on sockeye salmon in all areas from the combined dataset (2005 -2022) that had sufficient detail to differentiate louse stage.

PINK SALMON RETURNS TO THE FRASER RIVER

The Fraser River supports the largest pink salmon population in the northeast Pacific basin south of Alaska (95). Pink salmon have discrete odd and even year spawning populations. Fraser River pink salmon spawn in odd years only; hence, the even year abundance is insignificant and not included in these calculations (95). The Fraser River pink salmon run has historically experienced wide fluctuations in the number of spawners (Figure 16). This is broadly accepted as normal for pink salmon populations (96, 97).

Average adult returns of Fraser River pink salmon were not less when salmon farms were active along the ocean migration route. This is in contrast to concerns

communicated about the risk of salmon farms to wild salmon (for example, Routledge and Morton (94) and other peer-reviewed papers) that express concerns about sea lice and Fraser River pink salmon. According to Pacific Salmon Commission data, before salmon farming began in the Discovery Islands and Broughton Archipelago, Fraser River pink salmon adult returns averaged 10.4 million per year (1963 – 1987) (Figure 16). When salmon farms were active, returns averaged 13.2 million per year (1989 - 2021). From 1963-2021, the proportion of years with returns greater than 15 million doubled from 23% (three of 13) before salmon farming began to 47% (eight of 17) during the salmon farming years.

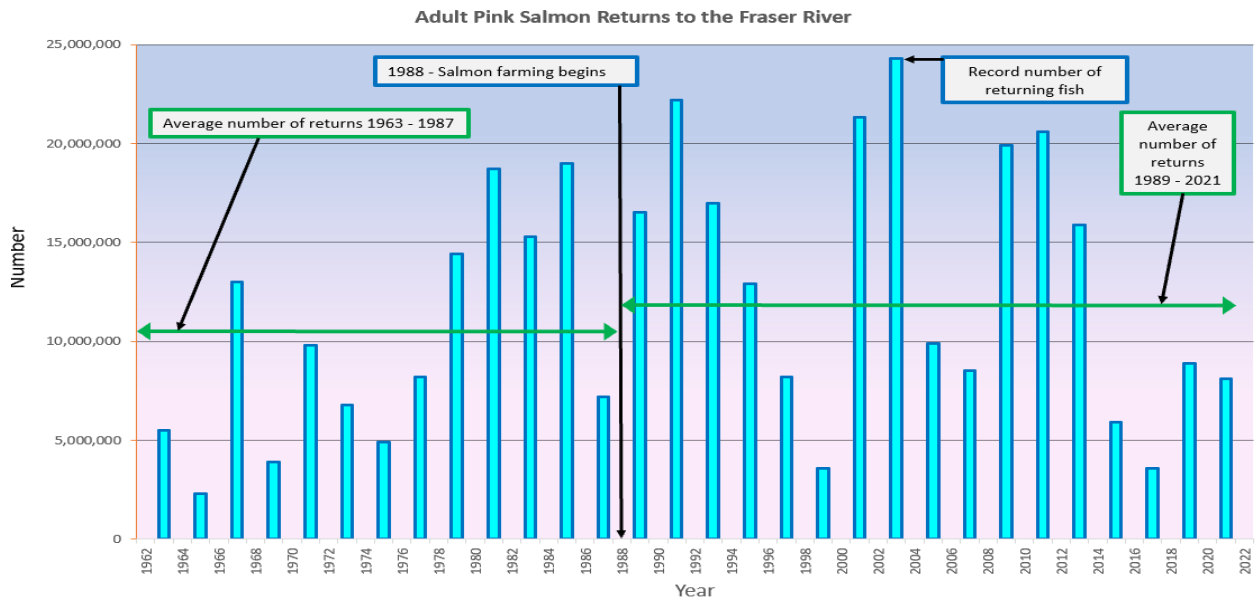


Figure 16. Number of pink salmon adults returning to the Fraser River (commercial catch plus spawners).

Note: Green lines are averages over time. Data from Pacific Salmon Commission (98).

Large pink salmon returns to the Fraser River have occurred more often during salmon farming years in the Broughton Archipelago and Discovery Islands than in years without salmon farming. Wild salmon returns are highly variable independent of salmon farms.

PINK SALMON RETURNS TO THE BROUGHTON ARCHIPELAGO

Wide fluctuation in the number of spawners is broadly accepted as normal for pink salmon populations (96, 97). This is evident in DFO records of the number of pink salmon spawners in the nine major rivers of the Broughton Archipelago rivers from 1950 to 2014 (see Figure 8). Before salmon farming began there in 1987, the population sometimes declined substantially from one generation to the next: 70% decline from 1967 to 1969 and 1975 to 1977, and 86% decline from 1985 to 1987. In other years, the population rebounded substantially from one generation to the next: a five-fold increase from 1969 to 1971.

Before salmon farming, adult returns exceeded two million twice (in 5% of the years); during salmon farming, adult returns exceeded two million four times (in 15% of the years). Before salmon farming, adult returns were less than 200,000 six times (in 16% of the years). During salmon farming, adult returns were less than 200,000 four times (in 15% of the years). From 2019 to 2021, incomplete data on some of the rivers in the Broughton Archipelago indicate that some of the runs have been the lowest on record.

The total number of adult pink salmon returns to the Broughton Archipelago did not decrease after salmon farming began there in 1987. From 1950 – 1987, prior to salmon farming, the total number of adult returns each year averaged 0.8 million. From 1988 – 2014, during salmon farming, adult returns averaged 1.1 million.

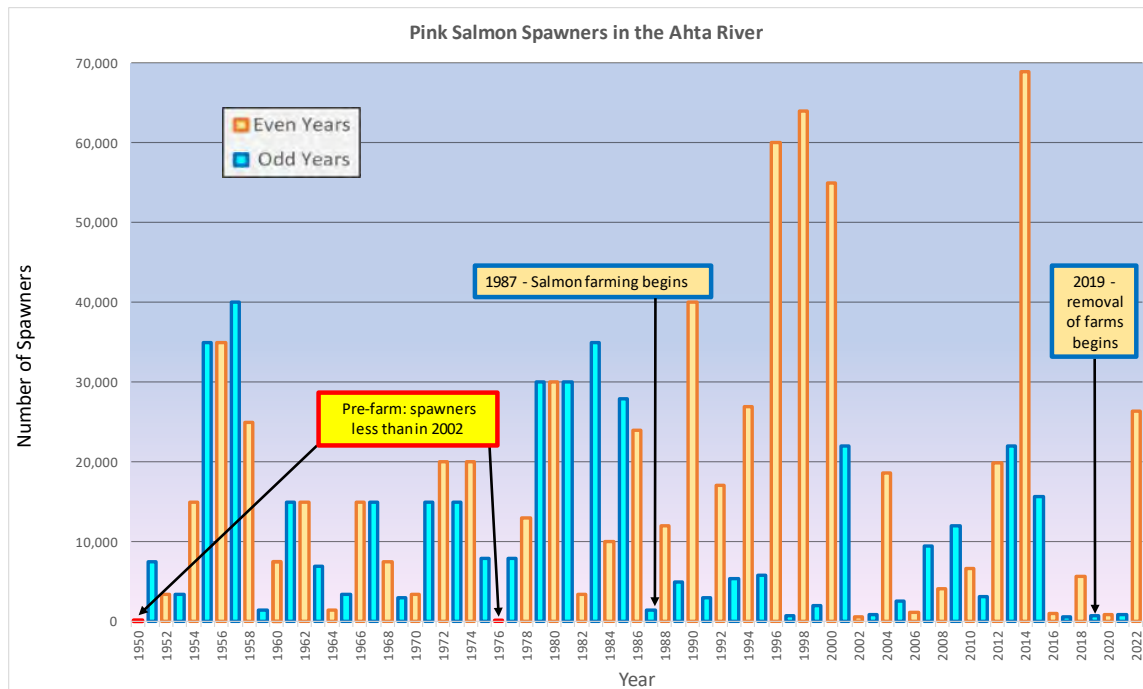


Figure 17. Number of pink salmon spawning in the Ahta River 1950-2022.

Note: Data source Fisheries and Oceans Canada (68).

Since 1950, higher than average pink salmon returns to the Broughton Archipelago have occurred more often during years with salmon farming in the Broughton Archipelago than in years without salmon farming. As long as environmental conditions are maintained, we can expect pink salmon runs to continue to be variable in the future regardless of the removal of salmon farms.

The Ahta River is one of the rivers in the Broughton Archipelago that has complete DFO pink salmon return data through 2022 (Figure 17). Before salmon farming (1952 - 1987), the average number of

spawners was 14,499 per year. During salmon farming (1988 - 2021), the average number of spawners was 15,166 per year. Note that prior to 2002, government



regulators had not prescribed a sea lice management threshold.

The number of pink salmon spawners declined more than 85% from the parent generation before salmon farming in five of 36 years (14%) and during salmon farming in four of 34 years (12%) (Figure

17). The number of spawners increased more than 25,000 from the parent generation before salmon farming in one of 36 times (2.8%) and during salmon farming three of 34 times (8.8%). Note that this analysis does not include capture fisheries because DFO does not report these data for individual rivers in the Broughton Archipelago.



Photo by Steel_Snorkel

SOCKEYE SALMON RETURNS TO THE FRASER RIVER

Sockeye salmon are the most valuable wild salmon species in British Columbia for capture fisheries, and the Fraser River is the most important source. In contrast to concerns about the risk of salmon farms to wild salmon (for example, Godwin et al (100)), and any other peer-reviewed paper that expresses concerns about sea lice and Fraser River pink salmon), average adult returns of Fraser River sockeye salmon were not less when salmon farms were active along the ocean migration routes (Figure 18). According to Pacific

Salmon Commission data, before salmon farming began in the Discovery Islands and Broughton Archipelago, Fraser River sockeye salmon adult returns averaged 6.8 million per year (1962 – 1989). When salmon farms were active, returns averaged 8.0 million per year (1990 – 2022). From 1962-2022, the proportion of years with returns greater than 15 million fish tripled from 7.1% (two of 28) before salmon farming began to 21% (seven of 33) during the salmon farming years.

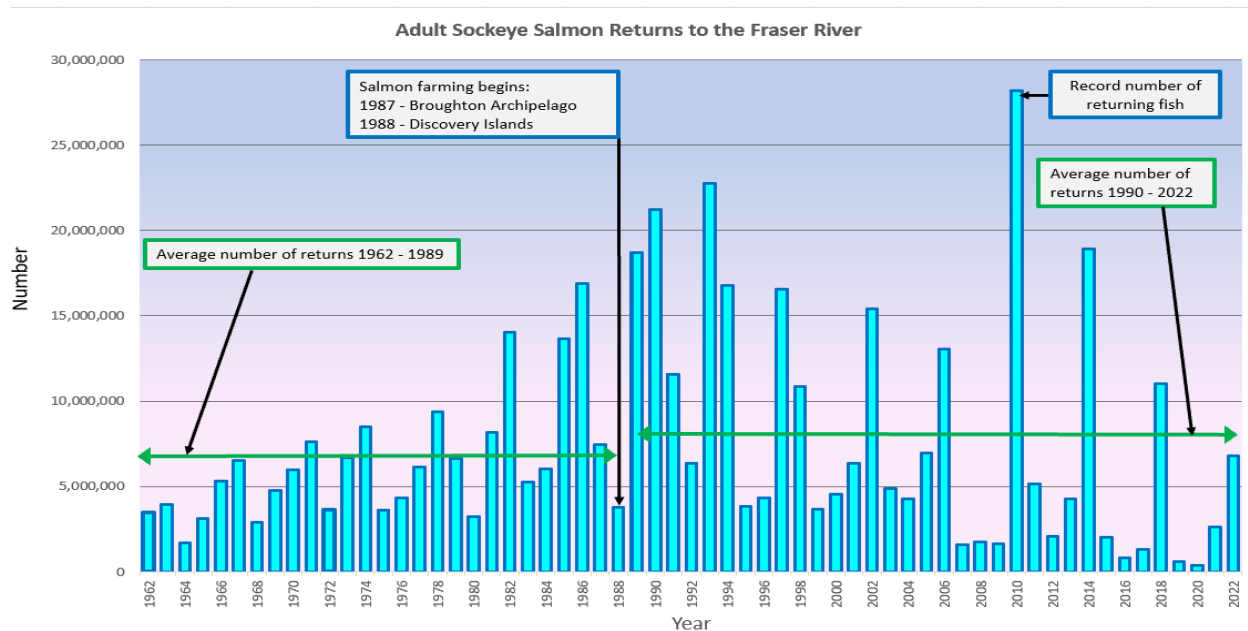


Figure 18. Number of sockeye salmon adults returning to the Fraser River (commercial catch plus spawners).

Note: Green lines are averages over time. Data from Pacific Salmon Commission (98)

In contrast to concerns about the risk of salmon farms to wild salmon, total sockeye salmon adult returns to the Fraser River did not decline when salmon farms were active along the ocean migration routes. Wild salmon returns are highly variable independent of salmon farms.



HOW DO SEA LICE VARY IN DIFFERENT COASTAL REGIONS?

Salmon farming occurs in ten coastal regions in central and southern BC. Monitoring of juvenile salmon occurs in all these regions (see Figure 9 for the map of sample areas).

Time of year, capture methods, fishing effort, and fish behaviour all play a role in fishing success. If a species is not in high abundance in these surveys it does not mean they are not present, just that they were not sampled under these conditions. Also, many times, a subset of the population captured by beach seine were selected for examination rather than the entire school. Regional analysis of the combined data set in the next sections focuses on lice levels in chum salmon. This is because chum salmon in all regions are commonly sampled and have a consistent yearly out-migration pattern, as opposed to the strong odd year pink spawning cycle.

REGIONAL TRENDS:

- o Regardless of the area, most fish in the combined data set were lice free from a low of 63.5% lice free in the Broughton Archipelago to 94% lice free in Muchalat Inlet (Table 3).
- o Chum salmon, which occur in all coastal regions, are the most frequently captured and widely distributed species within the combined dataset.
- o Coastwide comparisons show that pink, Chinook, and sockeye salmon are not prevalent in the samples in all regions, whereas coho salmon occur coastwide but are typically captured in low numbers (31 – 3,460 fish) by beach seine.

Table 3. Summary of the number of juvenile salmon analyzed for sea lice, and percent (%) lice free, by coastal region (combined dataset 2011-2022).

Area	Years	Number of Fish (% without lice)					
		Chinook	Chum	Coho	Pink	Sockeye	Total
Klemtu	2005-2022	6 (83.3)	8,240 (79.0)	132 (89.4)	15,508 (83.3)	0	23,886 (80.3)
Port Hardy	2014-2022	5 (60.0)	818 (82.3)	381 (58.3)	2,854 (83.9)	248 (58.1)	4,306 (79.8)
Quatsino Sound	2015-2022	39 (66.7)	2,814 (84.8)	306 (62.4)	1 (0.0)	33 (87.9)	3,193 (82.5)
Esperanza Inlet	2010-2012, 2017-2022	18 (83.3)	5,645 (80.5)	31 (64.5)	2 (50.0)	0	5,696 (83.9)
Muchalat Inlet	2004-2022	2,337 (94.5)	20,596 (95.4)	1,027 (91.8)	3 (100.0)	510 (86.5)	24,473 (95.0)
Clayoquot Sound	2003-2022	1,437 (81.6)	17,936 (81.4)	498 (75.9)	6 (16.7)	36 (77.8)	19,913 (81.2)
Sechelt and Jervis Inlets	2016-2022	6 (50.0)	4,511 (87.9)	18 (55.6)	2,098 (82.0)	1 (0.0)	6,634 (86.0)
Clio and Call Inlets	2019-2022	0	413 (77.7)	37 (83.8)	1,025 (83.5)	0	1,475 (81.9)
Discovery Islands	2017-2022	162 (93.8)	4,917 (81.5)	222 (81.9)	3,693 (80.6)	439 (44.4)	9,477 (79.5)
Broughton Archipelago	2001-2022	343 (94.1)	102,584 (63.5)	3,460 (55.7)	113,555 (71.2)	303 (16.5)	220,245 (67.5)
Total		4,353	168,474	6,112	138,751	1,570	319,254*

*Note 899 fish from other regions were not included in the area specific summaries, as these samples were obtained outside the operating areas.



Photo by Steel_Snorkel



KLEMTU (CENTRAL COAST)

Kitasoo Xai'xais First Nations Guardians monitored sea lice on juvenile wild salmon at 16 locations within their traditional territory from 2005 – 2020 and 2022 (101-106). The number and intensity of sampling periods varied from year to year but occurred between April and July. Fish were captured by beach seine, frozen, and examined in a laboratory for sea lice.

In total, 23,886 juvenile fish were captured: six Chinook salmon, 8,240 chum salmon, 132 coho salmon, 15,508 pink salmon and zero sockeye salmon. Of the 8,240 juvenile chum salmon sampled, 79.0% (n= 6,510) did not have any sea lice (Figure 19).

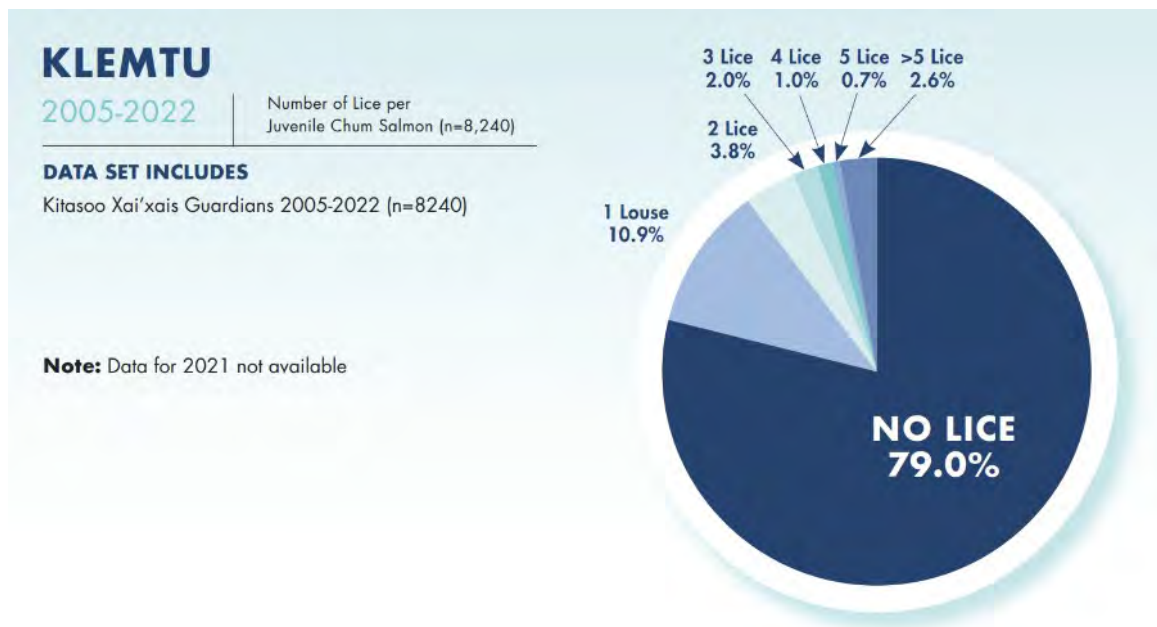


Figure 19. The number of sea lice per fish on the 8,240 juvenile chum salmon samples in the Kitasoo Xai'xais First Nations Guardian dataset (2005-2022).
Figure depicts any species of louse, all life stages.

PORT HARDY (NORTH VANCOUVER ISLAND)

A third-party professional biological consultant monitored sea lice on juvenile wild salmon at 20 locations in Goletas Channel, Shelter Channel, and the adjacent mainland coast from 2014 – 2022 (107-116). Sampling occurred annually in April and May. Fish were captured by beach seine, frozen and examined in a laboratory for sea lice. Note that exploratory monitoring also occurred in 2011 and 2013, but those results have not been included in this report due to variations in sample times and locations. The results of these years are available at [Juvenile Wild Salmon Sea Lice Monitoring - Mowi - Canada West](#). (89).

In total, 4,306 juvenile salmon were collected, consisting of five Chinook salmon, 818 chum salmon, 381 coho salmon, 2,854 pink salmon, and 248 sockeye salmon. Of the 818 juvenile chum salmon analyzed, 82.3% (n = 674) did not have any sea lice (Figure 20).

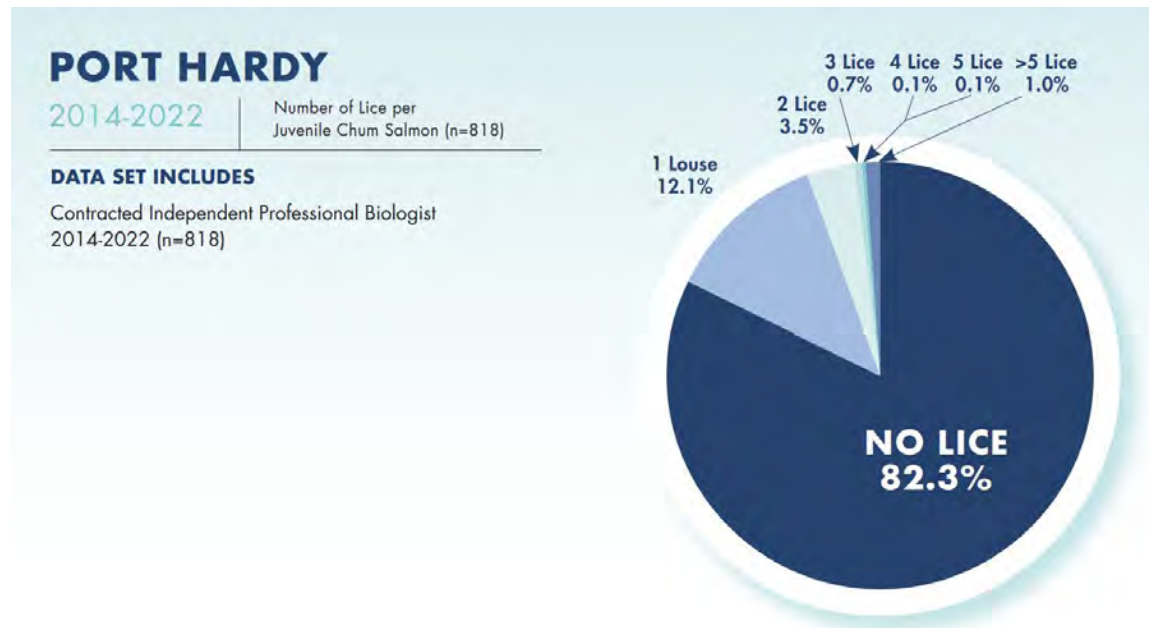


Figure 20. The number of sea lice per fish on the 818 juvenile chum salmon samples in the non-governmental dataset in the Port Hardy region (2014-2022).

Figure depicts any species of louse, all life stages.



QUATSINO SOUND (NORTHWEST VANCOUVER ISLAND)

A third-party professional biological consultant monitored sea lice on juvenile wild salmon at ten locations within Quatsino Sound: three locations in Holberg Inlet, and seven locations in the outer portion of Quatsino Sound west of Brockton Island (21, 23-28, 117). Sampling occurred annually from 2015-2022 in April and May. Fish were captured by beach seine, frozen, and examined in a laboratory for sea lice.

In total, 3,193 juvenile salmon were collected including: 39 Chinook salmon, 2,814 chum salmon, 306 coho salmon, one pink salmon and 33 sockeye salmon. Of the 2,814 juvenile chum salmon analyzed, 84.8% (n = 2,387) did not have any sea lice (Figure 21).

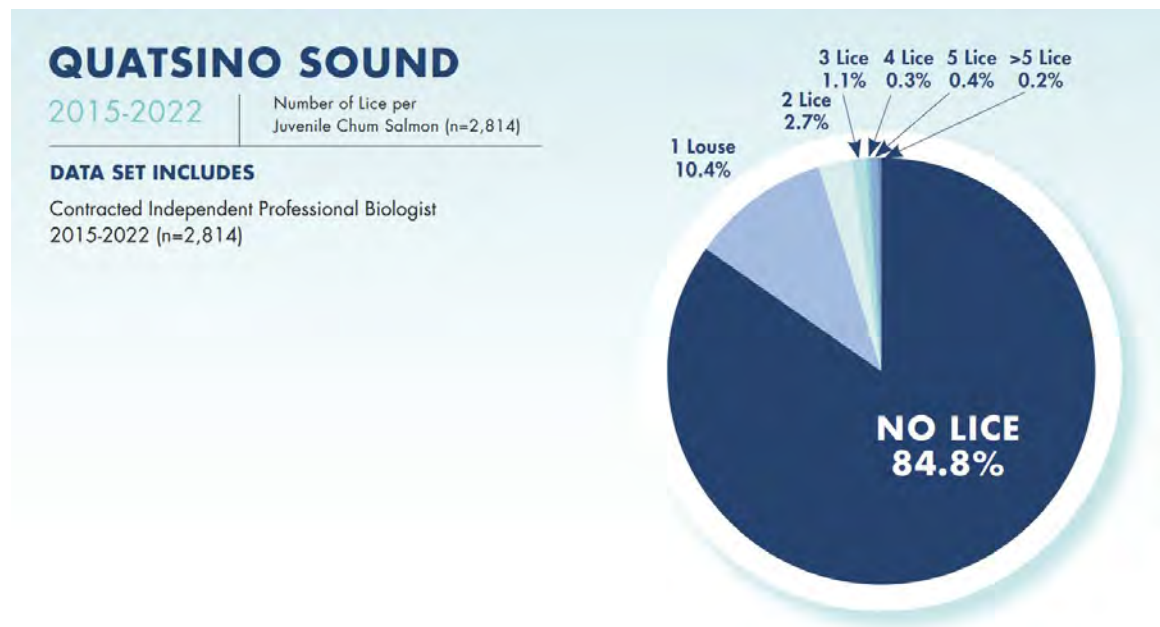


Figure 21. The number of sea lice per fish on the 2,814 juvenile chum salmon samples in the non-governmental dataset in the Quatsino Sound region (2015-2022). Figure depicts any species of louse, all life stages.

ESPERANZA INLET (NOOTKA SOUND NORTH, WEST COAST VANCOUVER ISLAND)

A third-party professional biological consultant monitored sea lice in Esperanza Inlet at 10 locations throughout Esperanza Inlet and Hecate Channel in 2010-2012 and 2017-2022 (118-126). Four additional sites were added at the outer end of Esperanza Inlet in 2020. The fish were frozen and later examined for sea lice under a microscope. Sampling occurred every two weeks from the beginning of April until the end of May.

In total, 5,696 juvenile salmon were sampled: 18 Chinook salmon, 5,645 chum salmon, 31 coho salmon, two pink salmon, and zero sockeye salmon. Of the 5,645 juvenile chum salmon analyzed, 80.5% did not have any sea lice (Figure 22).

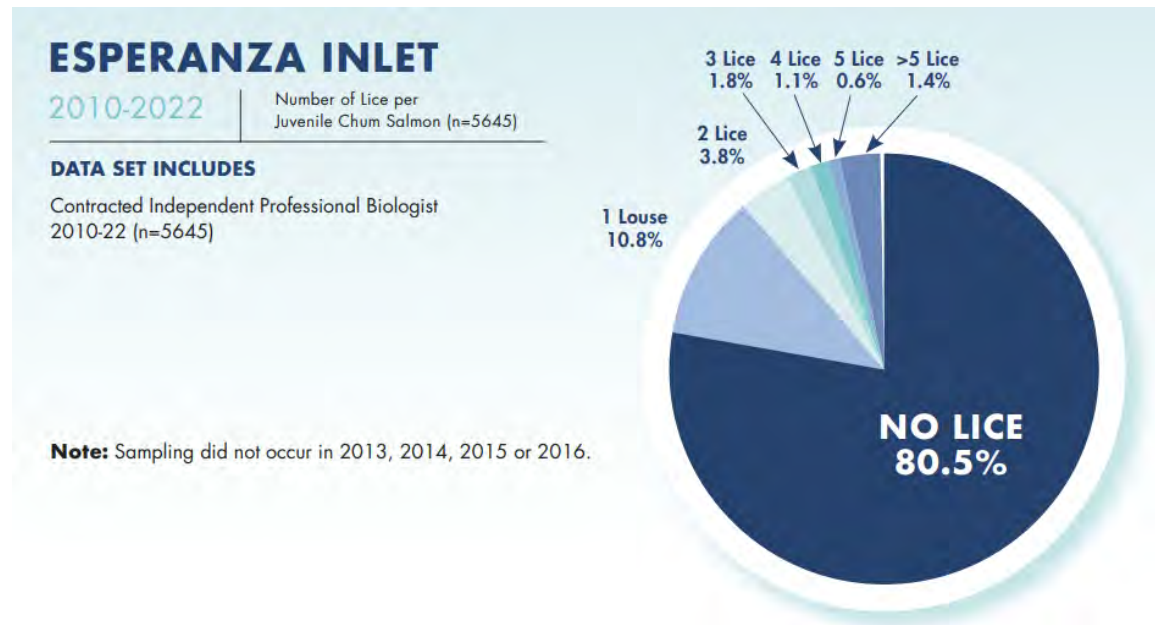


Figure 22. The number of sea lice per fish on the 5,645 juvenile chum salmon samples in the combined dataset in the Esperanza Inlet region (2010-2022).

Note: Figure depicts any species of louse, all life stages.



MUCHALAT INLET (NOOTKA SOUND SOUTH, WEST COAST VANCOUVER ISLAND)

A third-party professional biological consultant monitored sea lice at 11 locations in Muchalat Inlet, Zuciarte Channel and Hanna Channel between 2012 and 2020 (127-136). In 2021 and 2022 two of the 11 sites were dropped and an additional three sites in Eliza Passage were added to the program (137, 138). Sampling occurred every two weeks from the beginning of April until the end of May. Fish samples were frozen after collection and sea lice were counted

under a dissecting microscope in a laboratory.

In total, 24,473 juvenile salmon were sampled: 2,337 Chinook salmon, 20,596 chum salmon, 1,027 coho salmon, three pink salmon and 510 sockeye salmon. Of the 20,596 juvenile chum salmon, 95.4% did not have any sea lice (Figure 23).

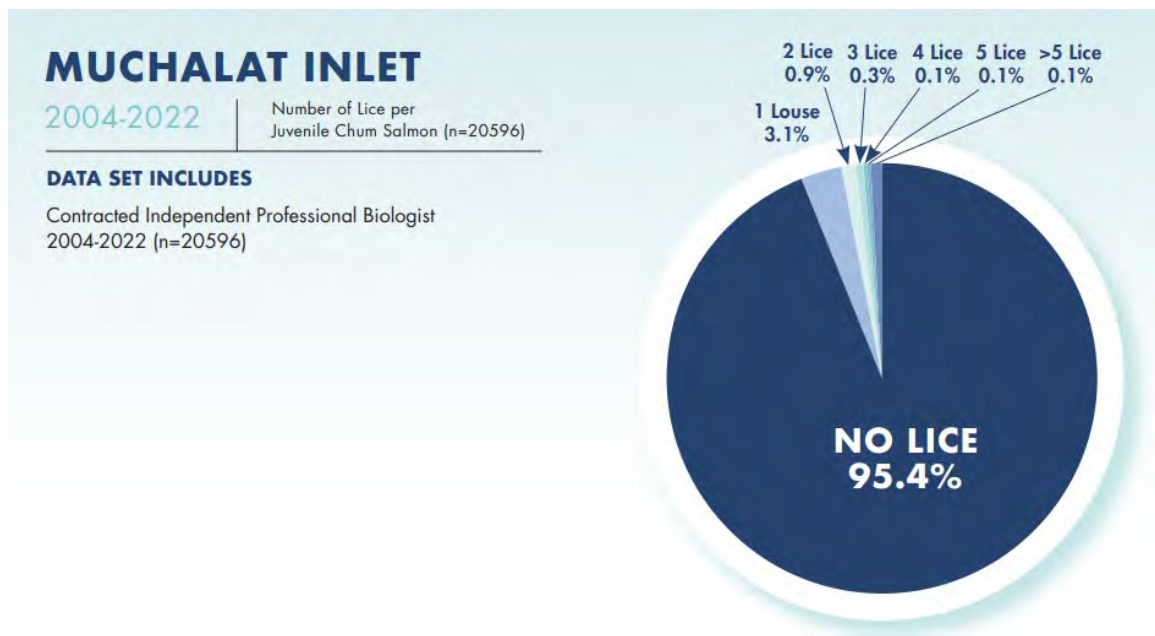


Figure 23. The number of sea lice per fish on the 20,596 juvenile chum salmon samples in the combined dataset in the Muchalat Inlet region (2004-2022).

Note: Figure depicts any species of louse, all life stages.

CLAYOQUOT SOUND (WEST COAST VANCOUVER ISLAND)

The Clayoquot Sound Sea Lice Working Group sampled juvenile wild salmon for sea lice each year from 2003 to 2011. The group was a collaboration between local First Nations, aquaculture companies operating in the area, and other stakeholder groups. Sampling locations were spread throughout Clayoquot Sound and an effort was made to sample regularly from April through June. However, the number of sites sampled, and the number of sampling periods varied widely from year to year and month to month throughout the program. Fish were frozen after collection and analyzed for sea lice using a microscope in a laboratory.

The NGO Cedar Coast Field Station sampled juvenile salmon for sea lice at up to 18 locations in Bedwell Sound between

2018 and 2022. Data are publicly available for 2018 - 2021 (88). Fish were collected weekly from the beginning of April to the end of June or early July. Sea lice were counted on live samples in the field and the fish were subsequently released.

A third-party professional biological consultant sampled wild salmon at 27 locations throughout Clayoquot Sound from 2016 to 2022 (139-145). An additional 11 locations were added in 2020 and two more locations were added in 2022 to bring the total sampling locations in Clayoquot Sound in 2022 to 35 sites. Sampling occurred every two weeks from the beginning of April until the end of May. Fish were frozen after collection and sea lice were counted under a dissecting microscope in a laboratory.

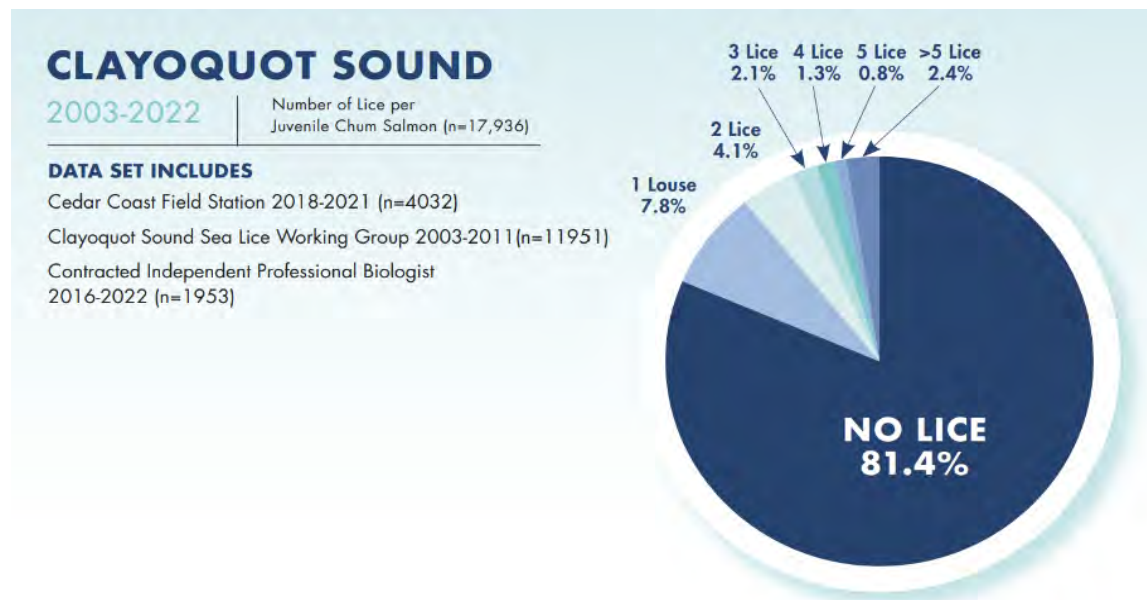


Figure 24. The number of sea lice per fish on the 17,936 juvenile chum salmon samples in the combined dataset in the Clayoquot Sound region (2003-2022).

Note: Figure depicts any species of louse, all life stages.



In total, the combined dataset consists of 19,913 juvenile salmon: 1,437 Chinook salmon, 17,936 chum salmon, 498 coho salmon, six pink salmon and 36 sockeye salmon. Of the 17,936 juvenile chum salmon, 81.4% did not have any sea lice (Figure 24).

SECHELT AND JERVIS INLET (MAINLAND COAST)

A third-party professional biological consultant sampled wild salmon at 15 locations in Sechelt, Salmon, and Jervis inlets from 2016 to 2022 (146-152). Sampling occurred every two weeks from the beginning of April until the end of May. Fish were frozen and analyzed for sea lice under a microscope in a laboratory for sea lice.

In total, 6,634 juvenile salmon were sampled: six Chinook salmon, 4,511 chum salmon, 18 coho salmon, 2,098 pink salmon and one sockeye salmon. Of the 4,511 juvenile chum salmon sampled, 87.9% did not have any sea lice (Figure 25).

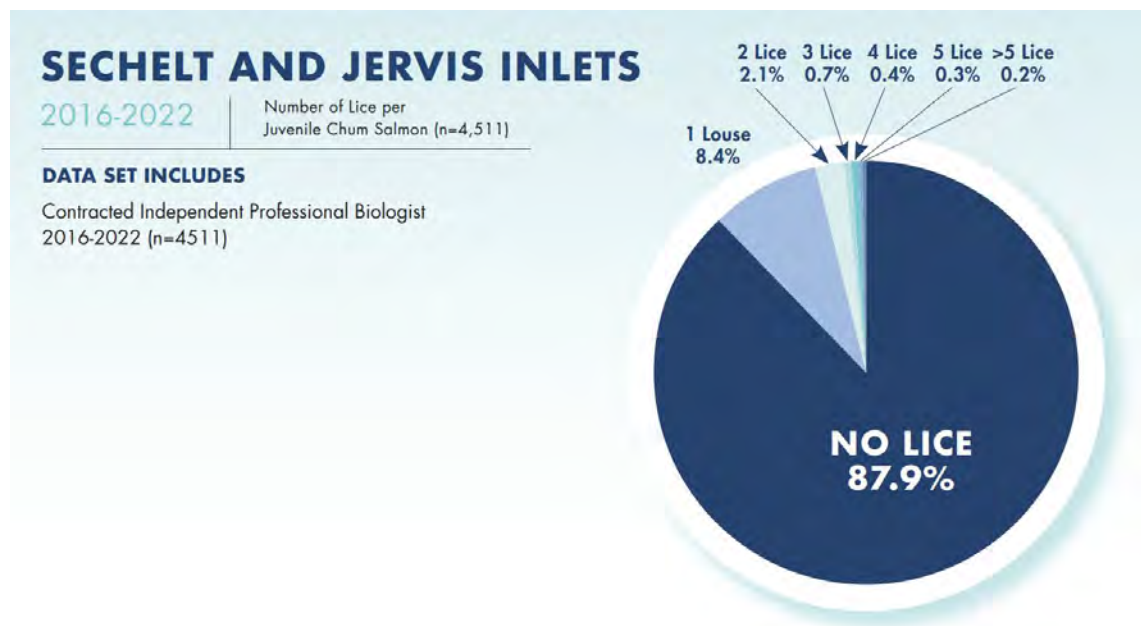


Figure 25. The number of sea lice per fish on the 4,511 juvenile chum salmon samples in the dataset in the Sechelt and Jervis Inlets region (2016-2022).

Note: Figure depicts any species of louse, all life stages.

CLIO AND CALL INLETS (MAINLAND COAST)

A third-party professional biological consultant sampled wild salmon at ten locations in Clio Channel, Call Inlet, and Havannah Channel in 2019 and 2020 (153, 154). Eight additional sample locations were added in Havannah Channel in 2021 (155). Sampling occurred every two weeks from the beginning of April until the end of May. Fish were frozen after collection and sea lice were counted under a dissecting microscope in a laboratory.

The Clio and Call inlets data set is comprised of results from 1,475 juvenile salmon samples: zero Chinook salmon, 413 chum salmon, 37 coho salmon, 1,025 pink salmon, and zero sockeye salmon. Of the 413 juvenile chum salmon analyzed, 77.7% did not have any sea lice (Figure 26).

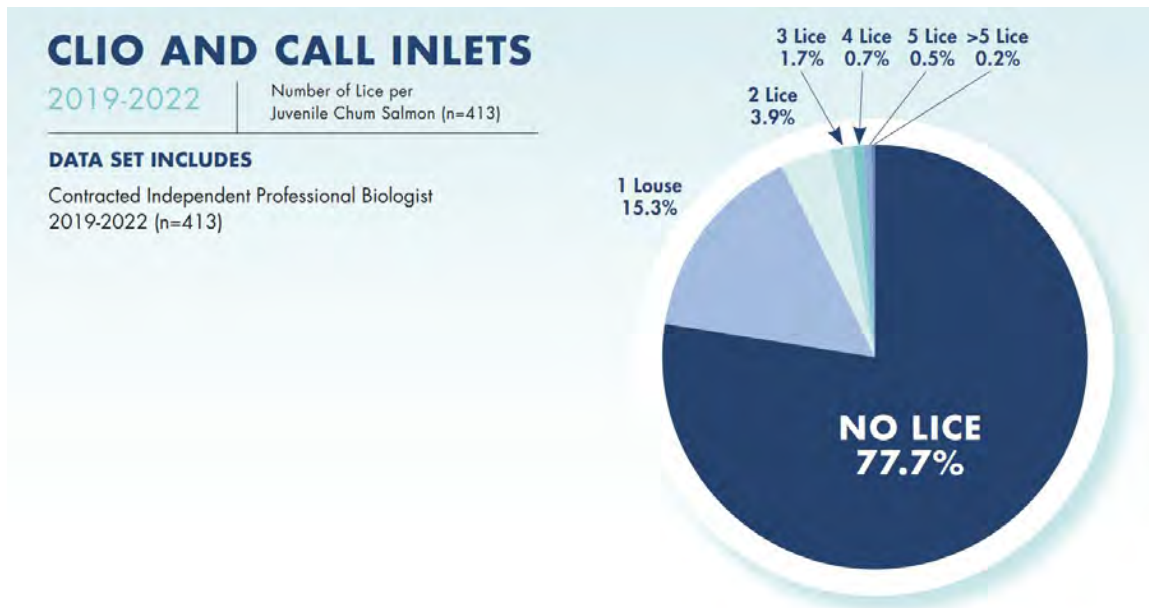


Figure 26. The number of sea lice on the 413 juvenile chum salmon samples in dataset in the Clio and Call Inlets region (2019 – 2022).

Note: Figure depicts any species of louse, all life stages.



DISCOVERY ISLANDS

Researchers from the Hakai Institute sampled sea lice on juvenile wild salmon at ten locations in the Discovery Islands and Johnstone Strait from 2017 to 2019 (156).

Fish were collected by purse seine every one to two weeks from May through July. Sea lice were identified either by viewing the fish through a hand-held lens in the field or by laboratory analysis. As purse seines must be used in deeper water than beach seines, larger fish were captured compared to those in other surveys.

To make the data comparable with the beach seine technique, only pink and chum salmon weighing 10 grams or less were included in this coastwide analysis.

All sockeye salmon were included in this report, as this species migrates at a larger size in deeper water and is typically not captured by beach seine (as is evidenced by the low number sampled in other regions).

Most of the fish captured had no attached sea lice. The herring louse, *C. clemensi*, was five to 37 times more abundant than *L. salmonis* (156), likely influenced by the presence of their main host, Pacific herring, which occurs in high abundance in the Strait of Georgia (Figure 27) (157). About 90% of the sockeye salmon had no adult *L. salmonis*.

Figure 27. California sea lions after feasting on spawning Pacific herring (Strait of Georgia).

A third-party professional biological consultant sampled wild salmon at 29 locations spaced throughout the surveyed area from the south end of Quadra Island (Francisco Point) to a point just south of Port Neville in Johnstone Strait from 2017 to 2022 (22, 30-35). Twenty-six of the beach seine sample locations were based on DFO purse seine locations established during previous sampling in the region with three more sample sites located in Fanny Bay, Cordero Channel and Owen Bay.

The study area was divided into 'pre-exposure' and 'post-exposure' based on a study design published in 2008 (48). Sampling occurred in April and May. Fish were frozen after collection and sea lice were counted under a dissecting microscope in a laboratory.

In total, the combined dataset consists of 9,477 juvenile salmon, including: 162 Chinook salmon, 4,917 chum salmon, 222 coho salmon, 3,693 pink salmon and 439 sockeye salmon. Of the 4,917 juvenile chum salmon analyzed, 81.5% did not have any sea lice (Figure 28).

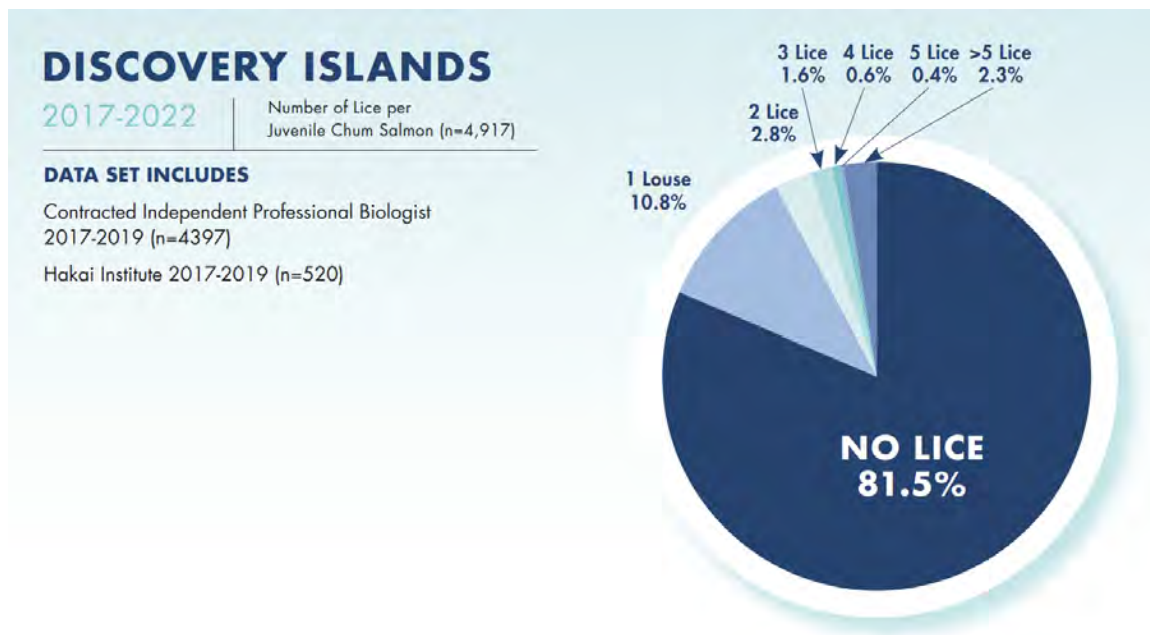


Figure 28. The number of sea lice per fish on the 4,917 juvenile chum salmon samples in dataset in the Discovery Island region (2017-2022).

Note: Figure depicts any species of louse, all life stages.



BROUGHTON ARCHIPELAGO

The majority of sea lice research and monitoring in BC has occurred in the Broughton Archipelago. It has been the focus for hundreds of researchers and tens of millions of dollars in research projects, including the BC Pacific Salmon Forum (2004-2009) commissioned by the Province of British Columbia (158).

The Salmon Coast Field Station sampled juvenile salmon for sea lice at three locations in Tribune Channel, Hornet Passage, and Fife Sound from 2001 to 2022 (87, 159, 160). At the time of this analysis, data were publicly available for 2001 to 2021. Fish were collected weekly from the beginning of April to the end of June or early July. Sea lice were counted on live samples in the field and the fish were subsequently released.

In 2010, salmon farmers in the Broughton Archipelago, DFO, ENGOs (David Suzuki Foundation, Watershed Watch, Georgia Strait Alliance, T. Buck Suzuki, Living Oceans Society) and a coalition of key researchers came together and formed the Broughton Archipelago Monitoring Plan (BAMP) to address concerns that salmon farms were amplifying sea lice and creating population-level concerns for juvenile wild salmon (161). The group designed rigorous sampling protocols, laboratory analysis procedures, selected sampling locations, monitored wild fish together in the archipelago, analyzed the results and published several research papers together.

The combined database from this coalition is included in this report's analysis. A third-party professional biological consultant sampled 45 locations throughout the Broughton Archipelago in April and May of 2016 to 2022 (162-169). Fish were frozen after collection and sea lice were counted under a dissecting microscope in a laboratory (78).

In total, the combined dataset consists of 220,245 juvenile salmon sampled: 343 Chinook salmon, 102,584 chum salmon, 3,460 coho salmon, 113,555 pink salmon and 303 sockeye salmon. Of the 102,584 juvenile chum salmon analyzed, 63.5% did not have any sea lice (Figure 29).

The dataset developed by the BAMP group is shown in Figure 30. Years 2003 – 2012 are combined datasets from independent scientific researchers, DFO and the BAMP field program (78); years 2015 – 2023 are Mainstream Biological Consulting monitoring results that continued to follow the established BAMP sampling protocols ([Juvenile Wild Salmon .Sea Lice Monitoring - Mowi - Canada West](#)) (162-170). Note that no monitoring took place in 2013 and 2014; and the 2015 data was for June only and not included in the larger dataset analysis. The 2023 monitoring data displayed below was not included in the overall coastwide analysis of the dataset in this report. The Salmon Coast Field Station was not part of the BAMP research group and data from the station has not been included in Figure 30.

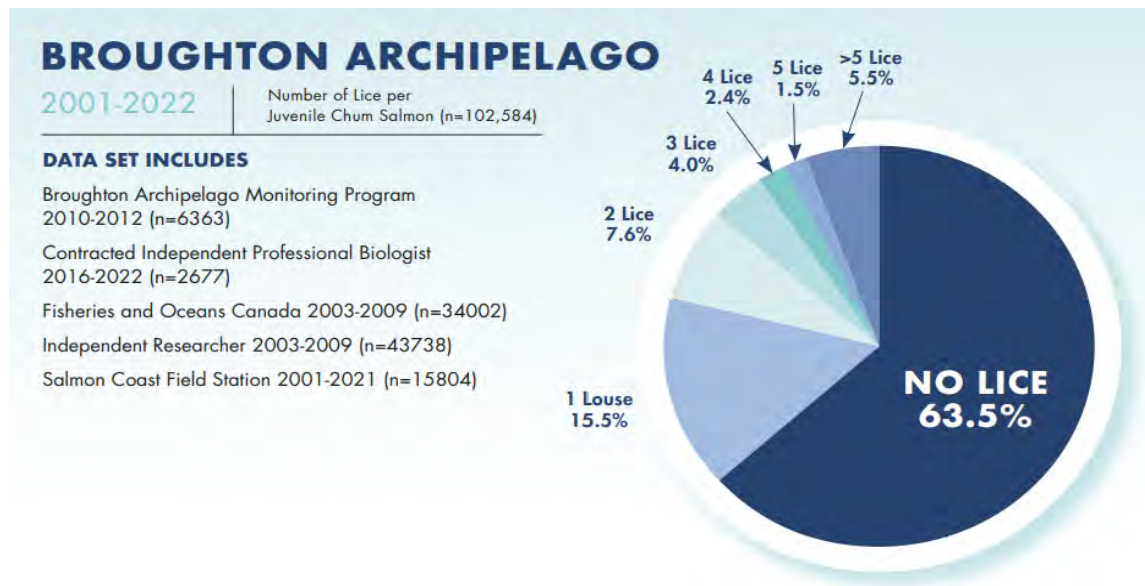


Figure 29. The number of sea lice per fish on the 102,584 juvenile chum salmon samples in the combined dataset in the Broughton Archipelago region (2001-2022).

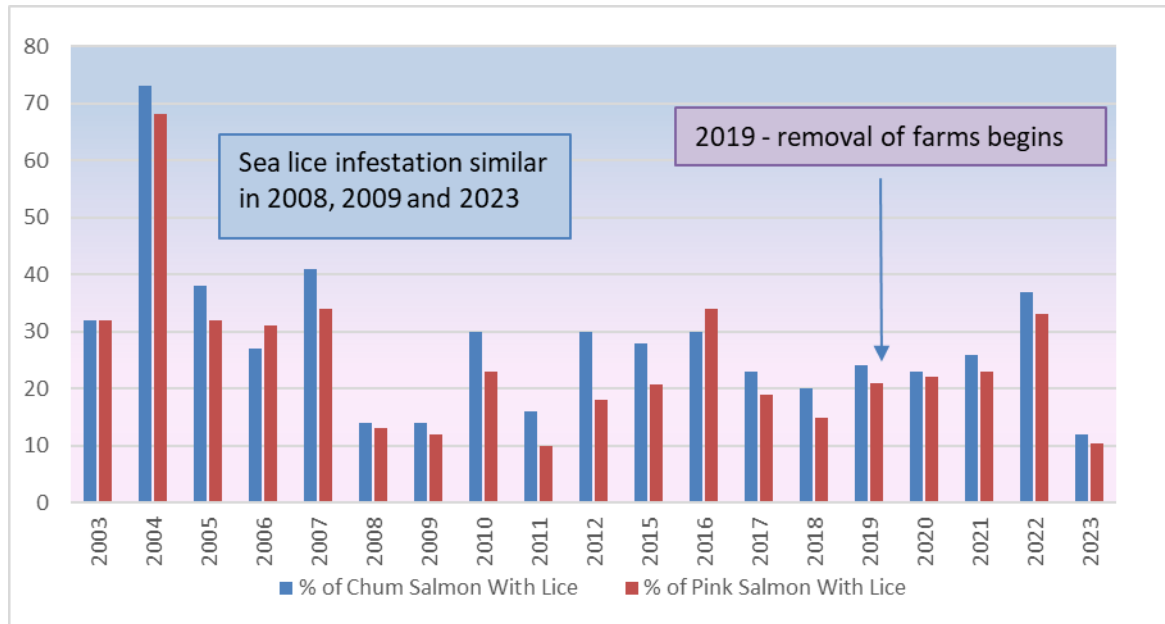
Note: Figure depicts any species of louse, all life stages.

In 2013, researchers used new data from the Broughton Archipelago to update earlier assessments that had previously documented sea lice infestations and population decline of wild pink salmon populations (19, 70, 171-173). They reported that sea lice treatments at salmon farms prior to the out-migration of wild juvenile salmon had reduced epizootics on pink salmon (174) (Figure 31).

Further, during the expansion of salmon farming in the 1990s and the years bracketing the highest sea lice numbers ever reported in the archipelago (1999 to 2005), researchers found no evidence of reduced productivity on chum salmon populations (52). This lack of effect was despite chum salmon having greater infestation rates and greater susceptibility to sea lice than pink salmon (52, 175).

Since the start of the removal of salmon farms from the Broughton Archipelago in 2019, sea lice levels on pink and chum salmon increased from 2020 to 2022, and then decreased in 2023 to levels reported in 2008, 2009, and 2011. These monitoring results provide evidence that since the mid 2000s, sea lice infestations on wild pink and chum salmon are mostly independent of farms. In other words, sea lice management measures minimize the transfer of sea lice to wild Pacific salmon.

This conclusion was supported in a 2023 Canadian Science Advisory Secretariat Science Response (CSAS) that stated: "No statistically significant association was observed between infestation pressure attributable to Atlantic salmon farms and the probability of *L. salmonis* [salmon louse] infestations on wild juvenile chum and pink salmon in Clayoquot Sound, Quatsino Sound, Discovery Islands and Broughton Archipelago." (176).



*Figure 30. Percentage of chum and pink salmon with sea lice (*L. salmonis* and/or *C. clemensi*) in the Broughton Archipelago during the spring out-migration. Adapted from Patanasatienkul et al (78). Data from 2015 – 2023 from Mainstream Biological Consulting (162-170). Note that 2015 data is for June only.*



Photo by Bill Pennell

Figure 31. Juvenile pink salmon.

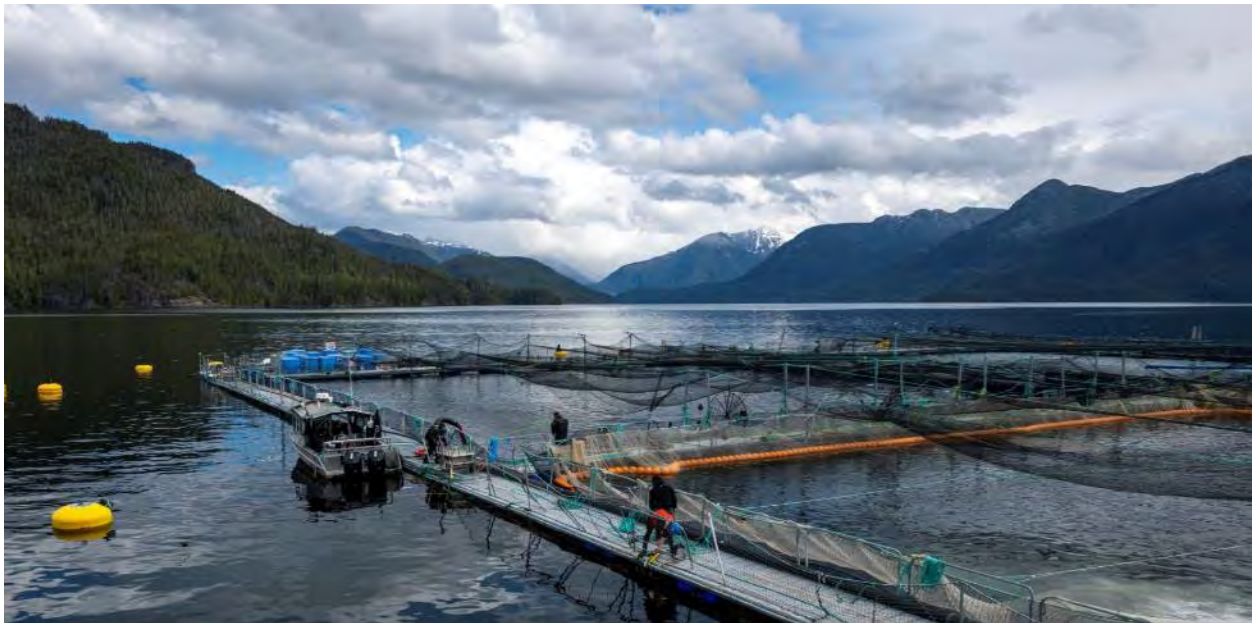
WHAT INFLUENCES THE NUMBER OF SEA LICE ON FARMS?

The number of sea lice on farm-raised Atlantic salmon is influenced by many factors including the time of year (season), environmental factors (location, temperature, salinity, oceanic currents), hosts (age and length of time farm-raised salmon have been in seawater, the proximity to Pacific salmon, returning adult Pacific salmon and other fish hosts), the application of sea lice treatments, and numerous other environmental factors affecting both the sea lice and the host.

Throughout the BC coastline, sea lice numbers on farms are influenced by the return of wild adult salmon. This is unique to BC, where the number of wild salmon greatly outnumbers populations of farm-

raised salmon. Scientists have reported that the number of pink salmon returning to spawn in the fall predicts the number of female *L. salmonis* on farm-raised Atlantic salmon and the prevalence of sea lice on migrating juvenile salmon in the Broughton Archipelago (67). Conversely, salmon farms are unlikely to be the primary source of *C. clemensi* given its natural broad and abundant host range (19), especially Pacific herring (82).

Through careful management practices, Atlantic salmon farmers aim to minimize transference of sea lice from farm-raised salmon to wild salmon during the spring out-migration window (Figure 32).



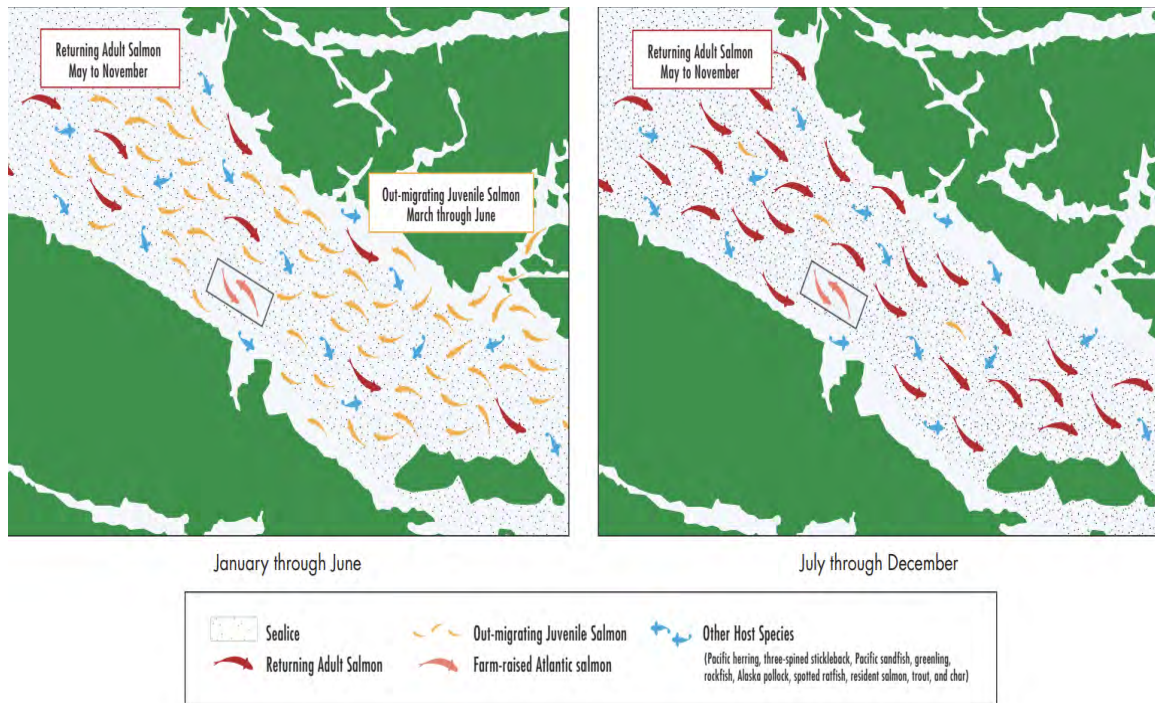


Figure 32. Schematic of sea lice transmission from natural and farm sources.

HOW MANY SEA LICE ARE ON ATLANTIC SALMON FARMS?

DFO has mandated a management threshold for *L. salmonis* during the spring out-migration of juvenile wild salmon (March through June). Farmers must take actions to reduce the average number of motile *L. salmonis* to below three per fish prior to and during the spring out-migration window. To meet the conditions of license, farmers must decrease sea lice numbers throughout the spring out-migration window according to timelines set by DFO.

A summary of coastwide trends from 2011 to 2023 is shown in Figure 33, with the out-

migration period highlighted. Region specific sea lice abundance on Atlantic salmon farms has been summarized by DFO and available on their website (177)

With few exceptions, salmon farmers have been successful at managing sea lice populations at Atlantic salmon farms during the out-migration window. Sea lice levels at most farms were below the regulated management threshold during the juvenile wild salmon outmigration window (Figure 34). All farms that exceeded the threshold-initiated management measures to reduce sea lice.

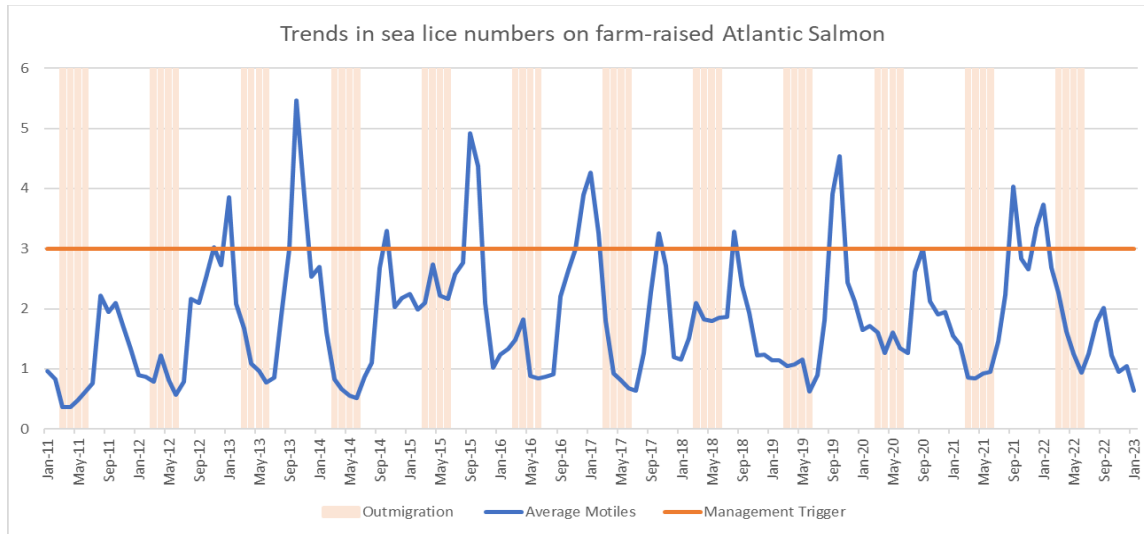


Figure 33. Average monthly coast-wide trend of the average number of motile sea lice per farm-raised Atlantic salmon (y axis) over the period 2011 – 2023.
Note: The outmigration window is highlighted. Management threshold (orange line) = average 3 motile *L. salmonis* per fish.

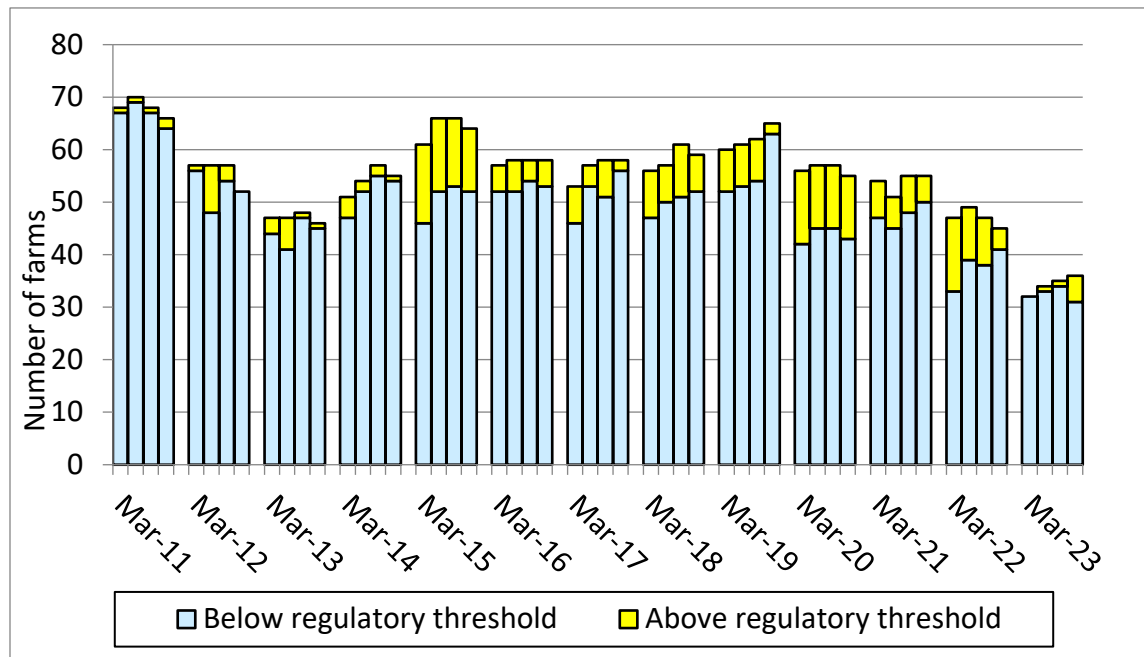


Figure 34. Number of active BC Atlantic salmon farms above or below the DFO sea lice regulatory management threshold (average of 3-motile *L. salmonis*) during the government defined wild salmon outmigration window (March – June 2011 to 2023).

Source: DFO [Open Canada Dataset](#) (178)

HOW DO SALMON FARMERS MANAGE SEA LICE?

PREVENTION

The first step in managing sea lice on farms is to minimize the number of sea lice on farm-raised fish. Measures to avoid sea lice on BC farms include:

- o Large capital investments in recirculating hatchery systems that produce larger juvenile salmon (Figure 35). Rearing larger juveniles in hatcheries can reduce the time that farm-raised salmon spend in the marine environment, reducing the time they are exposed to sea lice.
- o Years of selective breeding have produced smolts that grow faster, convert feed into flesh more efficiently, and are more resilient to environmental challenges. These changes collectively result in healthy fish that are grown at marine sites for shorter periods, reducing their exposure to sea lice.
- o Using technology such as aeration diffusers, bubble curtains, or physical barriers. These types of equipment, when placed around the circumference of pens, create a barrier that prevents sea lice from entering the salmon pen (Figure 36).



Figure 35. Recirculating aquaculture system at commercial hatchery.



Figure 36. Aeration/bubble curtain deter sea lice from entering net pens.

- o Using technology to feed fish below the preferred depth of sea lice (e.g., Akva Tubenet™). These systems help reduce sea lice infestation on farm-raised salmon by submerging the fish to depths where lice presence is minimal. A tube positioned in the center of the net creates a sea lice-free zone through which the salmon can access the water's surface (Figure 37).



Figure 37. Schematic of AKVA Tubenet™ illustrating how farm-raised salmon are grown at water depths below where sea lice generally occur.



- o Coordinating stocking for single year class on farms and fallowing farms after harvest. Fallowing before restocking allows the site to rest before stocking the next generation of fish. This can help any potential re-infection cycle.

MITIGATION

If sea lice cannot be prevented from settling on farm-raised salmon, farmers manage sea lice through a Sea Lice Management Plan, as explained in Figure 38 below.



Figure 38. Sea lice management process at BC salmon farms.

COMPONENTS OF IPM

Veterinarians use a holistic method to manage sea lice; an Integrated Pest Management (IPM) program. The IPM approach involves focusing on prevention, setting thresholds, continuously monitoring, and pro-actively rotating treatment tools to reduce the possibility of sea lice developing resistance to any one treatment method.

Farmed salmon in BC are lice-free when they are stocked in ocean pens. Sea lice on farms are largely managed as a measure to protect wild salmon. Farmed Pacific salmon almost never require treatment.

Farm-raised fish in BC are monitored and treated for sea lice in accordance with federal regulations. These requirements are for the protection of wild fish, not for the health of farm-raised salmon. Sea lice levels on farm-raised Atlantic salmon in BC are not a significant health concern for farm-raised fish. Note that farm-raised Pacific salmon almost never require treatment to remove sea lice.

Treatment:

- o Fish are treated for sea lice according to management thresholds that are either area-based, site-specific, or based upon the DFO threshold of an average of 3 motile *L. salmonis* per fish.
- o Treatments remove all species of sea lice from farm-raised fish.

Monitoring:

- o Routine weekly or bi-weekly monitoring of sea lice.

Sea lice monitoring and treatment options:

- o Post treatment sea lice monitoring to measure effectiveness of treatment.
- o Third-party laboratory analysis of sea lice sensitivity to treatment method. Four methods are approved to remove sea lice from farm-raised salmon in BC. This includes an in-feed treatment SLICE®, mechanical pressure-washers and in-vessel bath treatments of fresh water or hydrogen peroxide (Interox® Paramove 50).



TREATMENT

As a part of IPM, veterinarians rotate the use of the treatment options in consideration of bioassay results, sea lice life stages and previous treatments used at the farms. One of the options is the use of in-feed SLICE® treatments that can only be prescribed under the authority of a licensed veterinarian.

In-vessel bath treatments of fresh water or hydrogen peroxide ([Interox® Paramove 50](#)) are also used (Figure 39). Hydrogen peroxide can only be used in BC with a valid Pesticide use Permit issued by the

BC Ministry of Environment and Climate Change Strategy.

Different types of mechanical delousers are being used in BC. In general, fish are pumped from the cage through a mechanical system on the vessel where sea lice are removed by pressurized ambient sea water (Figure 40). After treatment, which in some cases lasts only a few seconds, fish are pumped back into their cage. For in-vessel and bath treatments and for pressure removal the effluent water is filtered to collect sea lice that are then disposed of on land.



Figure 39. Treatment vessel AquaTromØy.

This vessel is capable of in-vessel freshwater and hydrogen peroxide bath treatments for sea lice removal.

Having options for treating sea lice is important in maintaining effectiveness and minimizing resistance. Fish health teams are continually working with researchers and regulatory bodies to develop new methods of sea lice control. All sea lice counts as well as treatments are made publicly available on the Government of Canada Open Data website (179).



Figure 40. View of treatment vessel using low-pressure water to remove sea lice.

HOW DO WE KNOW IF SEA LICE MANAGEMENT MEASURES ARE EFFECTIVE?

An important step in sea lice management is to make sure the management processes are effective (Figure 41). Sea lice numbers are available at the Government of Canada Open Data website (179) and company websites that farm Atlantic salmon.

Hundreds of scientists have studied sea lice on farm-raised and wild fish over the past 20 years. The combined learnings have been used to update management of sea lice on farms.

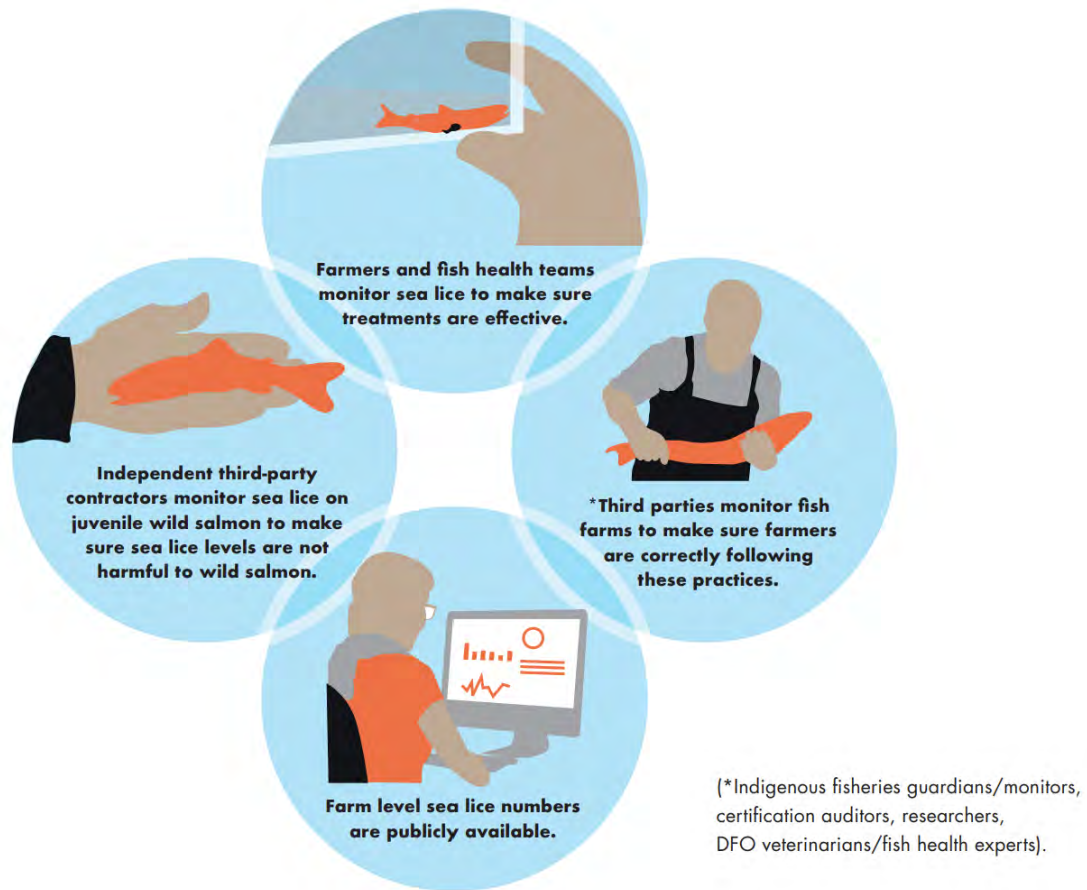


Figure 41. Sea lice management processes.

COOPERATION

To ensure that sea lice measures continue to be effective into the future, salmon farmers have developed a Memorandum of Understanding (MOU) for sector-wide Integrated Pest Management for sea lice. This is not a requirement of licence, but led by the sector.

The MOU describes how all BC Atlantic salmon farming companies cooperatively operationalize pest management, particularly during the juvenile wild

salmon out-migration period. It stipulates the degree of monitoring, use of bioassays to check for treatment sensitivity, rotation of treatments, equipment sharing, and response times. The goal is to effectively manage sea lice numbers in a way that prevents the development of resistant lice populations. The MOU also addresses steps to expand the range of sea lice tools currently available, including driving global research and techniques applicable to the BC coast.

WHAT WILL FUTURE SEA LICE MANAGEMENT IN BC LOOK LIKE?

The digital revolution brings game-changing technology to managing sea lice. Until very recently, BC salmon farmers lacked the technology to monitor the health status of individual fish within a pen. However, some companies are developing artificial intelligence and machine learning systems that can identify each fish in a net pen and provide health records for each fish. Sensors recognize each fish and record fish size and the number of sea lice. Once fully operational, individual fish requiring treatment can be directed through a separation system for treatment. New powerful monitoring and management tools will ensure a bright future for farm sea lice management.



Trials, in 2023, with floating, semi-closed containment systems (Figure 42) are looking at whether these systems can provide increased biosecurity and welfare for both farm-raised and wild salmon. These systems are a first step towards the development of in-water closed containment farming technology.

Semi-closed containment technology separates farm-raised fish from the ocean environment by surrounding the traditional salmon farm netting system with an impermeable barrier that prevents sea lice and harmful plankton from entering the pen. It also provides additional separation from wild salmon. Water from deep down, that is free of both sea lice and harmful plankton, is pumped into the farming enclosure. Oxygen is also added to the water, as required, via aeration systems.



Figure 42. Example of in-sea-closed-containment system in Millar Channel, Clayoquot Sound.

CARING FOR WILD SALMON

Salmon farmers know that wild salmon are under pressure and understand the importance of keeping sea lice levels low on farms to minimize potential spill-over effects to juvenile wild salmon. Farming companies have invested in state-of-the-art sea lice treatment tools that are very

effective in minimizing sea lice on farm-raised salmon. To make sure wild salmon are safe, we have engaged researchers and third-party experts for nearly two decades to monitor sea lice on juvenile wild salmon. The results are very encouraging.





REFERENCES

1. Heard WR. 1991. Life history of pink salmon (*Oncorhynchus gorbuscha*). In: Groot C, Margolis L, editors. Pacific salmon life histories. Vancouver, Canada: University of British Columbia Press. p. 119-230
2. Grant A, Gardner M, Nendick L, Sackville M, Farrell AP, Brauner CJ. 2009. Growth and ionoregulatory ontogeny of wild and hatchery-raised juvenile pink salmon (*Oncorhynchus gorbuscha*). Canadian Journal of Zoology. 87(3):221-228. [10.1139/z08-149](https://doi.org/10.1139/z08-149)
3. 2024. First Voices: First Peoples Cultural Council, First Peoples Cultural Foundation; [Available from: <https://www.firstvoices.com/>].
4. Beamish FWH. 1978. 2 - Swimming Capacity. In: Hoar WS, Randall DJ, editors. Fish Physiology. 7: Academic Press. p. 101-187. <https://www.sciencedirect.com/science/article/pii/S1546509808601648>
5. Brauner CJ, Sackville M, Gallagher Z, Tang S, Nendick L, Farrell AP. 2012. Physiological consequences of the salmon louse (*Lepeophtheirus salmonis*) on juvenile pink salmon (*Oncorhynchus gorbuscha*): implications for wild salmon ecology and management, and for salmon aquaculture. Philosophical Transactions of the Royal Society B: Biological Sciences. 367(1596):1770-1779. doi:10.1098/rstb.2011.0423
6. Thorstad EB, Todd CD, Uglem I, Bjørn PA, Gargan PG, Vollset KW, et al. 2015. Effects of salmon lice *Lepeophtheirus salmonis* on wild sea trout *Salmo trutta* a literature review. Aquaculture Environment Interactions. 7(2):91-113, <https://www.int-res.com/abstracts/aei/v7/n2/p91-113/>
7. Saksida SM, Bricknell I, Robinson S, Jones S. 2015. Population ecology and epidemiology of sea lice in Canadian waters. (CSAS) CSAS.
8. Nagasawa K. 2001. Annual changes in the population size of the salmon louse *Lepeophtheirus salmonis* (Copepoda: Caligidae) on high-seas Pacific Salmon (*Oncorhynchus spp.*), and relationship to host abundance. Hydrobiologia. 453(1):411-416. [10.1023/A:1013154403992](https://doi.org/10.1023/A:1013154403992)
9. Beamish R, Neville C, Sweeting R, Ambers N. 2005. Sea lice on adult Pacific salmon in the coastal waters of Central British Columbia, Canada. Fisheries Research. 76(2):198-208,
10. Beamish R, Neville C, Sweeting R, Jones S, Ambers N, Gordon E, et al. 2007. A proposed life history strategy for the salmon louse, *Lepeophtheirus salmonis* in the subarctic Pacific. Aquaculture. 264(1-4):428-440,
11. Jones SR, Beamish RJ. 2011. *Lepeophtheirus salmonis* on salmonids in the northeast Pacific Ocean. In: Jones SR, Beamish RJ, editors. Salmon lice: an integrated approach to understanding parasite abundance and distribution. West Sussex, UK: Wiley-Blackwell;
12. Jones SRM, Prosperi-Porta G. 2011. The Diversity of Sea Lice (Copepoda: Caligidae) Parasitic on Threespine Stickleback (*Gasterosteus aculeatus*) in Coastal British Columbia. Journal of Parasitology. 97(3):399-405, 7, <https://doi.org/10.1645/GE-2617.1>

13. Pert CC, Mordue AJ, Fryer RJ, O'Shea B, Bricknell IR. 2009. The settlement and survival of the salmon louse, *Lepeophtheirus salmonis* (Krøyer, 1837), on atypical hosts. *Aquaculture*.288(3):321-324.<https://doi.org/10.1016/j.aquaculture.2008.12.005>
14. Kabata Z. 1979. Parasitic copepoda of British fishes: Ray Society.
15. Price MHH, Probošycz SL, Routledge RD, Gottesfeld AS, Orr C, Reynolds JD. 2011. Sea Louse Infection of Juvenile Sockeye Salmon in Relation to Marine Salmon Farms on Canada's West Coast. *PLOS ONE*.6(2):e16851.10.1371/journal.pone.0016851
16. Boxaspen K, Næss T. 2000. Development of eggs and the planktonic stages of salmon lice (*Lepeophtheirus salmonis*) at low temperatures. *Contributions to Zoology*.69(1-2):51-55.<https://doi.org/10.1163/18759866-0690102005>
17. Hayward CJ, Andrews M, Nowak BF. 2011. Introduction: *Lepeophtheirus salmonis*-a remarkable success story. In: Jones S, Beamish R, editors. *Salmon lice: an integrated approach to understanding parasite abundance and distribution*. Chichester, UK: John Wiley and Sons. p. 1-28
18. Trudel M, Jones S, Thiess M, Morris J, Welch D, Sweeting RM, et al., editors. 2007. Infestations of motile salmon lice on Pacific salmon along the west coast of North America. *American Fisheries Society Symposium*; 2007: American Fisheries Society;
19. Krkošek M, Gottesfeld A, Proctor B, Rolston D, Carr-Harris C, Lewis MA. 2007. Effects of host migration, diversity and aquaculture on sea lice threats to Pacific salmon populations. *Proceedings of the Royal Society B: Biological Sciences*.274(1629):3141-3149.doi:10.1098/rspb.2007.1122
20. Butterworth KG, Cubitt KF, McKinley RS. 2008. The prevalence, density and impact of *Lepeophtheirus salmonis* (Krøyer) infestation on juvenile pink salmon (*Oncorhynchus gorbuscha*) from the central coast of British Columbia, Canada. *Fisheries Research*.91(1):35-41.<https://doi.org/10.1016/j.fishres.2007.11.018>
21. Stewardson L. 2015. Prevalence of Sea Lice (*Lepeophtheirus salmonis* and *Caligus clemensi*) on Juvenile Salmonids Captured in Quatsino Sound, BC 2015. Campbell River: Mainstream Biological Consulting.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/quatsino-wild-juvenile-salmonid-monitoring-2015.pdf>
22. Stewardson L. 2017. Wild Juvenile Salmonid Monitoring Program Discovery Islands 2017. Campbell River: Mainstream Biological Consulting.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/discovery-islands-juvenile-salmonid-monitoring-2017.pdf>
23. Stewardson L. 2021. Wild Juvenile Salmonid Monitoring Program 2021 Quatsino Sound, BC. Campbell River: Mainstream Biological Consulting.<https://mowi.com/caw/wp-content/uploads/sites/7/2021/07/Quatsino-Wild-Juvenile-Salmonid-Monitoring-2021.pdf>
24. Stewardson L. 2022. Wild Juvenile Salmonid Monitoring Program 2022 Quatsino Sound, BC. Campbell River: Mainstream Biological Consulting.<https://mowi.com/caw/wp-content/uploads/sites/7/2022/08/Quatsino-Wild-Juvenile-Salmonid-Monitoring-2022.pdf>
25. Stewardson L. 2019. Wild Juvenile Salmonid Monitoring Program 2019 Quatsino Sound, BC. Campbell River: Mainstream Biological Consulting.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/quatsino-wild-juvenile-salmonid-monitoring-2019.pdf>



26. Stewardson L. 2018. Wild Juvenile Salmonid Monitoring Program 2018 Quatsino Sound, BC. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/quatsino-wild-juvenile-salmonid-monitoring-2018.pdf>
27. Stewardson L. 2017. Wild Juvenile Salmonid Monitoring Program 2017 Quatsino Sound, BC. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/quatsino-wild-juvenile-salmonid-monitoring-2017.pdf>
28. Stewardson L. 2016. Wild Juvenile Salmonid Monitoring Program 2016 Quatsino Sound, BC. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/quatsino-wild-juvenile-salmonid-monitoring-2016.pdf>
29. Stewardson L. 2023. Wild Juvenile Salmonid Monitoring Program 2023 Quatsino Sound, BC. Campbell River: Mainstream Biological Consulting. https://mowi.com/caw/wp-content/uploads/sites/7/2023/08/Quatsino_Wild_Juvenile_Salmonid_Monitoring_2023.pdf
30. Stewardson L. 2018. Wild Juvenile Salmonid Monitoring Program Discovery Islands 2018. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/discovery-islands-juvenile-salmonid-monitoring-2018.pdf>
31. Stewardson L. 2019. Wild Juvenile Salmonid Monitoring Program Discovery Islands 2019. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/discovery-islands-juvenile-salmonid-monitoring-2019.pdf>
32. Stewardson L. 2020. Wild Juvenile Salmonid Monitoring Program Discovery Islands 2020. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2020/07/Discovery-Islands-Juvenile-Salmonid-Monitoring-2020-V2.pdf>
33. Stewardson L. 2021. Wild Juvenile Salmonid Monitoring Program Discovery Islands 2021. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2021/07/Discovery-Islands-Juvenile-Salmonid-Monitoring-2021-V3.pdf>
34. Stewardson L. 2022. Wild Juvenile Salmonid Monitoring Program Discovery Islands 2022. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2023/02/Discovery-Islands-Juvenile-Salmonid-Monitoring-2022-Version-3.pdf>
35. Stewardson L. 2023. Wild Juvenile Salmonid Monitoring Program Discovery Islands 2023. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2023/09/Discovery-Juvenile-Salmonid-Monitoring-2023.pdf>
36. Price MHH, Morton A, Reynolds JD. 2010. Evidence of farm-induced parasite infestations on wild juvenile salmon in multiple regions of coastal British Columbia, Canada. Canadian Journal of Fisheries and Aquatic Sciences. 67(12):1925-1932,
37. Centre for Aquatic Health Sciences. 2016. (Interim) Report on Sea Lice Assessment on Wild Salmon Collected in Strait of Georgia, Discovery Islands and Johnstone Strait, BC. Centre for Aquatic Health Sciences, <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/cr-sea-lice-interim-report-2016.pdf>

38. Braden LM, Sutherland BJG, Koop BF, Jones SRM. 2017. Enhanced transcriptomic responses in the Pacific salmon louse *Lepeophtheirus salmonis oncorhynchi* to the non-native Atlantic Salmon *Salmo salar* suggests increased parasite fitness. BMC Genomics.18(1):110.10.1186/s12864-017-3520-1
39. Fast M, D., Ross N, W. , Mustafa A, Sims D, E. , Johnson S, C. , Conboy G, A., et al. 2002. Susceptibility of rainbow trout *Oncorhynchus mykiss*, Atlantic salmon *Salmo salar* and coho salmon *Oncorhynchus kisutch* to experimental infection with sea lice *Lepeophtheirus salmonis*. Diseases of Aquatic Organisms.52(1):57-68, <https://www.int-res.com/abstracts/dao/v52/n1/p57-68/>
40. Jones SR, Fast MD, Johnson SC, Groman DB. 2007. Differential rejection of salmon lice by pink and chum salmon: disease consequences and expression of proinflammatory genes. Diseases of aquatic organisms.75(3):229-238,
41. Johnson SC, Albright LJ. 1991. Development, Growth, and Survival of *Lepeophtheirus Salmonis* (Copepoda: Caligidae) Under Laboratory Conditions. Journal of the Marine Biological Association of the United Kingdom.71(2):425-436.10.1017/S0025315400051687
42. Braden LM, Michaud D, Groman D, Byrne P, Hori TS, Fast MD. 2023. Rejection of *Lepeophtheirus salmonis* driven in part by chitin sensing is not impacted by seawater acclimatization in Coho salmon (*Oncorhynchus kisutch*). Scientific Reports.13(1):9685.10.1038/s41598-023-36632-0
43. Connors BM, Krkošek M, Ford J, Dill LM. 2010. Coho salmon productivity in relation to salmon lice from infected prey and salmon farms. Journal of Applied Ecology.47(6):1372-1377.<https://doi.org/10.1111/j.1365-2664.2010.01889.x>
44. Saksida S, Constantine J, Karreman G, Neville C, Sweeting R, Beamish R, editors. 2006. Evaluation of sea lice, *Lepeophtheirus salmonis*, abundance levels on farmed salmon in British Columbia, Canada. The Proceedings from the International Symposium on Veterinary Epidemiology and Economics XI; 2006: Cairns;
45. Jakob E, Sweeten T, Bennett W, Jones S. 2013. Development of the salmon louse *Lepeophtheirus salmonis* and its effects on juvenile sockeye salmon *Oncorhynchus nerka*. Diseases of aquatic organisms.106(3):217-227, <https://www.int-res.com/articles/dao2013/106/d106p217.pdf>
46. Long A, Garver KA, Jones SRM. 2019. Differential Effects of Adult Salmon Lice *Lepeophtheirus salmonis* on Physiological Responses of Sockeye Salmon and Atlantic Salmon. Journal of Aquatic Animal Health.31(1):75-87.<https://doi.org/10.1002/aah.10053>
47. Garzke J, Forster I, Godwin SC, Johnson BT, Krkošek M, Mahara N, et al. 2022. Dynamic coastal pelagic habitat drives rapid changes in growth and condition of juvenile sockeye salmon (*Oncorhynchus nerka*) during early marine migration. FACETS.7:1328-1347.10.1139/facets-2022-0068
48. Morton A, Routledge R, Krkošek M. 2008. Sea Louse Infestation in Wild Juvenile Salmon and Pacific Herring Associated with Fish Farms off the East-Central Coast of Vancouver Island, British Columbia. North American Journal of Fisheries Management.28(2):523-532.<https://doi.org/10.1577/M07-042.1>
49. Price MHH. 2011. Early marine ecology of Pacific salmon: interactions with sea lice



50. Sutherland BJG, Koczka KW, Yasuike M, Jantzen SG, Yazawa R, Koop BF, Jones SRM. 2014. Comparative transcriptomics of Atlantic *Salmo salar*, chum *Oncorhynchus keta* and pink salmon *O. gorbuscha* during infections with salmon lice *Lepeophtheirus salmonis*. BMC Genomics.15(1):200.10.1186/1471-2164-15-200
51. Ford JS, Myers RA. 2008. A Global Assessment of Salmon Aquaculture Impacts on Wild Salmonids. PLOS Biology.6(2):e33.10.1371/journal.pbio.0060033
52. Peacock SJ, Connors BM, Krkošek M, Irvine JR, Lewis MA. 2014. Can reduced predation offset negative effects of sea louse parasites on chum salmon? Proceedings of the Royal Society B: Biological Sciences.281(1776):20132913.10.1098/rspb.2013.2913
53. Krkošek M, Morton A, Volpe JP, Lewis MA. 2009. Sea lice and salmon population dynamics: effects of exposure time for migratory fish. Proceedings of the Royal Society B: Biological Sciences.276(1668):2819-2828,
54. Brauner C, Sackville M, Gallagher Z, Tang S, Nendick L, Farrell A. 2012. Physiological consequences of the salmon louse (*Lepeophtheirus salmonis*) on juvenile pink salmon (*Oncorhynchus gorbuscha*): implications for wild salmon ecology and management, and for salmon aquaculture. Philosophical Transactions of the Royal Society B: Biological Sciences.367(1596):1770-1779,
55. Tang S, Lewis AG, Sackville M, Nendick L, DiBacco C, Brauner CJ, Farrell AP. 2011. Diel vertical distribution of early marine phase juvenile pink salmon (*Oncorhynchus gorbuscha*) and behaviour when exposed to salmon louse (*Lepeophtheirus salmonis*). Canadian Journal of Zoology.89(9):796-807.10.1139/z11-049
56. Nendick L, Sackville M, Tang S, Brauner CJ, Farrell AP. 2011. Sea lice infection of juvenile pink salmon (*Oncorhynchus gorbuscha*): effects on swimming performance and postexercise ion balance. Canadian Journal of Fisheries and Aquatic Sciences.68(2):241-249.10.1139/f10-150
57. Sackville M, Tang S, Nendick L, Farrell AP, Brauner CJ. 2011. Pink salmon (*Oncorhynchus gorbuscha*) osmoregulatory development plays a key role in sea louse (*Lepeophtheirus salmonis*) tolerance. Canadian Journal of Fisheries and Aquatic Sciences.68(6):1087-1096.10.1139/f2011-037
58. BC Ministry of Agriculture and Lands. 2006. Fish Health Program 2003-2005. Victoria, BC: BC Ministry of Agriculture and Lands,.https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/fisheries-and-aquaculture/aquaculture-reports/fish_health_report_2003-2005.pdf
59. Brackett J, Newbound G, Speare D, J. 1991. A summer survey of saltwater morbidity and mortality of farmed salmon in British Columbia. Victoria, BC: British Columbia Ministry of Agriculture, Fisheries and Food.
60. Open Government. 2024. National Aquaculture Public Reporting Data Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/288b6dc4-16dc-43cc-80a4-2a45b1f93383>].
61. Stewart CJ, Jim WT, Sandra B, Kazuya N, Zbigniew K. 2004. A Review of the Impact of Parasitic Copepods on Marine Aquaculture. Zoological Studies.43(2):229-243, <https://www.cabdirect.org/cabdirect/abstract/20043166002>

62. Skern-Mauritzen R, Torrissen O, Glover KA. 2014. Pacific and Atlantic *Lepeophtheirus salmonis* (Krøyer, 1838) are allopatric subspecies: *Lepeophtheirus salmonis salmonis* and *L. salmonis oncorhynchi* subspecies novo. BMC Genetics.15(1):32.10.1186/1471-2156-15-32
63. Morton AB, Williams R. 2003. First report of a sea louse, *Lepeophtheirus salmonis*, infestation on juvenile pink salmon, *Oncorhynchus gorbuscha*, in nearshore habitat. The Canadian Field-Naturalist.117(4):634-641,
64. Grimnes A, Jakobsen PJ. 1996. The physiological effects of salmon lice infection on post-smolt of Atlantic salmon. Journal of Fish Biology.48(6):1179-1194.<https://doi.org/10.1111/j.1095-8649.1996.tb01813.x>
65. Bjorn PA, Finstad B. 1997. The physiological effects of salmon lice infection on sea trout post smolts. Nordic Journal of Freshwater Research.73:60-72,
66. Morton A, Volpe J. 2002. A description of escaped farmed Atlantic salmon *Salmo salar* captures and their characteristics in one Pacific salmon fishery area in British Columbia, Canada, in 2000. Alaska Fishery Research Bulletin.9(2):102-110,
67. Marty GD, Saksida SM, Quinn TJ. 2010. Relationship of farm salmon, sea lice, and wild salmon populations. Proceedings of the National Academy of Sciences.107(52):22599-22604,
68. Fisheries and Oceans Canada. 2024. NuSEDS-New Salmon Escapement Database System Ottawa: Open Government Canada; [Available from: <https://open.canada.ca/data/en/dataset/c48669a3-045b-400d-b730-48aaf8c5ee6>.
69. Bateman AW, Peacock SJ, Connors B, Polk Z, Berg D, Krkošek M, Morton A. 2016. Recent failure to control sea louse outbreaks on salmon in the Broughton Archipelago, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences.73(8):1164-1172.10.1139/cjfas-2016-0122
70. Krkošek M, Ford JS, Morton A, Lele S, Myers RA, Lewis MA. 2007. Declining Wild Salmon Populations in Relation to Parasites from Farm Salmon. Science.318(5857):1772-1775.10.1126/science.1148744
71. Krkošek M, Connors BM, Ford H, Peacock S, Mages P, Ford JS, et al. 2011. Fish farms, parasites, and predators: implications for salmon population dynamics. Ecological Applications.21(3):897-914,
72. Jones SRM, Hargreaves NB. 2009. Infection threshold to estimate *Lepeophtheirus salmonis*-associated mortality among juvenile pink salmon. Diseases of Aquatic Organisms.84(2):131-137, <https://www.int-res.com/abstracts/dao/v84/n2/p131-137/>
73. Nielsen J, Rosing-Asvid A, Meire L, Nygaard R. 2020. Widespread occurrence of pink salmon (*Oncorhynchus gorbuscha*) throughout Greenland coastal waters. Journal of Fish Biology.96(6):1505-1507.<https://doi.org/10.1111/jfb.14318>
74. FAO. 2023. Salmon - Main producers see record-breaking exports Rome: FAO Globefish; [Available from: <https://www.fao.org/in-action/globefish/market-reports/resource-detail/en/c/1640993/#:~:text=Global%20supply%20of%20Atlantic%20salmon%20reached%20around%20,down%201.4%20percent%20compared%20to%20the%20previous%20year.>



75. Saksida S, Karreman G, Constantine J, Donald A. 2007. Differences in *Lepeophtheirus salmonis* abundance levels on Atlantic salmon farms in the Broughton Archipelago, British Columbia, Canada. *Journal of Fish Diseases*.30(6):357-366,
76. Yazawa R, Yasuie M, Leong J, von Schalburg KR, Cooper GA, Beetz-Sargent M, et al. 2008. EST and Mitochondrial DNA Sequences Support a Distinct Pacific Form of Salmon Louse, *Lepeophtheirus salmonis*. *Marine Biotechnology*.10(6):741-749.10.1007/s10126-008-9112-y
77. Todd CD, Walker AM, Ritchie MG, Graves JA, Walker AF. 2004. Population genetic differentiation of sea lice (*Lepeophtheirus salmonis*) parasitic on Atlantic and Pacific salmonids: analyses of microsatellite DNA variation among wild and farmed hosts. *Canadian Journal of Fisheries and Aquatic Sciences*.61(7):1176-1190.10.1139/f04-069
78. Patanasatienkul T, Sanchez J, Rees EE, Krkošek M, Jones SR, Revie CW. 2013. Sea lice infestations on juvenile chum and pink salmon in the Broughton Archipelago, Canada, from 2003 to 2012. *Diseases of Aquatic Organisms*.105(2):149-161, <https://www.int-res.com/abstracts/dao/v105/n2/p149-161>
79. Elmoslemay A, Revie CW, Milligan B, Stewardson L, Vanderstichel R. 2015. Wild juvenile salmonids in Muchalat Inlet, British Columbia, Canada: factors associated with sea lice prevalence. *Diseases of Aquatic Organisms*.117(2):107-120, <https://www.int-res.com/abstracts/dao/v117/n2/p107-120/>
80. Saksida S, Constantine J, Karreman GA, Donald A. 2007. Evaluation of sea lice abundance levels on farmed Atlantic salmon (*Salmo salar* L.) located in the Broughton Archipelago of British Columbia from 2003 to 2005. *Aquaculture Research*.38(3):219-231,
81. Jones SR, Bruno DW, Madsen L, Peeler EJ. 2015. Disease management mitigates risk of pathogen transmission from maricultured salmonids. *Aquaculture Environment Interactions*.6(2):119-134,
82. Beamish R, Wade J, Pennell W, Gordon E, Jones S, Neville C, et al. 2009. A large, natural infection of sea lice on juvenile Pacific salmon in the Gulf Islands area of British Columbia, Canada. *Aquaculture*.297(1-4):31-37,
83. Nagasawa K. 1985. Comparison of the infection levels of *Lepeophtheirus salmonis* (Copepoda) on chum salmon captured by two methods. *Japanese Journal of Ichthyology*.32(3):368-370,
84. Nagasawa K, Ishida Y, Ogura M, Tadokoro K, Hiramatsu K. 1993. The abundance and distribution of *Lepeophtheirus salmonis* (Copepoda: Caligidae) on six species of Pacific salmon in offshore waters of the North Pacific Ocean and Bering Sea. In: Boxshall GA, Defaye D, editors. *Pathogens of Wild and Farmed Fish, Sea Lice*. 1: Ellis Horwood. p. 166-178
85. Johnson SC, Blaylock RB, Elphick J, Hyatt KD. 1996. Disease induced by the sea louse (*Lepeophtheirus salmonis*) (Copepoda: Caligidae) in wild sockeye salmon (*Oncorhynchus nerka*) stocks of Alberni Inlet, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences*.53(12):2888-2897.10.1139/f96-226
86. Rees E, St-Hilaire S, Jones S, Krkošek M, DeDominicis S, Foreman M, et al. 2015. Spatial patterns of sea lice infection among wild and captive salmon in western Canada. *Landscape Ecology*.30(6):989-1004,

87. Peacock SJ, Bateman AW, Krkosek M, Connors B, Rogers S, Portner L, et al. 2023. Sea-louse parasites on juvenile wild salmon in the Broughton Archipelago, British Columbia, Canada: Salmon Coast Field Station; [Available from: <https://github.com/salmoncoast/Sea-lice-database>.
88. Cedar Coast Field Station. 2021. Sea-lice-database: Monitoring sea-louse parasites on juvenile wild salmon in Clayoquot Sound on the West Coast of Vancouver Island, British Columbia, Canada: Cedar Coast Field Station; [Available from: <https://github.com/cedarcoastfieldstation/Sea-lice-database>.
89. MOWI. 2023. Juvenile Wild Salmon Sea Lice Monitoring: MOWI; [Available from: <https://mowi.com/caw/sustainability/wild-salmonid-lice-monitoring/>.
90. Grieg Seafood British Columbia. 2023. Wild Pacific salmon: Grieg Seafood ASA; [Available from: <https://griegseafood.com/bc-wild-pacific-salmon>.
91. Cermaq Canada. 2023. Sea lice reporting: Cermaq; [Available from: <https://www.cermaq.ca/public-trust/sea-lice-reporting>.
92. Jones S, Kim E, Bennett W. 2008. Early development of resistance to the salmon louse, *Lepeophtheirus salmonis* (Krøyer), in juvenile pink salmon, *Oncorhynchus gorbuscha* (Walbaum). Journal of Fish Diseases.31(8):591-600.<https://doi.org/10.1111/j.1365-2761.2008.00933.x>
93. Mages PA, Dill LM. 2010. The effect of sea lice (*Lepeophtheirus salmonis*) on juvenile pink salmon (*Oncorhynchus gorbuscha*) swimming endurance. Canadian Journal of Fisheries and Aquatic Sciences.67(12):2045-2051.10.1139/f10-121
94. Routledge R, Morton A. 2023. Effect of government removal of salmon farms on sea lice infection of juvenile wild salmon in the Discovery Islands. Canadian Journal of Fisheries and Aquatic Sciences.80(12):1984-1989.10.1139/cjfas-2023-0039
95. Department of Fisheries and Oceans. 1998. Fraser River Salmon Summary. Vancouver, BC.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/227528.pdf>
96. Atkinson E, Guinchard C, Kamarainen A, Peacock S, Bateman A. 2020. The status of Pacific salmon in the Broughton Archipelago, northeast Vancouver Island, and mainland inlets. Simoom Sound, BC Salmon Coast Field Station.https://www.salmoncoast.org/wp-content/uploads/2020/12/SCFS_RegionalReport_StatusofPacificSalmon.pdf
97. Ricker WE. 1954. Stock and Recruitment. Journal of the Fisheries Research Board of Canada.11(5):559-623.10.1139/f54-039
98. Commission PS. 2023. Data & Applications Vancouver, British Columbia,: Pacific Salmon Commission; [Available from: <https://www.psc.org/publications/data/>.
99. Williamson J. 2022. M.E.S.S.S. 2022 Salmon Enumeration Program Fisheries and Oceans Canada Area 12: Broughton Archipelago Musgamagw Dzawada'enuxw Territory: Mainland Enhancement of Salmonoid Species Society. Available from: https://www.messs.ca/files/ugd/2d934e_20c1dac48d3f496fb7d433323f430777.pdf.
100. Godwin SC, Dill LM, Reynolds JD, Krkošek MM. 2015. Sea lice, sockeye salmon, and foraging competition: lousy fish are lousy competitors. Canadian Journal of Fisheries and Aquatic Sciences.72(7):1113-1120.10.1139/cjfas-2014-0284

101. BC Centre for Aquatic Health Sciences. 2022. BC CAHS case no.: W0265 Juvenile Salmonid Sea Lice Assessment 2022: Klemtu. Campbell River: BC Centre for Aquatic Health Sciences.<https://mowi.com/caw/wp-content/uploads/sites/7/2023/09/Sea-Lice-Monitoring-of-Juvenile-Salmonids-in-Kitasoo-Territory-2022.pdf>
102. BC Centre for Aquatic Health Sciences. 2021. BC CAHS case no.: V0213 Juvenile Salmonid Sea Lice Assessment 2021: Klemtu. Campbell River: BC Centre for Aquatic Health Sciences.<https://mowi.com/caw/wp-content/uploads/sites/7/2022/02/Sea-Lice-Monitoring-of-Juvenile-Salmonids-in-Kitasoo-Territory-2021.pdf>
103. BC Centre for Aquatic Health Sciences. 2020. BC CAHS case no.: T0256 Juvenile Salmonid Sea Lice Assessment 2020: Klemtu. Campbell River: BC Centre for Aquatic Health Sciences.<https://mowi.com/caw/wp-content/uploads/sites/7/2020/12/Klemtu-Juvenile-Salmonid-Sea-Lice-Assesment-2020-.pdf>
104. BC Centre for Aquatic Health Sciences. 2019. BC CAHS case no.: R0325 v. Campbell River: BC Centre for Aquatic Health Sciences.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/klemtu-juvenile-salmonid-sea-lice-assessment-2019.pdf>
105. BC Centre for Aquatic Health Sciences. 2018. BC CAHS case no.: P0354 Juvenile Salmonid Sea Lice Assessment 2018: Klemtu. Campbell River: BC Centre for Aquatic Health Sciences.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/klemtu-juvenile-salmonid-sea-lice-assessment-2018.pdf>
106. BC Centre for Aquatic Health Sciences. 2018. BC CAHS case no.: N-0399 and P-0354 Juvenile Salmonid Sea Lice Assessment 2017: Klemtu. Campbell River: BC Centre for Aquatic Health Sciences.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/klemtu-juvenile-salmonid-sea-lice-assessment-2017.pdf>
107. Myers R. 2014. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 3. Port Hardy, BC: Pacificus Biological Services Ltd.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/sea-lice-study-goletas-channel-2014-final.pdf>
108. Nowak T. 2015. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 4. Port Hardy, BC: Pacificus Biological Services Ltd.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/sea-lice-study-goletas-channel-2015-final.pdf>
109. Pacificus Biological Services Ltd. 2016. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 5. Port Hardy, BC: Pacificus Biological Services.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/sea-lice-study-goletas-channel-2016-final.pdf>
110. Miles M. 2019. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 8. Port Hardy, BC: Pacificus Biological Services Ltd.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/sea-lice-study-goletas-channel-2019-final.pdf>
111. Pacificus Biological Services Ltd. 2018. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 7. Port Hardy, BC: Pacificus Biological Services Ltd.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/sea-lice-study-goletas-channel-2018-final.pdf>
112. Pacificus Biological Services Ltd. 2017. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 6. Port Hardy, BC: Pacificus Biological Services

- Ltd.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/sea-lice-study-goletas-channel-2017-final.pdf>
113. Miles M. 2019. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 8. Port Hardy, BC: Pacificus Biological Services Ltd.<https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/sea-lice-study-goletas-channel-2019-final.pdf>
 114. Pacificus Biological Services Ltd. 2021. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 10. Port Hardy, BC: Pacificus Biological Services.<https://mowi.com/caw/wp-content/uploads/sites/7/2021/08/MOWI-Sea-Lice-Study-Goletas-Channel-2021-Final.pdf>
 115. Pacificus Biological Services Ltd. 2020. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 9. Port Hardy, BC: Pacificus Biological Services Ltd.<https://mowi.com/caw/wp-content/uploads/sites/7/2020/09/Sea-Lice-Study-Goletas-Channel-2020-FINAL.pdf>
 116. Pacificus Biological Services Ltd. 2022. Sea lice monitoring study in Goletas channel and Queen Charlotte Strait, BC Year 11. Port Hardy, BC: Pacificus Biological Services Ltd.<https://mowi.com/caw/wp-content/uploads/sites/7/2022/08/MOWI-Sea-Lice-Study-Goletas-Channel-2022-FINAL-V2.pdf>
 117. Stewardson L. 2020. Wild Juvenile Salmonid Monitoring Program 2020 Quatsino Sound, BC. Campbell River: Mainstream Biological Consulting.<https://mowi.com/caw/wp-content/uploads/sites/7/2020/06/Quatsino-Wild-Juvenile-Salmonid-Monitoring-2020.pdf>
 118. Stewardson L. 2010. Wild Juvenile Salmonid Monitoring Program 2010 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.
 119. Stewardson L. 2011. Wild Juvenile Salmonid Monitoring Program 2011 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.
 120. Stewardson L. 2012. Wild Juvenile Salmonid Monitoring Program 2012 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.
 121. Stewardson L. 2017. Wild Juvenile Salmonid Monitoring Program 2017 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.
 122. Stewardson L. 2018. Wild Juvenile Salmonid Monitoring Program 2018 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.
 123. Stewardson L. 2019. Wild Juvenile Salmonid Monitoring Program 2019 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.
 124. Stewardson L. 2020. Wild Juvenile Salmonid Monitoring Program 2020 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.
 125. Stewardson L. 2021. Wild Juvenile Salmonid Monitoring Program 2021 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.
 126. Stewardson L. 2023. Wild Juvenile Salmonid Monitoring Program 2023 Esperanza Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting.<https://cdn.sanity.io/files/1gakia31/production/d71e879015e4bdcf35b5613448213284916bf05d.pdf?dl>



127. Stewardson L. 2011. Wild Juvenile Salmonid Monitoring Program 2011 Muchalat Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
128. Stewardson L. 2012. Wild Juvenile Salmonid Monitoring Program 2012 Muchalat Inlet, Nootka Sound, BC. Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
129. Stewardson L. 2013. Wild Juvenile Salmonid Monitoring Program 2013 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
130. Stewardson L. 2014. Wild Juvenile Salmonid Monitoring Program 2014 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
131. Stewardson L. 2015. Wild Juvenile Salmonid Monitoring Program 2015 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
132. Stewardson L. 2016. Wild Juvenile Salmonid Monitoring Program 2016 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
133. Stewardson L. 2017. Wild Juvenile Salmonid Monitoring Program 2017 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
134. Stewardson L. 2018. Wild Juvenile Salmonid Monitoring Program 2018 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
135. Stewardson L. 2019. Wild Juvenile Salmonid Monitoring Program 2019 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
136. Stewardson L. 2020. Wild Juvenile Salmonid Monitoring Program 2020 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting. <https://cdn.sanity.io/files/1gakia31/production/6fc48a4a40fa8c9c6e3f1dea77b95ab093807843.pdf?dl>
137. Stewardson L. 2021. Wild Juvenile Salmonid Monitoring Program 2021 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting.

138. Stewardson L. 2022. Wild Juvenile Salmonid Monitoring Program 2022 Muchalat Inlet, Nootka Sound, BC Campbell River: Mainstream Biological Consulting.
139. Stewardson L. 2022. Wild Juvenile Salmonid Monitoring Program Clayoquot Sound 2022. Campbell River: Mainstream Biological Consulting.
140. Stewardson L. 2021. Wild Juvenile Salmonid Monitoring Program Clayoquot Sound 2021. Campbell River: Mainstream Biological Consulting. <https://www.cermaq.ca/assets/Clayoquot-Wild-Juvenile-Salmonid-Monitoring-2021-V3.-FINAL.pdf>
141. Stewardson L. 2020. Wild Juvenile Salmonid Monitoring Program Clayoquot Sound 2020. Campbell River: Mainstream Biological Consulting. <https://www.cermaq.ca/assets/ClayoquotWildJuvenileSalmonidMonitoring2020V4.Final.pdf>
142. Stewardson L. 2019. Wild Juvenile Salmonid Monitoring Program Clayoquot Sound 2019. Campbell River: Mainstream Biological Consulting. <https://www.cermaq.ca/assets/ClayoquotWildJuvenileSalmonidMonitoring201925July2019.pdf>
143. Stewardson L. 2018. Wild Juvenile Salmonid Monitoring Program Clayoquot Sound 2018. Campbell River: Mainstream Biological Consulting. <https://www.cermaq.ca/assets/ClayoquotWildJuvenileSalmonidMonitoring2018.pdf>
144. Stewardson L. 2017. Wild Juvenile Salmonid Monitoring Program Clayoquot Sound 2017. Campbell River: Mainstream Biological Consulting.
145. Stewardson L. 2016. Wild Juvenile Salmonid Monitoring Program Clayoquot Sound 2016. Campbell River: Mainstream Biological Consulting.
146. Stewardson L. 2022. Wild Juvenile Salmonid Monitoring Program: Jervis Inlet and Sechelt Inlet 2022. Campbell River: Mainstream Biological Consulting.
147. Stewardson L. 2021. Wild Juvenile Salmonid Monitoring Program: Jervis Inlet and Sechelt Inlet 2021. Campbell River: Mainstream Biological Consulting.
148. Stewardson L. 2020. Wild Juvenile Salmonid Monitoring Program: Jervis Inlet and Sechelt Inlet 2020. Campbell River: Mainstream Biological Consulting.
149. Stewardson L. 2019. Wild Juvenile Salmonid Monitoring Program: Jervis Inlet and Sechelt Inlet 2019. Campbell River: Mainstream Biological Consulting.
150. Stewardson L. 2016. Wild Juvenile Salmonid Monitoring Program: Jervis Inlet and Sechelt Inlet 2016. Campbell River: Mainstream Biological Consulting.
151. Stewardson L. 2018. Wild Juvenile Salmonid Monitoring Program: Jervis Inlet and Sechelt Inlet 2018. Campbell River: Mainstream Biological Consulting.
152. Stewardson L. 2017. Wild Juvenile Salmonid Monitoring Program: Jervis Inlet and Sechelt Inlet 2017. Campbell River: Mainstream Biological Consulting.
153. Stewardson L. 2020. Wild Juvenile Salmonid Monitoring Program 2019 Clio Channel and Chatham Channel, BC. Campbell River: Mainstream Biological Consulting.



154. Stewardson L. 2019. Wild Juvenile Salmonid Monitoring Program 2020 Clio Channel and Chatham Channel, BC. Campbell River: Mainstream Biological Consulting.
155. Stewardson L. 2021. Wild Juvenile Salmonid Monitoring Program 2021 Clio Channel and Chatham Channel, BC. Campbell River: Mainstream Biological Consulting.
156. Brookson CB, Krkošek M, Hunt BPV, Johnson BT, Rogers LA, Godwin SC. 2020. Differential infestation of juvenile Pacific salmon by parasitic sea lice in British Columbia, Canada. Canadian Journal of Fisheries and Aquatic Sciences. 77(12):1960-1968. [10.1139/cjfas-2020-0160](https://doi.org/10.1139/cjfas-2020-0160)
157. Fisheries and Oceans Canada. Stock assessment and management advice for BC Pacific herring: 2018 status and 2019 forecast (online). DFO Can Sci Advis Sec Sci Resp2019. http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SCR-RS/2019/2019_001-eng.pdf
158. Forum BPS, editor 2009. Final Report & Recommendations to the Government of British Columbia 2009: BC Pacific Salmon Forum. <http://www.farmfreshsalmon.org/sites/default/files/BCPSFFinRptqSm.pdf>
159. Hummeny RG. 2021. Sea lice on juvenile wild salmon in the Broughton Archipelago, British Columbia in 2021. A report from the Salmon Coast Field Station Society.: Salmon Coast Field Station Society. https://www.salmoncoast.org/wp-content/uploads/2021/10/SCFS_SeaLiceReport_2021-1.pdf
160. Harrington P, Atkinson E. 2019. Sea lice on juvenile wild salmon in the Broughton Archipelago, British Columbia in 2019. A report from the Salmon Coast Field Station Society.
161. Revie CW, McKenzie P, Foreman M, DeDominicis S, Patanasatienkul T, Krkošek M. 2012. Trying to substitute light for heat in the debate around sea lice and aquaculture in British Columbia, Canada. Charlottetown, PEI: University of Prince Edward Island. <https://cdn.technologynetworks.com/ep/pdfs/trying-to-substitute-light-for-heat-in-the-debate-around-sea-lice-and-aquaculture-in-british.pdf>
162. Stewardson L. 2016. Wild juvenile salmonid monitoring program Broughton Archipelago. 2016. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/broughton-wild-juvenile-salmonid-monitoring-2016.pdf>
163. Stewardson L. 2017. Wild juvenile salmonid monitoring program Broughton Archipelago 2017. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/broughton-wild-juvenile-salmonid-monitoring-2017.pdf>
164. Stewardson L. 2018. Wild juvenile salmonid monitoring program Broughton Archipelago 2018. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/broughton-wild-juvenile-salmonid-monitoring-2018.pdf>
165. Stewardson L. 2019. Wild juvenile salmonid monitoring program Broughton Archipelago 2019. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/broughton-wild-juvenile-salmonid-monitoring-2019.pdf>
166. Stewardson L. 2020. Wild juvenile salmonid monitoring program Broughton Archipelago 2020. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2020/07/Broughton-Wild-Juvenile-Salmonid-Monitoring-2020.pdf>
167. Stewardson L. 2021. Wild juvenile salmonid monitoring program Broughton Archipelago 2021. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2021/07/Broughton-Wild-Juvenile-Salmonid-Monitoring-2021.pdf>

- [content/uploads/sites/7/2021/08/Broughton-Wild-Juvenile-Salmonid-Monitoring-2021-V2.pdf](#)
168. Stewardson L. 2022. Wild juvenile salmonid monitoring program Broughton Archipelago 2022. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2022/08/Broughton-Wild-Juvenile-Salmonid-Monitoring-2022-Final.pdf>
 169. Stewardson L. 2023. Wild juvenile salmonid monitoring program Broughton Archipelago 2023. Campbell River: Mainstream Biological Consulting. https://mowi.com/caw/wp-content/uploads/sites/7/2023/08/Broughton_Wild_Juvenile_Salmonid_Monitoring_2023.pdf
 170. Stewardson L. 2015. Prevalence of Sea Lice (*Lepeophtheirus salmonis* and *Caligus clemensi*) on Juvenile Salmonids Captured in the Broughton Archipelago. Campbell River: Mainstream Biological Consulting. <https://mowi.com/caw/wp-content/uploads/sites/7/2019/08/broughton-wild-juvenile-salmonid-monitoring-2015.pdf>
 171. Krkošek M, Lewis MA, Volpe JP. 2005. Transmission dynamics of parasitic sea lice from farm to wild salmon. *Proceedings of the Royal Society B: Biological Sciences*. 272(1564):689-696,
 172. Krkošek M, Lewis MA, Morton A, Frazer LN, Volpe JP. 2006. Epizootics of wild fish induced by farm fish. *Proceedings of the National Academy of Sciences*. 103(42):15506-15510. 10.1073/pnas.0603525103
 173. Krkošek M, Hilborn R. 2011. Sea lice (*Lepeophtheirus salmonis*) infestations and the productivity of pink salmon (*Oncorhynchus gorbuscha*) in the Broughton Archipelago, British Columbia, Canada. *Canadian Journal of Fisheries and Aquatic Sciences*. 68(1):17-29,
 174. Peacock SJ, Krkošek M, Proboyszcz S, Orr C, Lewis MA. 2013. Cessation of a salmon decline with control of parasites. *Ecological Applications*. 23(3):606-620. <https://doi.org/10.1890/12-0519.1>
 175. Rogers LA, Peacock SJ, McKenzie P, DeDominicis S, Jones SRM, Chandler P, et al. 2013. Modeling Parasite Dynamics on Farmed Salmon for Precautionary Conservation Management of Wild Salmon. *PLOS ONE*. 8(4):e60096. 10.1371/journal.pone.0060096
 176. DFO. 2023. Association between sea lice from Atlantic Salmon farms and sea lice infestations on wild juvenile Pacific Salmon in British Columbia. Ottawa: Fisheries and Oceans Canada. https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScRS/2022/2022_045-eng.pdf
 177. Fisheries and Oceans Canada. 2023. Average number of lice per fish on BC salmon farms. Ottawa: Government of Canada. <https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/lice-ab-pou/index-eng.html>
 178. Open Government. 2023. Industry sea lice counts at BC marine finfish aquaculture sites Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/3cafbe89-c98b-4b44-88f1-594e8d28838d>.
 179. Open Government. 2023. Sea lice mitigation events at BC marine finfish aquaculture sites Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/fdba4d10-51aa-40df-884e-09e1c29049d8>.

CHAPTER 11

CARING FOR FISH HEALTH



This document explains the holistic measures that keep salmon healthy now and into the future

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CHAPTER HIGHLIGHTS – CARING FOR FISH HEALTH

SALMON FARMERS CARE ABOUT THE HEALTH OF FISH, WILD AND FARM-RAISED

Salmon farmers and their fish health teams, regulatory agencies, and First Nation Rightsholders keep farm-raised fish healthy by selective breeding, minimizing pathogen entry and spread into hatcheries and marine net pens (e.g., vaccines), fish health monitoring and record keeping, prescribed treatments and being subject to fish health audits by government regulators.

Licensed salmon farm veterinarians base their fish health management decisions on validated test results generated by independently accredited diagnostic laboratories that follow established testing protocols.

Advances in salmon farming methods have decreased infectious diseases on salmon farms over the past 40 years. This minimizes the transmission of infectious diseases from farms to wild salmon.

Antibiotic treatments of farm-raised salmon in the marine environment have decreased to less than 20% of peak usage that occurred in 1997.

Salmon farm fish health teams have successfully decreased the prevalence of high-risk diseases. For example, outbreaks of the IHN virus decreased from 36 farms over 23 months (2001 – 2003), to three farms over three months (2012). Since 2012, all farm-raised Atlantic salmon are vaccinated against IHN, and no other outbreaks have occurred.

Today, only about 3% of farm-raised salmon in the marine environment die each year from infectious diseases.

About 17% of farm-raised Atlantic salmon and 10% of farm-raised Pacific salmon die each year from other causes, mostly from low dissolved oxygen, toxic algal blooms, and for Atlantic salmon—damage from mechanical treatments used to control sea lice.

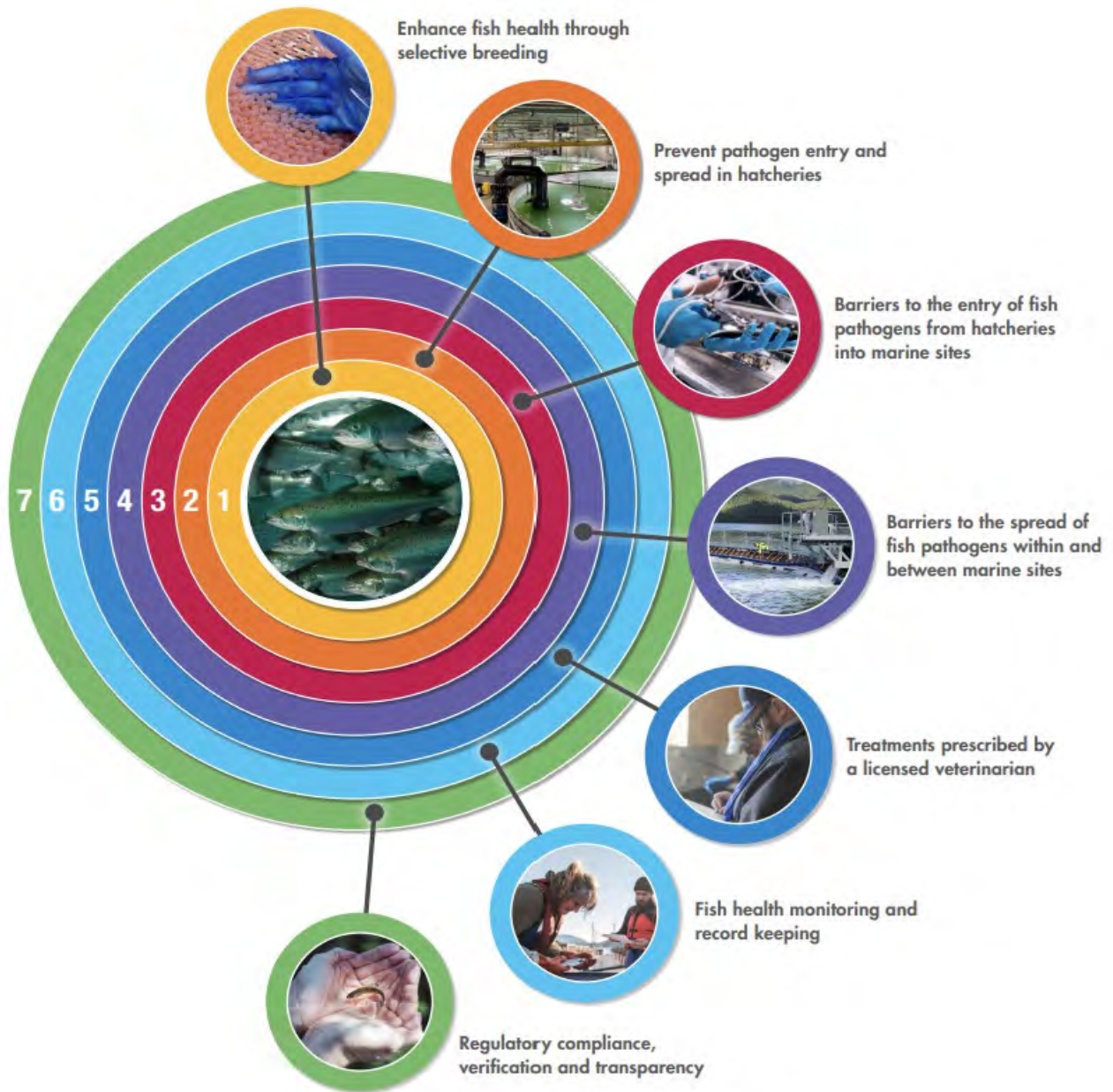
The remaining farm-raised Atlantic (80%) and Pacific (87%) salmon survive and grow to be harvested as one of the world's most sustainable animal proteins.





Dedicated fish health teams at every aquaculture company use *Evidence-based Medicine* to manage fish health. Over the past 40 years, fish health teams have

worked with regulatory agencies and First Nation Rightsholders to develop seven safeguards and proactive practices to keep farm-raised fish healthy and thriving.



MINIMAL RISK OF PATHOGEN TRANSFER FROM FARM-RAISED SALMON TO WILD SALMON

Many variables need to align for disease to occur within an individual fish, and other variables need to align for disease to spread to a population of fish.

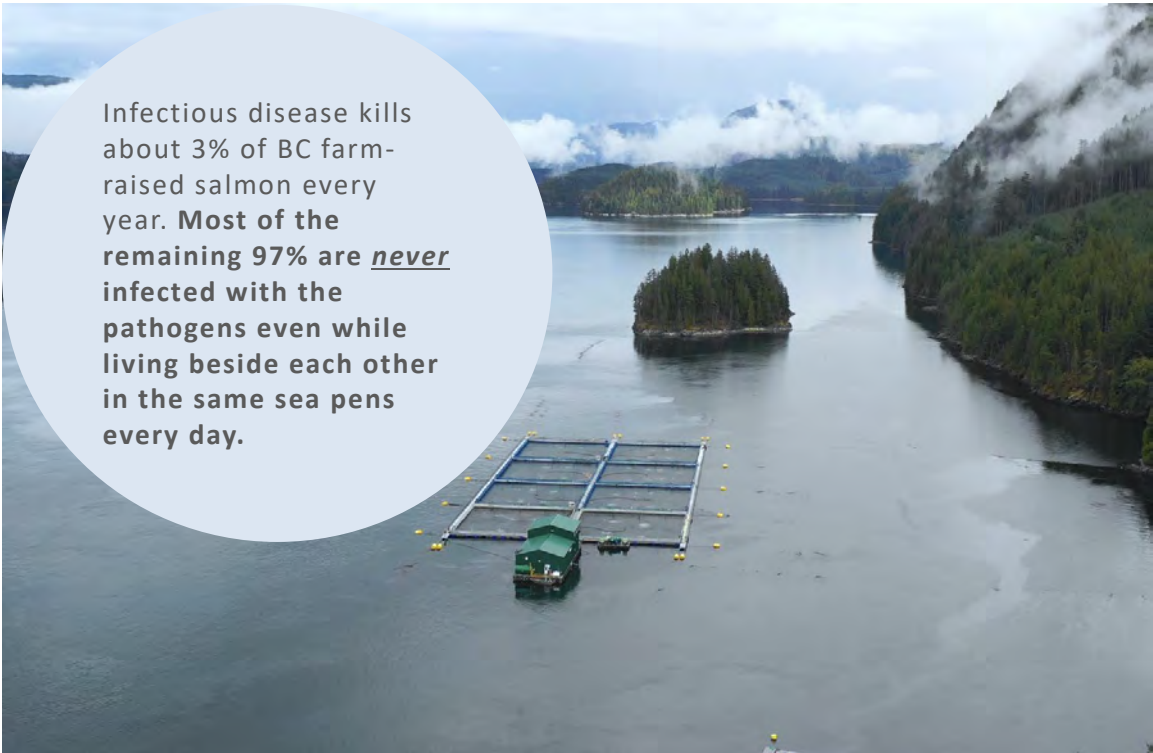
Safeguards reduce pathogen spread within farms. If pathogens do not spread, then disease does not spread.

Principles of population medicine inform us that if only 3% of salmon confined in the farms over an entire year die of infectious disease, we expect that even fewer wild salmon—dispersed in the environment—might die from farm-source diseases.

Pathogens shed by farms are diluted and degraded in the environment; this decreases the chance of wild fish getting infected from a farm-source disease.

Extensive salmon farm data over the past decade supports Justice Cohen's 2012 conclusion that "Data presented during this Inquiry did not show that salmon farms were having a significant negative impact on Fraser River sockeye."

Formal assessments of nine salmonid pathogens that occur or have occurred on farmed salmon in British Columbia concluded a "minimal risk" of each pathogen to Fraser River sockeye salmon abundance and diversity.



Infectious disease kills about 3% of BC farm-raised salmon every year. **Most of the remaining 97% are never infected with the pathogens even while living beside each other in the same sea pens every day.**



ICONIC SALMON POPULATIONS DID NOT DECLINE DURING THE SALMON FARMING YEARS

A 2022 scientific paper includes an unreliable estimate of increased mortality among juvenile Fraser River sockeye salmon due to the bacterium *Tenacibaculum maritimum* from salmon farms. This estimate is unreliable because the researchers did not follow their cited testing protocol; instead, they used test results that might be false positives.

Independent assessment of the threat of piscine orthoreovirus (PRV) concluded that “the virus poses a low risk to wild species of Pacific salmonids.” This assessment was conducted by the Pacific Northwest Fish Health Protection Committee, a group of fish health professionals in the USA.

As evidence that accounts for all salmon farm threats—known and unknown—adult

returns of iconic salmon populations were similar before and during the salmon farming years.

Indeed, total Fraser River sockeye salmon adult returns averaged 6.8 million per year before salmon farming began in the Discovery Islands region (1962 – 1989) and 8.0 million per year during the salmon farming years (1990 – 2022).

Total adult returns of pink salmon to rivers in the Broughton Archipelago averaged 0.8 million per year before salmon farming began (1950 – 1987) and 1.1 million per year during the salmon farming years (1988 – 2014; DFO records are incomplete after 2014).



Photo by Steel Snorkel

FISH HEALTH TEAMS ARE WELL INFORMED AND CONSTANTLY INNOVATING

Fish health teams receive continual information from a variety of sources.

Innovations in artificial intelligence, communications, analytics and data management are underway.





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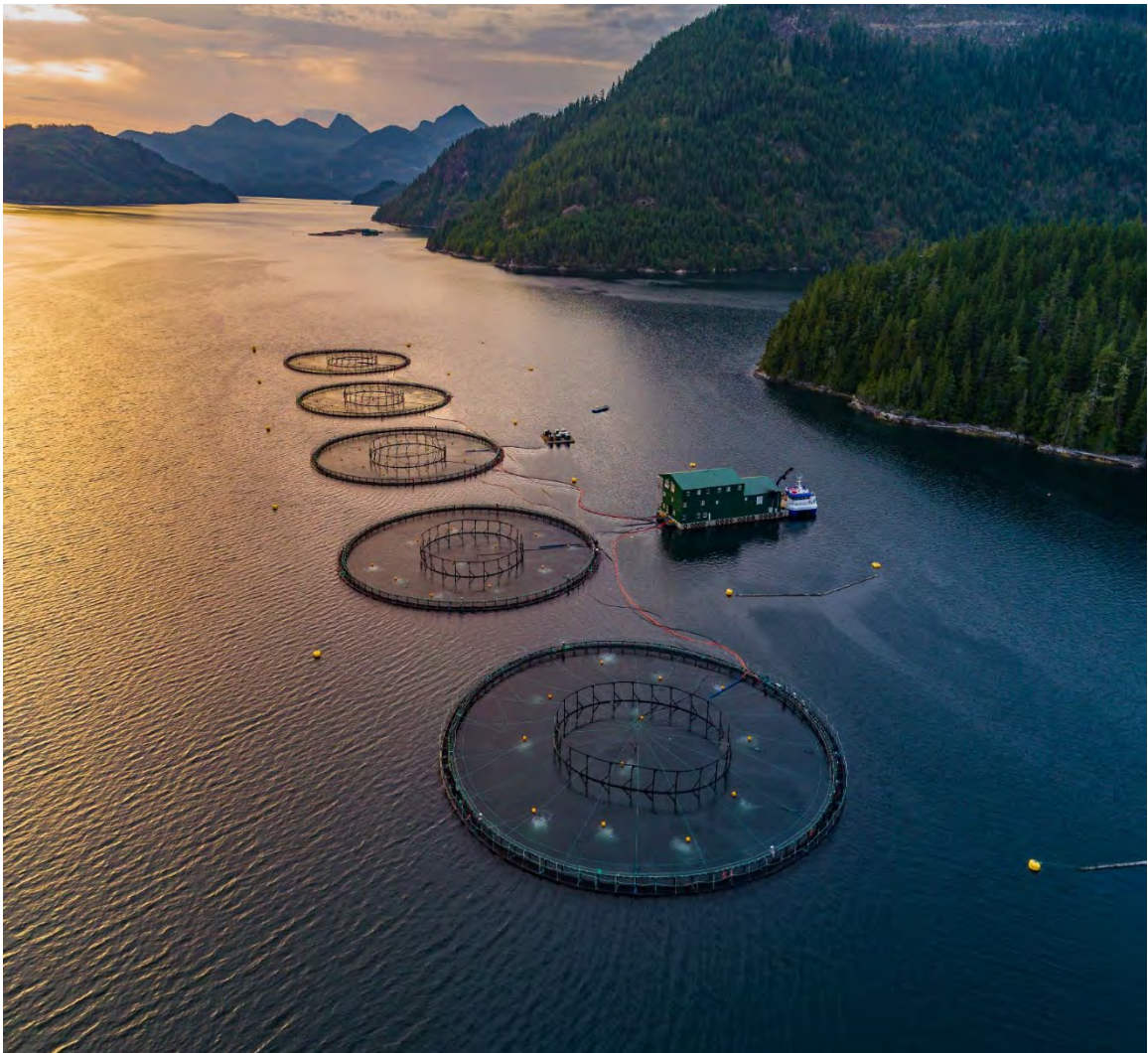
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WE HEARD YOU

We share the concern of First Nations and members of the public that farm-raised salmon shed pathogens and might cause population-level effects on wild salmon. Salmon farmers recognize the importance of safeguarding fish health and supporting wild salmon conservation. We know we

must also demonstrate to others that our fish health measures have been effective. This chapter describes (i) the proactive steps salmon farmers use to keep fish healthy on farms and (ii) the verification for those critical steps.



SALMON FARMERS CARE ABOUT THE HEALTH OF WILD FISH

Salmon farmers live and work in the small communities and remote areas of coastal British Columbia (Figure 1).

Fish farmers come from diverse backgrounds - many have worked in commercial fishing, recreational fishing, or wild salmon enhancement and have family members who rely on wild salmon. They understand and agree that wild salmon are iconic to BC.

Most people in salmon farming believe they are helping to take pressure off wild

salmon to feed the world, as well as farming one of the world's most climate-friendly animal proteins (6-8).

Farmers the licensed veterinarians, and fish health professionals in the salmon farming sector apply best practices and the highest standards in fish health care (Figure 2). These practices have been developed over the past 40 years through gains in veterinary medicine, farming technologies, and partnerships with First Nations communities.



Figure 1. View of Gold River, Vancouver Island. A salmon farm hatchery (near the water) has operated since 1998 in the community of approximately 1,300 residents.



Figure 2. Fish health inspection and testing

ROLE OF LICENSED VETERINARIANS

Licensed veterinarians are the cornerstone of maintaining good fish health at farms (Figure 3). They are the only professionals legally authorized to diagnose disease and prescribe treatment for animals.

Veterinarians that work with salmon farms have the same training and licence as veterinarians that work with other animal species in BC. Aquaculture veterinarians apply several steps to keep fish healthy:

- a) Prevention – a series of structured barriers or “safeguards” to prevent disease outbreaks and potential transmission,
- b) Detection – continuous and careful monitoring of fish behaviour and health at farms by veterinarians, fish health staff and farm staff; this is aided by advanced technologies that continuously monitor fish in real-time or near real-time; collection of fish tissue samples and submission to accredited laboratories for analysis (Figure 4),
- c) Diagnosis – veterinarians review all available information (on-site observations, the pattern of clinical signs and mortality, medical history of the fish population, farm environmental conditions and laboratory test results) to diagnose (or not) a fish disease or health condition following accepted criteria for diagnosis of the disease (i.e., the medical case definition),
- d) Treatment – the licensed veterinarian prescribes an appropriate treatment plan and follow up according to the diagnosis; this may include medicines (such as antimicrobials) or changes in fish husbandry practices,
- e) Follow-up – veterinarians track the treatment results and incorporate the information from all of the steps into fish health databases; this information is constantly reviewed,

- which allows for continual improvements in prevention, detection, diagnosis and treatment,
- f) Record keeping – veterinarians maintain accurate and complete medical records. This includes several types of records,
 - g) Surveillance for pathogens and disease, including sampling and diagnostics,
 - h) Medicine use,
 - i) Fish mortalities by pen, including classifying cause of death,
 - j) Farm hygiene, disinfection and biosecurity requirements,
 - k) Reporting – the fish health team is responsible for timely reporting to various regulatory agencies.



Figure 3. All farms are supported by licensed veterinarians and fish health teams.



Licensed veterinarians are highly trained health professionals dedicated to keeping animals healthy, whether pets, terrestrial livestock, wildlife or farm-raised fish.



Figure 4. Sea lice and fish health check on farm-raised salmon.

When making a diagnosis, the veterinarian takes all available information into account: the pattern of clinical signs, medical history, observations (for example, feeding behaviour), data on the farm including environmental conditions and lab results.

The veterinarian's team includes trained staff at each site who observe the fish daily for signs of health and early detection of disease. In addition, the veterinarian, or fish health staff, visits the hatcheries and farms monthly, at a minimum, to monitor fish health and performance (Figure 5). This includes a close look at fish behaviour, feeding, fish condition and growth. Veterinary medical records document all of this information, along with the pattern of clinical signs, life history of the fish, and environmental conditions on the farms. These records must be accurate and complete for the veterinarian to diagnose health problems with the fish.

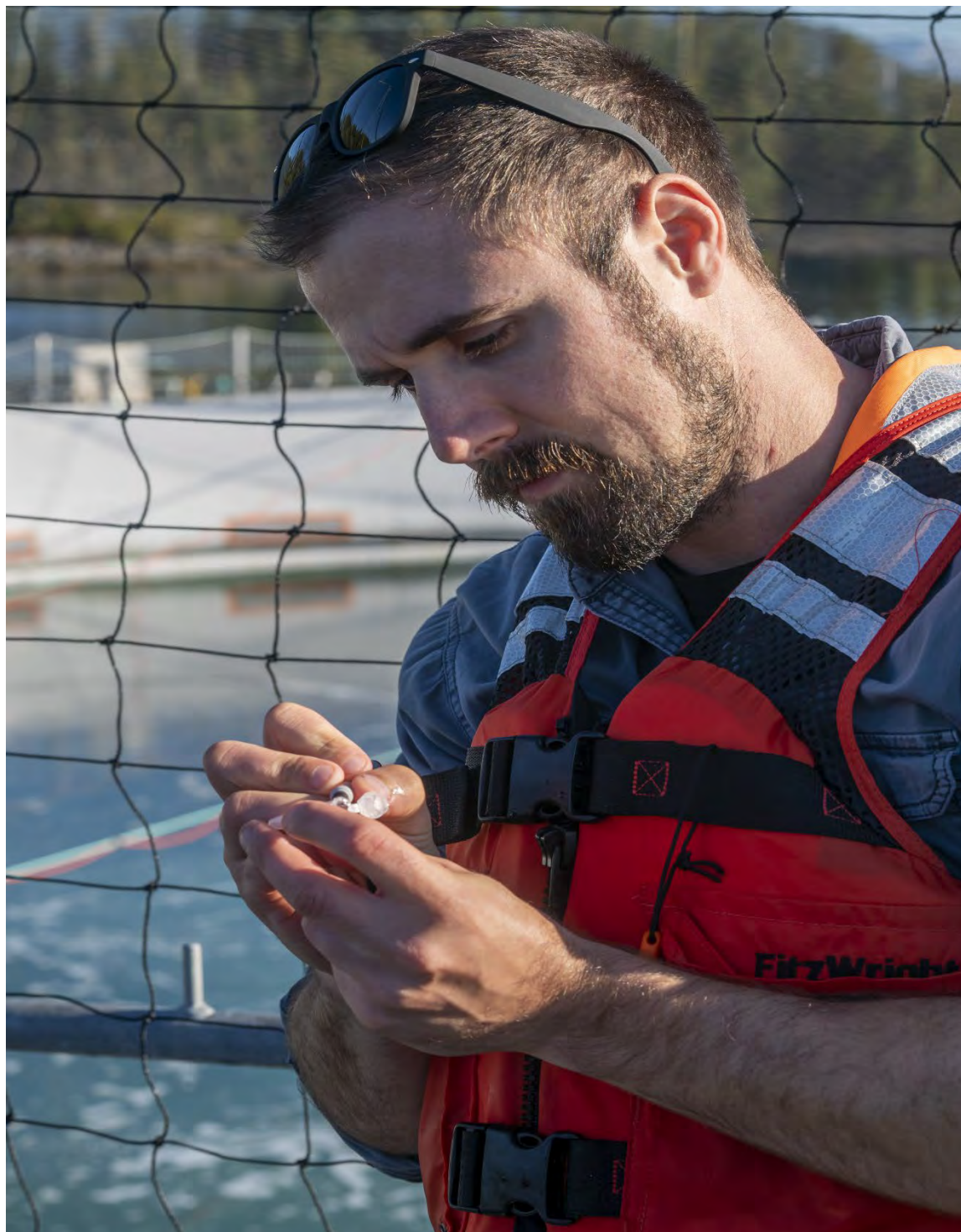


Figure 5. Licensed veterinarian, preparing sample container for next generation genetic sequencing sampling.



HISTORY OF FARM-RAISED FISH HEALTH (1980S – 2020S)

The medical profession has played a huge role in improving human health care and quality of life in the past hundred years. Medical doctors built the foundations in the twentieth century by developing the first widely distributed vaccines (e.g., polio; vaccines for childhood diseases), antimicrobials (Penicillin and sulfa drugs) and lifesaving medications like insulin and digoxin. The second half of the twentieth century saw an explosion of drug development and major advances in cancer and other treatments.

In the same way doctors have advanced human medicine over the past 100 years, aquatic animal veterinarians have brought their professionalism and proficiency to improve fish health in the last 40 years.



Veterinarians use *Evidence-based Medicine* to solve clinical problems. Working with fish health and site staff, they have spearheaded major improvements in the farms' understanding of fish diseases, developing vaccines, optimizing the nutrition and growth rate of the fish and significantly decreasing mortality rates due to several infectious diseases.

Advancements in veterinary practices for farm-raised salmon have been applied to enhancement facilities raising wild Pacific salmon in British Columbia.

Veterinarians undertook disease surveillance that became the foundation for the current body of knowledge about fish diseases in farm-raised salmon. They were essential in the development of vaccines administered to salmon for furunculosis, vibriosis and Infectious Hematopoietic Necrosis (IHN). Their Findings spilled over into knowledge about diseases in salmon enhancement hatcheries and in wild salmon.

Veterinarians developed biosecurity practices to prevent introduction and spread of pathogens and disease.



The result of these practices was reviewed favourably by the Cohen Commission of Justice Cohen who concluded that “Data presented during this Inquiry did not show that salmon farms were having a significant negative impact on Fraser River sockeye.” Justice Cohen’s final report describes the salmon farm disease data presented during the hearings as “impressive,” and he noted, “There was a statistically significant declining trend in the number of high risk diseases reported by salmon farms between 2003 and 2010.”

Veterinarians began categorizing mortalities by cause on the farms for early disease detection so they could monitor and address changing trends in mortality. Surveillance and consistent categorizing of mortality causes shows that the prevalence of significant pathogens and infectious diseases is very low.



HOW HEALTHY ARE FARM-RAISED SALMON?

Only about 3% of BC farm-raised salmon in marine net pens die each year from infectious disease (Figure 6). For Atlantic salmon, another 17% die from other causes (e.g., low dissolved oxygen, toxic algal bloom, or handling), and 80% remain alive and grow to be harvested. For Pacific salmon, another 10% die from other causes (e.g., poor performers, early maturity, and predator attacks), and 87% remain alive and grow to be harvested.

According to the Canadian Food Inspection Agency (CFIA), no reportable diseases exotic to BC have been confirmed in farm-raised salmon in BC (9).

There are only two federally reportable viral diseases that naturally occur among wild fish in BC, but these diseases are rare among farm-raised salmon in BC.

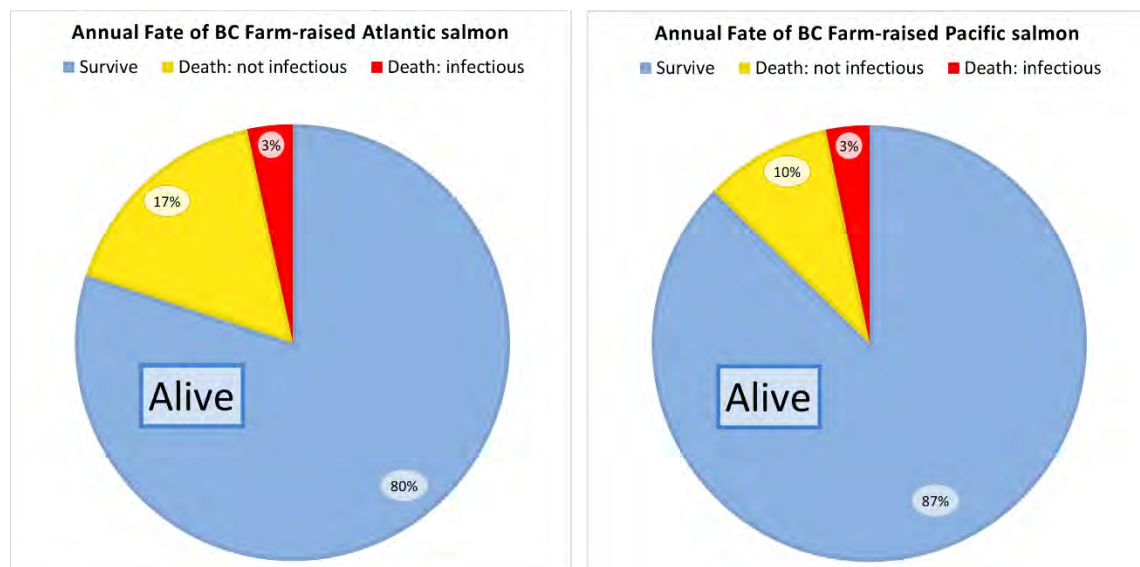


Figure 6. *Annual fate of BC farm-raised Atlantic and Pacific salmon, 2018-2022.*
These numbers, averaged from 2018 – 2022, are derived from two public sources:
[Results of DFO fish health audits of British Columbian marine finfish aquaculture sites, by facility](#)
[Carcass classification of cultured salmon at British Columbian aquaculture sites by facility](#)

Outbreaks of Infectious Haematopoietic Necrosis (IHN) have not occurred among BC farm salmon since 2012, when three farms were affected (10). DFO's Fish Health Audit Program reports 12 PCR+ test results for the Viral Haemorrhagic Septicemia (VHS) virus from 2011 – 2022. (11), but most of these results are associated with minimal mortality, and CFIA reports only three outbreaks of VHS among BC farm-raised salmon since 2011: one each in 2014, 2021, and 2022 (12).

With the introduction of effective vaccines, the use of antimicrobials on BC salmon farms declined from the high in 1997 to a

low in 2020, from 516g to 50g per tonne of salmon (Figure 7) (13).

Farm-raised salmon are very healthy. About 87% of Pacific salmon and 80% of Atlantic salmon survive each year on farms in BC. Only 3% die of infectious disease.

Veterinarians are working to reduce usage even further, in accordance with Canadian Veterinary Medical Association (CVMA) guidelines (14).

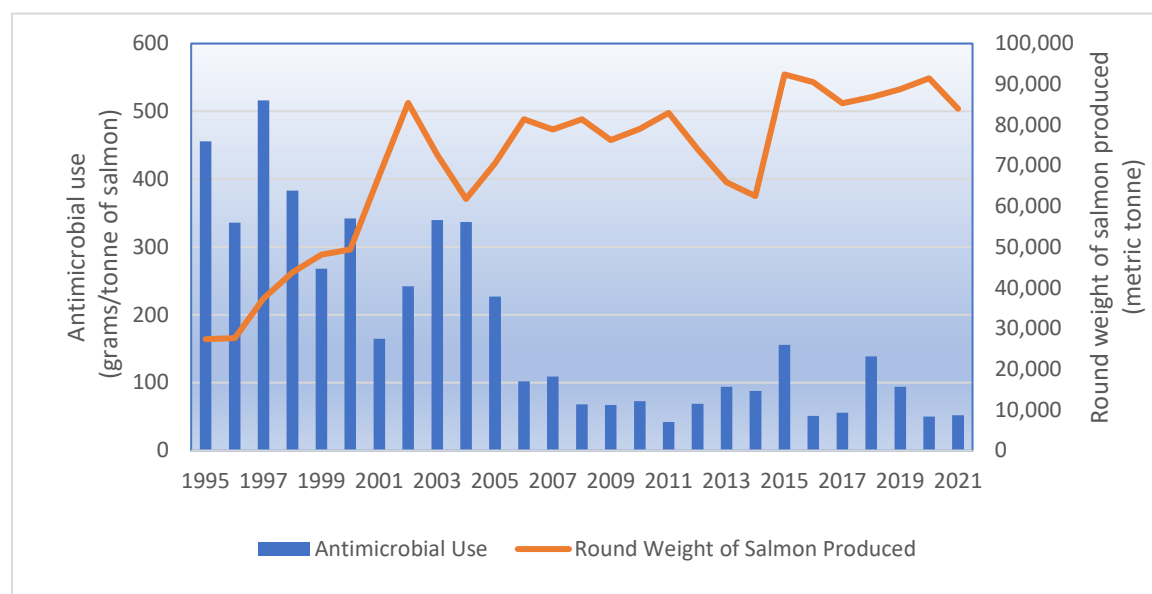


Figure 7. Reduction in antibiotic use in farm-raised Atlantic salmon in BC, 1995 – 2021.
Source [DFO open data](#) (13)

Antimicrobial use at BC salmon farms has decreased by about 80% over the past 28 years with improved husbandry practices and the development of effective vaccines. Research is ongoing to develop additional vaccines.



Veterinarians have also contributed to large, collaborative fish health research projects. They provided robust data sets to support research or formal risk assessments on *Piscine orthoreovirus* (PRV) (15), *Tenacibaculum maritimum* (1), sea lice (16) and other initiatives and contributed to current environmental modeling for sea pens. They also play a significant role in food safety as discussed in “Chapter 12 – Caring for Communities – Food Safety and Security”.

FISH HEALTH MONITORING RESULTS

DFO collects and publicly reports data from salmon farmers about fish health (17). A summary of the health of salmon at BC farms is presented below.

FISH HEALTH EVENTS

A “Fish Health Event” refers to any suspected or confirmed disease that occurs within an aquaculture facility, that requires the involvement of a veterinarian, and warrants mitigation measures. Fish Health Events have been reported to DFO as a condition of license since 2016. Sea lice reporting and management are not included as Fish Health Events.

Each BC salmon farm, on average, reports about one Fish Health Event each year (from 2016 – 2022, 284 reports averaged 41 per year) (Figure 8).

From 2016 to 2022,
each BC salmon farm
on average, reported
about one Fish Health
Event each year.

Among the 284 farm salmon Fish Health Events reported to DFO from 2016 – 2022, 12 (4.2%) were from Pacific salmon species, and the veterinary diagnosis for all 12 was bacterial kidney disease; all of these reports were associated with broodstock that were not experiencing an outbreak but were treated to control background levels of infection before the fish were spawned.

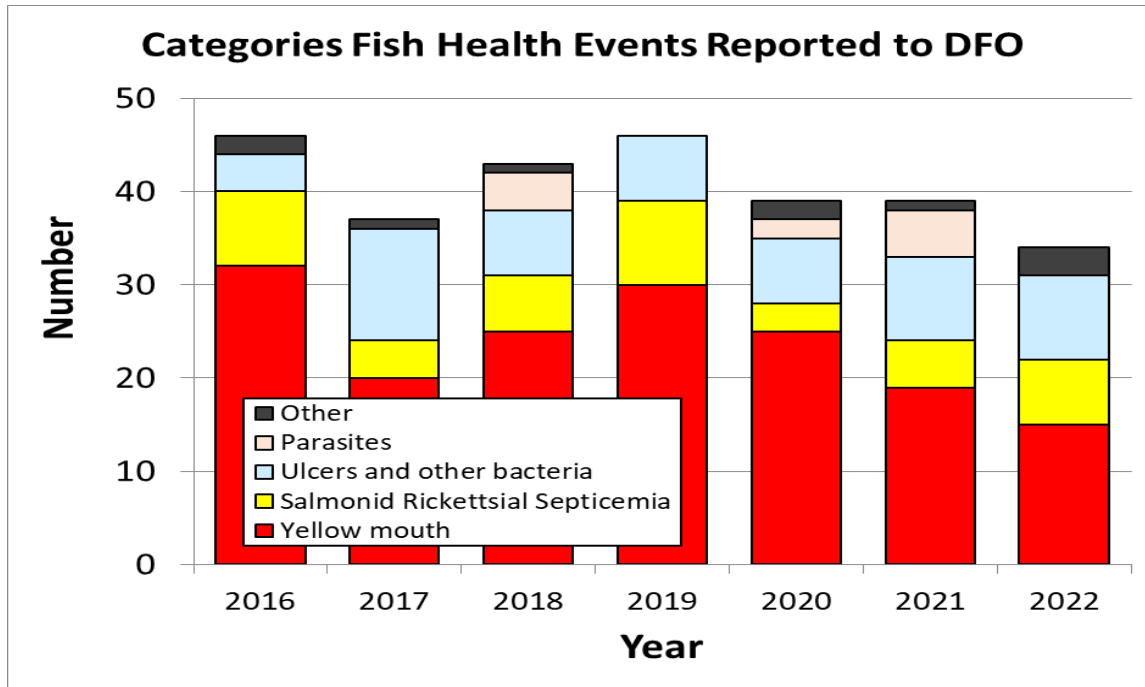


Figure 8. Fish health events at BC Atlantic and Pacific salmon farms, by category, 2016-2022.

Source DFO Open Data (18).

MORTALITY EVENTS

A “Mortality Event” must be reported to DFO within 24 hours of discovery if the number of dead fish at a farm exceeds the thresholds outlined in the conditions of the license. The threshold is specific to each facility and is determined by DFO based on variables that include the size of the farm, the species being farmed, and environmental conditions. Companies must continue to update DFO every 10 days for the duration of the mortality event, including daily mortality counts, mitigation applied, determination of the cause(s) of the event and any updated plan (18). Some Mortality Events require

several reports before they are resolved. Mortality Events have been reported to DFO since 2011.

Each BC salmon farm, on average, reports about one Mortality Event each year (from 2011 – 2022, 579 reports averaged 48 per year) (Figure 9). Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 24 (4.1%) were due to infectious disease, and five (0.9%) involved Pacific salmon species (two of these were infectious disease).

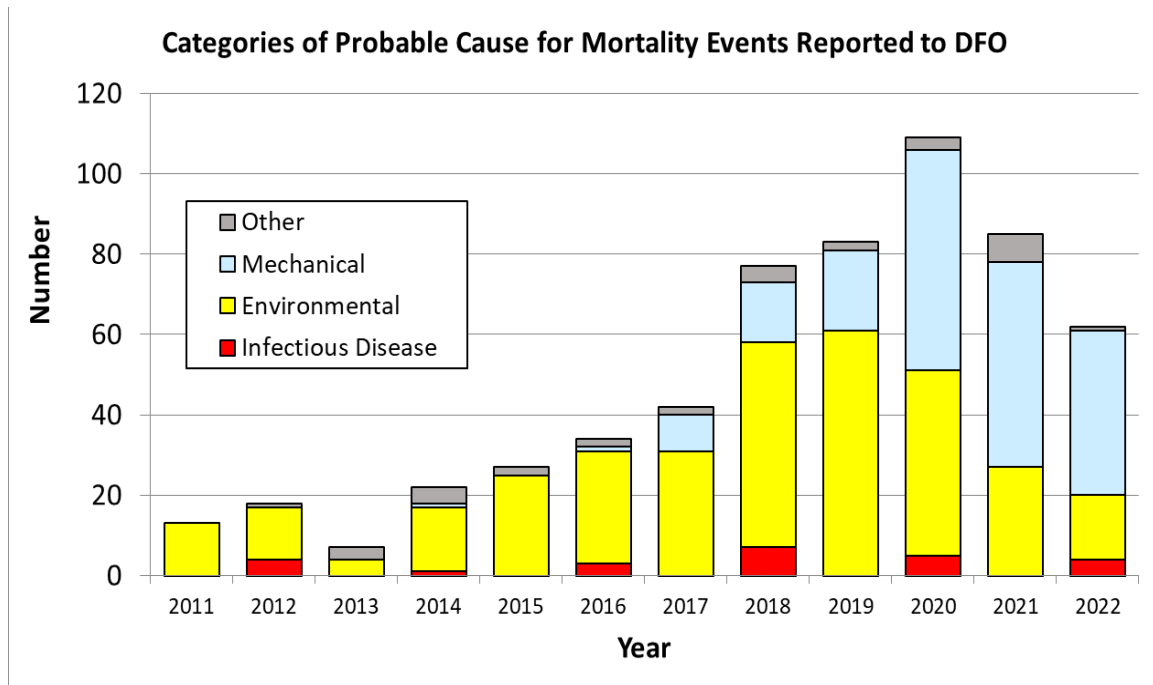


Figure 9. Probable causes of mortality events at BC Atlantic and Pacific salmon farms, 2011 – 2022.

Source DFO Open Data (19).

CARCASS CLASSIFICATION

BC aquaculture licence holders are required to remove dead fish from net pens on a regular basis and categorize the fish according to the cause of death (20). This “Carcass Classification” has been reported to DFO since 2013, as a condition of license.

Most infectious disease occurs in the “Fresh silver” and “Decomposed” categories; other than a spike in “Fresh silver” mortality. In 2018, the average

annual mortality for these two categories combined was about the same from 2013 – 2017 (6.6%) as for 2019 – 2022 (6.3%) (Figure 10). In contrast, the average annual mortality for all other categories combined increased nearly 60% from 2013 – 2017 (7.2%) to 2019 – 2022 (11.4%). Most of this increase is a result of environmental issues (low dissolved oxygen and toxic algal blooms) and increased use of mechanical treatments to control sea lice. Salmon farmers are working to decrease these sources of mortality.

From 2011 to 2022, each BC salmon farm on average, reported about one Mortality Event each year; 4.1% involved infectious diseases. Most infectious diseases in BC salmon farms kill only a few fish daily. It is rare for infectious disease to kill enough fish to be reported as a Mortality Event.

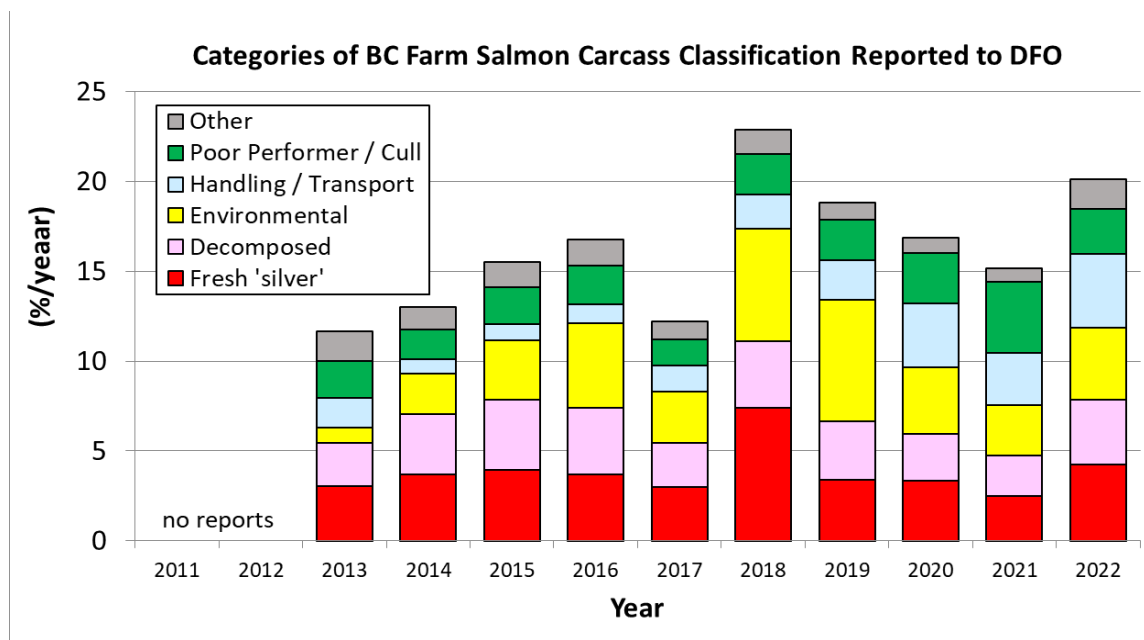


Figure 10. Cause of death of farm-raised Atlantic and Pacific salmon at BC farms 2013 to 2022.

Source [DFO Open Data \(20\)](#)

GOVERNMENT FISH HEALTH AUDITS

While Fish Health Events, Mortality Events, and Carcass Classification are all reported to DFO by salmon farm fish health teams, the reliability of these reports is confirmed through government “Fish Health Audits” (21). These audits were first developed in the early 2000s, when the Province of BC licensed salmon farms. Since DFO took over licensing of BC salmon farms in 2011, the audits have been conducted by DFO.

Each quarter, DFO biologists audit approximately 18 randomly selected farms based on species grown and location. During each fish health audit, the auditors sample dying and fresh-dead farmed fish for diseases.

These samples are similar to the “Fresh silver” Carcass Classification category reported by salmon farmers. For years with sufficient data (2006 – 2009 and 2014 – 2022), total annual sample size for the Audit Program varied from 470 – 784 Atlantic salmon and 61 – 134 Pacific salmon.

The government audit program increases the chance of finding new infectious diseases five- to 10-fold by focusing on “Fresh Silvers”. This narrow category is for recently deceased fish that have not died from obvious causes such as plankton blooms or mechanical injury. “Fresh Silvers” are about 4% of deceased fish. Within this narrow category, audit program pathologists diagnosed infectious disease as the cause of death in 13 – 30% of Atlantic



salmon samples (average = 22%) and 25 – 62% of Pacific salmon samples (average = 42%) (Figure 11). Over the 16-year span of these data, there is no obvious trend in these proportions.

DFO routinely confirms the reliability of reports submitted by licensed veterinarians that oversee farm-raised salmon. **Nowhere else in the world is a livestock sector subject to this level of auditing and public reporting.**



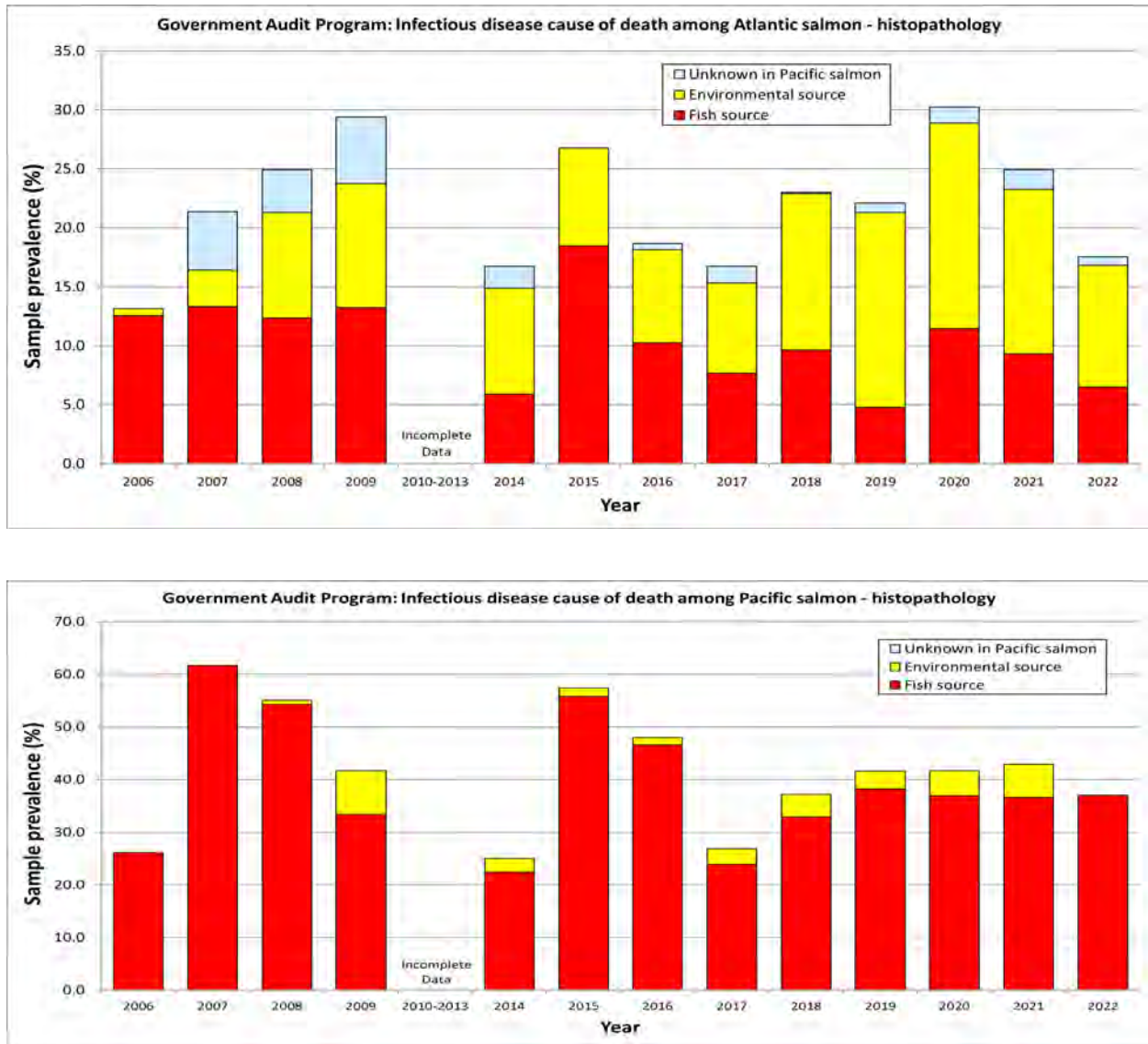


Figure 11. Among government audit program samples of BC farm-raised “fresh silvers,” the proportion diagnosed as having died from infectious disease. “Fish source” diseases mostly come from other infected fish (e.g., bacterial kidney disease), while “Environmental source” diseases mostly come from infectious agents in the water (e.g., yellow mouth).”

Source DFO data 2011 – 2022 [DFO Open Data](#) and Data from BC, 2006 – 2010: [Cohen Commission Exhibit #1678 \(22\)](#).



DFO confirms the low prevalence of infectious disease in Mortality Events by reviewing diagnostic reports submitted by salmon farm veterinarians for each Mortality Event.

To increase the chance of finding new diseases during audits, government audits limit detailed diagnostic analysis of fish that have any obvious single disease (i.e., auditors are more interested in searching for new diseases than confirming well-known diseases). This protocol results in common diseases like yellow mouth being underrepresented in Atlantic salmon audit samples. Therefore, for a better estimate of the proportion of “Fresh silvers” dying of infectious disease, salmon farm veterinarians recommend doubling the average prevalence of infectious disease in audit samples (23.6%) to 47%. Also, the prevalence of infectious disease among carcasses classified as “Decomposed” is probably about the same as for “Fresh silvers.”

Therefore, a reasonable estimate of total annual marine mortality of BC farm-raised Atlantic salmon due to infectious disease is 3%, which is:

- (i) the average proportion of “Fresh silver” and “Decomposed” categories combined in the Carcass Classification from 2018 – 2022 (7.2%), times
- (ii) the doubled average prevalence of infectious disease in Audit Program samples from 2018 – 2022 (47%).

No single disease dominates Pacific salmon mortality enough to require adjustment from Audit Program results. Therefore, **a reasonable estimate of total annual marine mortality of BC farm-raised Pacific salmon due to infectious disease is also 3%, which is:**

- 1. the average proportion of “Fresh silver” and “Decomposed” categories combined in the Carcass Classification from 2018 – 2022 (8.1%), times
- 2. the average prevalence of infectious disease in Audit Program samples from 2018 – 2022 (40%).



WHAT DID JUSTICE COHEN SAY ABOUT THE IMPACT OF SALMON FARMS AND FRASER RIVER SOCKEYE SALMON?



Photo by Brian Kingzett

In 2009, Canada established the Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River to investigate the perceived decline of sockeye salmon stocks. Salmon farms were assessed as one of the potential reasons for the decline.

The Honourable Justice Cohen stated, ***"Data presented during this Inquiry did not show that salmon farms were having a significant negative impact on Fraser River sockeye."***¹ Justice Cohen's final report describes the salmon farm disease data presented during the hearings as ***"impressive,"***¹ and he noted, ***"There was a statistically significant declining trend in the number of high-risk diseases reported by salmon farms between 2003 and 2010."***¹

Justice Cohen also said (emphasis added), ***"I therefore conclude that the potential harm posed by salmon farms to Fraser River sockeye salmon is serious or irreversible."*** Cohen Commission Final Report, Volume 3, p. 92 col 2 (23) This is not a statement based on evidence presented during the hearings; instead, it is a statement of fact consistent with the science of disease in populations (epidemiology).

Any disease that can impact individuals has the *potential* to impact populations. The key word in Justice Cohen's statement is **"potential."** If Justice Cohen had concluded that salmon farms were causing serious or irreversible harm to Fraser River sockeye salmon, he could have recommended immediate termination of all aquaculture licences. He did not do this. Instead, he recommended, ***"Precautionary measures should focus on filling the knowledge***



gaps and enabling DFO to adapt mitigation measures to new scientific information." Cohen Commission Final Report, Volume 3, p. 93 (23)

In the decade since Justice Cohen's final report was published, the new scientific information demonstrates the *potential* is minimal as described in the next section

FORMAL RISK ASSESSMENTS OF SALMON PATHOGENS

In response to Justice Cohen, the Canadian Science Advisory Secretariat (CSAS) completed risk assessments for nine pathogens to determine the risk of pathogen transfer from farm-raised Atlantic salmon to Fraser River sockeye salmon. In all cases, the assessment concluded that the risk to Fraser River sockeye salmon populations is minimal (24, 25).

See Appendix A for details on each pathogen, the results of the assessment, and veterinary measures to reduce the risk of transmission to farm-raised and wild salmon.

A recent "Perspective" paper in the Canadian Journal of Fisheries and Aquatic Sciences includes concerns about the independence of the CSAS process: "Idiosyncrasies of this process, however, preclude independent review and undermine the ability of CSAS to provide

robust science advice, especially on controversial topics like salmon aquaculture." (26) The paper used PRV as an example, but the paper does not include results from an independent body that assessed the threat of PRV to Pacific salmon as low.

In 2017, the Pacific Northwest Fish Health Protection Committee (PNFHPC), an American organization of technical and policy representatives from conservation agencies, indigenous peoples, and commercial fish producers from the Pacific Northwest concluded, "The ubiquitous nature of piscine orthoreovirus (PRV), its apparent historic presence in wild Pacific salmonid stocks in the Pacific Northwest and the lack of clear association with disease in Pacific salmonids suggest the virus poses a low risk to wild species of Pacific salmonids." (27)

Similar to the Canadian Science Advisory Secretariat (CSAS), the Pacific Northwest Fish Health Protection Committee of the United States concluded that PRV "poses a low risk to wild species of Pacific salmonids".

This conclusion was updated in 2022 by the lead author of the 2017 paper: "The scientific information continues to support the conclusion that endemic PRV-1a in the PNW should be considered as posing a low risk (not zero) to Pacific salmon, thus requiring no significant changes to agency fish health policies..." (27, 28). This independent assessment is

consistent with the CSAS assessment of minimal risk of PRV. Unlike the CSAS assessment, which was limited to the threat of PRV from Discovery Islands fish farms to Fraser River sockeye salmon, the American organization assessed the threat of PRV, regardless of source, to all Pacific salmon.



WHAT HAS HAPPENED WITH FISH HEALTH ON SALMON FARMS SINCE THE COHEN COMMISSION OF 2012?

In the decade since Justice Cohen's final report was published, scientific information demonstrates the continued declining trend in significant infectious diseases affecting farm-raised salmon.

Two such diseases include the virus that causes the disease Infectious Hematopoietic Necrosis (IHN) and the bacterium that causes bacterial kidney disease (*Renibacterium salmoninarum*).

From 2001 to 2003, an outbreak of IHN among BC farm-raised Atlantic salmon spanned 23 months and affected 36 farms

(29). The only IHN outbreak on BC salmon farms since then, in 2012, was limited to three farms and spanned only 3 months (10). All BC farm-raised Atlantic salmon are now vaccinated against IHN, and BC salmon farms have had no IHN outbreaks since 2012.

Among government samples of sick and freshly dead BC farm-raised Atlantic salmon, bacterial kidney disease decreased from 40% in the early 1990s (30-33), to 9.2% in 2006, and even further to 1.1% in 2022 (11).



WHAT DOES THE LOW FARM-RAISED SALMON DISEASE MORTALITY MEAN FOR WILD SALMON?

Infectious disease kills only about 3% of BC farm-raised salmon every year. Most of the 97% that do not die of infectious disease are never even infected with the pathogens that kill 3% of their cohort (11, 34-36).

Unlike farm-raised salmon, which spend their entire life in salmon farms, juvenile Fraser River sockeye salmon spend only a few minutes to hours of their life near salmon farms (37). Therefore, we expect infectious disease from salmon farms to infect and kill *much* less than 3% of Fraser River sockeye salmon.

Other salmon species might spend more time around salmon farms (e.g., some Chinook salmon), but we have no

evidence that any diseases that affect farm-raised salmon are more likely to spread among wild Pacific salmon species.

Therefore, based on basic principles of population medicine, which informs us that disease spreads more readily among concentrated farm fish than among dispersed wild fish, we expect farm-source disease to kill less than 3% of all species of wild Pacific salmon.

Diseases that affect Atlantic salmon more than Pacific salmon are readily identified, as was the case for the IHN virus, which is carried by migrating sockeye salmon with little affect but is highly lethal to unvaccinated farm-raised Atlantic salmon (38, 39).



Photo by Bill Pennell



Photo by Steel_Snorkel

Other than sea lice, which are strictly regulated to protect wild salmon, we have no evidence that Atlantic salmon carry diseases that affect Pacific salmon but not Atlantic salmon. Pacific salmon species like coho salmon and steelhead have been cultured for more than 30 years in regions with abundant farmed Atlantic salmon (e.g., Norway and Chile), and no such diseases have been identified.



ADULT RETURNS OF ICONIC WILD SALMON POPULATIONS WERE SIMILAR BEFORE AND DURING THE SALMON FARMING YEARS

Wild salmon populations are naturally highly variable. An important measure of the success of salmon farmers in controlling infectious disease is whether changes in infectious disease on farms are associated with changes in wild salmon populations. Infectious disease is a natural component of all animal populations, including humans, and diseases in every population pose a potential threat to all susceptible populations in contact with those diseases. However, potential threats of infectious disease rarely result in real consequences at the population level.

Like humans, all animals have well-developed immune systems that protect them against ongoing exposure to infectious diseases in their environment. We understand that places people gather can be a source of infectious disease for other people, but those disease rarely—if ever—result in human population decline. Likewise, wild salmon are a source of infectious diseases for farm salmon, and farm salmon are a source of infectious diseases for wild salmon. As with people, diseases in one population (salmon farms) rarely impact other populations (wild salmon).

Iconic salmon populations in the Fraser River and the Broughton Archipelago provide an excellent example to examine the effect of salmon farms. Between 2019 and 2023, nearly all salmon farms in the

Broughton Archipelago and Discovery Islands were removed, primarily because of perceived concerns about the threat of salmon farm diseases to wild salmon.

These regions had salmon farms since the late 1980s, and government records of wild salmon runs date back to at least the early 1960s. Because population trends account for all threats—known and unknown—data on population size over time help answer questions about the impact of salmon farms on wild salmon populations:

- A. During the time that wild salmon populations were exposed to salmon farms, were average adult returns less than they were before salmon farming?
- B. Did wild salmon populations exposed to salmon farms vary in relation to nearby wild salmon populations not exposed to salmon farms?

Answering these questions also requires understanding whether any trends in wild salmon populations are explained by natural population change or variables other than salmon farms (e.g., changes in climate, habitat, food availability, predators, or the human population).

The lack of population impact of salmon farms among three iconic wild salmon populations supports the conclusion that salmon farms have no more than minimal impact on wild salmon populations:

- o Fraser River **sockeye salmon**, average total adult returns (40).
 - o 6.8 million per year before salmon farming began (1962 – 1989)
 - o 8.0 million per year during the salmon farming years (1990 – 2022)
- o Fraser River **pink salmon**, average total adult returns (40)
 - o 11.9 million per year, before salmon farming began (1963 – 1987)
 - o 13.2 million per year, during the salmon farming years (1989 – 2021)
- o Broughton Archipelago **pink salmon**, average total adult returns (16, 41)
 - o 0.8 million per year, before salmon farming began (1950 – 1987)
 - o 1.1 million per year, during the salmon farming years (1988 – 2014); DFO data for this region are incomplete after 2014.

See “Chapter 10 – Caring for Wild Salmon – Sea Lice Management” Figures 17, 18 and 30 for charts of the fisheries data.

HOW HAVE ADVANCES IN AQUACULTURE VETERINARY MEDICINE HELPED TO IMPROVE WILD SALMON ENHANCEMENT?

Only a small proportion of the science behind aquaculture veterinary practice is published in peer-reviewed scientific journals; instead, much of the supporting science is generated through propriety research conducted or contracted by aquaculture companies.

Transfer of this technology among government and private veterinarians occurs through meetings of relevant organizations (e.g., The Association of Aquaculture Veterinarians of British Columbia) and informal discussions.

Examples important to government-run wild salmon enhancement hatcheries in

British Columbia include the following (42):

- o Increase water use efficiency by replacing rectangular raceways with circular tanks (Figure 12),
- o Prevent and control bacterial kidney disease through screening and treatment methods,
- o Early detection of “atypical gill disease”,
- o Control of fungus-like oomycetes (*Saprolegnia* and related species), and
- o Optimize feeding methods to ensure that all hatchery fish get enough to eat and grow at rates like their cohorts.

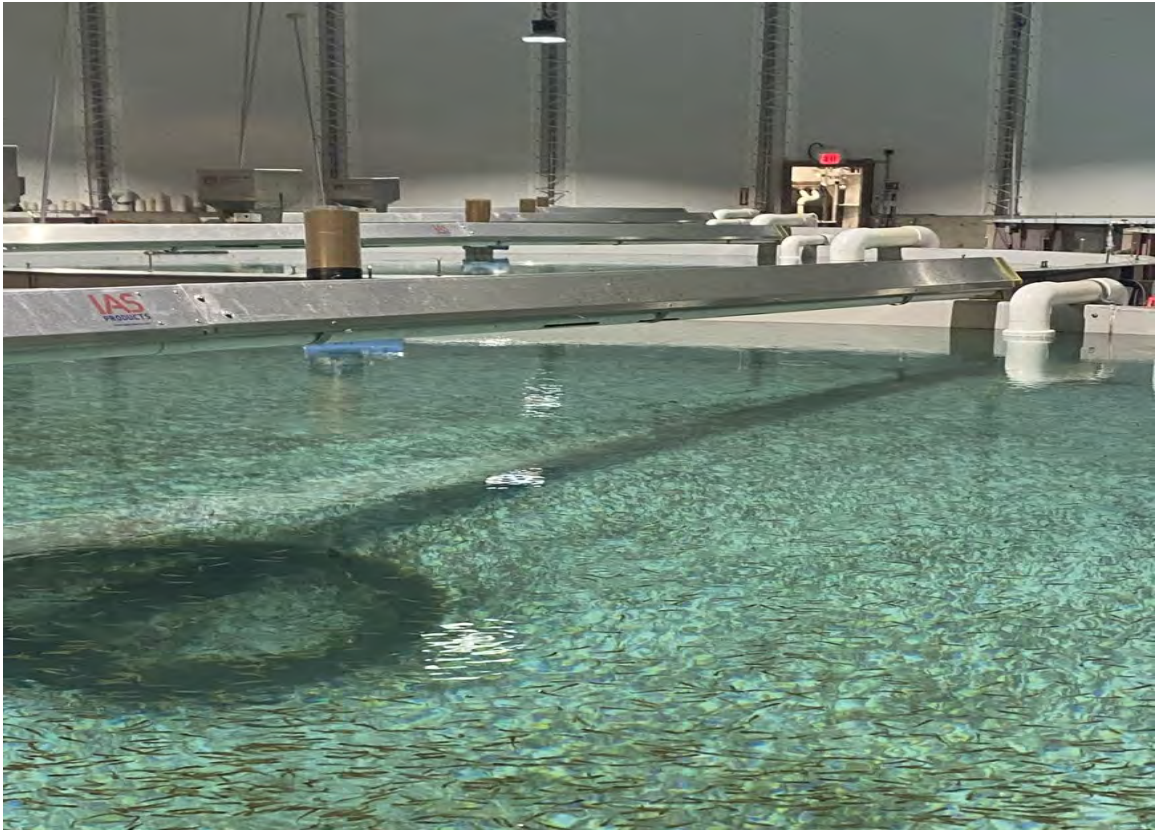


Figure 12. Circular tank system at recirculating hatchery.

WHAT SAFEGUARDS KEEP FARM-RAISED SALMON HEALTHY?

Many safeguards are in place during a farm-raised salmon's journey from hatchery to marine site to harvest vessel. Fish health starts with the careful selection of healthy parent fish. This leads to healthy eggs in the hatchery. Veterinarians apply proactive health measures at the hatcheries to produce healthy smolts for marine sites. Because wild fish are a common source for many high-risk

pathogens, several hatcheries are land-based closed containment sites that have no contact with wild fish. Other hatcheries use ground water in which no fish have been present and/or filter and disinfect their water if using surface water. All hatcheries keep out predators and pests that could carry disease. The marine sites have further safeguards in place to keep fish healthy while at sea.

Seven safeguards protect wild fish from exposure to farm-source pathogens (Figure 13):

- o **Safeguard 1:** enhance fish health through selective breeding (Table 1)
- o **Safeguard 2:** prevent pathogen entry and spread in hatcheries (Table 2)

- o **Safeguard 3:** barriers to the entry of fish pathogens from hatcheries into marine sites (Table 3)
- o **Safeguard 4:** barriers to the spread of fish pathogens within and between marine sites (Table 4)
- o **Safeguard 5:** treatments prescribed by a licensed veterinarian (Table 5)
- o **Safeguard 6:** fish health monitoring and record keeping (Table 6)
- o **Safeguard 7:** regulatory compliance, verification and transparency (Table 7)

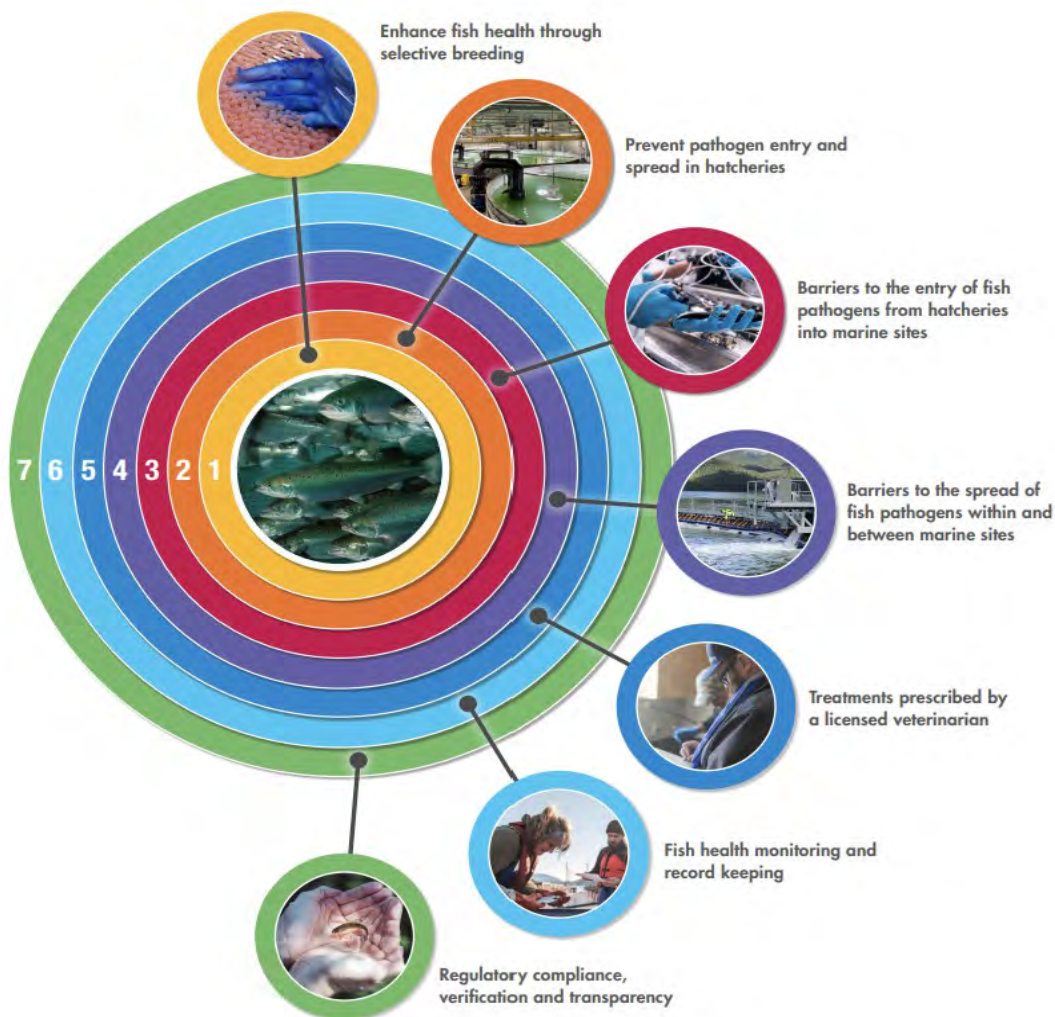


Figure 13. Seven safeguards protect wild fish from exposure to farm-source pathogens.

*Table 1. Safeguard 1 – Enhance Fish Health Through Selective Breeding*

Objective	Measures
Domestic BC broodstock programs only	No imports of eggs or breeding stock into Canada since 2012.
Selection of the healthiest fish	Modern genetic technologies, such as DNA markers and genomic selection, enable salmon farmers to make more informed decisions about broodstock selection. These tools provide valuable insights into the genetic profiles of fish, allowing salmon farmers to select individuals with desired traits more accurately (Figure 14).
Fish tagging and tracking	To aid in the selection process, salmon farmers collect fin clippings from brood fish and send them for analysis. All fish, upon selection, are tagged for tracking.
Maintain genetic diversity	To ensure genetic diversity and minimize the risk of inbreeding, salmon genetics programs often maintain multiple breeding lines. These lines may come from different generations of selected broodstock. Genetic diversity helps to maintain robustness and adaptability in the farm-raised salmon population.
Disease resistance	Breeding programs select individuals with strong innate immunity and disease resistance.
Growth performance	Selective breeding aims to enhance growth rates and feed conversion efficiency in farm-raised fish. Populations with improved growth performance are often healthier and more robust (Figures 15 and 16).
Stress tolerance	Fish in aquaculture systems often face various stressors, such as handling, transportation, and environmental fluctuations. Selective breeding programs improve stress tolerance and adaptability.
Reproductive performance	Breeding programs also select broodstock based on reproductive traits such as fertility, egg quality, and reproductive success to help ensure healthy and viable offspring.



Figure 14. Selection of brood fish is a complex process involving modern genetic technologies.



Figure 15. The selection of broodfish is made with genetic experts, veterinarians and farm staff.



Figure 16. All fish family groups are tagged and monitored throughout their life cycle.

Table 2. *Safeguard 2 – Prevent Pathogen Entry and Spread in Hatcheries*

Objective	Measures
Eggs and hatchery fish are separated from ambient water containing significant pathogens	Most hatcheries are closed containment land-based systems using ground water that has not had wild fish in it. Some hatcheries use recirculating ground water or flow through that is filtered and disinfected to keep out fish pathogens (Figure 17).
Eggs are free of significant pathogens when arriving at the hatchery	Eggs come from domestic BC broodstock, i.e., brood fish that have been raised in BC for several generations in closed broodstock programs. No new eggs or stocks have been introduced for more than a decade. Most domestic broodstock have been raised in land based closed containment systems. Some eggs come from marine broodstock sites in which the fish are kept healthy and closely monitored so no pathogens are passed to the eggs. Some broodstock get booster vaccines prior to spawning. All brood females are screened for salmon pathogens during spawning. Egg lots that do not meet strict cutoff standards are segregated and destroyed. Eggs are disinfected at water hardening, before being transported to the hatchery, or at the hatchery after eggs and milt were transported separately.
Pathogens are prevented from entering on equipment or clothing	Gear is dedicated to each hatchery. Strict biosecurity measures: cleaning and disinfection of all egg trays, fish tanks and equipment (small and large) prior to stocking the next generation of fish. Access is limited to authorized personnel and only with management instructions. Visitors must use dedicated boots and protective clothing. In some facilities staff are dedicated to separate parts of the hatchery to prevent cross contamination between different fish groups.
Pathogens are prevented from entering on/in biological vectors	Methods include pest control programs, including barriers like lids and bird netting for outside tanks, keeping bays closed, and physical barriers in all entry ways.
Pathogens are prevented from entering in/on fish feed	Production of commercial fish feeds include a high temperature process that kills any fish pathogens (e.g., parasites and bacteria). No farm-raised salmon are



	included in commercial diets. Feed is packaged in bags or totes that create barriers to possible contamination during transport and storage.
Boosting the fishes' immune system	Hatchery Atlantic salmon are vaccinated for the major pathogens (e.g., IHNV, <i>Aeromonas salmonicida</i> (Furunculosis), <i>Vibrio anguillarum</i> (2 types), <i>Vibrio salmonicida</i> (Cold Water Vibriosis), and <i>Moritella viscosa</i> (Winter Ulcer). Some are also vaccinated against BKD. Pacific salmon are vaccinated for BKD and Vibriosis (Figure 18).
Early detection of disease	Fish are constantly monitored for abnormal behaviour including subtle changes in feeding. Hatchery staff have been trained to look for early signs of disease and fish health challenges (Figure 19).
	Most hatcheries have invested in newer equipment and monitoring that gives hatchery staff near real-time feedback and early detection capabilities.
	Mortalities are collected daily, classified and examined for signs of disease. Trends are followed closely.
	Site and fish health staff do routine fish health sampling and screening for pathogens and disease.
	Most hatcheries have a minimum of monthly fish health team visits, and some much more frequently.
Prevent pathogen movement within the site	Strict biosecurity measures are in place, including dedicated equipment for each tank or group of fish, cleaning and disinfection of any equipment used for different fish groups. At some hatcheries, dedicated sections and dedicated staff and water filtration separate groups of fish.
	Staff handling dead fish wear special clothing, gloves and/or other protective equipment.
	Some hatcheries have separate water filtration and fallowing between parts of hatchery.
Maintain and monitor healthy growing conditions for fish	Stock at optimal densities to reduce stress for fish.
	Continuously monitor water quality inside hatchery (Figure 20).
	Continuously monitor feed consumption, fish behaviour, growth and any behavioural changes.
Further investigation	Further fish health visits, investigation, and sampling in the event of elevated mortality or unusual behaviour.



Figure 17. Grieg Seafood's BC Gold River hatchery.

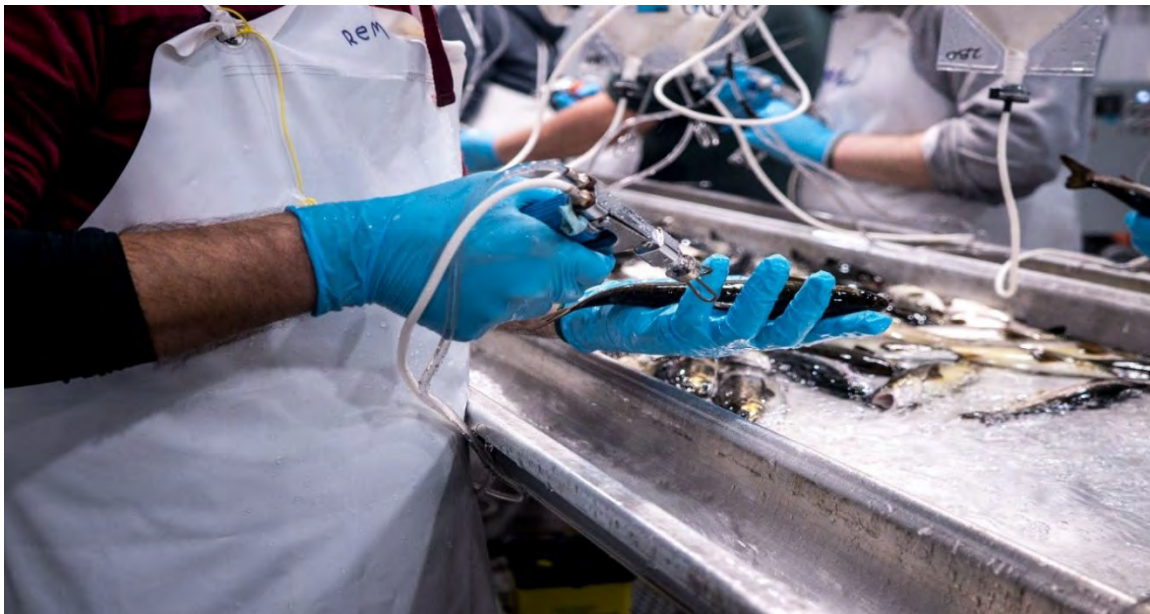


Figure 18. Vaccines boost the fishes' immune system.



Figure 19. Routine fish health visit by a licensed veterinarian to hatchery.



Figure 20. Water quality and growing conditions are constantly monitored at hatcheries.

Table 3. Safeguard 3 – Barriers to the Entry of Fish Pathogens from Hatcheries into Marine Sites

Objective	Measures
Only healthy fish populations can be stocked at sea sites	Fish health must be approved by the federal and provincial governments <u>before</u> transferring to sea sites.
	Pre-transfer sampling program for viruses and bacteria according to the BC Introduction and Transfers Committee (a joint federal-provincial committee comprised of members from DFO, the BC Ministry of Environment and Climate Change Strategy, and the BC Ministry of Forests, Lands & Natural Resource Operations).
	No fish can be transferred without regulatory approval from the BC Introductions and Transfers Committee.
	Veterinarians examine the fish and review fish health data and lab reports before transfer to ensure that they are healthy, doing additional testing if indicated.
	If mortality exceeds 0.05% for four consecutive days in the thirty days before transfer (not including fungus or handling), it must be reported to the regulator, who may block the transfer or request additional requirements.
New fish only go into cleaned and fallowed sites	Each production site is fallowed between crops. During the fallow, farms are thoroughly cleaned and disinfected before stocking (Figure 21). Nets are removed for cleaning and the site infrastructure is cleaned and disinfected. Benthic monitoring is done prior to new fish introduction ¹ . In the rare cases where small numbers of broodstock are retained, they are kept at a distant and physically separate part of the site.
Transport water is contained	The fish are moved in clean water sourced from the hatchery. Fish may be dewatered prior to going into saltwater on the transport vessels. If saltwater is used, it is sourced away from any marine site. In most cases only small amounts of that water is discharged when transferring the fish from vessels to the net pens.
Fish are transported in cleaned and disinfected vehicles and vessels	Each transport vehicle and vessel is thoroughly cleaned and disinfected before the fish are onboarded (Figure 22).
	Each vehicle/vessel has dedicated equipment for mechanical transfer of the fish and, in most cases, crew clothing that only travels with them.
	Vehicles, vessels and equipment are thoroughly disinfected after each group of fish has been delivered.

¹ See "Chapter 8 – Caring for the Environment – Protecting Biodiversity" for information on benthic monitoring requirements.



Figure 21. Staff setting up farm site to receive fish.



Figure 22. Specialized transport vessels and equipment are used to transport fish into sea sites.



Table 4. Safeguard 4 – Barriers to the Spread of Fish Pathogens Within and Between Marine Sites

Objective	Measures
Minimize susceptibility to infectious disease	Before fish are transferred from the hatchery, they are vaccinated for major pathogens (see Safeguard 1 for details).
Maintain and monitor healthy growing conditions for fish	Pens are stocked at optimal densities to reduce stress for fish.
	Water quality is continuously monitored to minimize any environmental challenge for fish (plankton, water temperature, oxygen levels). Many marine sites have invested in extensive and sophisticated oceanographic and weather monitoring and instrumentation that gives staff near real-time feedback from each pen (Figure 23).
	Daily system inspections by the site staff, which include the visible sections of the nets from the surface and from the underwater cameras, as well as the visible system moorings and cage arrays (Figure 24).
	At a minimum, diver inspection of all nets on the system every 60 days, and divers keep an eye on the nets every time they are in the pens. Predator nets that are secondary containment nets that encompass the entire system are inspected as well. Some sites have remotely operated underwater vehicles (ROVs) that inspect nets and other infrastructure. Net washers may use ROVs as well (Figure 25).
	Daily inspection of fish; continuous monitoring for feed consumption, fish behaviour, mortalities and growth.
	Marine site staff are on the pen systems daily (unless conditions are unsafe, such as during extreme seas or weather). They have been trained to look for early signs of disease and fish health challenges. Updating and on-the-job training provides for consistency in monitoring.
	Careful handling of any live fish during treatments, grading, and transport to harvest.
	Pathogens are prevented from entering in/on fish feed. Commercial fish feeds include a high temperature process that kills any fish pathogens, e.g., parasites and bacteria.
	No farm-raised salmon are included in commercial diets.
Prevent pathogen movement within the site	Strict biosecurity measures including dedicated equipment for each site or group of fish within a site where practicable; cleaning and disinfection of any equipment used for different fish groups.
	Dedicated equipment is used where possible. Every effort is made to reduce the use of equipment at multiple sites to help maintain each site's

	biosecurity. If equipment must be shared, it is only used on fish of the same age (year class) (Figure 26).
	Site staff and visitor protocols include using footbaths to disinfect footwear on site.
	Keep nets clean. Nets are frequently inspected. Approximately every 10-14 days (maximum 28 days), each salmon net is cleaned using high volume water jets and then inspected by divers, cameras and/or underwater ROVs (Figure 27).
	Unless conditions are unsafe, each day staff retrieve carcasses and classify the cause of death. For smaller fish this might be twice weekly.
	Dedicated clothing and equipment are set aside for staff handling mortalities.
	Dedicated staff for each site. In the few sites where this is not possible, there are strict biosecurity protocols in place.
No, or minimal access by personnel to multiple sites	Strict visitor protocols upon entering a site including contractor protocols.
	Visitors require management and/or veterinary approval before going on a site. Some sites have visitor protocols in which the fish groups are visited in a specific order as directed by veterinarians.
No, or minimal, transfer of fish between sites	Fish transfers between marine sites are not common and are governed by Fish Health Zones as defined by DFO; transfers require a BC Introductions and Transfer Committee permit. No fish are moved without regulatory and veterinary/management approval.
Fish are transported in cleaned and disinfected vehicles and vessels	Strict biosecurity measures with respect to boats, feed, people or equipment taken into farms. All movements require management approval. Strict cleaning and disinfection protocols are in place.
	Boats and equipment are cleaned and disinfected on a regular basis and after every use.
	Where between-site usage is necessary, boats and equipment are cleaned and disinfected between sites and must show evidence of effective cleaning and disinfection prior to the next use.
Early detection of disease	Farm fish behaviour and the ambient water are frequently monitored visually and/or with sophisticated instruments capable of collecting large amounts of real-time data or near real-time data.
	Routine fish health sampling and screening for pathogens and disease, as per veterinary direction, supervision and/or training (Figure 28).

	Daily dead fish retrieval and classification allows rapid and frequent evaluation of trends in mortality.
	Onsite contact information and staff are trained to report any abnormal behaviour or mortality to the fish health team.
	Minimum of monthly Fish Health Team visits as per veterinary direction, supervision and/or training.
Further investigation	Further fish health visits, investigation, and sampling in the event of elevated mortality or unusual behaviour. Veterinarians diagnose problems as they arise.
Plan next steps	Veterinarians provide fish health recommendations, proactively and in real time.



Figure 23. Water quality and plankton are continuously monitored at each site.



Figure 24. Daily inspections of farm systems. Fish are secured within the cages with additional jump fences, bird nets and secondary predator nets.

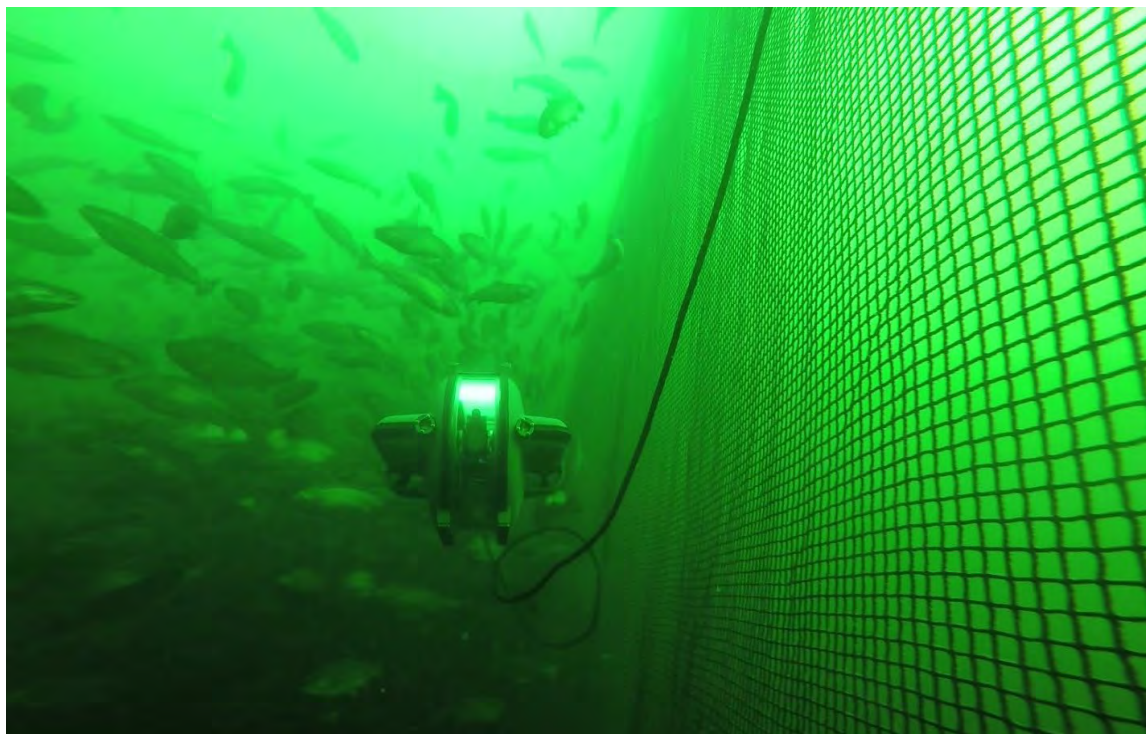


Figure 25. ROV inspection of a net pen.



Figure 26. Transport to and between marine sites is through authorized crew boats.





Figure 27. Net cleaning devices are used to keep containment nets clean to maximize water flow for fish health.



Figure 28. Routine fish health and sea lice check.

Care for fish continues through to harvest, where specialized vessels have been purpose built to harvest salmon safely and humanely from marine pens (Figures 29 and 30).



Figure 29. Specialized vessels have been purpose built to harvest salmon safely and humanely from marine pens.



Figure 30. Staff getting equipment ready for harvesting fish from the farm.

Table 5. Safeguard 5 – Treatments Prescribed by a Licensed Veterinarian

Objective	Measures
Identify the need	Veterinarians determine if treatment is needed to enhance fish health and welfare, including welfare of wild fish (e.g., sea lice treatments).
Treat as needed	Ensure that treatment dose and duration meet medical best practice standards and government regulations.
Integrated Pest Management (IPM)	Best practices in management of pests like sea lice include coordination of treatment timing and method with all farms in a region (regardless of who owns each farm), rotating treatments to minimize development of resistance, and coordinated stocking and fallowing of farms in a region (Figures 31 and 32).
Monitor effectiveness	Monitor effectiveness of treatments (e.g., antimicrobials or sea lice treatments) and continued health and welfare of the fish.



Figure 31. Veterinary practices are supported by specialized equipment, such as the hydrolicer barge shown above that removes sea lice with water jets.



Figure 32. Specialized ships, such as the Aqua Tromøy, allow for freshwater bath treatments to remove sea lice under the supervision of licensed veterinarians.



Figure 33. Licensed veterinarians maintain extensive records of all practices.

Table 6. Safeguard 6 – Fish Health Monitoring and Record Keeping

Objective	Records
Extensive Veterinary documentation and record keeping	Records of surveillance for pathogens and disease, including sampling and diagnostics (Figure 33).
	Records of any medicine use.
	Records of any fish mortalities by pen, including classifying cause of death.
	Records of farm hygiene, disinfection, and biosecurity requirements and actions.
	Records of any stock movement between pens, including stocking densities and origins.
	Tracking of the specific growth and feeding rates of each pen of fish, expressed as the percentage body weight gain per day.
	Details of the feed used, including composition of the feed, quantity used and manufacturing date.
	Video clips of fish behavior including feeding sent to veterinarian and management if anything unusual seen.
Fish Health Management Plans	Environmental conditions that the fish experience, including extensive and robust monitoring of water quality parameters.
	Annual review and continuous updates of each company's Fish Health Management Plan, which include detailed Standard Operating Procedures.

Stringent regulatory record keeping requirements for farm fish health are overseen by multiple agencies, including the Canadian Food Inspection Agency (CFIA) and Fisheries and Oceans Canada (DFO). Required record-keeping includes health records for all aquaculture sites.

The data systems provide the backbone for accurate and timely required reporting to government agencies. They also provide information for reports to First Nations Rightsholders and third-party certification programs.

Table 7. *Safeguard 7 - Regulatory Compliance, Verification and Transparency*

Objective	Measures
Compliance with federal and provincial regulations, licenses and reporting requirements	Meet requirements of the Canadian Food Inspection Agency, Environment and Climate Change Canada, Health Canada, Transport Canada, Agriculture and Agri-Food Canada and Fisheries and Oceans Canada (DFO); BC Ministry of Agriculture and Food, BC Ministry of Environment & Climate Change Strategy
Mandatory reporting of fish health and disease per provincial and federal regulatory requirements	HATCHERIES
	Structured federal regulatory program for land-based facilities, with detailed Freshwater Land-Based Aquaculture License Conditions (43).
	MARINE SITES
	Structured federal regulatory program for all marine facilities (44).
	Mandatory reporting of sea lice treatments (13). This includes treatments without medicinal products (e.g., freshwater bath treatments).
	Regular reporting of Fish Health status and events to First Nations under collaborative agreements.
	HATCHERIES and MARINE SITES
	Mandatory reporting of Fish Health Events – When a suspected or active disease occurrence arises, veterinarians must notify, report, and take immediate and follow-up actions, including additional diagnostic testing and reporting to address the concern as per the conditions of the DFO Freshwater/land-based condition of license (43) or Marine Finfish Aquaculture License (45).
	Mandatory reporting of Mortality Events - Immediately notify DFO within 24 hours of discovery and report and address mortality events, which may include additional diagnostic testing and reporting to address the concern as per the conditions of the DFO Freshwater/land-based condition of license (43) or Marine Finfish Aquaculture License (45)
	Report the use of all medicines and water treatment chemicals to DFO (46).
Multiple third-party verifications that proactive fish health	Mandatory reporting of listed reportable and immediately notifiable diseases to CFIA (9) and all reportable and notifiable diseases to the BC Chief Veterinarian (47).
	Mandatory reporting of antibiotic usage (13).
	HATCHERIES
	Unannounced audits by DFO regulators to ensure compliance with all regulatory requirements (48).

practices are being followed	Audits by third-party certification auditors to monitor compliance with certification standards.
	Audits by First Nations through partnership agreements to ensure fish are healthy and standards are met.
	Additional oversight by First Nations and third-party certification schemes can occur in the hatcheries to ensure fish are healthy prior to moving them to sea.
	MARINE SITES
	Unannounced and announced audits by DFO regulators to ensure compliance with all regulatory requirements.
	Audits by third-party certification auditors to monitor compliance with certification standards.
	Sites with organic certification have audits as per CFIA's organic Standards Program for aquaculture (49).
	Audits by First Nations partners through partnership agreements to ensure fish are healthy and standards are met.

Salmon aquaculture is the only commercial animal farming in Canada for which all health events, mortality events, and veterinary treatments must be reported to regulatory veterinarians (e.g., DFO). Salmon farmers must seek permission from DFO for any fish transfers to the ocean. DFO fish health staff audit the fish health status on multiple farms every three months (21); nothing like these

audits occurs with other livestock-rearing farming anywhere else in the world.

Additional oversight requirements for certification programs ([ASC Salmon Standard](#), [BAP Farm Standard](#)) and First Nation partners can lead to a triple on-site review of veterinary practices at farms (Table 8 and Figure 34).



Figure 34. Rightsholders First Nations are leading the oversight and monitoring of aquaculture operations within their traditional territories using their Guardian and stewardship programs.

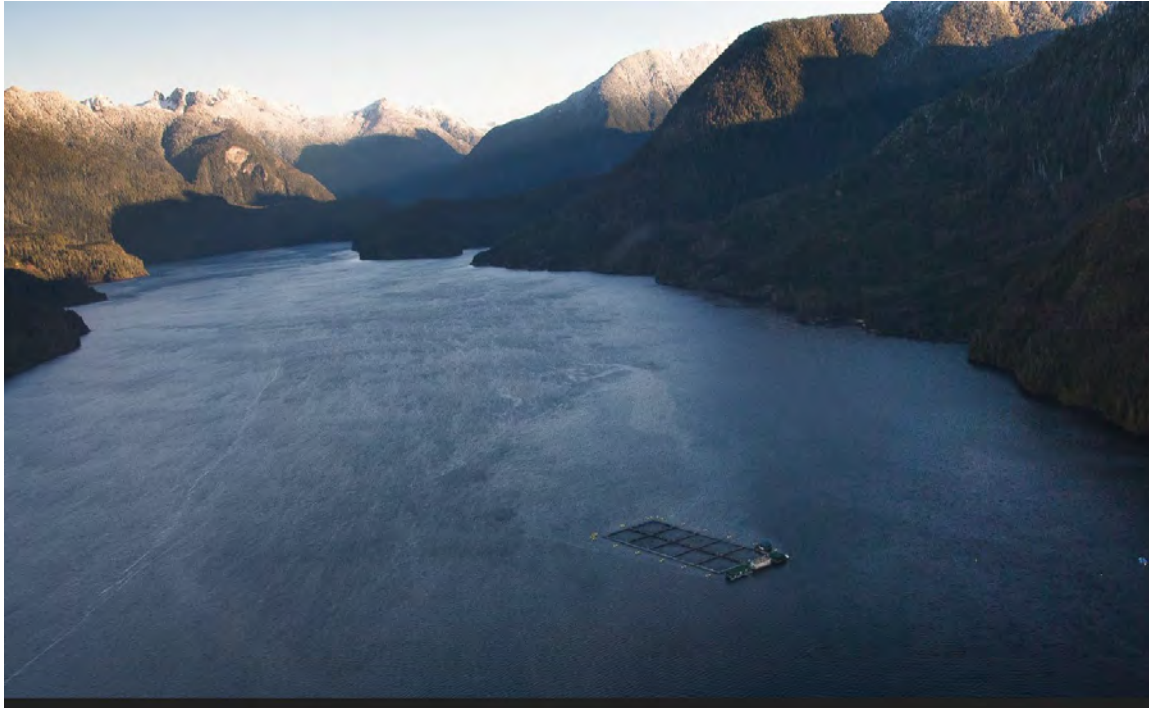




Table 8. Summary of independent oversight of fish health practices at salmon farms.

Oversight	Description
Veterinary Practices at the Farm	Follow approved veterinary practices as per professional medical licensing BC industry-wide Memorandums of Understanding for Integrated Pest Management for Sea Lice and Viral Management.
First Nation Partners and Businesses	Oversight as per collaborative partnership agreements.
Provincial Level	BC Introductions & Transfers Committee. Control movements of fish into and between sites.
Federal level	National Aquatic Animal Health Program (NAAHP). Co-chaired by CFIA and DFO. Control export and imports of aquatic species, domestic disease controls, and emergency response (contingency) plans as these relate to diseases regulated under the Health of Animals Act (Health of Animals Regulations and Reportable Disease Regulations).
	Canadian Food Inspection Agency (CFIA). Canadian authority to control imports, exports, disease management and control, domestic movements of aquatic animals, and biosecurity.
	DFO. Primary regulator of salmon farms in British Columbia.
International Level	World Organization for Animal Health (WOAH) . Prevent the spread of diseases that are a significant threat to sustainable farm-raised and wild aquatic stocks worldwide.
	WOAH maintains a list of fish diseases of international concern (50).
Certification Bodies	Aquaculture Stewardship Council (ASC) . Additional requirements for veterinary practices, including limiting the amount and types of medicines used and public reporting elements.
	Global GAP Best Aquaculture Practices (BAP) . Additional requirements for veterinary practices including procedures for fish movements and the use of medicines.
	Global GAP Best Aquaculture Practices (BAP) . Additional requirements for veterinary practices including procedures for fish movements and the use of medicines.

EYES ON THE OCEAN – IMPORTANT DIGITAL ADVANCES



With the advent of high-speed internet in remote areas, salmon farms are incorporating automation to rapidly improve data collection. Communication with sites is real time even if they are remotely situated.

Instrumentation can record oceanic conditions every few minutes at multiple depths in every pen (for example, see Figure 35). Many of these sites also collect detailed weather information. Government agencies like DFO and Environment Canada use some of the sites' infrastructure and weather instrumentation to collect data for their forecasts. They also collect information on previously undocumented microclimates in remote inlets. Some sites are also coastal zooplankton reference monitoring sites. The large data sets generated by this equipment are being shared with

universities for specific collaborative projects.

Artificial intelligence programs at several sites are rapidly evolving to help evaluate the fishes' general health status. On some sites, camera trials in pens can capture up to 150,000 images per day (Figure 36).

Programs have been developed on other sites to combine several kinds of data streams (e.g., camera data, water quality data) to look at complex indices like fish behaviour, health and welfare. Feedback from these data streams can be as frequent as minute-by-minute. These data are constantly being compiled to refine understanding of complex interactions (Figure 37). Other sites use more manual recording but do similar analysis of the information.

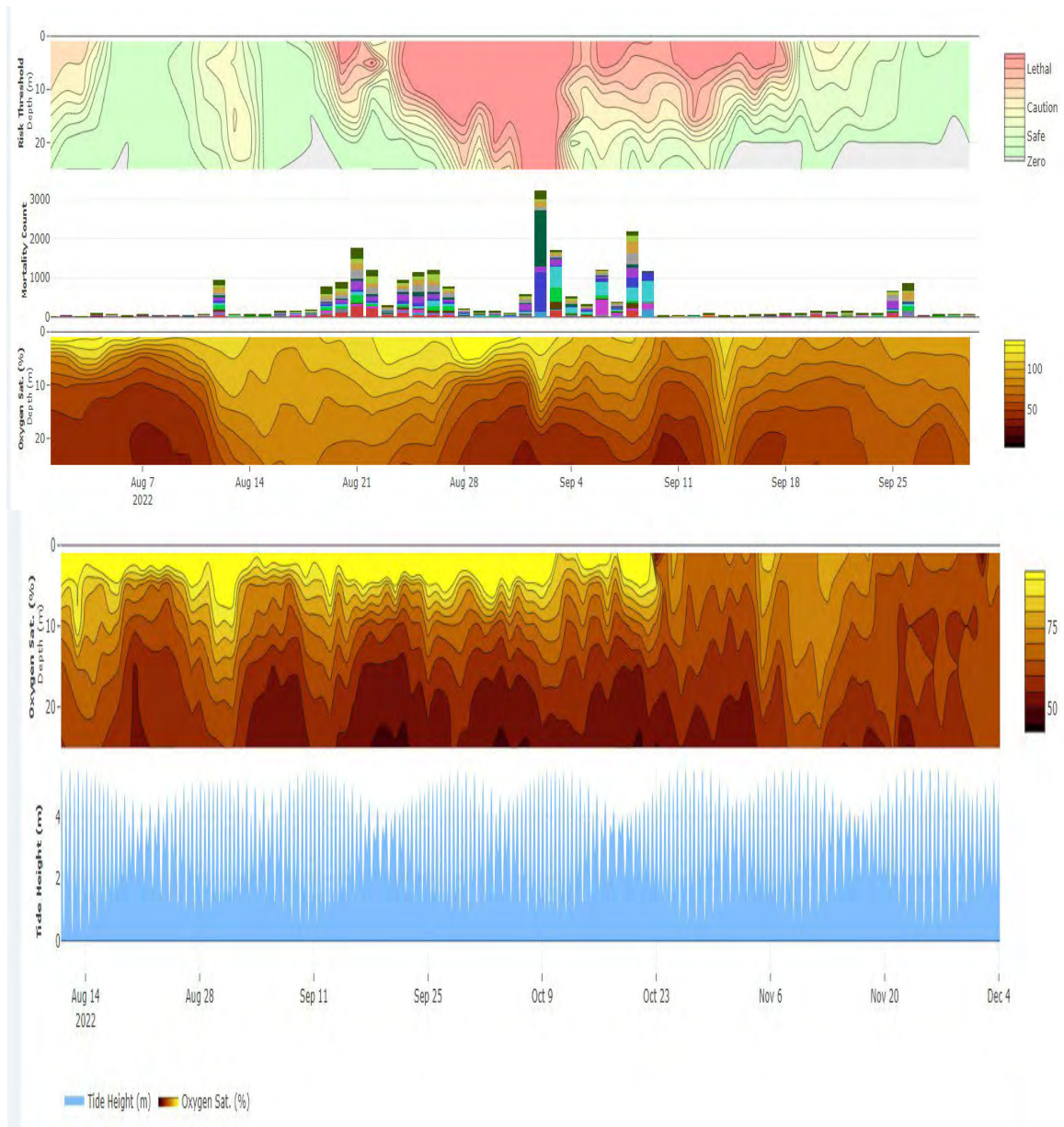


Figure 35. Example of pen tracking data, which charts oxygen saturation, tidal heights, documented fish mortality and calculates the potential risks for salmon in each pen.

Data collection is undergoing a digital revolution. With the arrival of in-sea data loggers, wireless point-to-point communication towers and artificial intelligence, farmers are installing technology at many sites that can collect several hundred thousand data points daily at each farm. This amounts to collecting millions of datapoints on oceanic conditions each day in BC.



Figure 36. Cameras are used to monitor fish. Some farms collect up to 150,000 images per day.



Figure 37. Site staff constantly monitor fish behaviour during feeding using underwater cameras.



Some in-pen underwater cameras now utilize optical recognition to identify the characteristics of individual fish. This is being used to further fine tune feeding, optimize growth rates and further minimize already significantly reduced feed waste.

Farms add other observations to this automated data collection. This can include:

- o video clips of any abnormal behaviours or findings,
- o 2-3 times-per-day plankton observations (more when there are plankton blooms),
- o jellyfish and hydroid observations,
- o daily mortality numbers and attributable causes,
- o results of veterinary and fish health team visits to the sites, including sampling and diagnostic testing,
- o results of audits for third party certification,
- o handling and weight sampling as they occur, and
- o information from major handling events is recorded, such as seines

being pulled and mechanical delousing with boats.

Coupled with the rapid advancement of tools, communications and databases, this huge amount of accessible data is a game changer for veterinarians and farm managers. BC salmon farms are spread over 400 km of our coastline, and aquaculture veterinarians cannot be at all sites all the time. With these tools, veterinarians successfully manage fish health without needing to be at all sites all the time.

Treatments, should they occur, are recorded in detail including duration, feeding and fish response (see Figure 38). Farms have internal systems that combine important fish health data to forecast growth rates and assess trends and changes in population parameters. Some sites have early alerts set for abnormal behaviour and other unusual findings so site staff can react immediately. These systems use both the frequent data coming in and the years of data from individual sites to provide accurate information for planning and forecasting, trend analysis and decision making.

Sites can be reliably monitored remotely, so the veterinarian is made aware of unusual findings much more rapidly. For many sites, data is frequently sent to veterinarians and company management, some in near real time. This facilitates many eyes on the data and more likely detection of, and quick responses to, early signs of disease and other fish health issues.



Figure 38. View of pen monitoring system during sea lice treatment.

UNDERSTANDING DISEASE IN SALMON

WHAT ARE MICROBES AND PATHOGENS?

Microscopic organisms (also known as ‘microbes’) are organisms that are too small to be seen with the naked eye. Examples of microbes include bacteria, plankton, viruses, and animals such as the dust mite and other parasites.

Microbes are among the most diverse and abundant organisms in nature. Their abundance is staggering; a simple teaspoon of seawater typically contains about 50 million viruses (51). The genetic material (DNA or RNA) from microbes can be detected everywhere we look in the environment.



Pathogens are organisms that can cause disease. They can be microscopic like viruses and bacteria, or macroscopic (visible to the naked eye) like external parasites (e.g., sea lice). Pathogens have co-existed with other species for millions of years. All animals, including salmon, live in environments with potential pathogens.



The rapidly evolving field of microbiology has shown that microorganisms and hosts can cooperatively co-exist, and in fact, the co-existence may be mutually beneficial for survival (52). For example, microbiota (large populations of microorganisms) can be found on every surface - inside and outside - of the human body. Massive numbers of microbes in the human gut (the microbiome) are beneficial for digestive health and other functions in the human body.

Salmon and their pathogens have co-evolved over time. Animals can co-exist with pathogens and not be diseased. If this were not true, virtually all organisms, including people, would be diseased almost all the time.

Researchers currently estimate that there are about 30 trillion cells in each person and an additional 39 trillion cells that are other microorganisms (e.g., in the human gut, air passages and skin) – meaning that as an organism we are only about 43% “human” (Figure 39) (53).



Figure 39. *Study: less than half of the human body is human.*
[Click link for video](#) (53)

WHAT IS MOLECULAR DETECTION?

Medical technology has advanced very rapidly in the last two decades. Many laboratory tests have become exquisitely sensitive in detecting pathogens and very small fragments of their genetic code using polymerase chain reaction (PCR) tests and other molecular testing. When correctly used and correctly interpreted, these are extremely useful tools.

Fish represent about 50% of the vertebrate species on earth and likely host an enormous diversity of yet undiscovered viruses (54), some of which might benefit fish, while others might not.

Detecting the genetic material of an organism in a fish or in the fish's environment by environmental DNA (eDNA) techniques does not necessarily mean that the detected genetic code can sicken or kill fish (55). Only a handful of viruses have been documented to cause massive losses and rapid disease spread in salmon populations (e.g., Infectious Hematopoietic Necrosis virus [IHNV]) (56).

The finding of a "new" potential pathogen must be evaluated carefully. In 2022, independent fish health professionals developed a stepwise decision tree to guide fish health practitioners and managers when a potential pathogen is detected by molecular technology (Figure 40) (28). This includes multiple tests to confirm the valid detection of the pathogen. Proof is then required to show that the pathogen is the causative agent of infection and disease.

In veterinary medicine, this is usually shown in infection challenge studies conducted in laboratories. If yes, the decision tree also requires testing to show whether the pathogen can be detected in clinically healthy fish. Very importantly, if there is no mortality and associated disease but the potential pathogen can be detected in clinically healthy fish, then a risk assessment should be conducted by fully qualified professionals to determine whether further follow up and surveillance is necessary.



Photo by Steel_Snorkel

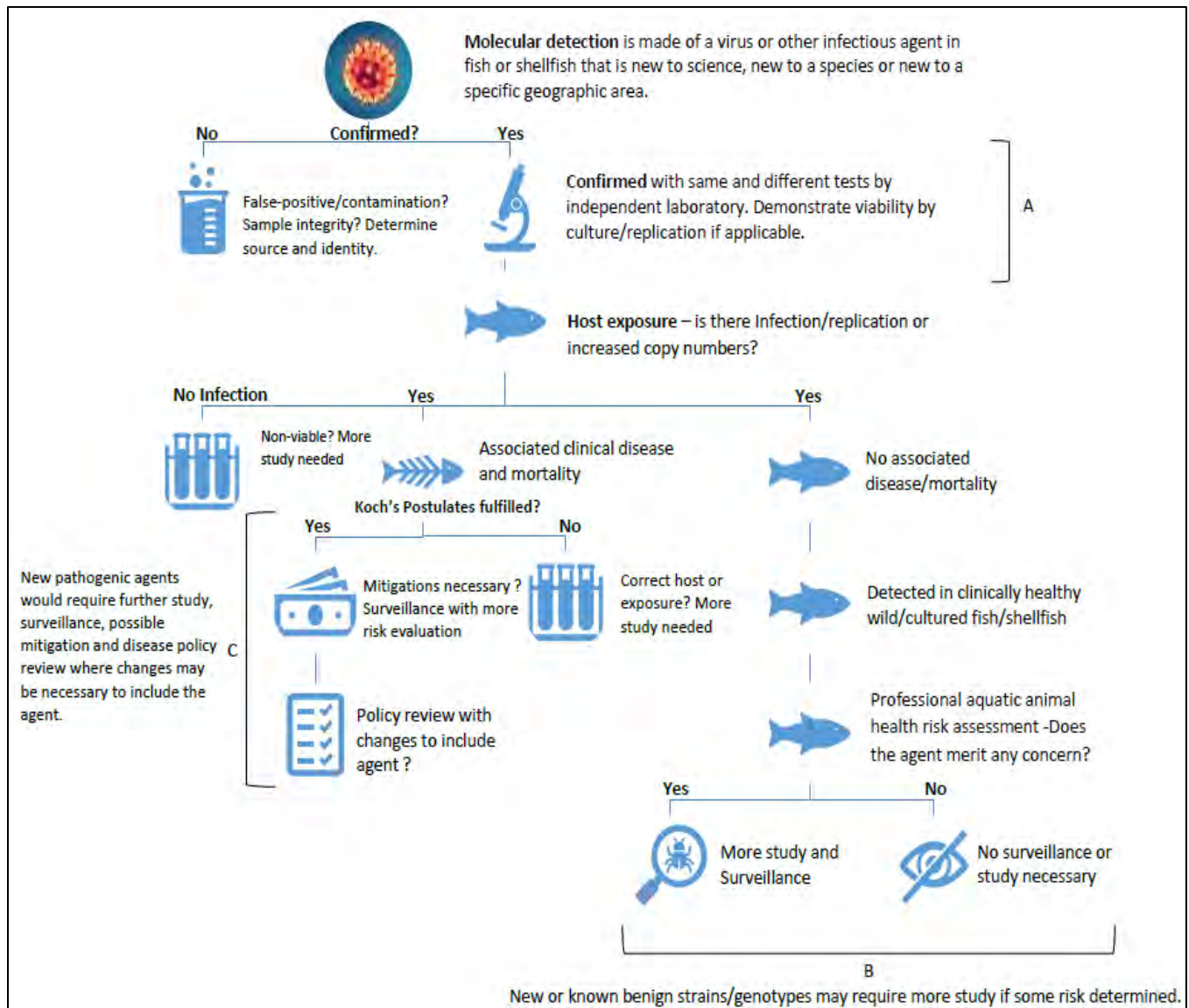


Figure 40. Decision tree following molecular detection of a new infectious agent (28)

WHAT CAUSES INFECTIOUS DISEASE IN FISH?

The spread of infectious disease in fish, like infectious disease in people or terrestrial animals, is a complex process. Fish live in an environment with vast numbers of microbes, only some of which are sometimes harmful (pathogenic). Many variables must align for infectious disease to occur, and other variables must align for disease to spread within a population; fish health professionals call this process "the chain of infection" (Figure 41). If any one step does not occur, then the population does not become diseased.

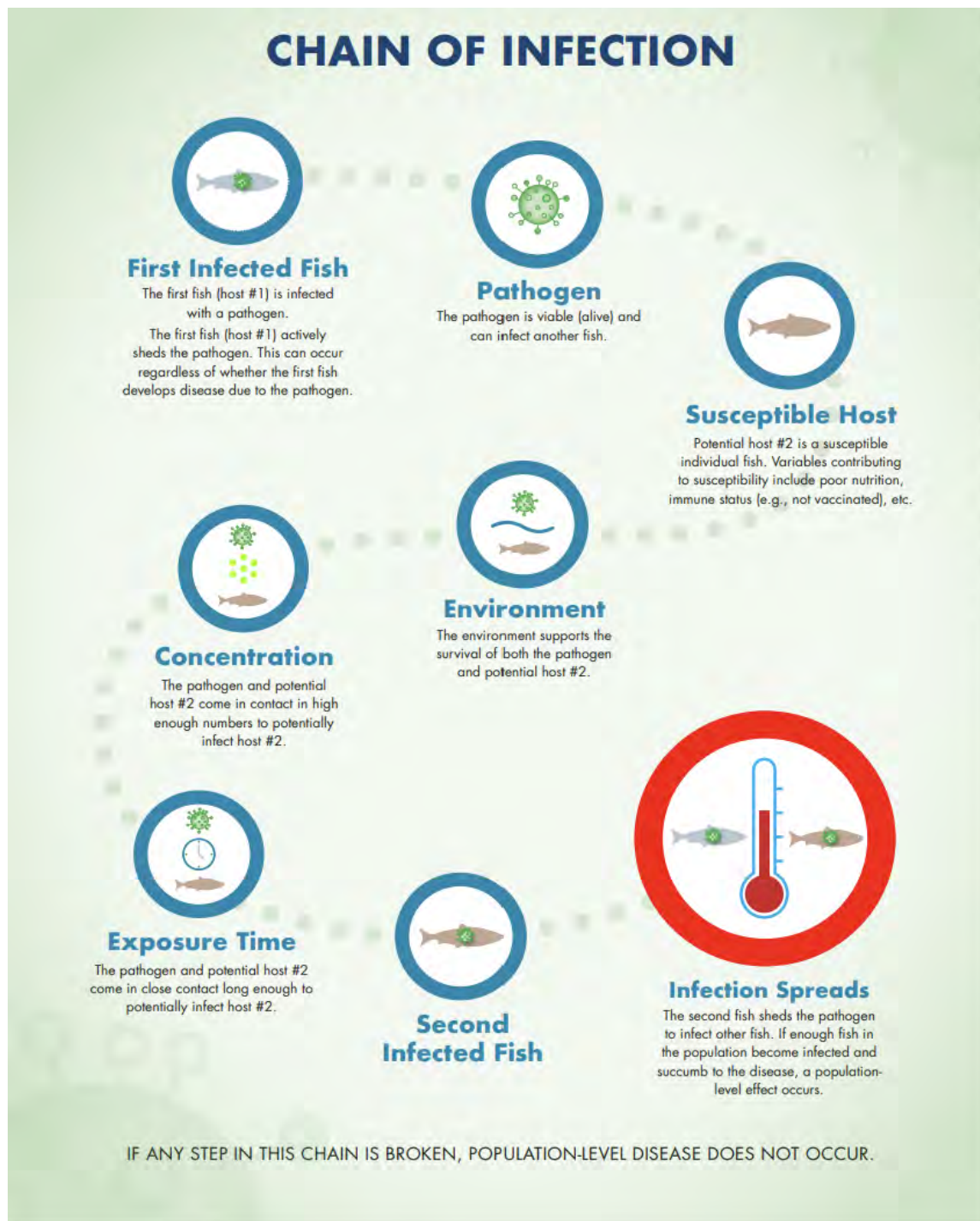


Figure 4I. Variables that must align in order for infection to spread and population-level disease to occur. If any step in this chain is broken, population-level disease does not occur.



OUTCOMES

If the second fish has become infected (i.e., all the above conditions are in place) then the fish may succumb to the disease. However, if the fish's immune system clears the pathogen, then the fish may recover. Treatment such as antimicrobial therapy might be required to support the fish's immune system in clearing the pathogen out of its system. If enough fish in the population are resistant to the infective organism or have recovered from infection, then herd immunity occurs.

Disease can **ONLY** occur if there is a specific alignment of host, pathogen and the environment. If the alignment does not occur, neither does disease.

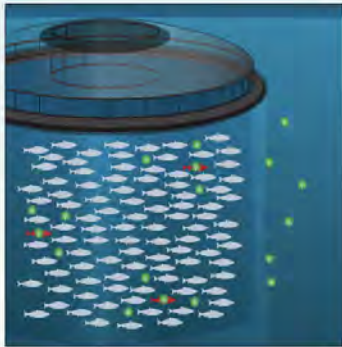
If the correct alignment of host, pathogen, and environment does not happen, then disease does not occur. As in terrestrial livestock farming, salmon farmers have figured out ways to intervene – put up effective barriers – so the perfect

alignment of host, pathogen and environment are less likely to occur. Some of these may be physical separation (walls and enclosures) and some may be functional (i.e., preventative or mitigative action).

Differences in conditions within farms and the surrounding environment minimize the spread of infectious diseases from farm salmon to wild salmon (Figure 42). Pathogens shed by farms are diluted and degraded in the environment (see Table 9.1 in (57)); this decreases the chance of the first wild fish getting infected from a farm-source disease. Most wild fish are more dispersed than farm fish; this decreases the chance that the first infected wild fish will spread the pathogen to other wild fish.

For example, an otherwise healthy person vaccinated for flu, measles or chicken pox has an immune system that is primed to respond to those pathogens if encountered in the environment (e.g., someone else who is sick with flu, measles or chicken pox). The vaccinated person has a much lower chance of becoming infected and diseased from those pathogens than a person who is not vaccinated.

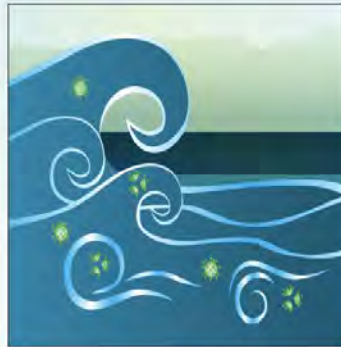
HOW 7 SAFEGUARDS AND NATURE REDUCE SPREAD



Farm Controls

7 Safeguards minimize pathogens in farm-raised salmon.

- 3% of farm-raised salmon die each year of infectious disease.
- Farm-raised salmon swim beside each other 24 hours a day, each day of their lives.
- Fish health teams constantly monitor fish health.



Natural Controls

Environmental conditions break the Chain of Infection:

- Decreased concentration of the pathogen.
- Decreased exposure time to the pathogen.
- Environmental degradation of the pathogen (ultraviolet light, pathogens of pathogens, predators of pathogens, etc.).



Low Prevalence and Risk to Wild Salmon

- Wild salmon immune systems fight pathogens.
- We expect far less than 3% of wild salmon to die each year from infectious disease from salmon farms.
- Wild salmon swim in a vast ocean, magnitudes larger than salmon farms. They do not swim near each other for 24 hours a day, for their entire lives.

Figure 42. Farm controls and nature reduce spread of infectious disease from farm-raised to wild salmon.



HOW DO SALMON FARM VETERINARIANS DETERMINE THE CAUSES OF DISEASE IN THEIR FISH?



When aquaculture veterinarians investigate the cause of disease in their fish, they rely on a wide range of information, including farm history, water quality, feeding, growth, recent mortality, and several types of diagnostic test results:

1. **Physical examination** – “look at the fish” is a simple, yet powerful, diagnostic tool; abnormalities include ulcers, red spots (hemorrhage), or pale spots (inflammation or dead tissue).
2. **Histopathology** – probably the best single method for diagnosing the cause of disease in sick animals, histopathology uses microscopic examination of thin sections of tissues sampled from the fish. This method requires referral to a pathologist that is trained to identify parasites and bacteria in the sections. A trained pathologist can also identify abnormalities associated with viral infections, toxin exposure, nutritional state, and new diseases.
3. **Immunohistochemistry** – this is a special type of histopathology in which tissue sections are specifically stained to identify proteins specific for microorganisms; this method helps the pathologist identify parasites, bacteria, and viruses in the sections.
4. **In situ hybridization** – this is a special type of histopathology in which tissue sections are specifically stained to identify specific genetic codes of microorganisms; this method helps the pathologist to identify parasites, bacteria, and viruses in the sections.
5. **Molecular tests** – PCR tests are used to detect specific genetic codes of microorganisms; this method helps the veterinarian to identify parasites, bacteria, and viruses in the fish.²
 - a. **Screening tests** – this term is used for PCR tests that are not validated for diagnostic purposes or for results reported by a laboratory

² Polymerase chain reaction (PCR) is a method widely used to make millions to billions of copies of a specific DNA sample rapidly, allowing

scientists to amplify a very small sample of DNA (or a part of it) sufficiently to enable detailed study. [Source Wikipedia](#)

that is not accredited as a diagnostic laboratory

- i. Veterinarians use these tests to help confirm other findings like lesions detected by histopathology.
 - ii. Veterinarians do not use screening tests alone as the basis for making decisions (i.e., the screening test results need to be corroborated with consistent lesions or clinical signs).
- b. **Validated tests** – this term is used for PCR tests that are validated for diagnostic purposes. Several levels of validation are possible.
- i. The highest level of validation described by the World Organisation for Animal

Health (WOAH) is needed for demonstrating that a region is free from a given pathogen (58). This level of validation is expensive and not needed for routine diagnostic investigation.

- ii. Most tests used by accredited diagnostic laboratories will be validated for sensitivity (ability to detect the genetic code when it is in the sample) and specificity (ability to generate a negative result when the tested genetic code is not in the sample).
6. **Synthesis** – salmon farm veterinarians follow best practices for diagnostic medicine and ensure that they have confirmatory information from more than one diagnostic test before making a final diagnosis.



Photo by Steel_Snorkel



WHAT IS THE SIGNIFICANCE OF MOLECULAR DETECTION OF A PATHOGEN IN A FISH?

The significance of pathogen detection in a fish increases with each of five stages described below:

1. **Exposure** – The fish is in contact with the pathogen. For example, a bacterium in the water might adhere to the surface of the gill.
2. **Infection** – The invasion and growth of the pathogen in the fish. Methods to confirm infection include histopathology and immunohistochemistry.
3. **Lesion** – The pathogen causes an area of abnormal tissue (e.g., a skin ulcer). Methods to confirm this include physical examination and histopathology.
4. **Disease** – The pathogen causes illness or sickness characterized by specific clinical signs.
 - a. Clinical signs are defined as any objective evidence of disease.
 - b. Examples includes not eating, gasping at the water surface, or congregating at the corner of the net pen.
 - c. Clinical signs also include demonstrated effects on fish growth, survival, and reproduction.
5. **Population decline** – the pathogen decreases the population size of infected fish. Because the diagnosis of disease depends on observing clinical signs, which is difficult in wild fish, and wild fish might die before they are sampled to confirm lesions, mathematical models can be used to

assess the relation of the pathogen and fish survival.

For assessment of whether PCR detection causes population decline, mathematic models most likely to produce reliable results are based on evidence rather than imagination/hypothesis. Lines of evidence that increase the reliability of mathematical models of disease impacts include the following:

- Results from controlled laboratory exposure challenge trials can answer several questions:
 - o Does the pathogen cause disease in the species of interest? Disease significant in wild fish includes impacts on swimming ability, predator avoidance, feeding, and growth.
 - o What markers of infection, if any, occur before the fish becomes diseased (e.g., gene expression or microscopic lesions)?
 - o How much of a pathogen is needed to infect and cause disease in the species of interest?
 - o How much of the pathogen is shed from an infective host?
 - o After being shed, how long does the pathogen survive in the environment?
- What proportion of PCR+ test results in wild fish are associated with changes known to be associated with the tested pathogen under controlled laboratory conditions?
 - o For example, if a bacterium is known to cause skin ulcers under

controlled laboratory conditions, PCR+ test results for that bacterium in wild fish are more likely to be significant if they are associated with skin ulcers in the wild fish.

- Are the PCR+ test results associated with changes in population structure of the exposed wild fish population but not adjacent unexposed populations?





When BC licensed aquaculture veterinarians examine PCR+ test results for a pathogen from such scientific studies, they must determine whether the results are significant and interpret the results in context:

1. Reliability of the PCR test result.
 - a. Results generated by accredited diagnostic laboratories are more reliable than results from other laboratories.
 - i. Accreditation is "a voluntary, third party-reviewed process by a certifying body providing formal recognition of laboratory competence and quality (2)."
 - ii. Laboratories used by salmon farm veterinarians are accredited by the American Association of Veterinary Laboratory Diagnosticians (AAVLD), the Standards Council of Canada (SCC), or the Canadian Association for Laboratory Accreditation (CALA).
2. Results generated using a validated standard operating procedure are more reliable than results from tests that do not follow a validated standard operating procedure.
 - a. Validation is "a process that determines the fitness of an assay, which has been properly developed, optimised and standardised, for an intended purpose." (4)
 - b. Validation provides confidence that the test can detect a pathogen when the pathogen is present in the fish.
 - c. Just as important, validation provides confidence that the test will *not* detect the pathogen when the pathogen is *not* present in the fish.
3. A standard operating procedure (SOP) is "a set of written instructions that describes, in detail, how to perform a laboratory process or experiment safely and effectively." (5)
4. Status of interaction of the PCR+ test result and the tested fish. The significance of the interaction increases with each of five stages from exposure to population (exposure – infection – lesion – disease – population decline).
5. Synthesis of information
 - a. If a bacterium is known to produce lesions, but the PCR+ test results are not associated with lesions among sampled fish, then the veterinarian is confident that the sampled fish do not have disease associated with the PCR+ test result.
 - b. Lack of lesions in a PCR+ fish does not rule out the potential that disease might have developed if the fish had been sampled later, but the more PCR+ fish are sampled without lesions, the greater the confidence that the PCR+ test result is not a marker of disease.
6. Significance of information
 - a. In practice, the transition between exposure, infection, lesion, and disease is not always easy to determine, particularly in wild fish.
 - b. Along the continuum from exposure to disease, by definition only disease might impact wild or farmed salmon growth, reproduction, or survival.
 - c. A virus or bacterium is not a threat to wild or farm-raised salmon if its interaction with fish never exceeds exposure, infection, or lesions.

RECENT CONCERNS



Recent concerns have been raised about *Tenacibaculum maritimum* and Piscine Orthoreovirus (PRV). These concerns are partly due to detections in the environment surrounding fish farms.

“Decisions should not be made solely on the basis of diagnostic test results, especially in the absence of corroborating epidemiological, clinical, or gross evidence.” (3)

TENACIBACULUM MARITIMUM

What is it?

Tenacibaculum maritimum is a bacterium that is common in ocean environments worldwide. Under the right conditions, it can cause disease in some marine fish species. In most parts of the world an infection with *T. maritimum* bacteria can result in a condition called

tenacibaculosis; however, among farm-raised Atlantic salmon in BC and the US Pacific Northwest, infection can lead to a unique form of tenacibaculosis called “yellow mouth”.³ This disease has yellow bacterial mats in and around the teeth and mouth of marine fish.

³ Also known as “mouth rot”

**Is this a new disease?**

Yellow mouth is not new to the region. By 1989, it was widely known to affect cultured salmon in BC, where it typically affected smolts within six to eight weeks of introduction into the ocean (59). Yellow mouth is what veterinarians consider a “production disease”, that is, it mostly manifests in animals held under production conditions, in this case on a salmon farm.

Is it harmful?

Yellow mouth has never been described for any wild fish in BC or Washington State (1). There has only been one report of “jaw plaques consistent with mouthrot” in three farm-raised Chinook salmon (15-20g) from a farm in Discovery Passage in 2009 (1), and in a single farm-raised coho salmon sampled from a farm on the Sunshine Coast in 2014; however, these findings were not associated with farm-level disease by the government veterinarians in charge of the audits (11).

From 2002 – 2018, government veterinarians in BC diagnosed farm-level yellow mouth in 106 of 1446 Atlantic salmon farm audits but 0 of 273 Pacific salmon farm audits (1).

T. maritimum is not harmful to humans but can kill affected fish if left untreated. Young Atlantic salmon are most susceptible, with yellow mouth generally appearing in the first 3-4 months after transfer from a hatchery to sea cages.

What is the risk to wild Pacific salmon?

In 2019, DFO conducted a risk assessment to determine the potential magnitude of impacts on the abundance and diversity of Fraser River sockeye salmon from *T. maritimum* from farm-raised Atlantic salmon in the Discovery Islands area. The overall assessment concluded that *T. maritimum* attributable to these Atlantic salmon farms posed a minimal risk to Fraser River sockeye salmon abundance and diversity (60).

Since this assessment was conducted, a few papers have been published that could be examined to determine if the risk has increased. The potential for revision is typical of any risk assessment.

One new study that might be considered is a recent scientific report on juvenile Fraser River sockeye salmon migrating away from the mouth of the Fraser River (61). The report includes two major findings related to potential *T. maritimum* exposure from farms:

1. “Our best models (with 99.8% empirical support) describe constant background infection pressure, except around Discovery Islands salmon farms, where farm-origin infection pressure peaked at 12.7 (approximate 95% CI: 4.5 to 31) times background levels.”
2. “...between 6.5% and 56.1% of sockeye smolts appear to die as a result of farm-origin *T. maritimum* exposure (61)”.

A case study on how licensed veterinarians review information provided in this research paper follows.

CASE STUDY: A VETERINARY PERSPECTIVE OF *TENACIBACULUM MARITIMUM* AND FRASER RIVER SOCKEYE SALMON

Based on the veterinary approach to assessing the significant of PCR+ test results (see previous sections), the diagnostic results supporting these estimates come with extreme uncertainty and are, therefore, not reliable to (i) make decisions about how *T. maritimum* affects sockeye salmon, or (ii) estimate the role of farms increasing *T. maritimum* infection in wild salmon (Table 9 [follows]).



In summary, the research paper did not provide evidence of the first step in the Chain of Infection – the First Infected Fish (Figure 41). Rather, the lack of infection, lesions, or disease in salmon sampled in this research paper supports an evidence-based hypothesis that 0% of Fraser River sockeye smolts die because of farm-origin *T. maritimum* exposure.

*Table 9. Veterinary approach to reviewing the analysis and conclusions of a recent research paper on *T. maritimum*, salmon farms, and Fraser River sockeye. (61)*

Veterinarian’s Question	Answer	Comment
Were the PCR tests for <i>T. maritimum</i> conducted in a laboratory accredited for diagnostic testing?	No	The tests were conducted in a research laboratory that is not accredited for diagnostic testing.
Was the PCR test used for <i>T. maritimum</i> validated for diagnostic testing?	No	The research paper cites a CSAS report (62) as a reference for test validation; however, the cited CSAS report does not include information about <i>T. maritimum</i> (62). Also, the cited CSAS report says, “We did not evaluate the platform for diagnostic use...” and, “We contend that the purpose of the assay, in its current application, is research rather than diagnosis.”

Veterinarian's Question	Answer	Comment
Can PCR results from tests not validated for diagnostic purposes still be used to corroborate other findings?	Yes	Such tests are called "screening tests. These test results are not reliable when used on their own, but they may be used to help corroborate other tests (e.g., histopathology) or clinical signs (e.g., skin ulcers or gill lesions).
Does the research paper report corroborating evidence to confirm the PCR+ test results for <i>T. maritimum</i> ?	No	Among the 2,270 juvenile Fraser River sockeye salmon sampled, none were reported to have skin ulcers or gill lesions, and no histopathology results were reported.
Can the false positive rate be estimated for the <i>T. maritimum</i> PCR test?	Yes	<i>T. maritimum</i> does not grow in fresh water (63). Therefore, the <i>T. maritimum</i> prevalence in freshwater samples provides a good estimate of false positive rate for the PCR test. For the laboratory that conducted these tests, the demonstrated false positive rate is 4.2%. ⁴
Can PCR+ test results be adjusted to account for the false positive rate?	Yes	The CSAS report cited for test validation says, "...it is imperative that the assays run on the platform be carefully evaluated for sensitivity (limit of detection) ...so that the limitations of what can and cannot be concluded are well established and measures are implemented to minimize the potential for false positive or negative results."
Does the research paper apply a limit of detection to minimize the potential for false positive test results for <i>T. maritimum</i> ?	No	The research paper does not mention a limit of detection; instead, "If duplicate qPCR tests on the same sample both detected the bacterium, we considered that sample to be positive..."
Does the research paper provide PCR results in a	No	This research paper does not provide the data it analyses. This lack of data transparency precludes independent assessment of the analysis (26).

⁴ 18 of 427 (4.2%) of fish sampled from fresh water are reported as PCR+ for *T. maritimum* in another paper by the same research group: Bateman, A.W., Schulze, A.D., Kaukinen, K.H., Tabata, A., Mordecai, G., Flynn, K., et al. 2021. Descriptive multi-agent epidemiology via molecular screening on Atlantic salmon farms in the Northeast Pacific Ocean. Sci. Rep. 11: 3466. doi:10.1038/s41598-020-78978-9. PMID:33568681.

Veterinarian's Question	Answer	Comment
dataset that can be independently reviewed?		
Does the research paper demonstrate that the sampled fish were exposed to <i>T. maritimum</i> ?	No	The laboratory's false positive rate (4.2%) is greater than the PCR+ rate for many of the samples in the research paper, but the research paper did not adjust results based on this information. Therefore, the proportion of test results that are true positives cannot be independently estimated.
Does the research paper demonstrate that the sampled fish with PCR+ test results were infected with <i>T. maritimum</i> ?	No	The CSAS report cited for test validation says, "As with any PCR-based assay, a_molecular assay alone cannot discern whether an animal is diseased or if a microbe is infective..." The research paper provides no corroborative evidence that the PCR+ fish were infected.
Does the research paper demonstrate that the sampled fish had lesions associated with the PCR+ test results for <i>T. maritimum</i> ?	No	Among the 2,270 juvenile Fraser River sockeye salmon sampled, none were reported to have skin ulcers or gill lesions, which can be detected by looking at the fish when they are sampled.
Does <i>T. maritimum</i> infection result in lesions in other Pacific salmon species?	Yes	<i>T. maritimum</i> infection has not been described in sockeye salmon. However, other studies report <i>T. maritimum</i> in Pacific salmonids: 1. Infected rainbow trout had "severe tail rot, frayed fins, haemorrhagic mouth with a compromised jaw (Figure 1 [in the research paper]) and, occasionally, damaged gills..." (64) 2. "The gills of 10 of 15 moribund chinook salmon...had severely eroded, white to pale pink areas (Figure 1 [in the research paper]) associated with rapid mortality." (65)
Does the research paper use the best estimate of mortality related to <i>T. maritimum</i> infection?	No	The research paper several times mentions the severity of <i>T. maritimum</i> in farm-raised BC Atlantic salmon, but it does not mention the lack of disease associated with <i>T. maritimum</i> in farm-raised BC Pacific salmon species. From 2002 – 2018, government



Veterinarian's Question	Answer	Comment
		veterinarians in BC diagnosed farm-level yellow mouth in 106 of 1446 Atlantic salmon farm audits but 0 of 273 Pacific salmon farm audits (1).
Does the research paper demonstrate that the PCR+ test results for <i>T. maritimum</i> are associated with decreased population-level survival of Fraser River sockeye salmon?	No	A study of 64 stocks of sockeye salmon from BC, Washington, and Alaska from 1950 – 2009 reported that recent decreases in abundance and productivity of Fraser River sockeye salmon occurred across a large geographic area ranging from Washington, BC, southeast Alaska, and up through the Yakutat peninsula, Alaska (66). The new research paper does not cite or update this analysis.
Did changes in Discovery Islands farm practices after 2009 increase the potential for farm-source <i>T. maritimum</i> to impact sockeye salmon?	No	Instead, changes in farm practices decreased the potential for farm-source <i>T. maritimum</i> to impact sockeye salmon. Around 2010, farmers stopped stocking Discovery Island farms with Atlantic salmon directly from hatcheries—instead stocking these farms with larger fish, which are resistant to yellow mouth. Fish Health Events due to yellow mouth reported by Discovery Islands farms decreased 90% from 2004 – 2007 (71 reports) to 2016 – 2019 (7 reports) (1).
Does the research paper demonstrate that the <i>T. maritimum</i> PCR+ test results in the Discovery Islands region are “farm-origin”?	No	Telemetry studies provide evidence that 27 – 50% of Fraser River sockeye migrate through Discovery Passage, where Atlantic salmon farms are absent (37, 67). Bateman et al. (2022) does not differentiate results from Discovery Islands' passages with and without salmon farms. Therefore, the proportion of the increase in PCR+ test results originating from salmon farms vs. the environment cannot be independently assessed.



Photo by Brian Kingzett

PISCINE ORTHOREOVIRUS (PRV)

What is it?

Briefly, PRV is a common virus of salmonids worldwide(68). PRV was initially identified from Atlantic salmon in Norway diagnosed with heart-skeletal muscle inflammation (HSMI), using advanced (next-generation) molecular sequencing methods (68-70). HSMI is an infectious disease (71). Since PRV was first identified, three different genotypes have been identified (PRV-1, 2, and 3), and PRV-1 has been identified in the Northeastern Pacific (including BC) (68, 70). The history and current body of knowledge regarding piscine orthoreovirus (PRV) in BC has been summarized in recent studies by the DFO's Aquatic Animal Health Laboratory at the Pacific Biological Station (68), as well as the U.S. Geological Survey (70).

Is this a new virus?

When PRV-1 was first reported in farm-raised Atlantic salmon in BC in 2013, it was assumed to be a virus that had been introduced to the region recently (72). Subsequently, PRV-1 has been identified among wild salmonids in the Northeastern Pacific ranging from Alaska through BC and Washington State (73) and in archived fish tissue samples since as early as the 1970's (34, 74-76).

Is it harmful?

One research group diagnosed HSMI in BC farm-raised salmon,(77) and they speculated that PRV was the cause, but they did not confirm that the lesions they diagnosed as HSMI were infectious. Speculations were raised that PRV could reduce fitness or cause disease such as jaundice syndrome among local Pacific salmon species (78, 79). However, these studies did not examine the actual effects

of the virus on fish, only if it was detected. About 0.3% of BC farm-raised Atlantic salmon die each year with various types of unexplained heart disease, and many of these fish are positive for PRV (15, 80). Controlled laboratory infection challenges using a PRV-1 isolate from BC have demonstrated that the virus multiplies in new hosts and sometimes causes minor microscopic changes (lesions), but it does

not cause disease among Pacific salmon (70, 81, 82) or Atlantic salmon (15, 81-84).

What is the risk to wild Pacific salmon?



Photo by Brian Kingzett

In 2019, DFO conducted a risk assessment to determine the potential magnitude of impacts on the abundance and diversity of Fraser River sockeye salmon from PRV from farm-raised Atlantic salmon in the Discovery Islands area. The overall assessment concluded that PRV attributable to these Atlantic salmon farms posed a minimal risk to Fraser River sockeye salmon abundance and diversity.

In 2020, DFO convened a workshop of veterinarians from Canada, the United States, and Norway. The majority of workshop participants agreed there was not sufficient evidence to demonstrate population-level HSMI in BC, nor was there enough evidence to confirm a causal link between PRV and the development of jaundice in Chinook salmon (85).

Since this assessment was conducted, a few papers have been published that could be examined to determine if the risk has increased. As discussed for *T. maritimum* above, each of these papers could be examined to determine if their results are based on sound science and warrant an updated risk assessment. As of early 2024, this work has not been undertaken by DFO.

As discussed earlier in this chapter, the Pacific Northwest Fish Health Protection Committee (independent fish health professionals from the USA) also concluded that Piscine orthoreovirus (PRV) is low risk to Pacific salmon.

FUTURE GOALS

We visualize a future where First Nations and the general public are confident that farm-raised salmon and wild Pacific salmon can successfully coexist in BC. We believe that significant changes within the social-political and scientific landscape enable this.

Firstly, all salmon raised in farms are under the watch and guidance of First Nations who have been the stewards of their lands, water and wild salmon since time immemorial. Traditional knowledge, which has been learned over many generations, is now being shared with fish health teams, bringing powerful knowledge together.

Secondly, innovative advancements in artificial intelligence, machine learning, digital platforms, molecular science, continuous in-pen monitoring of environmental and fish conditions, trend analysis and communications are rapidly improving veterinary oversight of farms and ultimately veterinary medicine. Active engagement with universities, such as identifying better methods to minimize outbreaks of yellow mouth, will continue to have a large role in the future of salmon farming.



APPENDIX A. SUMMARY OF SALMON PATHOGENS SUBJECTED TO FORMAL RISK ASSESSMENT BY THE DFO CSAS PROCESS

From 2017 – 2020, DFO completed formal risk assessments on nine salmonid pathogens that occur or have occurred on farm salmon in British Columbia (25). The assessments focused on the effect of the pathogens among salmon farms in the Discovery Islands region on Fraser River sockeye salmon. The assessments were led by the Canadian Science Advisory Secretariat (CSAS). The CSAS concluded that the risk to Fraser River Sockeye salmon from each pathogen is minimal. Highlights of each assessment are included below.

This section also includes (i) information about how salmon farm veterinarians prevent specific diseases from occurring, and (ii) a summary of salmon farm reports to DFO of Fish Health Events (2016 – 2022) and Mortality Events (2011 – 2022).

Methods used by salmon farmers to minimize spread of all diseases include (i) strict biosecurity measures, (ii) daily mortality monitoring, and (iii) regular diagnostic investigation.

Definitions (48):

Fish Health Event – Any suspected or confirmed disease that occurs within an aquaculture facility, requires the involvement of a veterinarian, and warrants mitigation measures. Not included is routine management of the salmon louse (*Lepeophtheirus salmonis*). Fish Health Events have been reported to DFO as a condition of license since 2016. Each BC salmon farm, on average, reports about one Fish Health Event each year (from 2016 – 2022, 284 reports averaged 41 per year).

Mortality Event – A Mortality Event must be reported to DFO within 24 hours of discovery if the number of dead fish at a farm exceeds the thresholds outlined in the conditions of the license. The threshold is specific to each facility and is determined by DFO based on variables that include the size of the farm, the species being farmed, and environmental conditions. Mortality Events have been reported to DFO since 2011. Each BC salmon farm, on average, reports about one Mortality Event each year (from 2011 – 2022, 579 reports averaged 48 per year).

AEROMONAS SALMONICIDA AND FURUNCULOSIS:

Characterization – *Aeromonas salmonicida* is a bacterium that causes furunculosis in salmon and trout species around the world. BC farm-raised Atlantic salmon are vaccinated for *A. salmonicida* before being transferred to the ocean. Cases develop among a small proportion of farm salmon as vaccine immunity fades when fish approach harvest size. For sockeye salmon, infections have been detected most commonly among adults that have returned to freshwater to spawn (86).

CSAS Assessment – The risk to Fraser River sockeye salmon from *A. salmonicida* is **minimal** (87).

- The key reason for this conclusion is that the amount of *A. salmonicida* released from an infected farm is estimated to be lower than what is required to cause infection or mortality in Fraser River sockeye salmon.
- The main uncertainties are:
 - the unknown number of fish with *A. salmonicida* infection on farms, and
 - the unknown consequences to sockeye salmon from an infection that does not cause mortality.

Occurrence – (18, 19)

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, 11 (4.0%) were due to *A. salmonicida* infection.
- Among 849 dead or dying BC farm-raised Pacific salmon sampled as part of the DFO Fish Health Audit Program from 2011 – June 2022, only 2 (0.2%) were positive for *A. salmonicida* infection (one each sampled in 2012 and 2015).
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 4 (0.7%) were due to *A. salmonicida* infection.

Prevention – Some Atlantic salmon farmers vaccinate against *A. salmonicida* with an effective commercial vaccine.

INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS (IHNV):

Characterization – IHNV is a virus native to the Pacific Northwest. IHNV infection can cause a disease called infectious hematopoietic necrosis (IHN). Atlantic salmon are highly susceptible, while Pacific salmon species in marine waters are resistant to disease. No cases of IHN have been confirmed among farm-raised Pacific salmon species in BC (88).

CSAS Assessment – The risk to Fraser River sockeye salmon from IHNV is **minimal** (89).

- Key reasons:
 - o All farm-raised Atlantic salmon have been vaccinated against IHN since 2012,
 - o no outbreaks have occurred among farm salmon since 2012, and
 - o if infection does occur, the aquaculture companies will remove all infected fish
- The main uncertainty is the unknown impact to sockeye salmon from IHNV exposure in the marine environment.

Occurrence –(18, 19)

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, 0 (0%) were due to IHNV infection.
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 2 (0.3%) were due to IHNV infection (both were in 2012).

Prevention – All Atlantic salmon farmers vaccinate against IHNV with an effective commercial vaccine.

MORITELLA VISCOSA:

Characterization – *Moritella viscosa* is a bacterium that causes a disease called winter ulcer in farm-raised Atlantic salmon(90). As the name suggests, it typically occurs in the winter, when water temperatures drop below 10° C. Winter ulcer is not known to occur among Pacific salmon species in British Columbia. Among affected Atlantic salmon, the ulcers are disfiguring, but associated mortality is usually low, and fish recover with warming temperatures in the spring.

CSAS Assessment – The risk to Fraser River Sockeye salmon from *M. viscosa* is **minimal** (91).

- The key reason is that winter ulcers on Discovery Islands farms do not occur when Fraser River sockeye salmon are in the area.
- Uncertainties: none are significant.

Occurrence –(18, 19)

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, 16 (5.9%) were due to ulcers, including *M. viscosa* infection.
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 1 (0.2%) was due to ulcers, including *M. viscosa* infection.

Prevention – Some Atlantic salmon farmers vaccinate against *M. viscosa* with a new effective commercial vaccine.



PISCINE ORTHOREOVIRUS (PRV):

Characterization – Different forms of PRV occur around the world, but only PRV-1 has been reported in North America(92). Nearly all sea-farm-raised salmon eventually become infected with PRV before harvest, and PRV-1 has been detected in archived specimens dating back to at least the mid 1980's in British Columbia. Among BC farm salmon infected with PRV-1, Heart and Skeletal Muscle Inflammation (HSMI) has been diagnosed in Atlantic salmon, and some Chinook salmon develop jaundice; controlled laboratory studies confirm that the PRV from these fish is infectious, but the infected fish do not develop HSMI or jaundice. The prevalence of PRV in sockeye salmon in Western North America over the past decade is approximately 1.5%. Experimental infection of sockeye salmon with BC PRV-1 leads to abundant virus replication in the blood and minor transient impairment of blood function, but no significant disease.

CSAS Assessment – The risk to Fraser River sockeye salmon from PRV is **minimal**. (93)

- The key reason is scientific evidence that PRV-1 infection does not cause disease, mortality, or physiologically relevant swimming impairment in sockeye salmon.
- An uncertainty is how to apply laboratory study results to interactions that occur in the marine environment.

Occurrence –(18, 19)

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, none (0%) were due to PRV infection.
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 0 (0%) were due to PRV infection.

Prevention – Juvenile Atlantic salmon and Pacific salmon in freshwater hatcheries are screened for PRV, and only PRV-negative populations are transferred into seawater.

***PISCIRICKETTSIA SALMONIS* AND SALMONID RICKETTSIAL SEPTICAEMIA (SRS):**

Characterization – *Piscirickettsia salmonis* is a bacterium that can cause a disease called salmonid rickettsial septicaemia (SRS) in marine fish species (94). The bacterium infects many organs, with the liver often the most severely affected; a significant proportion of infections are limited to the brain. Among farm-raised salmon, SRS is a problem during peak water temperatures that occur most commonly on the west side of Vancouver Island in the late summer and early fall (i.e., not during migrations of juvenile sockeye salmon). SRS has not been reported in sockeye salmon, but Chinook salmon are susceptible.

CSAS Assessment – The risk to Fraser River sockeye salmon from *P. salmonis* is **minimal**. (95)

- The key reason is that *P. salmonis* on a farm is very unlikely to infect Fraser River sockeye salmon.
- Uncertainties:
 - how much bacteria are shed by fish infected with *P. salmonis*,
 - how long the bacteria can survive in the marine environment, and
 - the minimum dose required to cause infection and disease in sockeye salmon.

Occurrence –(18, 19)

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, 42 (15%) were due to *P. salmonis* infection.
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 7 (1.2%) were due to *P. salmonis* infection.

Prevention – use methods common for all diseases



RENIBACTERIUM SALMONINARUM AND BACTERIAL KIDNEY DISEASE (BKD):

Characterization – *Renibacterium salmoninarum* is a bacterium that can cause bacterial kidney disease (BKD) in salmon. (96) Despite its name, the bacterium infects many organs, and a significant proportion of infections are limited to the brain. BKD is a global disease and occurs in both freshwater and marine environments. Under controlled laboratory conditions, sockeye salmon and Chinook salmon are more susceptible to infection and disease than Atlantic salmon. Among farm salmon, BKD is most common in the spring.

CSAS Assessment – The risk to Fraser River sockeye salmon from *R. salmoninarum* is **minimal** (97).

- The key reason is that the concentration of *R. salmoninarum* estimated on a farm is much lower than the one required to cause infection or death in Chinook salmon, which are more vulnerable to *R. salmoninarum* infection than sockeye salmon.
- The key uncertainty is the unknown minimum dose of *R. salmoninarum* needed to infect and cause disease in sockeye salmon in the marine environment.

Occurrence –(18, 19)

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, 10 (3.7%) were due to *R. salmoninarum* infection.
- Among the 12 Chinook salmon Fish Health Events reported to DFO from 2016 – 2022, all (100%) were due to *R. salmoninarum* infection. All of these were associated with broodstock that were not experiencing an outbreak but were treated to control background levels of infection before the fish were spawned.
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 0 (0%) were due to *R. salmoninarum* infection.

Prevention –

- Some Atlantic salmon farmers and all Pacific salmon farmers vaccinate against BKD with an effective commercial vaccine
- Comprehensive broodstock monitoring for *R. salmoninarum* minimizes spread from the parent fish to eggs.

TENACIBACULUM MARITIMUM:

Characterization – *Tenacibaculum maritimum* is a marine bacterium that occurs worldwide in the environment and in several species of marine fish (1). *T. maritimum* does not occur in fresh water. It is an opportunistic bacterium, meaning that it occurs on healthy fish but can cause disease in fish that are stressed. In BC, the bacterium causes the disease yellow mouth (also called mouthrot), primarily in Atlantic salmon within a few months of transfer from fresh water to seawater.

CSAS Assessment – The risk to Fraser River sockeye salmon from *T. maritimum* is **minimal**. (60)

- Key reasons
 - Pacific salmon are less susceptible than Atlantic salmon to disease, and
 - Fraser River Sockeye salmon have a short and limited interaction with the farms in the area.
- The key uncertainty is whether sockeye salmon can get infected with *T. maritimum* and develop mouthrot.

Occurrence –

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, 166 (61%) were due to *T. maritimum* infection.
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 7 (1.2%) were due to *T. maritimum* infection.
- From 2002 – 2018, government veterinarians diagnosed farm-level yellow mouth in 106 of 1446 (7.3%) Atlantic salmon audits but 0 of 273 (0%) Pacific salmon audits (1).⁵

Prevention – (18, 19)

- Because *T. maritimum* is common in the marine environment, and younger fish are generally more susceptible to infection and disease, a key to prevention is minimizing stress when fish are transferred from freshwater hatcheries to seawater. To do this, fish are tested in hatcheries to ensure that their body is ready to transfer to seawater.
- When outbreaks occur, antimicrobial treatments minimize disease and transmission to other fish.

⁵ The number of Pacific salmon audits was provided by Howie Manchester, DFO, personal communication)



VIRAL HEMORRHAGIC SEPTICEMIA VIRUS (VHSV):

Characterization – Viral hemorrhagic septicemia virus (VHSV) is the causative agent of viral hemorrhagic septicemia (VHS), which can occur in a wide range of cultured and wild fish species in both marine and freshwater environments(98). Different forms of VHSV occur around the world, but only Genotype IVa has been reported in BC and the surrounding northeastern Pacific Ocean. VHSV-IVa causes recurring mortality events in Pacific herring and Pacific sardine. A risk factor for farm salmon developing VHS is proximity to abundant herring. Sockeye salmon are not susceptible to VHSV-IVa under controlled laboratory conditions.

CSAS Assessment – The risk to Fraser River sockeye salmon from VHSV-IVa is **minimal**. (99)

- The key reason for this conclusion is that sockeye salmon are not susceptible to VHSV.
- Uncertainties: none are significant.

Occurrence – (18, 19)

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, 2 (0.7%) were due to VHSV-IVa infection.
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 1 (0.2%) was due to VHSV-IVa infection.

Prevention – use methods common for all diseases

YERSINIA RUCKERI AND ENTERIC REDMOUTH DISEASE (ERM):

Characterization – *Yersinia ruckeri* is a bacterium that causes enteric redmouth disease (ERM) (100).

It is primarily a freshwater pathogen and rarely causes disease in healthy and unstressed fish in the marine environment. Controlled laboratory studies are limited, but the consensus is that sockeye salmon are less susceptible than Atlantic salmon to infection and disease.

CSAS Assessment – The risk to Fraser River sockeye salmon from *Y. ruckeri* is **minimal** (101).

- The key reason is that *Y. ruckeri* infection on farms in the Discovery Islands area is extremely rare, and there is no evidence of spread within farm-raised Atlantic salmon.
- The main uncertainty is the unknown susceptibility of sockeye salmon. ERM has not been reported in sockeye salmon.

Occurrence –(18, 19)

- Among the 272 Atlantic salmon Fish Health Events reported to DFO from 2016 – 2022, 4 (1.5%) were due to *Y. ruckeri* infection.
- Among the 579 farm salmon Mortality Events reported to DFO from 2011 – 2022, 0 (0%) were due to *Y. ruckeri* infection.
- Among 849 dead or dying BC farm-raised Pacific salmon sampled as part of the DFO Fish Health Audit Program from 2011 – June 2022, none (0.0%) were positive for *Y. ruckeri* infection (11).

Prevention – Some Atlantic salmon farmers vaccinate against *Y. ruckeri* with an effective commercial vaccine.



REFERENCES

1. Wade AJ, Weber L. 2020. Characterization of *Tenacibaculum maritimum* and mouthrot to inform pathogen transfer risk assessments in British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS). https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2020/2020_061-eng.pdf
2. AAVLD. 2017. AAVLD Accreditation Program Visalia, CA: American Association of Veterinary Laboratory Diagnosticians; [Available from: <https://www.aavld.org/accreditation-explained#:~:text=AAVLD%20Accreditation%20does%20not%20certify,relability%2C%20and%20consistency%20of%20services>].
3. Middleton JR, Getchell RG, Flesner BK, Hess WJ, Johnson PJ, Scarfe AD, Starling DE. 2021. Considerations related to the use of molecular diagnostic tests in veterinary clinical and regulatory practice. *Journal of the American Veterinary Medical Association*.259(6):590-595.10.2460/javma.259.6.590
4. WOAH. 2021. Principles and methods of validation of diagnostic assays for infectious diseases. *Manual of Diagnostic Tests for Aquatic Animals* 12 ed. Paris, France: World Organisation for Animal Health. p. 26. https://www.woah.org/fileadmin/Home/eng/Health_standards/aahm/current/1.1.02_VALIDATION.pdf
5. Environmental Health and Safety. 2024. Standard Operating Procedures - SOPs Ames, IA: Iowa State University of Science and Technology; [Available from: [https://www.ehs.iastate.edu/research/laboratory/SOPs#:~:text=A%20standard%20operating%20procedure%20\(SOP,or%20experiment%20safely%20and%20effectively](https://www.ehs.iastate.edu/research/laboratory/SOPs#:~:text=A%20standard%20operating%20procedure%20(SOP,or%20experiment%20safely%20and%20effectively)].
6. Macleod MJ, Hasan MR, Robb DHF, Mamun-Ur-Rashid M. 2020. Quantifying greenhouse gas emissions from global aquaculture. *Scientific Reports*.10(1).10.1038/s41598-020-68231-8
7. Ritchie H. 2020. “You want to reduce the carbon footprint of your food? Focus on what you eat, not whether your food is local”: Published online at OurWorldInData.org.; [Available from: <https://ourworldindata.org/food-choice-vs-eating-local>].
8. Bianchi M, Hallström E, Parker RWR, Mifflin K, Tyedmers P, Ziegler F. 2022. Assessing seafood nutritional diversity together with climate impacts informs more comprehensive dietary advice. *Communications Earth & Environment*.3(1):188.10.1038/s43247-022-00516-4
9. Canadian Food Inspection Agency. 2024. Federally reportable aquatic animal diseases in Canada Ottawa: Government of Canada; [Available from: <https://inspection.canada.ca/animal-health/aquatic-animals/diseases/reportable-diseases/federally-reportable-aquatic-animal-diseases/eng/1339174937153/1339175227861>].
10. Canadian Food Inspection Agency. 2024. Locations infected with infectious haematopoietic necrosis Ottawa: Government of Canada; [Available from: <https://inspection.canada.ca/animal-health/aquatic-animals/diseases/reportable-diseases/ihn/locations-infected/eng/1528474948446/1528475054383>].

11. Open Government. 2024. Results of DFO fish health audits of British Columbian marine finfish aquaculture sites, by facility Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/6c891715-317c-4d4d-9fe8-ea425e01d9d2>].
12. Canadian Food Inspection Agency. 2024. Locations infected with viral haemorrhagic septicaemia Ottawa: Government of Canada; [Available from: <https://inspection.canada.ca/animal-health/aquatic-animals/diseases/reportable-diseases/vhs/locations-infected/eng/1533702435557/1533702489304>].
13. Fisheries and Oceans Canada. 2022. Use of therapeutants Ottawa: Government of Canada; [Available from: <https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/therapeut/index-eng.html#antibacterial-data>].
14. Association CVM. 2024. CVMA Guidelines for Veterinary Antimicrobial Use: Canadian Veterinary Medical Association [Available from: <https://www.canadianveterinarians.net/veterinary-resources/antimicrobial-stewardship-resources/cvma-guidelines-for-veterinary-antimicrobial-use/>].
15. Polinski MP, Gross LA, Marty GD, Garver KA. 2022. Heart inflammation and piscine orthoreovirus genotype-1 in Pacific Canada Atlantic salmon net-pen farms: 2016–2019. BMC Veterinary Research.18(1):306.10.1186/s12917-022-03409-y
16. Marty GD, Saksida SM, Quinn TJ. 2010. Relationship of farm salmon, sea lice, and wild salmon populations. Proceedings of the National Academy of Sciences.107(52):22599-22604,
17. Fisheries and Oceans Canada. 2022. Regulating and monitoring British Columbia's marine finfish aquaculture facilities - 2020 Ottawa: Government of Canada; [Available from: <https://www.dfo-mpo.gc.ca/aquaculture/management-gestion/mar-rep-rap-2020/index-eng.html>].
18. Open Government. 2023. Fish health events at British Columbia marine finfish aquaculture sites - Data - Fish health events - English Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/deefd1d7-7184-44c7-83aa-ec0db91aad27/resource/8d2a641b-7745-36b8-a5e7-075a6ec263c1>].
19. Open Government. 2023. Mortality events at British Columbia marine finfish aquaculture sites Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/7fbb2662-391a-4df7-99b4-3343fa68fc93>].
20. Open Government. 2023. Carcass classification of cultured salmon at British Columbian aquaculture sites by facility, 2013 onwards - Data - Carcass classification of cultured salmon - English Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/0a8c5505-ecb3-4d8b-8120-462bd7def6bb/resource/9e05d55a-ade6-34cc-9b85-b369c63fe1d7>].
21. Fisheries and Oceans Canada. 2023. DFO marine finfish aquaculture audit activities in British Columbia Ottawa: Government of Canada; [Available from: <https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/mer-mar-audit-verif/index-eng.html>].
22. Marty GD. Histopathology FHAS 2006-2010, Histopathology of Atlantic salmon sampled as part of the BC Auditing and Surveillance Program Exhibit 1678 ed: Cohen Commission; 2010.<https://epe.lac-bac.gc.ca/100/206/301/pco->

bcp.commissions/cohen/cohen_commission/LOCALHOS/EXHIBITFILES/EXH_1678_BCP002864.ZIP

23. Cohen BI. 2012. The Uncertain Future of Fraser River Sockeye: Volume 3, Recommendations. Ottawa. ON: Canada. Privy Council Office. <https://publications.gc.ca/site/eng/420577/publication.html>
24. Fisheries and Oceans Canada. 2020. Aquaculture research related to Cohen Commission recommendation 19 Ottawa: Government of Canada; [Available from: <https://www.dfo-mpo.gc.ca/cohen/recherche-aquaculture-research-eng.html>].
25. Fisheries and Oceans Canada. 2022. Summaries of the risk assessments for the Discovery Islands area. Ottawa: Government of Canada. <https://www.dfo-mpo.gc.ca/cohen/iles-discovery-islands-eng.html>
26. Godwin SC, Bateman AW, Mordecai G, Jones S, Hutchings JA. 2023. Is scientific inquiry still incompatible with government information control? A quarter-century later. Canadian Journal of Fisheries and Aquatic Sciences.10.1139/cjfas-2022-0286
27. Meyers TR. 2017. Piscine Orthoreovirus (PRV) in the Pacific Northwest appears to be of low risk to wild Pacific salmonids. Available from: <https://drive.google.com/file/d/1OxHv7GXddmEXA7pRH4N4MGACzdZUhUL8/view?usp=sharing>.
28. Meyers TR, Hickey N. 2022. A Perspective: Molecular Detections of new agents in finfish: interpreting biological significance for fish health management. Journal of Aquatic Animal Health.34:47-57. <https://doi.org/10.1002/aah.10155>
29. Saksida SM. 2006. Infectious haematopoietic necrosis epidemic (2001 to 2003) in farmed Atlantic salmon *Salmo salar* in British Columbia. Dis Aquat Organ.72(3):213-23.10.3354/dao072213
30. Brackett J, Newbound G, Speare D, J. 1991. A summer survey of saltwater morbidity and mortality of farmed salmon in British Columbia. Victoria, BC: British Columbia Ministry of Agriculture, Fisheries and Food.
31. Brackett J, Newbound G, Coombs MP, Ferguson HW, Speare D, J. 1990. A winter survey of saltwater morbidity and mortality in farmed salmon in British Columbia. Victoria BC: Province of British Columbia Ministry of Agriculture and Fisheries. <http://library.nrs.gov.bc.ca/digipub/wintersurvey.pdf>
32. Brackett J, Newbound G. 1991. A spring survey of saltwater morbidity and mortality in farmed salmon in British Columbia. Victoria BC: Province of British Columbia Ministry of Agriculture and Fisheries. <https://www.for.gov.bc.ca/HFD/library/Documents/Bib92994.pdf>
33. Brackett J, Newbound G, Speare D, J. 1991. A fall survey of saltwater morbidity and mortality in farmed salmon in British Columbia. Victoria BC: Province of British Columbia Ministry of Agriculture and Fisheries. <http://library.nrs.gov.bc.ca/digipub/1990NovemberFishHealthSurvey.pdf>
34. Marty GD, Bidulka J, Joseph T. 2020. Cross-sectional study of histopathology and piscine orthoreovirus during a marine production cycle of farmed Atlantic salmon (*Salmo salar* L.) in British Columbia, Canada. Journal of Fish Diseases.43(9):1019-1028. <https://doi.org/10.1111/jfd.13210>

35. Marty GD. Independent assessment by Dr. Gary D. Marty, Senior Fish Pathology Consultant, of Bateman et al. 2021. Scientific Reports 11(1):3466 In: BCSFA, editor. 2023
36. Bateman AW, Schulze AD, Kaukinen KH, Tabata A, Mordecai G, Flynn K, et al. 2021. Descriptive multi-agent epidemiology via molecular screening on Atlantic salmon farms in the northeast Pacific Ocean. Scientific reports.11(1):1-15,
37. Rechisky EL, Porter AD, Johnston SD, Stevenson CF, Hinch SG, Hunt BPV, Welch DW. 2021. Exposure Time of Wild, Juvenile Sockeye Salmon to Open-Net-Pen Atlantic Salmon Farms in British Columbia, Canada. North American Journal of Fisheries Management.41(3):650-660.<https://doi.org/10.1002/nafm.10574>
38. Armstrong R, Robinson J, Rymes C, Needham T. 1993. British Columbia. Infectious hematopoietic necrosis in Atlantic salmon in British Columbia. Can Vet J.34(5):312-3,
39. Traxler G, Roome J, Kent M. 1993. Transmission of infectious hematopoietic necrosis virus in seawater. Diseases of Aquatic Organisms.16:111-111, <https://www.int-res.com/articles/dao/16/d016p111.pdf>
40. Commission PS. 2023. Report of the Fraser River Panel to the Pacific Salmon Commission on the 2021 Fraser River Sockeye and Pink Salmon Fishing Season. Vancouver, B.C.: Pacific Salmon Commission.<https://www.psc.org/download/32/frp-annual-reports/15093/2021-frp-annual-report.pdf>
41. Fisheries and Oceans Canada. 2024. NuSEDS-New Salmon Escapement Database System Ottawa: Open Government Canada; [Available from: <https://open.canada.ca/data/en/dataset/c48669a3-045b-400d-b730-48aaf8c5ee6>.
42. Keith I. Examples important to government-run wild salmon enhancement hatcheries in British Columbia In: Marty GD, editor.: Personal Communication; 2023
43. Fisheries and Oceans Canada. 2017. Freshwater/land-based aquaculture licence under the Fisheries Act Ottawa: Government of Canada; [Available from: <https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/licence-cond-permis-fresh-douce/index-eng.html>.
44. Fisheries and Oceans Canada. 2018. Aquaculture Activities Regulations guidance document. Ottawa: Government of Canada; Sept. 9, 2018. Contract No.: March 2024.<https://www.dfo-mpo.gc.ca/aquaculture/management-gestion/aar-raa-gd-eng.htm#purpose>
45. Fisheries and Oceans Canada. 2023. Marine finfish B.C. aquaculture licence and conditions of licence. Nanaimo: Government of Canada.<https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/licence-cond-permis-mar/index-eng.html>
46. Open Government. 2024. National Aquaculture Public Reporting Data Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/288b6dc4-16dc-43cc-80a4-2a45b1f93383>.
47. Office of the Chief Veterinarian. 2024. Reportable and notifiable diseases Victoria: Government of British Columbia; [Available from: <https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/animal-health/reportable-notifiable-diseases>.



48. Fisheries and Oceans Canada. 2022. Regulating and monitoring British Columbia's marine finfish aquaculture facilities - 2020: What happens during a fish health audit Ottawa: Government of Canada; [Available from: <https://www.dfo-mpo.gc.ca/aquaculture/management-gestion/mar-rep-rap-2020/index-eng.html#audit>.
49. Canadian General Standards Board. 2023. Organic production systems. Ottawa, Ontario: Canadian General Standards Board.https://publications.gc.ca/collections/collection_2023/ongc-cgsb/P29-32-312-2023-eng.pdf
50. World Organisation for Animal Health. 2022. Aquatic Animal Health Code: World Organisation for Animal Health [Available from: https://www.woah.org/en/what-we-do/standards/codes-and-manuals/aquatic-code-online-access/?id=169&L=1&htmlfile=chapitre_diseases_listed.htm.
51. Suttle CA. 2007. Marine viruses — major players in the global ecosystem. *Nature Reviews Microbiology*.5(10):801-812.10.1038/nrmicro1750
52. Eufic. 2021. What is the microbiome and why is it important?; (March 2024). Available from: <https://www.eufic.org/en/food-production/article/what-is-the-microbiome-and-why-is-it-important>.
53. Lee E. We're Only About 43% Human, Study Shows. Washington D.C.: Voice of America (VOA) 2019.<https://www.voanews.com/a/research-estimates-we-are-only-about-43-percent-human/4932876.html>
54. Zhang YZ, Wu WC, Shi M, Holmes EC. 2018. The diversity, evolution and origins of vertebrate RNA viruses. *Curr Opin Virol*.31:9-16.10.1016/j.coviro.2018.07.017
55. Fisheries and Oceans Canada. 2018. Diagnostic Testing Ottawa: Government of Canada; [Available from: <https://www.dfo-mpo.gc.ca/science/aah-saa/testing-analyses-eng.html>.
56. Saksida SM. 2006. Infectious haematopoietic necrosis epidemic (2001 to 2003) in farmed Atlantic salmon *Salmo salar* in British Columbia. *Diseases of Aquatic Organisms*.72(3):213-223, <https://www.int-res.com/abstracts/dao/v72/n3/p213-223/>
57. Saksida SM, Fast MD, Garver KA, Johnson SC. Movement of Infectious Agents between Wild and Farmed Fish. 2023. In: *Climate Change on Diseases and Disorders of Finfish in Cage Culture* [Internet]. St James's Place, London, UK: CAB International. 3d. [351-386]. Available from: <https://doi.org/10.1079/9781800621640.0009>.
58. WOAH. 2023. Principles and methods of validation of diagnostic assays for infectious diseases. *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* 12 ed. Paris, France: World Organisation for Animal Health. p. 27.https://www.woah.org/fileadmin/Home/fr/Health_standards/tahm/1.01.06_VALIDATION.pdf
59. Hicks BD. 1989. British Columbia salmonid disease handbook. Province of British Columbia, Ministry of Agriculture and Fisheries. Report No.: 0772612730.https://www.crownpub.bc.ca/Product/Details/7610001108_S
60. Mimeault C, Nekouei O, Garver KA, Jones SRM, Johnson S, Aubry P, et al. 2020. Assessment of the risk to Fraser River Sockeye Salmon due to *Tenacibaculum maritimum* transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia. Ottawa, Ont.:

- Canadian Science Advisory Secretariat (CSAS). 49
[p.https://publications.gc.ca/collections/collection_2021/mpo-dfo/fs70-5/Fs70-5-2020-059-eng.pdf](https://publications.gc.ca/collections/collection_2021/mpo-dfo/fs70-5/Fs70-5-2020-059-eng.pdf)
61. Bateman AW, Teffer AK, Bass A, Ming T, Kaukinen K, Hunt BPV, et al. 2022. Atlantic salmon farms are a likely source of *Tenacibaculum maritimum* infection in migratory Fraser River sockeye salmon. *Canadian Journal of Fisheries and Aquatic Sciences*.79(8):1225-1240.10.1139/cjfas-2021-0164
 62. Miller KM, Gardner IA, Vanderstichel R, Burnley T, Angela D, Li S, et al. 2016. Report on the performance evaluation of the Fluidigm BioMark platform for high-throughput microbe monitoring in salmon. Ottawa, Ontario: DFO, Can. Sci. Advis. Sec. Res. Doc.<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/364015.pdf>
 63. Wakabayashi H, Hikida M, Masumura K. 1986. *Flexibacter maritimus* sp. nov., a Pathogen of Marine Fishes. *International Journal of Systematic and Evolutionary Microbiology*.36(3):396-398.<https://doi.org/10.1099/00207713-36-3-396>
 64. Valdes S, Irgang R, Barros MC, Ilardi P, Saldarriaga-Córdoba M, Rivera-Bohle J, et al. 2021. First report and characterization of *Tenacibaculum maritimum* isolates recovered from rainbow trout (*Oncorhynchus mykiss*) farmed in Chile. *Journal of Fish Diseases*.44(10):1481-1490.<https://doi.org/10.1111/jfd.13466>
 65. Chen ME, Henry-Ford D, Groff JM. 1995. Isolation and Characterization of *Flexibacter maritimus* from Marine Fishes of California. *Journal of Aquatic Animal Health*.7(4):318-326.[https://doi.org/10.1577/1548-8667\(1995\)007<0318:IACOMF>2.3.CO;2](https://doi.org/10.1577/1548-8667(1995)007<0318:IACOMF>2.3.CO;2)
 66. Peterman Randall M, Dorner B. 2012. A widespread decrease in productivity of sockeye salmon (*Oncorhynchus nerka*) populations in western North America. *Canadian Journal of Fisheries and Aquatic Sciences*.69(8):1255-1260.10.1139/f2012-063
 67. Stevenson CF, Hinch SG, Porter AD, Rechisky EL, Welch DW, Healy SJ, et al. 2019. The Influence of Smolt Age on Freshwater and Early Marine Behavior and Survival of Migrating Juvenile Sockeye Salmon. *Transactions of the American Fisheries Society*.148(3):636-651.<https://doi.org/10.1002/tafs.10156>
 68. Polinski MP, Vendramin N, Cuenca A, Garver KA. 2020. Piscine orthoreovirus: Biology and distribution in farmed and wild fish. *Journal of Fish Diseases*.43(11):1331-1352.<https://doi.org/10.1111/jfd.13228>
 69. Palacios G, Lovoll M, Tengs T, Hornig M, Hutchison S, Hui J, et al. 2010. Heart and Skeletal Muscle Inflammation of Farmed Salmon Is Associated with Infection with a Novel Reovirus. *PLOS ONE*.5(7):e11487.10.1371/journal.pone.0011487
 70. Purcell MK, Powers RL, Taksdal T, McKenney D, Conway CM, Elliott DG, et al. 2020. Consequences of Piscine orthoreovirus genotype 1 (PRV-1) infections in Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*) and rainbow trout (*O. mykiss*). *J Fish Dis*.43(7):719-728.10.1111/jfd.13182
 71. Kongtorp RT, Taksdal T, Lyngøy A. 2004. Pathology of heart and skeletal muscle inflammation (HSMI) in farmed Atlantic salmon *Salmo salar*. *Diseases of Aquatic Organisms*.59(3):217-224, <https://www.int-res.com/abstracts/dao/v59/n3/p217-224/>



72. Kibenge MJT, Iwamoto T, Wang Y, Morton A, Godoy MG, Kibenge FSB. 2013. Whole-genome analysis of piscine reovirus (PRV) shows PRV represents a new genus in family Reoviridae and its genome segment S1 sequences group it into two separate sub-genotypes. *Virology Journal*.10(1):230.10.1186/1743-422X-10-230
73. Purcell MK, Powers R, Evered J, Kerwin J, Meyers TR, Stewart B, Winton J. 2018. Molecular testing of adult Pacific salmon and trout (*Oncorhynchus spp.*) for several RNA viruses demonstrates widespread distribution of piscine orthoreovirus in Alaska and Washington. *Journal of Fish Diseases*.41(2):347-355,
74. Marty GD, Morrison DB, Bidulka J, Joseph T, Siah A. 2015. Piscine reovirus in wild and farmed salmonids in British Columbia, Canada: 1974–2013. *Journal of Fish Diseases*.38(8):713-728.<https://doi.org/10.1111/jfd.12285>
75. Siah A, Breyta RB, Warheit KI, Gagne N, Purcell MK, Morrison D, et al. 2020. Genomes reveal genetic diversity of Piscine orthoreovirus in farmed and free-ranging salmonids from Canada and USA. *Virus evolution*.6(2):veaa054-veaa054.10.1093/ve/veaa054
76. Siah A, Morrison DB, Fringuelli E, Savage P, Richmond Z, Johns R, et al. 2015. Piscine Reovirus: Genomic and Molecular Phylogenetic Analysis from Farmed and Wild Salmonids Collected on the Canada/US Pacific Coast. *PLOS ONE*.10(11):e0141475.10.1371/journal.pone.0141475
77. Di Cicco E, Ferguson HW, Schulze AD, Kaukinen KH, Li S, Vanderstichel R, et al. 2017. Heart and skeletal muscle inflammation (HSMI) disease diagnosed on a British Columbia salmon farm through a longitudinal farm study. *PLOS ONE*.12(2):e0171471.10.1371/journal.pone.0171471
78. Di Cicco E, Ferguson HW, Kaukinen KH, Schulze A, Li S, Tabata A, et al. 2018. The same strain of Piscine orthoreovirus (PRV-1) is involved in the development of different, but related, diseases in Atlantic and Pacific Salmon in British Columbia. *FACETS*.3(1):599-641.10.1139/facets-2018-0008
79. Morton A, Routledge R, Hrushowy S, Kibenge M, Kibenge F. 2017. The effect of exposure to farmed salmon on piscine orthoreovirus infection and fitness in wild Pacific salmon in British Columbia, Canada. *PLOS ONE*.12(12):e0188793.10.1371/journal.pone.0188793
80. Polinski MP, Marty GD, Snyman HN, Garver KA. 2019. Piscine orthoreovirus demonstrates high infectivity but low virulence in Atlantic salmon of Pacific Canada. *Scientific Reports*.9(1):3297.10.1038/s41598-019-40025-7
81. Garver KA, Marty GD, Cockburn SN, Richard J, Hawley LM, Müller A, et al. 2016. Piscine reovirus, but not jaundice syndrome, was transmissible to chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), sockeye salmon, *Oncorhynchus nerka* (Walbaum), and Atlantic Salmon, *Salmo salar* L. *Journal of fish diseases*.39(2):117-128,
82. Garver KA, Johnson SC, Polinski MP, Bradshaw JC, Marty GD, Snyman HN, et al. 2016. Piscine Orthoreovirus from Western North America Is Transmissible to Atlantic Salmon and Sockeye Salmon but Fails to Cause Heart and Skeletal Muscle Inflammation. *PLOS ONE*.11(1):e0146229.10.1371/journal.pone.0146229
83. Polinski MP, Zhang Y, Morrison PR, Marty GD, Brauner CJ, Farrell AP, Garver KA. 2021. Innate antiviral defense demonstrates high energetic efficiency in a bony fish. *BMC Biology*.19(1):138.10.1186/s12915-021-01069-2

84. Wessel Ø, Hansen EF, Dahle MK, Alarcon M, Vatne NA, Nyman IB, et al. 2020. Piscine Orthoreovirus-1 Isolates Differ in Their Ability to Induce Heart and Skeletal Muscle Inflammation in Atlantic Salmon (*Salmo salar*). *Pathogens*.9(12).10.3390/pathogens9121050
85. Gardner I. 2020. Marine finfish and land-based fish health technical working group Appendix 6 - Final report of the veterinary workshop: Fisheries and Oceans Canada,; [Available from: <https://www.dfo-mpo.gc.ca/aquaculture/publications/fhtwg-ttsp-eng.html#app6>.
86. Boily F, Malcolm G, Johnson SC. 2019. Characterization of *Aeromonas salmonicida* and furunculosis to inform pathogen transfer risk assessments in British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2019/2019_016-eng.html
87. Mimeault C, Aubry P, Wan D, Wade J, Boily F, Jones SRM, et al. 2020. Assessment of the risk to Fraser River Sockeye Salmon due to *Aeromonas salmonicida* transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2019/2019_017-eng.html
88. Garver K, Wade J. 2017. Characterization of infectious hematopoietic necrosis virus (IHNV). Canada FaO, Ottawa: DFO Canadian Science Advisory Secretariat (CSAS).https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2017/2017_073-eng.html
89. Mimeault C, Wade J, Foreman MGG, Chandler PC, Aubry P, Garver KA, et al. 2017. Assessment of the risk to Fraser River Sockeye Salmon due to Infectious Hematopoietic Necrosis Virus (IHNV) transfer from Atlantic Salmon farms in the Discovery Islands, British Columbia. Canada FaO, Ottawa: DFO Canadian Science Advisory Secretariat (CSAS). Assessment of the risk to Fraser River Sockeye Salmon due to Infectious Hematopoietic Necrosis Virus (IHNV) transfer from Atlantic Salmon farms in the Discovery Islands, British Columbia
90. Wade J, Weber L. 2020. Characterization of *Moritella viscosa* and winter ulcer to inform pathogen transfer risk assessments in British Columbia. Canada FaO, Ottawa: Canadian Science Advisory Secretariat (CSAS).<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/40952770.pdf>
91. Mimeault C, Nekouei O, Garver KA, Jones SRM, Johnson S, Holt K, et al. 2020. Assessment of the risk to Fraser River Sockeye Salmon due to *Moritella viscosa* transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia. Canada FaO, Ottawa: Canadian Science Advisory Secretariat (CSAS).https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2020/2020_058-eng.html
92. Polinski M, Garver K. 2019. Characterization of piscine orthoreovirus (PRV) and associated diseases to inform pathogen transfer risk assessments in British Columbia. Ottawa ON: Canadian Science Advisory Secretariat (CSAS). Report No.: 1919-5044.http://epe.lac-bac.gc.ca/100/201/301/weekly_acquisitions_list-ef/2019/19-39/publications.gc.ca/collections/collection_2019/mpo-dfo/fs70-5/Fs70-5-2019-035-eng.pdf
93. Mimeault C, Polinski M, Garver K, Jones S, Johnson S, Boily F, et al. 2019. Assessment of the risk to Fraser River Sockeye Salmon due to piscine orthoreovirus (PRV) transfer from

- Atlantic Salmon farms in the Discovery Islands area, British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).https://epe.lac-bac.gc.ca/100/201/301/weekly_acquisitions_list-ef/2019/19-39/publications.gc.ca/collections/collection_2019/mpo-dfo/fs70-5/Fs70-5-2019-036-eng.pdf
94. Jones SRM. 2019. Characterization of *Piscirickettsia salmonis* and salmonid rickettsial septicaemia to inform pathogen transfer risk assessments in British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/40852854.pdf>
 95. C. M, Jones SRM, Wade J, Aubry P, Johnson S, Foreman MGG, et al. 2019. Assessment of the risk to Fraser River Sockeye Salmon due to *Piscirickettsia salmonis* transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2019/2019_021-eng.html
 96. Rhodes LD, Mimeault C. 2019. Characterization of *Renibacterium salmoninarum* and bacterial kidney disease to inform pathogen transfer risk assessments in British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/40852817.pdf>
 97. Mimeault C, Wade J, Boily F, Johnson S, Jones SRM, Aubry P, et al. 2019. Assessment of the risk to Fraser River Sockeye Salmon due to *Renibacterium salmoninarum* transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2019/2019_019-eng.html
 98. Garver KA, Hawley LM. 2020. Characterization of viral haemorrhagic septicaemia virus (VHSV) to inform pathogen transfer risk assessments in British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).<https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/40953270.pdf>
 99. Parsons GJ, Burgetz, I.J., Weber, L., Garver, K.A., Jones, S.R.M., Johnson, S., Hawley, L.M., Davis, B., Aubry, P., Wade, J. and Mimeault, C. 2021. Assessment of the risk to Fraser River Sockeye Salmon due to viral haemorrhagic septicaemia virus IVa (VHSV-IVa) transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2020/2020_065-eng.html
 100. Wade AJ. 2019. Characterization of *Yersinia ruckeri* and enteric redmouth disease (ERM) to inform pathogen transfer risk assessments in British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).<https://waves-vagues.dfo-mpo.gc.ca/Library/40853032.pdf>
 101. Mimeault C, Wade J, Boily F, Johnson S, Jones SRM, Aubry P, et al. 2019. Assessment of the risk to Fraser River Sockeye Salmon due to *Yersinia ruckeri* transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia. Ottawa, Ont.: Canadian Science Advisory Secretariat (CSAS).https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2019/2019_023-eng.html

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CHAPTER 12

CARING FOR COMMUNITIES

FOOD SAFETY AND SECURITY



This document describes the health benefits of farm-raised salmon and measures farmers take to ensure food safety

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CHAPTER HIGHLIGHTS – CARING FOR COMMUNITIES – FOOD SAFETY

Healthy – supports heart and eye health

Nutritious – high protein, rich in essential omega-3 fatty acids, vitamins and minerals

American Heart Association – recommends eating fish rich in omega-3 fatty acids twice a week

Safe – rigorously tested by the Canadian Food Inspection Agency

By Canadians – provides 38 million meals per year

No growth hormones

Locally grown

All chemical residues - well below food safety limits

Processed in licensed facilities





Did you know that three-quarters of the salmon harvested in British Columbia are raised on farms yearly? BC salmon farmers proudly grow healthy, high-quality food for Canadian families like terrestrial farmers. BC produces approximately 56,000 tonnes of farm-raised salmon annually, or about 38 million healthy, nutritious meals.

Farm-raised salmon is a healthy food, recommended by experts, as it is rich in essential fatty acids and low in mercury. Studies have demonstrated the many

health benefits of omega-3 fatty acids found in farm-raised salmon, including reducing the risks of heart disease and supporting eye health.

To ensure that BC farm-raised salmon is safe to eat, there are safeguards in place. For example, fish can only be processed in licenced processing facilities. Farm-raised salmon are regularly tested for residues, including antibiotics and pesticides, heavy metals, and PCBs, by the sector and the Canadian Food Inspection Agency to ensure fish are safe for Canadians to eat.



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ARE FARM-RAISED SALMON SAFE TO EAT?

Yes. Farm-raised salmon are safe to eat, and experts recommend eating it! Farm-raised salmon is a nutrient-rich protein high in healthy omega-3 fatty acids. Many of the essential vitamins and minerals that the American Heart Association highly recommends are highly recommended by Canada's new Food Guide (1). Canada's Heart and Stroke Foundation recommends eating fish high in omega-3 fatty acids and low in mercury, such as Atlantic salmon, as an essential part of a heart-healthy diet (2).



FARM-RAISED SALMON IS GOOD FOR THE BODY AND THE MIND

Omega-3 fatty acids, found commonly in salmon, have been shown to reduce triglycerides in your blood, reduce the risk of developing an irregular heartbeat, slow the build-up of plaque, and may help lower blood pressure (3). Omega-3 fatty

acids have been demonstrated to support eye health (4) and help maintain brain health and reduce cognitive decline (5). Skin and hair also benefit from omega-3 fatty acids (6).



Total mercury in BC farm-raised salmon is well below limits set by Health Canada and similar to or lower than that of BC wild caught salmon.

DO I HAVE TO BE WORRIED ABOUT MERCURY IN FARM-RAISED SALMON?

No. The Canadian Food Inspection Agency tests fish, including farm-raised salmon, for mercury at each processing plant. Results have shown that mercury in farm-raised salmon is well within safe eating limits. A recent study has also demonstrated that total mercury in BC farm-raised salmon was below the limit of 0.5 µg/g set by Health Canada; at 0.021 µg/g- similar to or lower than that of wild BC-caught salmon (0.013-0.077 µg/g)(7, 8).

Some fish species have high mercury levels, while salmon, farm-raised or wild, do not. Some species of tuna, shark and swordfish can have unsafe levels of mercury.

Mercury is a naturally occurring metal found in the environment in soil, rocks, and water. Some environments can have higher levels of mercury caused by human activities such as burning waste, mining, and coal fire power generation. Fish bioaccumulate mercury in their tissues as a result of eating foods with mercury, including plants or other fish. This is why long-lived top predatory fishes such as some tuna species, which consume other fish, can have higher levels of mercury in their tissues. They have consumed mercury through bioaccumulation in many other fish.

The BC Centre for Disease Control (BCCDC) has stated that mercury toxicity in humans is rare in Canada. The two likely sources of exposure are the consumption of large predatory fish high in mercury and occupational exposure, including working around smelting, recycling, and other industries. Salmon, farm-raised or wild, does not appear on their list of fish species commonly found with moderate or high levels of mercury.

ARE GROWTH HORMONES USED?

No. Growth hormones are not approved for use in farm-raised fish in Canada nor used in most animal food production.



ARE FARM-RAISED ATLANTIC SALMON HIGH IN PCBs?

No. Levels of polychlorinated biphenyls (PCBs) and dioxins in farm-raised Atlantic salmon from BC are up to 71 times *lower* than Health Canada's level of 2000 parts per billion for edible fish products (7). Several recent studies have demonstrated that levels of PCBs in fish are very low, similar, or less than in other foods such as beef, chicken, and pork (9).

Health Canada is currently reviewing its limits for a number of substances in food, including PCBs (8).

Dioxins and PCBs are toxic, environmentally persistent substances that accumulate in the food chain. They are a class of industrial chemicals that were once used in the manufacturing of goods such as electronics. Because of both environmental and human health concerns, the import, manufacture and sale in Canada was banned in 1977; their release into the environment was made illegal in 1985 (8).



Farm-raised Atlantic salmon have PCBs in their flesh, albeit at extremely low levels, because of the ingredients that go into their feed, specifically fish oils. In order to minimize the amount of PCBs potentially getting into Atlantic salmon feeds,

manufacturers source raw materials from areas known to have lower environmental levels of PCBs and continue to decrease the dependence on fish oils by substituting other sustainable ingredients.



PCBs in farm-raised salmon are very low and similar or less than in other foods such as beef, chicken and pork.

ARE DRUGS AND ANTIMICROBIALS USED?

BC farm-raised Atlantic salmon are rarely treated with antimicrobials (antibiotics). BC farm-raised certified organic Chinook salmon are not treated with any antimicrobials during grow-out to maintain their organic status. Should they need to be treated, they cannot be sold as certified organic.

Many countries, including the United States of America (USA), use more antimicrobials in agriculture than in humans, but the data are not always

reported. For example, in the USA, more than 70% of the antimicrobials identified as medically important for humans are sold for use in animals (10). The United Nations warns that by 2030, antimicrobial resistance at livestock farms could force more than 24 million people into extreme poverty, and drug-resistant diseases in humans will likely result in 10 million deaths yearly by 2050 (10) (11).

Medicines used in farming salmon are regulated differently than in other agriculture sectors. In Canadian aquaculture, antimicrobials can only be prescribed by a licenced veterinarian; they cannot be prescribed prophylactically (preventively) to prevent a disease from occurring or for growth promotion. They may only be used when a clinical disease is diagnosed. There are only four antimicrobials licenced for use in BC salmon farming. In BC, all antimicrobials used must be reported to DFO and data on the treatment of fish with antibiotics is made publicly available in Fish Health Event Reports on Canada's Open Government portal (12).

The use of antimicrobials in farm-raised Atlantic salmon in BC has decreased dramatically in the past 20 years due to improvements in production, health management, and livestock selection (Figure 1). Most bacterial infections in Atlantic salmon can now be prevented with vaccines. However, antimicrobials are occasionally needed to treat diseases such as yellow mouth and SRS (Salmon Rickettsial Septicaemia). The development of effective vaccines could further reduce the need to treat these diseases with antimicrobials.

The Canadian Food Inspection Agency and producers test fish, including farm-raised salmon, for antimicrobial residue at each processing plant.



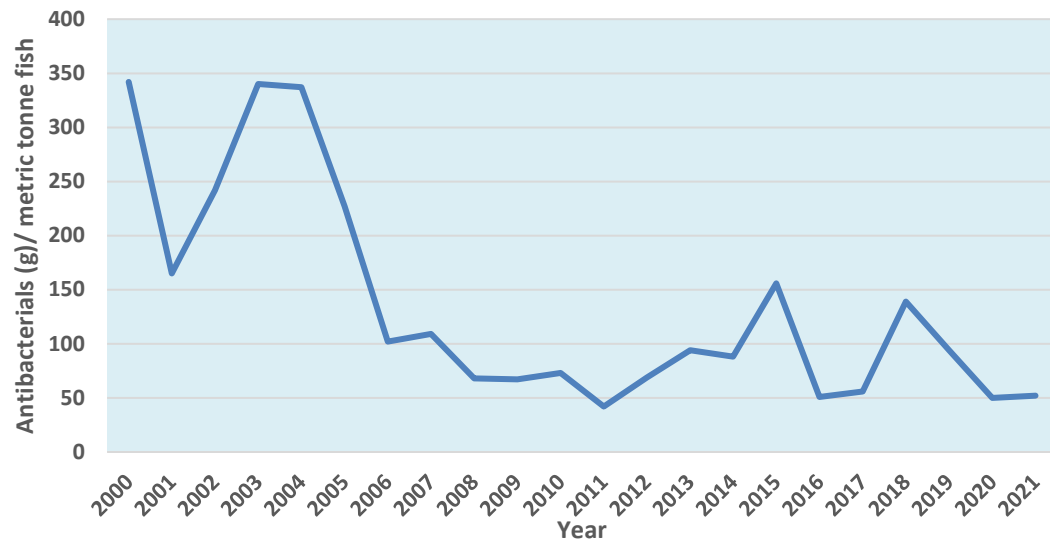


Figure 1. Reduction in antimicrobial use in farm-raised Atlantic salmon in BC, 2000 – 2021.

Source [DFO open data \(13\)](#)



HOW DO I KNOW THE FISH ARE SAFE TO EAT?

All farm-raised salmon are processed in licenced, inspected processing plants following Preventive Control Plans and HACCP (hazard analysis and critical control points) principles (14). In Canada, there are regulations which require farmers to demonstrate that fish do not exceed acceptable levels of a number of compounds to ensure the fish is safe for human consumption. Fish are tested for the following groups of compounds: heavy metals, pesticides and herbicides, antibiotics, polyaromatic hydrocarbons, dyes, dioxins, and furans. In addition, any fish being exported may have other testing requirements to comply with importing country's specific regulations.

To ensure quality, companies also test their fish for dozens of different nutritional parameters including protein, calories, and fatty acids. Third-party certifications, including Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP), also have their own testing and food safety requirements; BC organically certified Chinook salmon farmers must follow the Organic Aquaculture Standard (15-17). All Atlantic salmon farms in BC are BAP-certified, and

many are ASC certified. In addition, processing facilities can be BAP certified themselves. Guidelines for these standards are available online (18).

In Canada, there is a very short list of therapeutants can be used to treat farm-raised Atlantic salmon. Therapeutants can be drugs or pesticides. They are all administered under prescription by a licenced veterinarian. Veterinary drugs authorized for sale by Health Canada for use in farm-raised salmon include four antimicrobials, one anesthetic, two parasiticides and one fungicide (19).

The Veterinary Drug Directory (VDD) through Health Canada is responsible for protecting both human and animal health and Canada's food supply. The VDD determines the withdrawal times and residue limits for farm-raised Atlantic salmon for all veterinary drugs. A list of all approved drugs as well as withdrawal periods is provided to the public by Health Canada (19). Residue limits for these drugs are monitored in the muscle and or skin. If residue limits are exceeded, the product will not enter the food chain (20).



ARE FARM-RAISED SALMON PINK BECAUSE THEY ARE DYED?

No. Wild and farm-raised salmon have pink flesh because of the foods that they eat. Salmon, both in the wild and those raised on farms, have pink flesh from consuming carotenoids.

Carotenoids are essential pigments produced by bacteria, fungi, algae and plants. Since animals cannot make carotenoids on their own, these pigments are accumulated from food or partly modified through their own metabolic reactions (21). Many carotenoids have been shown to be antioxidants, directly

improving the immune system aiding in disease resistance, improved growth, survival, and egg quality (22).

Wild salmon consume prey species such as krill which are high in carotenoids, particularly astaxanthin and canthaxanthin. Farm-raised Atlantic salmon fish pellets are supplemented with naturally-sourced as well as synthetic astaxanthin. Farm-raised organically certified Chinook salmon feed is supplemented with a natural astaxanthin pigment to maintain compliance with their organic certification.

ARE BC FARM-RAISED SALMON GENETICALLY MODIFIED?

No. There are no genetically modified (GM) farm-raised salmon produced in BC.

Health Canada and the Canadian Food Inspection Agency have approved the genetically modified AquAdvantage Salmon to be sold in Canada for human consumption and livestock feed (23). In BC, there are no AquAdvantage Salmon being produced.





REFERENCES

1. Canada Go. 2024. Canada's Food Guide Ottawa: Government of Canada; [Available from: <https://food-guide.canada.ca/en/>].
2. Rosenbloom C. 2021. Your healthy fish guide. Heart and Stroke [Internet]. Available from: <https://www.heartandstroke.ca/articles/your-healthy-fish-guide>.
3. Mayo Clinic Staff. 2023. Omega-3 in fish: How eating fish helps your heart. Available from: <https://www.mayoclinic.org/diseases-conditions/heart-disease/in-depth/omega-3/art-20045614>.
4. B. Domènech E, Marfany G. 2020. The Relevance of Oxidative Stress in the Pathogenesis and Therapy of Retinal Dystrophies. *Antioxidants*.9(4):347, <https://www.mdpi.com/2076-3921/9/4/347>
5. Giudici KV. 2021. Nutrition-Based Approaches in Clinical Trials Targeting Cognitive Function: Highlights of the CTAD 2020. *The Journal of Prevention of Alzheimer's Disease*.8(2):118-122.10.14283/jpad.2021.6
6. Huang T-H, Wang P-W, Yang S-C, Chou W-L, Fang J-Y. 2018. Cosmetic and Therapeutic Applications of Fish Oil's Fatty Acids on the Skin. *Marine Drugs*.16(8):256, <https://www.mdpi.com/1660-3397/16/8/256>
7. Ikonomou MG, Higgs DA, Gibbs M, Oakes J, Skura B, McKinley S, et al. 2007. Flesh Quality of Market-Size Farmed and Wild British Columbia Salmon. *Environmental Science & Technology*.41(2):437-443.10.1021/es060409+
8. Health Canada. 2020. Health Canada's Maximum Levels for Chemical Contaminants in Foods Ottawa: Government of Canada; [Available from: <https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/chemical-contaminants/maximum-levels-chemical-contaminants-foods.html#a4>].
9. Mozaffarian D, Rimm EB. 2006. Fish Intake, Contaminants, and Human Health Evaluating the Risks and the Benefits. *JAMA*.296(15):1885-1899.10.1001/jama.296.15.1885
10. O'Neill J. 2016. Tackling drug-resistant infections globally: final report and recommendations: Government of the United Kingdom.<https://apo.org.au/node/63983>
11. New report calls for urgent action to avert antimicrobial resistance crisis [press release]. New York NY: World Health Organization, 29 April 2019 2019.
12. Open Government. 2023. Fish health events at British Columbia marine finfish aquaculture sites - Data - Fish health events - English Ottawa: Government of Canada; [Available from: <https://open.canada.ca/data/en/dataset/deefd1d7-7184-44c7-83aa-ec0db91aad27/resource/8d2a641b-7745-36b8-a5e7-075a6ec263c1>].
13. Fisheries and Oceans Canada. 2022. Use of therapeutants Ottawa: Government of Canada; [Available from: <https://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/therapeut/index-eng.html#antibacterial-data>].
14. Canadian Food Inspection Agency. 2021. Preventive control plan (PCP) Ottawa: Government of Canada; [Available from: <https://inspection.canada.ca/preventive-controls/preventive-control-plans/eng/1512152894577/1512152952810>].
15. ASC. 2024. Aquaculture Stewardship Council [Available from: <https://asc-aqua.org/>].

16. Best Aquaculture Practices. 2024. Keeping Fish in Our Future Portsmouth, NH, USA Global Seafood Alliance; [Available from: <https://www.bapcertification.org/>].
17. Standards Council of Canada. 2013. Organic production systems : aquaculture - general principles, management standards and permitted substances lists. Ottawa: Government of Canada; [Available from: <https://publications.gc.ca/site/eng/9.919789/publication.html>].
18. Best Aquaculture Practices. 2024. Program Standards Portsmouth, NH, USA Global Seafood Alliance; [Available from: <https://www.bapcertification.org/Standards>].
19. Health Canada. 2010. List of Veterinary Drugs that are Authorized for Sale by Health Canada for Use in Food-Producing Aquatic Animals - Health Canada Ottawa: Government of Canada; [Available from: <https://www.canada.ca/en/health-canada/services/drugs-health-products/veterinary-drugs/legislation-guidelines/policies/list-veterinary-drugs-that-authorized-sale-health-canada-use-food-producing-aquatic-animals.html>].
20. Canadian Food Inspection Agency. 2018. CFIA aquaculture therapeutant residue monitoring list Ottawa: Government of Canada; [Available from: <https://inspection.canada.ca/preventive-controls/fish/aquaculture-therapeutant-residue-monitoring-list/eng/1515417397242/1515417466758>].
21. Maoka T. 2020. Carotenoids as natural functional pigments. Journal of Natural Medicines.74(1):1-16.10.1007/s11418-019-01364-x
22. Colombo S, cartographer The colour of farmed salmon comes from adding an antioxidant to their feed, with benefits for everyone2023.
23. Health Canada and Canadian Food Inspection Agency approve AquAdvantage Salmon [press release]. Ottawa2016.



CHAPTER 13

CARING FOR COMMUNITIES

SALMON AQUACULTURE IN COASTAL COMMUNITIES



This document describes the benefits to communities
from salmon farming in coastal British Columbia

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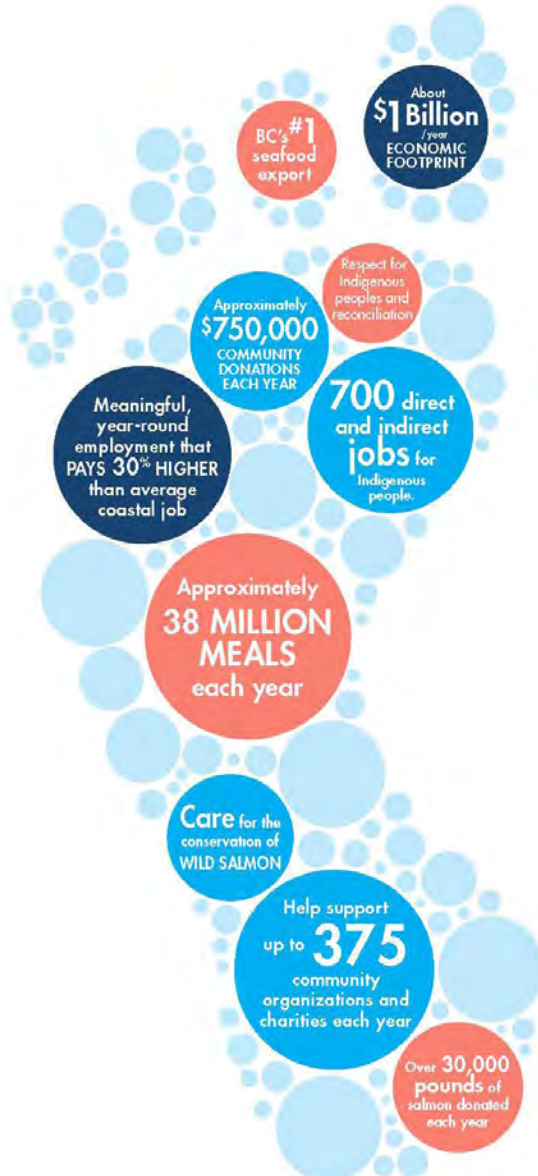
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CHAPTER HIGHLIGHTS - CARING FOR COMMUNITIES – SALMON AQUACULTURE IN COASTAL COMMUNITIES



OUR COMMUNITY FOOTPRINT

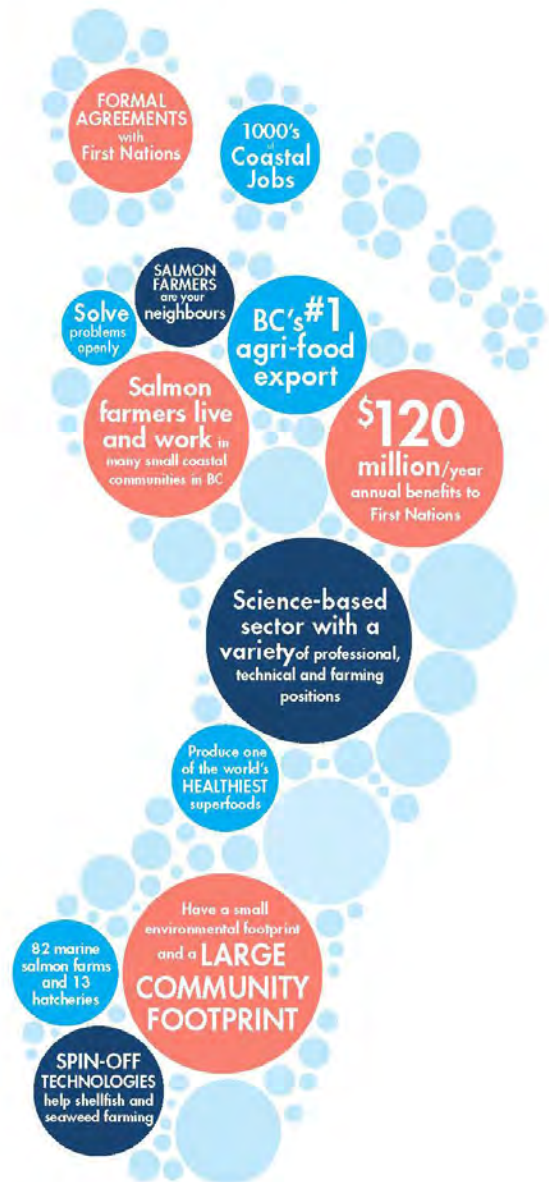




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INTRODUCTION

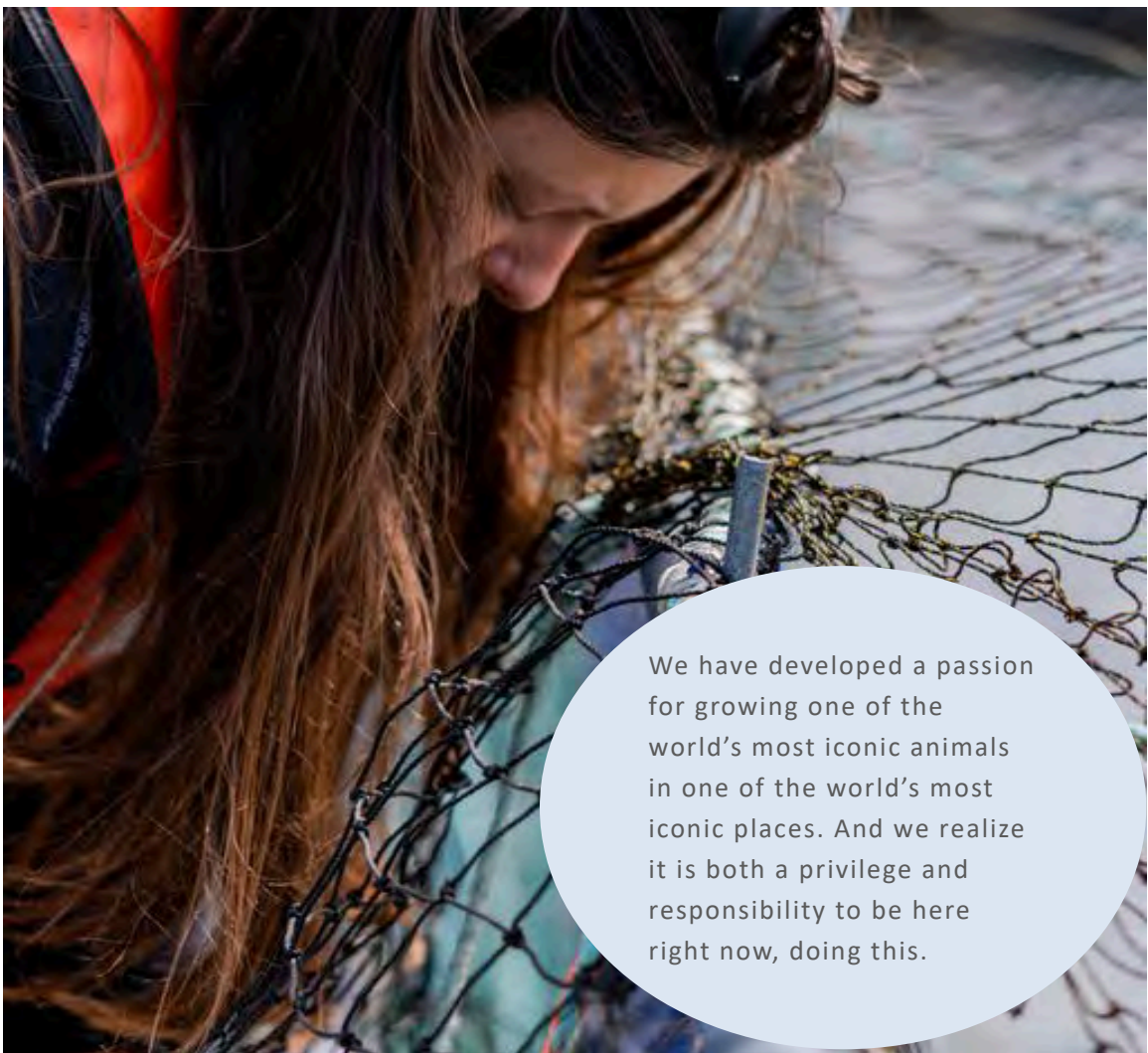
Have you ever wondered what it's like to be a salmon farmer? What is it that makes people so passionate about growing fish? It's hard to believe, but 45 years ago, there was no salmon farming in British Columbia.

Over the years, we have made incredible progress in shrinking our environmental footprint while growing our community footprint.

We know our role is to grow salmon in harmony with nature and the communities

of coastal British Columbia. The well-being of our fish relies on the vitality of the ocean. Knowing this, we are focused on being part of the solution for climate change, feeding the world, and conserving wild salmon by taking pressure off wild stocks.

We wholeheartedly dedicate ourselves to the prosperity of the ocean and coastal communities while also extending our support to First Nations in whose territories we operate.



We have developed a passion for growing one of the world's most iconic animals in one of the world's most iconic places. And we realize it is both a privilege and responsibility to be here right now, doing this.

WORKING WITH OTHERS – COMMUNITY EMPLOYMENT

Salmon farmers live and work in many coastal communities in British Columbia. We have operations that stretch from Klemtu on the central coast, southward along both sides of Vancouver Island, and mainland BC along the Sunshine Coast and Vancouver (Figure 1).

While the actual footprint of farms in the ocean is extremely small (less than the size of Stanley Park in Vancouver), salmon

farming creates thousands of year-round jobs that, in turn, support thousands of families year-round.

This creates a ripple effect that many communities feel, where the first dollar is often generated and spent by salmon farmers and their suppliers and contractors (Figure 2). Collectively, these ripples provide economic stability to small coastal communities.



Figure 1. Location of salmon farm operations in British Columbia.

As of 2023, there are 82 marine salmon farms and 13 land-based hatcheries and farms. Species grown include Atlantic and Chinook salmon.



SALMON FARMING'S RIPPLE EFFECT

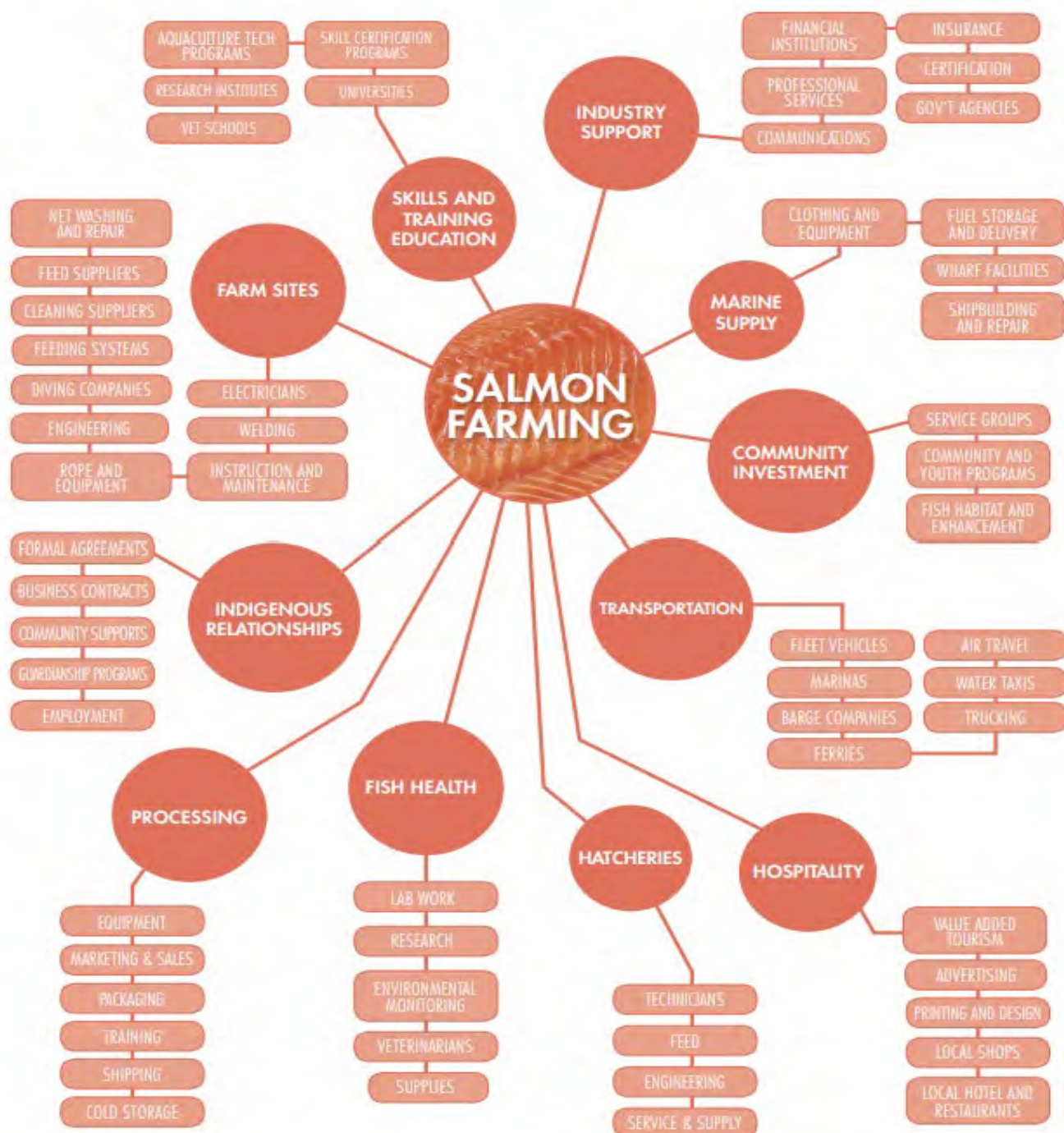


Figure 2. The ripple effect of salmon farming on coastal communities of British Columbia.



The average sector wage is 30% higher than the provincial median employment income. These jobs are typically created in areas of higher unemployment, particularly North Vancouver Island (1). In 2019, salmon farming generated 6,370 full-time equivalent (FTE) positions, including 2,860 direct FTEs, 2,620 indirect FTEs and 890 induced employment (2).

In 2019, salmon farming revenues in BC were \$819M and the total economic activity generated by the salmon farming sector across the province amounted to almost double that amount (\$1,615.1M)

(2). The total direct, indirect, and induced economic impacts of salmon farming by region are shown in Table 1.

Farm-raised salmon is BC's number one seafood commodity export and its top agrifood commodity export.

*Table 1. Regional impacts of salmon farming operations in British Columbia (2019).*

Source: (2)

Location	Jobs (FTE)	Labor Income (\$M)	GDP (\$M)	Revenue (\$M)	Number of local vendors	Annual spending on local vendors (\$M)
Comox Valley	193	14.3	17.4	48.1	178	27.2
Campbell River, Sayward, Discovery Islands	1,274	93.9	115	324.3	678	132.6
Port Hardy, Port McNeill	512	37.7	46.6	135.1	145	25.7
Port Alberni, Tofino, Ucluelet	215	15.9	19.5	55.3	104	20.3
West Coast Vancouver Island	181	13.4	16.4	47.3	56	13.3
Sunshine Coast, Metro Vancouver	1,373	101.2	122.1	325.7	447	282.9
Other Coastal	114	8.4	10.4	29.3	112	9
Additional Un-allocated Economic Impacts	2,507	185	229.6	650.1	N/a	N/a
Total	6,370	469.8	576.8	1,615.10	1,720	511

Despite recent downsizes in the salmon farming sector in BC, farm-raised salmon continued to lead the province in agricultural farm cash receipts from 2017 – 2021, surpassing dairy, vegetables and nursery plants (Figure 3). A June 2023 report for BCSFA estimates that the salmon farming sector currently generates “approximately \$1 billion in total economic activity, \$358 million in GDP, and \$223 million in income for families within BC annually, and creates 3,950 good paying jobs in the province, mainly in remote Indigenous and coastal communities of BC where there are very few alternative employment opportunities.” (3)

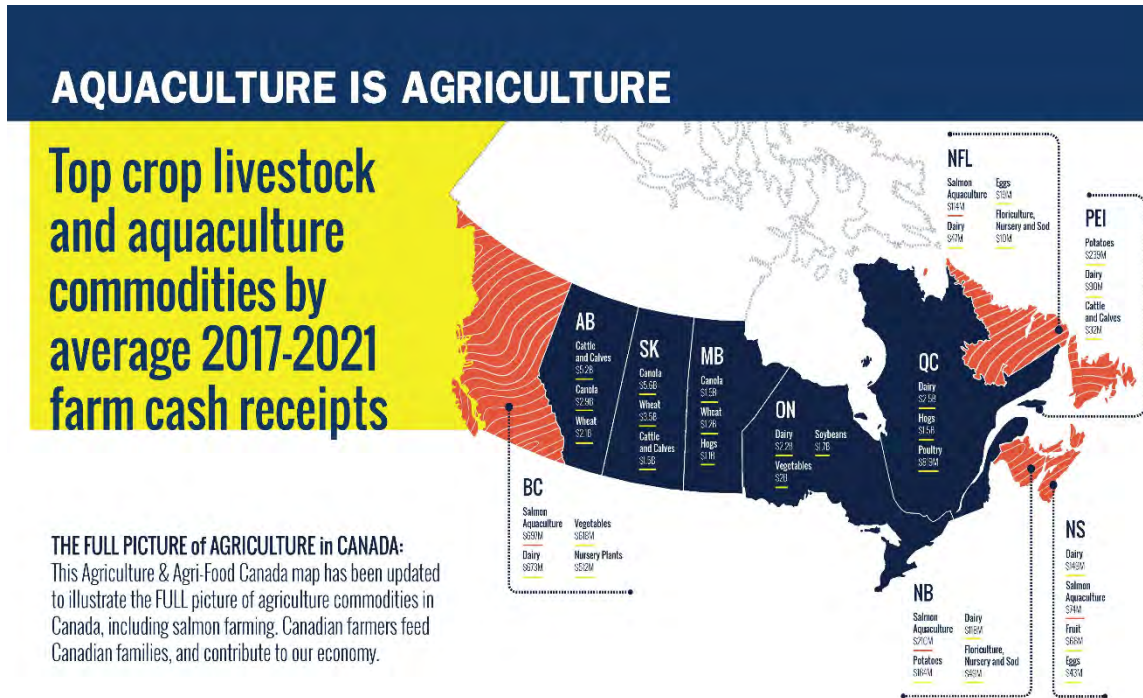


Figure 3. Top agricultural farm cash receipts, including aquaculture, by province in Canada (2017 – 2021).

Adapted from Government of Canada, Agriculture and Agri-food Canada (4).

CARING FOR OTHERS – COMMUNITY SUPPORTS

Each year, BC salmon farmers support hundreds of individual initiatives for education, health and well-being, arts, and sports (Figure 4). In 2018, BC salmon farmers made 375 contributions to organizations and charities, totaling over \$750,000 and over 30,000 pounds of farm-raised salmon.

During the Covid-19 pandemic, salmon farmers stepped up their donations to 120,000 pounds (about 500,000 meals) to help communities in need (Figure 5).

To us, it just makes sense to care for others.



Figure 4. Salmon farming companies help support up to 375 associations and charities each year within the local coastal communities of British Columbia.



Figure 5. BC salmon farmers partnered with Food Banks BC to produce and distribute 86,000 cans of salmon across the province during the Covid-19 pandemic.

Building strong communities starts with mentoring youth. The Young Salmon Farmers of BC are active in many communities with annual beach clean-ups, volunteering at eelgrass restoration projects, and fundraising for food bank donations. It is gratifying to know that these efforts are making a difference in coastal BC.





CONNECTING ON THE WATER AND AT THE TABLE



As part of our commitment to trust and transparency, BC salmon farmers provide tours to those interested in visiting a farm.

BC salmon farmers have hosted tours for hundreds of community members, First Nations, elected officials, special interest groups, and students so they can better understand the operations and ask the farmers questions.

Farm tours offer valuable educational opportunities, allowing community members to learn about sustainable farming practices, animal welfare, and environmental stewardship. This empowers individuals to make informed choices about their food and supports the growth of a more sustainable and responsible food system.



CONNECTING WITH THE CULINARY COMMUNITY

BC salmon farmers have ongoing initiatives connecting with young chefs in our communities as we understand the importance of knowing where your food comes from. BC salmon farmers have partnered and provided tours and salmon donations to Culinary Team British Columbia, Vancouver Island University and North Island College's culinary programs, and the BC Agriculture in the Classroom Foundation's Take a Bite of BC program, among many others (Figure 6 and 7).

Connecting chefs and farmers promotes a more sustainable and ethical food system. Chefs can work closely with our farmers to better understand farming practices and operations. This collaboration improves transparency and traceability and supports our local food supply. Chefs can develop a greater understanding of the growing process and harvest times. By prioritizing freshness and quality, chefs can provide their customers with an exceptional dining experience.



Figure 6. Chef Heejo Jung, part of Culinary Team British Columbia, with a prepared plate of Atlantic salmon.



Figure 7. Chef Heejo Jung and Aaron Hoffman from Culinary Team BC touring a salmon farm.

SUPPORTING COASTAL COMMUNITIES

As part of the sector's corporate responsibility, BC Salmon Farmers supports many community events and sponsorships within the coastal communities we operate in every year. Below are just a few examples.

Each July, Creative Salmon donates and barbecues for Ukee Days as part of its

commitment to community engagement. Ukee Days is a cherished annual Ucluelet festival that celebrates West Coast life.

Creative Salmon's involvement in this event spans over two decades and the company continues to support it by providing delicious fish each year.



Abby Fortune, Director of Parks and Recreation at the District of Ucluelet, appreciates Creative Salmon's longstanding support for Ukee Days. *"Every summer, Ukee Days brings our community together. Creative Salmon has been an integral part of this event for over 20 years, donating product, labour, and time to help make the evening a hit."*



"Without the generous contributions from industry like Grieg Seafood we would not have the successful program that we have now.", said Shane Dobler, Hatchery Manager, Powell River Salmon Society.

Grieg Seafood BC has been a key supporter of the Powell River Salmon Society. The donations received from Grieg Seafood BC help create employment opportunities as well as help pay for our operating expenses that are essential to our salmon enhancement and education programs.



Salmon farming companies like Grieg Seafood BC help our local hockey athletes with their expenses through their donation and sponsorship programs. Their generous funding allows the development of not just our Campbell River athletes but also their elite teammates all the way from Tri-Port, Powell River and as far as the Cowichan Valley, as they travel extensively all over BC, Alberta, and the U.S.

"It also plays an essential role in the awareness and promotion of girls/women's hockey programs.", said Jade Lontayao, Parent of Ashley Lontayao #5 - U18 North Island Impact Women's Hockey Team.



Mowi Canada West is proud to be a sponsor of K'awat'si Economic Development Corporation's (Gwa'sala-'Nakwaxda'xw Nations) Pack the Pantry Events that took place from March to September 2023. The purpose of these events is to collect donations of non-perishable goods to help with food

security in the Port Hardy area. Food security continues to be a big challenge, particularly for members and families of local First Nations. Donated items are given to the local Food Bank and First Nation Communities. There will be more events in the months to come.

Community Partnerships Manager, Kelly Osborne said, *"we are very grateful to have been invited to take part in these important events. It is about all of us working together to help people in need."*



BC Salmon Farmers support local community restoration projects like Project Watershed's Kus-kus-sum project. Kus-kus-sum is located along a major fish-bearing stream at the mouth of a class one estuary in the heart of the Comox

Valley. Once restored, the site will create 8.3 acres of fish and wildlife habitat, provide recreational and educational opportunities, help mitigate climate change, attenuate localized flooding, and put Indigenous reconciliation into action.



CONTINUING OUR COMMITMENTS

Like the rest of our neighbours in the small communities of coastal British Columbia, we are resilient to change, positive toward our future, and we are proud of what we have accomplished together.

Through all the changes we have experienced and through all the changes yet to come, we continue our commitment to the following principles:

- o Respect for rights and title and continuation on the path to reconciliation with First Nations,
- o Respect for wild salmon and the marine environment and an ongoing commitment to continued innovation and constant improvement,
- o To operate responsibly and sustainably to support the needs of Canadians now and in the future,
- o Build trust and transparency with our partners and the public,
- o Volunteering and donating in the communities we operate,
- o Build a diverse and inclusive sector, and
- o Hold ourselves accountable and always strive to be better.

IMAGINE THE FUTURE

BC salmon farmers contribute to Canada's sustainable, climate-friendly, and healthy food system. We imagine a bright future for salmon farming in British Columbia, a vision where this flourishing sector can continue to bring value to our coastal neighbours. Such a future holds tremendous potential, offering numerous benefits to both the economy and the environment. With increased investment and certainty, salmon farming in BC could provide substantial career opportunities, foster economic growth in coastal communities, and lead the Blue Economy for Canadians.

Moreover, it has the power to enhance food security by supplying a sustainable source of protein to meet rising global demand. Through responsible innovations and practices, salmon farming can preserve wild salmon populations and protect delicate marine ecosystems.

This future envisions a harmonious coexistence between aquaculture and the natural world, where the benefits of salmon farming are maximized while ensuring a healthy and thriving marine environment for generations to come.



Photo credit Brian Kingzett



REFERENCES

1. Collins B, McCannel J. Aquaculture on Vancouver Island. Prepared for the Vancouver Island Economic Alliance and Foreign Trade Zone Vancouver Island. Nanaimo, BC: Vancouver Island Economic Alliance; 2019. p. 16.<http://viea.ca/wp-content/uploads/2019/07/Aquaculture.pdf>
2. RIAS Inc. Raising Opportunity: How Farm-Raised Salmon Can Lead BC's Post-COVID Recovery. BC Salmon Farmers Association; 2020. p. 21.<https://bcsalmonfarmers.ca/news/salmon-farmers-poised-to-support-bcs-economic-recovery-with-1-4-billion-in-new-investment-independent-report-finds/>
3. RIAS Inc. Economic and Financial Impacts of Minister Murray's Transition Plan for BC Salmon Farms. Ottawa, Ont.: Prepared for the BC Salmon Farmers Association; 2023. p. 7
4. Agriculture and Agri-Food Canada. 2023. Book 4: Overview of the agriculture and agri-food sector Ottawa: Government of Canada; [Available from: <https://agriculture.canada.ca/en/departement/transparency/briefing-documents/book-4-overview-agriculture-and-agri-food-sector>.

