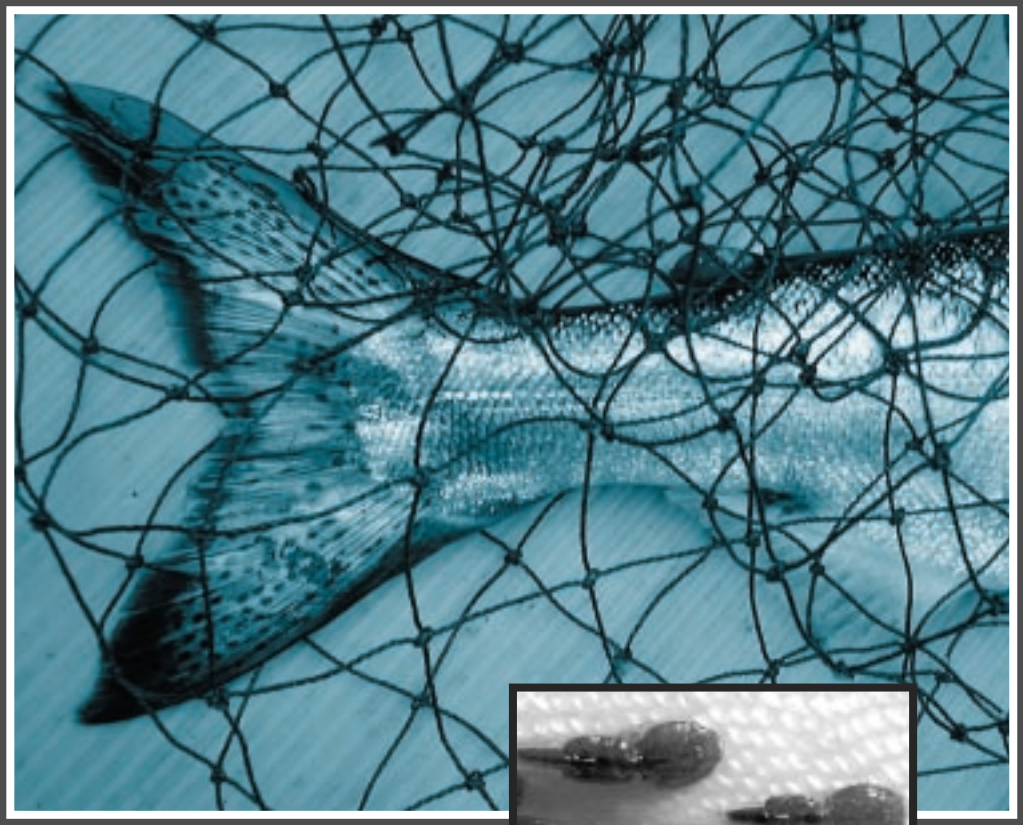
Sea Lice AND Salmon



Watershed Watch
SALMON SOCIETY

Elevating the dialogue on the farmed-wild salmon story

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Foreword

British Columbia boasts one of the greatest diversities of wild salmon on the planet. Some 8,000 races or "runs" of wild Pacific salmon still survive in BC's rivers, a diminished but still incredible tapestry of richness too often taken for granted.

It's hardly secret that BC's rich-but-fragile legacy—its natural, cultural and economic bounty—is under increasing assault from a host of human-related activities. It's also no secret that if we are truly interested in preserving wild salmon for the future, all threats to local populations of salmon must be carefully examined, including those posed by open net-cage aquaculture.

Watershed Watch, a science-based salmon conservation organization, spends much of its time "elevating the dialogue." Lately, Watershed Watch's efforts have focused on the connection between salmon farms and lice infestations of wild juvenile salmon. The "sea lice story" has resonated now for months—in meetings, on riverbanks, in the media, in scientific papers and workshops, and with an increasingly-concerned public.

Watershed Watch believes that the sustainable future of salmon hinges on the public being properly informed. Accordingly, Watershed Watch has produced 'fact sheets' that deal directly with questions concerning sea lice and salmon: What is a sea louse? How do lice harm fish? How many eggs do lice lay? How long do lice live? What's being done to deal with the lice threat?

Watershed Watch also recognizes that there is a bigger story—one involving other aquaculture and wild salmon issues and players—that needs to be told in order to provide the necessary context for the information on sea lice. Though the essays are science-based, they are written in lay language. Watershed Watch hopes they elevate the dialogue and improve our collective understanding of what is required to ensure that this modern story has a happy ending—for both wild salmon, and people.

Watershed Watch believes that the sustainable future of salmon hinges on the public being properly informed.

Steelhead being released on the Dean River.

Craig Orr photo

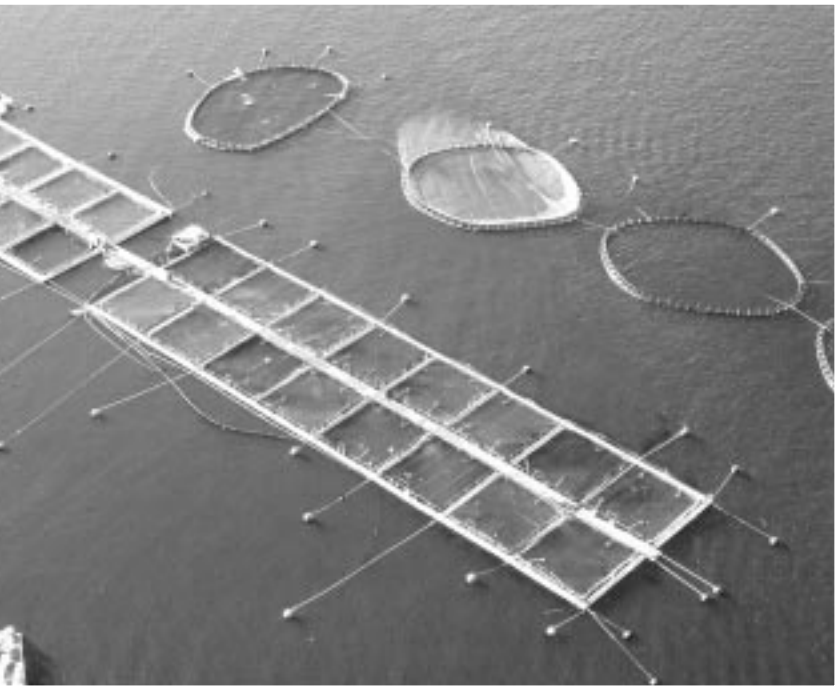
Aquaculture

1. WHAT IS AQUACULTURE?

Aquaculture refers to the raising of aquatic organisms such as fish, molluscs, crustaceans, and aquatic plants in environments modified to produce enhanced harvest rates, and includes fish farms and some fish hatcheries. Aquaculturists own the animals and plants they raise. [1]

There is evidence that aquaculture has been practiced the world over, for thousands of years—in China beginning about 4000 years ago, and in Mesopotamia, about 3500 years ago. The Roman Empire's aquacultural practices in the Mediterranean were later adopted by Christian monasteries throughout central Europe. [2]

Many people hope aquaculture will supplement or even replace many of the traditional commercial fisheries now in decline. Some believe fish farming is preferable to harvesting wild fish because fish farmers have considerable control over the environment in which their fish grow, and can provide consistent quality fish year-round.



Salmon farms are floating pens used for growing salmon.

David Suzuki Foundation photo

The finfish farming industry is relatively new to British Columbia, and salmon are the main crop. Though salmon are an integral part of British Columbia's economy, history and culture, runs of wild salmon have declined so precipitously that many of those who once worked in the commercial salmon fishery—and would prefer to do so now—are obliged to work in the salmon farming industry. The shift raises a number of social and environmental concerns, and helps explain why salmon farming has been controversial since it began here over three decades ago.

2. WHAT IS A SALMON FARM?

Most commonly, farmed salmon are raised in open net cages or mesh nets placed in sheltered bays and fjords along a coast. The nets of open-net farms are placed side by side, and are usually accessed by a floating wharf. Individual net pens used in BC are usually square or circular, have surface areas ranging from 150 to 1000 m^2, and are about 10 m deep. [3, 5]

BC's farmed salmon are hatched in privately owned land-based hatcheries. 'Brood-stock' eggs and milt are selected to produce fast-growing, big fish—that is, fish that efficiently convert food into flesh and mature quickly—that can tolerate crowding. The salmon eggs are fertilized and incubated and the young salmon are raised in hatcheries until able to live in saltwater pens, where they remain until they are harvested. [3]

3. CHRONOLOGY OF SALMON FARMING IN BC

Salmon farming began in BC in the early 1970s. [4] Here are some of the industry's milestones:

1970s Salmon farming in BC begins with small, locally-owned farms, mainly on the Sunshine Coast. Poor environmental conditions, diseases and market challenges force many out of business;

1980s First Nations, local communities, fishermen and environmentalists voice concerns about fish farms and their impact on the ocean and communities;

1985 Fisheries and Oceans Canada (DFO) permits Atlantic salmon eggs to be imported into BC despite disease dangers and possible displacement of native wild salmon;

1986 Gillespie Inquiry. Massive losses of farmed salmon, poor placement of salmon farms and growing complaints from the public force the provincial government to impose a month-long moratorium against approving new farm sites;

1985–90 BC's salmon farming industry expands from 10 to over 180 sites; [3]

1991 First report of Atlantic salmon attempting to spawn in a Pacific stream;

1995 Provincial government moratorium prevents new fish farms, and caps the number of tenures at 121. However, the size of farms is allowed to increase. Fish production increases during the moratorium;

1995–97 Environmental review of the fish farming industry (the Salmon Aquaculture Review—SAR) is initiated, presumably to address public concerns;

1997 The SAR's 49 recommendations are made public. The provincial government and the BC Salmon Farmers Association support the findings, and announce plans to implement them; [5]

2000 Federal Auditor General's audit identifies a conflict of interest between the Department of Fisheries and Oceans' promotion of salmon farming and its mandate to protect wild fish and wild fish habitat; [6]

2001 Standing Senate Committee on Fisheries' report reveals that DFO disregards its mandate to protect wild fish stocks; [7]

2001 David Suzuki Foundation-funded critique of the aquaculture industry (Leggatt Inquiry) is conducted; [8]

2002 Government of BC lifts its 1995 moratorium on new tenures;

2002 Broughton Archipelago pink salmon stocks crash. Fewer than 5% of the expected run returns. Both DFO and the Pacific Fisheries Resource Conservation Council (PFRCC) agree that the low numbers are exceptional. [9] Academic and independent scientists, First Nations, environmental groups, and local communities suspect sea lice infestations are responsible;

2002 The PFRCC releases an advisory to federal and provincial fisheries ministers, urging the immediate removal of Broughton Archipelago salmon farms in order to protect outward bound juvenile pink salmon in 2003; [9]

2003 Broughton Archipelago salmon farms remain open despite widespread media coverage on the issue and increasing public opposition to salmon aquaculture.

Runs of wild salmon have declined so precipitously that many of those who once worked in the commercial salmon fishery are obliged to work in the salmon farming industry.

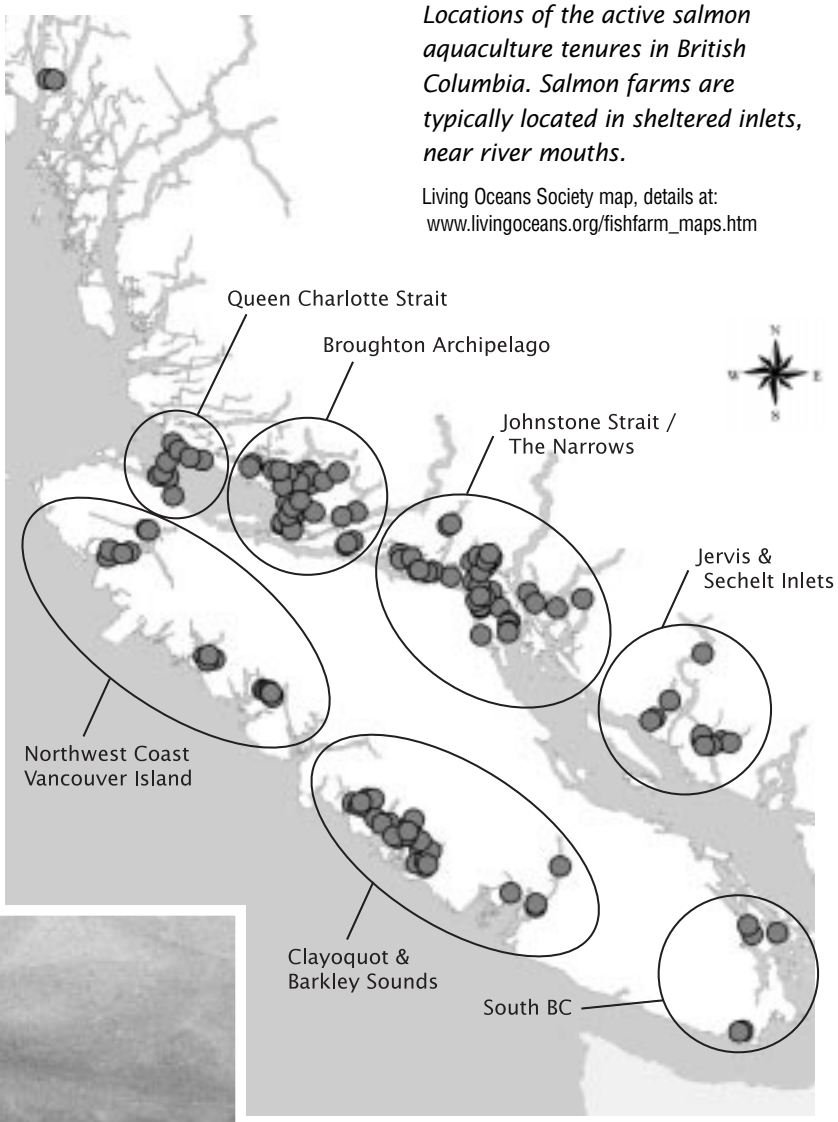
4. HOW MANY SALMON FARMS ARE THERE IN BC?

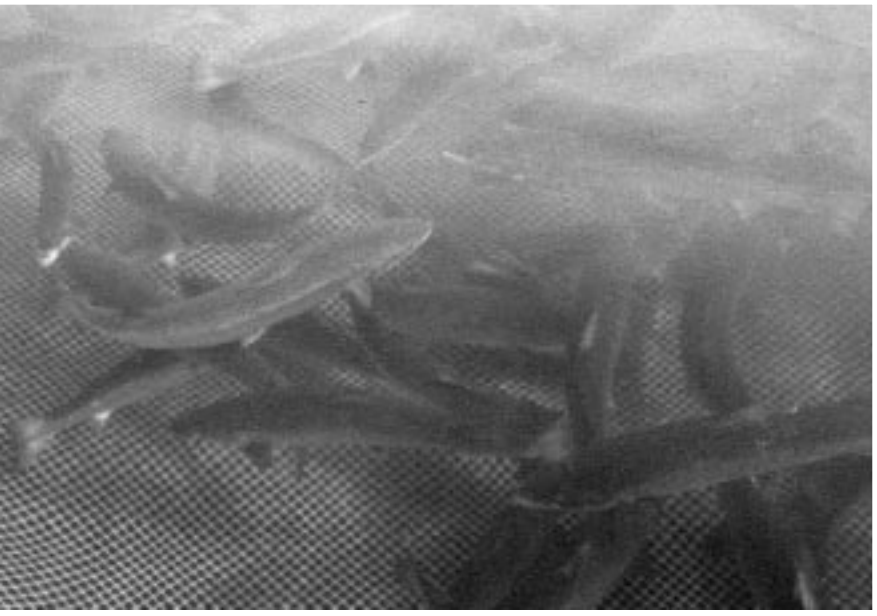
BC's coastline currently hosts 121 fish farm tenures, 80 of them active.[10] "Tenures" are legal entitlements issued by BC Land and Water, and "rule" how fish farms must operate on Crown Land. The number of tenures does not equal the number of fish farms. It identifies the number of government-approved fish farm sites.

FIGURE 1

Locations of the active salmon aquaculture tenures in British Columbia. Salmon farms are typically located in sheltered inlets, near river mouths.

Living Oceans Society map, details at: www.livingoceans.org/fishfarm_maps.htm





The average stocking density for Pacific salmon is 5–10 kg of fish per cubic metre.

David Suzuki Foundation photo

5. HOW MANY FISH ARE HOUSED IN THE FARMS?

BC fish farm pens of 1000 m^2 can house 35,000 to 90,000 fish depending on fish size and species.[3] Stocking densities range from 8–18 kg per m^3 for Atlantic salmon and 5–10 kg per m^3 for Chinook salmon.[5] To maximize growth and minimize losses associated with overcrowding, salmon farmers adjust stocking densities as penned salmon grow.

6. WHAT SPECIES OF SALMON ARE FARMED IN BC?

Over 80% of the salmon currently raised in BC's fish farms are Atlantic salmon. The remainder are two of the Pacific species, Chinook and coho. [10] Until 1985, fish farmers relied on the native coho and Chinook, and did poorly. The industry prospered after it switched to the easier-to-raise Atlantic salmon. From 1986 to 2001, the production of farmed salmon increased from 400 to 68,000 tonnes [11] —despite the moratorium which prevented expansion of the industry from 1995 to 2002.

7. HOW ADEQUATE ARE BC'S SALMON FARMING REGULATIONS?

Salmon farming in BC is conducted pretty much as it is elsewhere throughout the world. Fish in large, open net-pens in shallow bays are fed commercial feed, treated with antibiotics and other drugs, harvested at a specified size, and sold the world over. What differs are the regulations from one country to another. Although BC's aquaculture industry is relatively small (Norway had 854 salmon farms in 2000) [12], the province has yet to establish regulations beyond pollution control—which seems inadequate considering what BC has to lose. Although BC still has many of its original races of wild salmon, many of them are now at risk—from overfishing, habitat loss, and other problems. [13, 14] The diversity of wild Pacific salmon populations is a product of thousands of years of evolution. There are six main species of Pacific salmon (coho, sockeye, pink, chum, steelhead and Chinook) and only one species of Atlantic salmon. That BC still has vast areas of wilderness and that many animals, people and ecosystems rely on wild salmon underscores how foolhardy it is to introduce an alien species.

That BC still has vast areas of wilderness and that many animals, people and ecosystems rely on wild salmon underscores how foolhardy it is to introduce an alien species.

8. WHY ARE ATLANTIC SALMON FARMED ON THE PACIFIC OCEAN?

Commercial salmon farming originated in Europe, and then expanded to Canada's Maritime Provinces. Atlantic salmon were, and still are, the preferred salmon. They are more easily domesticated, have higher net-pen growth rates, and are more stress-resistant than their Pacific relatives. British Columbian fish farmers were having limited success farming Pacific salmon, so they pressured the Provincial and Federal governments to permit the introduction of Atlantic salmon into Canada's Pacific region—as Washington State had already been pressured into doing. [15]

9. ARE THERE MORE FARMED OR WILD SALMON IN THE OCEAN?

There are still more wild than farmed salmon in BC's coastal waters. However, in coastal waters of countries such as Norway—where salmon farming is more intensive and where wild salmon stocks have severely declined—farmed salmon often outnumber wild salmon by a wide margin.

FIGURE 2
BC Farmed Salmon Production 1986–2001

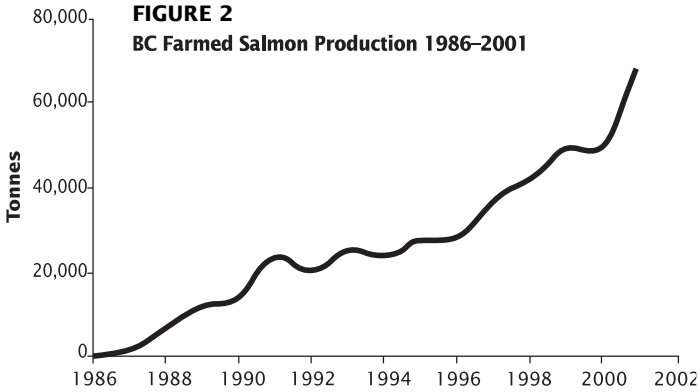
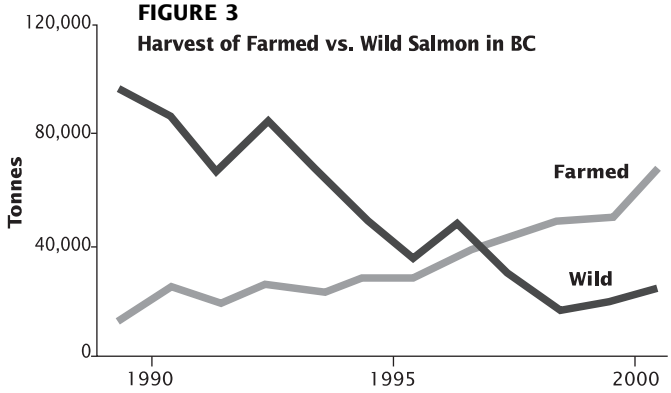


FIGURE 3
Harvest of Farmed vs. Wild Salmon in BC



10. WHAT HAPPENS WHEN SALMON ESCAPE FROM FARMS?

Farmed salmon can and do escape into the natural environment, but the seriousness of the problem is unknown. All aspects of the issue are debated—from the numbers of fish that escape to the impact that farmed fish have on the genetic, biological and ecological status of wild salmon.

More than 80 percent of the farms operating in BC aren't owned locally, but by large multinational corporations.

Genetic risks to wild salmon are greatest with Pacific farmed salmon, almost all of which are now Chinook. The potential for interbreeding between farmed and wild Chinook is high, whereas genetic differences make it unlikely that farmed Atlantic salmon would breed with wild Pacific salmon. [32] Because interbreeding decreases genetic diversity, disease resistance and adaptability, the genetic risks associated with escaped native farmed salmon are serious. [17]

The main ecological concern is how farmed fish may impact wild fish. Escaped farmed salmon—both Atlantic and Pacific—are capable of competing with wild salmon for food and habitat. Invertebrates and juvenile fish (including salmon) have been found in the stomachs of farmed Atlantic salmon. [33] Particularly worrisome are interactions between wild and feral farmed salmon on the same spawning grounds. [17] Regardless of unsuccessful attempts to introduce Atlantic salmon to BC from 1905 to 1934, [34, 35] escaped Atlantic salmon have now been documented in some 80 BC rivers [113] and are known to have spawned in the Tsitika River on northern Vancouver Island. [18] Rivers or streams with diminished wild Pacific salmon have lower 'biotic resistance' to colonization by Atlantics. [19]

It is difficult to determine the disease risk posed by escaped farmed salmon. Since the current number of escaped farm fish is relatively small compared to wild salmon, the threat of disease transfer may also be relatively low (depending on the disease). Disease transmission is more likely among net-penned farmed salmon and between farmed and wild salmon that swim by, or through, fish farms. [17]

It is one thing for the provincial government to ask or even require salmon farmers to report fish escapes and quite another thing to enforce the requirement and/or to determine whether the escapes occur. Understandably, the number and magnitude of the escapes are difficult to determine. The BC Ministry of Agriculture, Food and Fisheries (MAFF) reports a total of 500,000 farm salmon (mostly Atlantics) escaped from pens between 1992 and 2000. [20] With an estimated continuous leakage of 3%, some 2,800,000 fish may have escaped from farms over the past 8 years. [21]

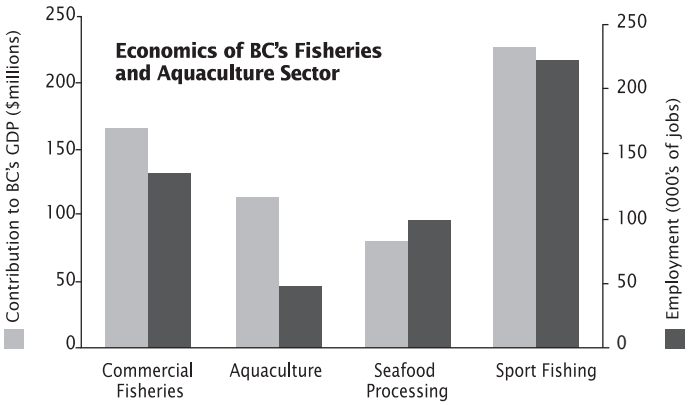
The impact escaped farmed Atlantic salmon have on wild Pacific salmon depends on how effectively the Atlantics adapt after escaping. One European study indicates that farmed Atlantic salmon adapt very well. Farmed salmon are routinely caught by commercial fishermen seeking wild salmon. In the Faroe Islands, between 20 and 40% of all fish caught are escaped farmed Atlantic salmon. [22]

11. DOES SALMON FARMING HELP BC'S ECONOMY?

Industry and government often claim that aquaculture contributes handsomely to the BC economy, both in terms of jobs created and money generated. [10, 23, 24] The reality is that aquaculture is a relatively modest contributor within the marine industry. [25]

In 2001, the entire BC aquaculture industry, from fish and shellfish farmers to feed producers to fish processors, employed fewer than 2,000 people, and generated less than $40 million in wages. The marine sports fishery alone contributed 4,700 jobs and $72 million in wages; marine tourism contributed 4,300 jobs and $134 million in wages. [26-28]

More than 80% of the farms operating in BC aren't owned locally, but by large multinational corporations based in Norway (Pan Fish, Stolt-Nielson, Ewos International), the Netherlands (Nutreco), and Eastern Canada (George Weston). [29] The benefits to the province appear to be much less than advertised.



12. WHY ARE PEOPLE CONCERNED ABOUT SALMON FARMING?

Along with salmon farming come concerns about how the salmon farming industry affects our economy and our environment. Salmon farming certainly hasn't relieved the pressure on wild salmon. Indeed it might even be part of the problem. Questions: Does the risk of transferring diseases to wild salmon and other marine animals exceed the salmon farming industry's contribution to BC's economy? What impact do escaped farmed salmon have on wild salmon populations? How much do fish farms pollute sea water next to the farms and the sea floor beneath the net-pens? How many seals, birds, and other animals are killed in order to discourage predation on farmed fish? What lower food-chain species are harvested as feed for pen-reared salmon? [3]

The threat of disease transfer between wild and farmed salmon is serious, both to wild salmon and to the salmon farming industry. Both Bacterial Kidney Disease (BKD) and Infectious Hematopoietic Necrosis (IHN) are common throughout the salmon farming industry. BKD is a leading cause of death to farmed Chinook and coho, and a serious danger to wild pink, sockeye, and chum salmon; [3] IHN, a virus carried by adult wild salmon without visible symptoms, is particularly dangerous both to juvenile wild sockeye [30] and to farmed Atlantic salmon which have little natural resistance. [17] So long as open-net pens permit constant exchange of water between contained and unrestrained environments, diseases and parasites can and will be exchanged between wild and farmed salmon.

Farmed salmon escape into the wild through net-pen tears resulting from storm damage or marine animal assaults. Since 1987, farmed Atlantic salmon have appeared in commercial fishing catches off the coasts of BC and Washington, and even where there is no salmon farming—in Alaska. [31]

Does the risk of transferring diseases to wild salmon and other marine animals exceed the salmon farming industry's contribution to BC's economy?

Sea Lice

1. WHAT IS A SEA LOUSE?

A sea louse is a small marine copepod that lives and feeds on fish. The term sea lice refers to several species of the Family Caligidae that infect fish. [36] Sea lice are ectoparasites, meaning they attach to the outside of fish, either on skin, fins, or gills.

The sea lice of BC's coastal waters are not the same as the 'sea lice' that cause painful rashes on people who swim in Florida. Those skin rashes are caused by the larvae of thimble jellyfish *Linuche unqui culata*. [37]

Sea lice clustered near the fin of a wild Chinook salmon.

Craig Orr photo

2. ARE SEA LICE HARMFUL TO PEOPLE?

Sea lice do not harm people, only fish. Sea lice can't parasitize humans, and because sea lice live on the outside of fish, there is no risk of eating them. In fact, sea lice are scraped off or fall off soon after fish are caught, which is why you rarely see them on the salmon you might buy. [47]

3. ARE THERE DIFFERENT TYPES OF SEA LICE?

At least thirteen different species of sea lice live in BC waters. Only *Caligus clemensi, Lepeophtheirus cuneifer,* and *Lepeophtheirus salmonis* have been reported on farmed and wild salmon in BC. *Caligus clemensi* occurs throughout the north Pacific, [38] and along the west coast of BC and northwest coast of Washington. [39] *Lepeophtheirus cuneifer* occurs along the northern Pacific coast of Alaska and BC, [40] while *Lepeophtheirus salmonis* is found throughout the northernmost portion of the Northern Hemisphere. [38] All sea lice parasitize fish, but some sea lice are more specialized than others. *Lepeophtheirus salmonis,* for example, is almost always found only on salmon.

In BC waters, *Caligus clemensi* and *Lepeophtheirus salmonis* may damage both farmed and wild salmon, and are a major concern both for the fish farming industry and for salmon conservationists. While *Lepeophtheirus salmonis* is often more prevalent and more damaging than *Caligus clemensi,* [38, 110] studies in the Broughton Archipelago in 2003 indicated that 20% of chum salmon were infected with *Caligus* and only 7% with *Lepeophtheirus.* [109]

4. HOW DO SEA LICE HARM FISH?

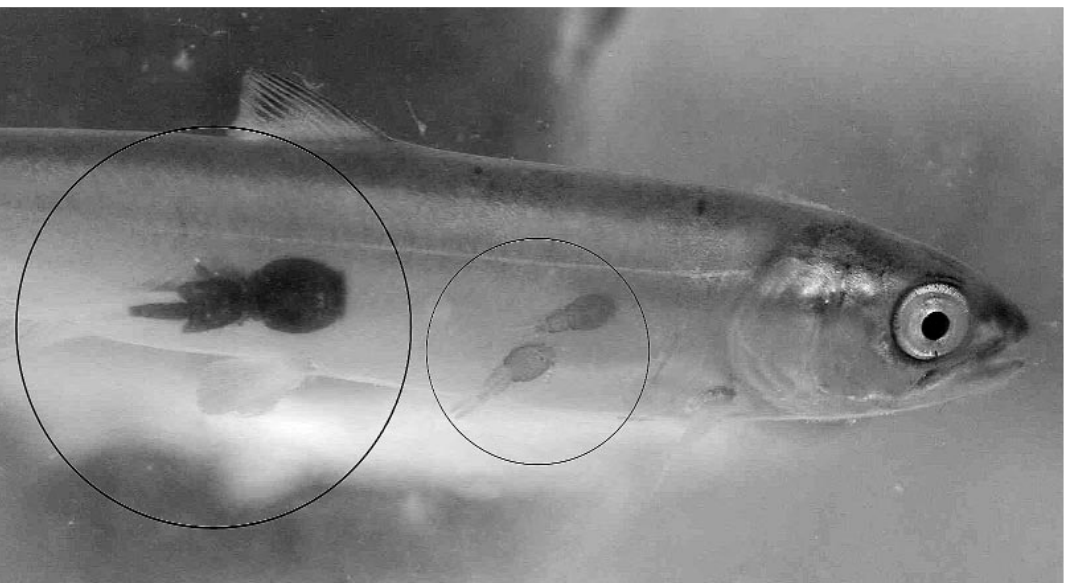
Sea lice eat the mucous, blood and skin of salmon. While a few lice on a large salmon may not cause serious damage, large numbers of lice on that same fish, or just a couple of lice on a juvenile salmon, can be harmful or fatal. The feeding activity of sea lice can cause serious fin damage, skin erosion, constant bleeding, and deep open wounds. [41]

The sea louse—which resembles a tiny horseshoe crab—is well adapted to life as a marine ectoparasite. [42] Their flattened head is covered by a shield, and their legs are specialized to allow them to grasp and feed on fish. Most of the female's body is dedicated to producing large numbers of eggs. What looks like two tails trailing behind are actually strings of eggs. Only gravid (pregnant) females carry them.

5. ARE SEA LICE EQUALLY HARMFUL TO ALL TYPES OF SALMON?

The way salmon react to, and how badly they are harmed by, sea lice infestations depend on: [36]

- The size and age of the fish. Smaller and younger salmon are more at risk;



Lepeophtheirus salmonis (left) and Caligus clemensi (right) on a pink salmon smolt.

Alexandra Morton photo

- The health of the fish. The weaker a salmon, the more likely it is to succumb —to either the lice or to disease;
- The life stages and the number of lice on the fish. The more sea lice, the more likely they are to cause stress, disease, and death to the salmon;
- The species of salmon. Some salmon are more susceptible than others. Adult pink salmon generally carry the most lice (5.8 adult sea lice per fish) and have the most infected population (92% of adult pink salmon have sea lice). Coho are the most resistant to lice. Chinook and Atlantic salmon have mid-range susceptibility. [43]

It is also possible for sea lice to carry diseases between farmed and wild salmon. This disease "vector" has already been shown for Infectious Salmon Anemia (ISA) on the Atlantic coast. [44, 45] The furunculosis bacterium has also been found on the bodies of sea lice, making it likely that sea lice spread this disease as well. [36]

6. HOW MANY SEA LICE IS TOO MANY?

If infection is severe, salmon can die from lice. As few as five lice may seriously harm a juvenile Atlantic salmon of 15 grams or less, while 11 or more can kill it. [46] However, lesser numbers of lice can harm or kill salmon indirectly, by increasing the fishes' stress levels and weakening their immune systems. A "load" of only one louse larva per gram of fish can be lethal. [70] Weakened salmon are more prone to infections and parasites. The open wounds caused by sea lice allow diseases and parasites to enter the fishes' bodies. [41]

7. ARE SEA LICE FOUND EVERYWHERE?

Sea lice are common throughout the Northern Hemisphere, and have been reported on wild salmonids along the North Atlantic and North Pacific coasts and in the open sea. Natural populations of sea lice seldom harm wild salmon, [48] although outbreaks can occur from time to time. [49] However, adjacent to salmon farms, where thousands of fish are contained in small areas, sea lice populations can become very large. Overcrowding stresses farmed salmon making them more susceptible to infection. [50, 51] Sea lice thrive only in salt water. They die when their adult salmon hosts enter fresh water. How long sea lice can survive in fresh water is not yet known. One study found that most lice fell off and died within two days of being in fresh water, [52] but other studies have shown that over 60% of the lice were still alive after one week and that some survived up to three weeks in fresh water. [53]

Just a couple of lice on a juvenile salmon can be harmful or fatal.

8. HOW MOBILE ARE SEA LICE?

Sea lice move from place to place in two ways—as free swimming larvae, and as adults attached to fish. In their larval stages, sea lice drift about on ocean currents as part of the plankton community. In their mature life stages, sea lice are parasitic hitchhikers riding wherever their fish hosts take them. During their travels, female lice may spread their eggs over large distances.

Juvenile pink salmon smolts with lethal loads of sea lice.

Alexandra Morton photo

9. WHAT IS THE SEA LOUSE LIFE CYCLE?

Sea lice have a complicated life cycle. Each of the cycle's ten different stages is separated by a molt, or shedding of the outer skin. With each molt, the louse's body and appearance change.

After hatching from the egg, a louse grows through two nauplius stages, both planktonic (which means the louse drifts with currents rather than swims). The louse then becomes a copepodid, and this is the only time in its short life that the sea louse can latch onto a fish. Once the copepodid finds a fish, it becomes a chalimus, and affixes itself toward the back of the fish near its dorsal or pelvic fins. Each of the four different chalimus stages is slightly bigger than its predecessor. After the last chalimus stage, the louse becomes a pre-adult. It can move about on the body of its host during both of its pre-adult stages. It makes its way from the back of its host to its head and gills, where it finally becomes an adult and the female produces eggs. [40, 54, 55] The entire life cycle takes just over one month (38 days at 10°C). [70]

10. ARE ALL SEA LOUSE STAGES HARMFUL TO FISH?

The only sea louse stages that can harm salmon are those following the infectious copepodid stage, that is, the chalimus, pre-adult, and adult stages during which lice attach to, and feed upon, the host fishes' body tissues and blood.

11. HOW MANY EGGS DOES A FEMALE SEA LOUSE LAY?

Female sea lice lay more eggs in the winter than in the summer, but winter eggs are smaller and less hardy. [56] Generally, a female sea louse will lay from fewer than 100 to several hundred eggs at one time, [55] and may have about six broods in her lifetime. [56]

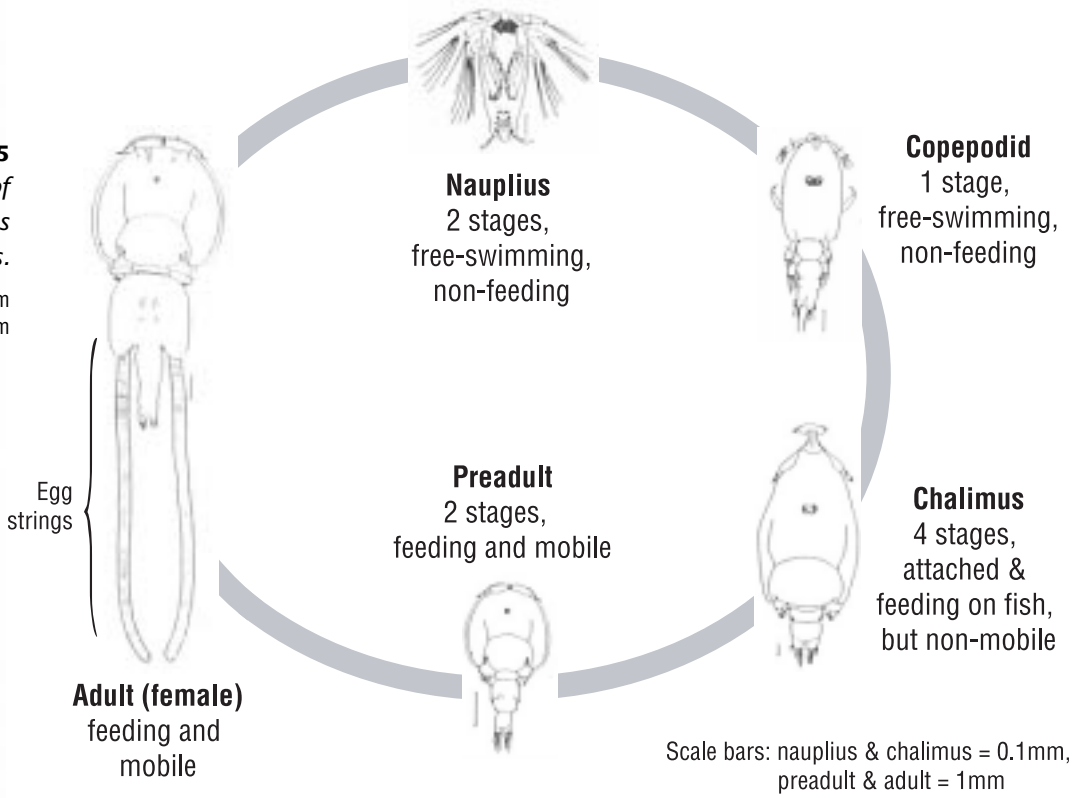


FIGURE 5
Life cycle of Lepeophtheirus salmonis.
Thomas Schram diagram

Sea Lice & Salmon Farming

1. WHY ARE SEA LICE OFTEN MENTIONED IN DISCUSSIONS OF SALMON FARMING?

Although sea lice occur naturally in the Northern Hemisphere, lice infestations have only recently put wild salmon populations at risk. The stocking of thousands of fish in small areas makes fish farms ideal breeding grounds for lice, and drastically increases the number of lice in surrounding waters. Understandably, lice find it easy to parasitize farmed fish because of their high densities. Additionally, the stress levels associated with crowding make farmed salmon more susceptible to lice infestation. [50, 51] Nor should we forget that 80% of BC's farmed salmon are of the Atlantic variety, [10] which are inherently more susceptible to sea lice than many other salmon species. [57, 58]

Fish farms are typically located in sheltered bays and inlets near rivers on or near the migratory routes juvenile salmon use to reach the ocean. In the pre salmon-farming era, sea lice numbers were typically low in the spring because the number of available hosts in coastal areas was also low. That salmon farms create an unnatural reservoir of sea lice is especially serious for juvenile wild pink and chum salmon heading for the ocean simply because of their small size and because of the stresses associated with changes that occur when they enter saltwater. One or two sea lice may be enough to kill a juvenile pink salmon newly arrived in saltwater. Much higher numbers have been observed recently on juvenile pink salmon near BC's salmon farms.

2. DO SEA LICE MOVE FROM FARMED TO WILD FISH?

There is much debate about whether sea lice on net-penned farmed salmon can infect wild salmon in their natural environment. For 10 years, industry and government have insisted that the sea lice in salmon farms do not constitute a risk to wild salmon. Meanwhile, significant findings—including a growing body of circumstantial evidence from studies throughout the Northern Hemisphere—suggest the opposite: that sea lice are dangerous to wild salmon.

Common sense suggests that sea lice can transfer from farmed to wild salmon. Farmed salmon juveniles are raised in large, land-based freshwater tanks. Because sea lice cannot survive in fresh water for more than two or three weeks at most, [60, 70] juvenile farmed salmon host no sea lice when they are transferred to marine net pens.

The sea lice's free-swimming stage, and the open nature of salmon farm net pens, make farm smolts vulnerable to infestation from older farmed salmon [61] and/or nearby wild salmon. Sea lice outbreaks can occur because the breeding conditions for sea lice are ideal on a salmon farm. Untreated, sea lice outbreaks can result in large numbers of free-swimming larvae in and around the salmon farm. The distance these larvae travel from the farm depends largely on ocean currents.

Adjacent to salmon farms, where thousands of fish are contained in small areas, sea lice populations can become very large.

One or two sea lice may be enough to kill a juvenile pink salmon.

Alexandra Morton photo

Given that salmon farms can have very high levels of sea lice infestation, that the farms are often located on migration routes of adult and juvenile wild salmon, that the farms' net pens permit sea lice to disperse throughout the marine environment, that the probability of being infected with sea lice—or any other disease—increases with proximity to, and numbers of, sea lice, it is more than likely that farmed salmon infect wild salmon.

3. DO SEA LICE DAMAGE FARMED & WILD FISH IN THE SAME WAY?

Sea lice are costly to the world's fish farmers. They injure and kill fish, reduce growth rates, and oblige expensive control treatments. One study estimated that a 20-net pen fish farm with 10,000 salmon per pen, can lose $336,000/crop due to sea lice. [41]

On Scotland's west coast farms, farmed salmon produced 78 to 97 percent of all Scottish lice, and wild salmon produced fewer than 1 percent.

4. IS THE SEA LICE PROBLEM LIMITED TO BC?

Sea lice do not cause problems only for the wild and farmed salmon of British Columbia. Major infestations of sea lice—both on wild and farmed salmon—have been reported everywhere salmon farms have been established. [81] Untreated infections have resulted in serious and costly consequences. [55, 62, 63] In 1996, the total cost of treatments and of the losses associated with injuries and deaths caused by lice in Norway and Scotland were $33 million and $25 million (US), respectively. [64, 65]

5. CAN THE ATLANTIC AND PACIFIC BE COMPARED?

Despite the environmental differences between the Atlantic and Pacific Oceans, the impacts of sea lice outbreaks on salmon farms and on wild salmon are similar. By taking advantage of years of sea-lice research, we can avoid reinventing the wheel, and can focus on deserving issues, such as how to eliminate lice impacts. BC cannot assume that the future health and biodiversity of its wild salmon are secure. It could be that restoring salmon biodiversity proves impossible or at least, prohibitively expensive. The sea-lice problem, here and there, is serious now.

6. ARE THERE MORE SEA LICE NEAR FARMS?

While sea lice occur naturally in coastal waters, studies in Norway, [59] Ireland, [66] and Scotland [67] suggest that most lice larvae originate on farmed salmon, and that densities of larval [68] and adult [69] lice are much higher in farms than in the wild. Wild salmon captured near

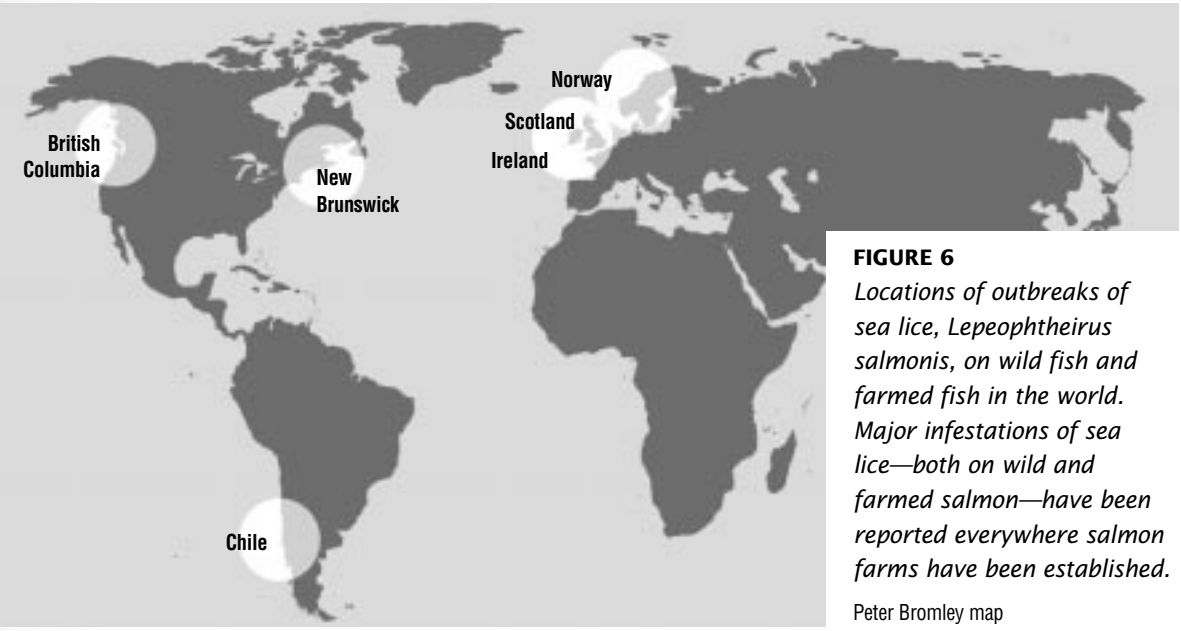


FIGURE 6
Locations of outbreaks of sea lice, Lepeophtheirus salmonis, on wild fish and farmed fish in the world. Major infestations of sea lice—both on wild and farmed salmon—have been reported everywhere salmon farms have been established.

Peter Bromley map

salmon farms carried an average of 100 lice per fish. Salmon captured away from farms carried an average of 13 lice. [70] A recent study in the Broughton Archipelago found sea lice were almost 9 times more abundant on juvenile wild salmon near farms holding adult salmon and 5 times more abundant near farms holding smolts, than in areas distant from fish farms. [110]

7. HOW MANY SEA LICE EGGS CAN A SALMON FARM PRODUCE?

Though impossible to determine exactly how many sea lice eggs can be produced by lice from a single salmon farm, scientists can estimate lice egg production. Based on what is known about lice and about the number and species of the fish in the farms, some 29 billion sea lice eggs may have been produced by Norwegian farmed salmon in the year 2000 — assuming that the Norwegian regulation allowing a maximum of 0.5 gravid (pregnant) female lice/fish was followed. [59] Another study on Scotland's west coast farms found that farmed salmon produced 78 to 97% of all Scottish lice, and that wild salmon produced fewer than 1%. Escapees from salmon farms accounted for the remainder. [71]

8. ARE THERE DIFFERENCES BETWEEN LICE FROM FARMED & WILD FISH?

It has been suggested that lice on farmed Atlantic salmon produce fewer eggs than lice on wild Atlantic salmon—500 eggs/brood and 1000 eggs/brood respectively. [66] However, there are no visual differences between sea lice found on farmed salmon and those found on wild salmon. Also, although scientists have not yet definitively determined whether sea lice move from farmed salmon to wild salmon (or vice versa), a large body of circumstantial evidence suggests that salmon farming contributes to sea lice abundance, and negatively affects wild salmon. Because sea lice infestations more commonly occur on wild fish that happen to be near fish farms, it seems likely that the farms are implicated. [17]

Lice from farmed and wild fish look the same.

Alexandra Morton photo

The Broughton Archipelago

1. WHERE IS THE BROUGHTON ARCHIPELAGO?

The Broughton Archipelago is a group of islands north of Johnstone Strait, off the northeast coast of Vancouver Island.

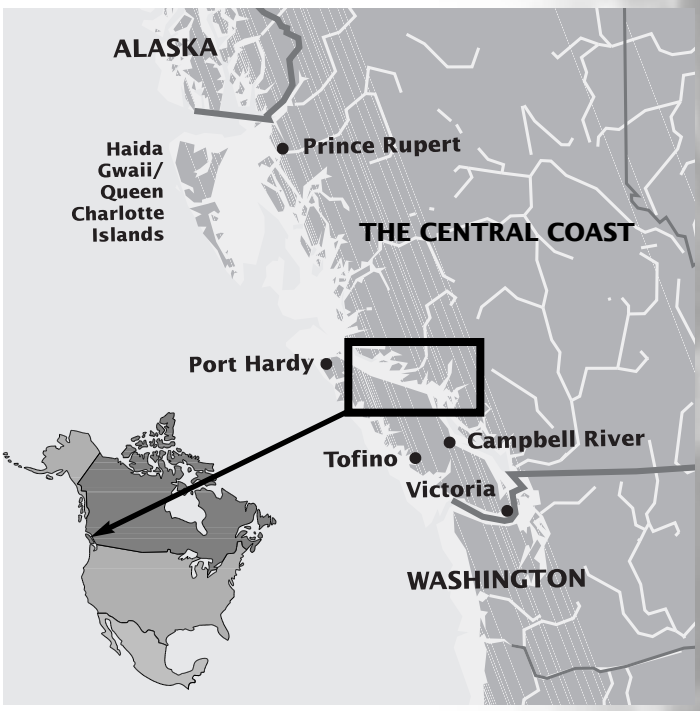


FIGURE 7 *Location of the Broughton Archipelago.*

The Broughton Archipelago.

Maple Leaf Adventures photo

2. WHY IS THE BROUGHTON AREA GETTING SO MUCH ATTENTION?

Many people believe that the pink salmon collapse stemmed from a massive kill of juvenile pink salmon in 2001, caused by sea lice originating in local salmon farms.

The Broughton Archipelago has received enormous attention since the collapse of its 2002 pink salmon run. From an expected 3,600,000, only 147,000 spawners returned. Though wide fluctuations in pink salmon populations are natural, analyses conducted by both the Department of Fisheries and Oceans Canada (DFO) and the Pacific Fisheries Resource Conservation Council (PFRCC) showed that the Broughton collapse was not "natural". [9] Many people, including fisheries biologists, First Nations, other local residents, commercial fishermen, and conservationists believe that the pink salmon collapse stemmed from a massive kill of outward migrating juvenile pink salmon in 2001, and that the kill was caused by sea lice originating in local salmon farms. The Broughton Archipelago has British Columbia's densest concentration of fish farms, with 29 farm tenures, 17 of them active in 2003. [101] Most of the farms are located directly on salmon migration routes. [72] Evidence suggests that juvenile pinks were infested with sea lice during their outward migration, when the threat from sea lice is normally low, because adult salmon are normally scarce at that time of year. The salmon farms made sea lice available precisely when the pinks were most vulnerable to them. [9]

3. ARE THE AREA'S WILD SALMON AT RISK FROM SEA LICE?

Nobody knows exactly what the ultimate impact of sea lice will be on wild salmon. But fish farms can produce much higher than "natural" numbers of sea lice, and lice do not differentiate between wild and farmed salmon. Therefore, wild salmon must be at risk from sea lice produced on fish farms. Only the extent of the risk is debatable. While some agency scientists, including those from DFO, acknowledge that fish farms produce sea lice, they don't yet publicly admit that wild salmon are in any danger, and deny there is evidence linking sea lice infestations on wild fish to salmon farms. However, a large, and growing, body of circumstantial evidence from around the world leads other experts to believe that the Broughton Archipelago's wild salmon are at great risk. A ten-week study in the Broughton Archipelago found that juvenile salmon near salmon farms were infected with more than 1.6 lice per gram—a probable lethal limit—while sea lice levels were near zero in all areas distant from farms. [110] The provincial and federal governments' current sea lice studies in the Broughton Archipelago have been initiated in response to a growing public outcry.

It seems reasonable to conclude that exposure to unnaturally high levels of sea lice results in high levels of sea-lice infestation, and unnaturally high levels of disease and death. [41]

4. WHEN DO PINK SALMON JUVENILES ENTER THE OCEAN?

Juvenile pink salmon emerge from their stream-bed gravel in late-winter and early spring, and almost immediately start making their way to the ocean. They are only 3.5 cm long when they reach salt water [73] and weigh only 0.3 grams. [110] They live in the shallow, productive waters of estuaries and coastlines, where a plentiful food supply allows them to grow rapidly before they migrate farther out to sea. [74]

5. THROUGH WHAT PARTS OF THE BROUGHTON DO PINKS MIGRATE?

During their initial stages in the sea, juvenile pinks rely heavily on the food-rich, shallow, coastal saltwater zones—estuaries, wetlands and beaches. Brackish estuaries are especially important as they provide ideal conditions for adapting to salt water. In addition to providing juvenile pinks with plentiful food, the shallow coastal waters offer protection from predators and strong ocean currents. After several weeks feeding on small, planktonic creatures, the juvenile pinks migrate to sea where they stay for 12–16 months. [74–76]

6. WHERE ARE THE SALMON FARMS RELATIVE TO MIGRATION ROUTES?

Of the Broughton Archipelago's 27 farm tenures, 16 are located directly in the path of migrating juvenile pink salmon. [72] These farms, most of which are owned by Stolt Sea Farms, a multinational industry based in Norway, may hold more than one million fish. [77] The remainder are owned by George Weston Ltd. [29]

7. ARE OTHER BROUGHTON ARCHIPELAGO SALMON AT RISK?

Pink salmon aren't the only salmon living in the waters of the Broughton Archipelago. Chum, coho, and Chinook salmon are also found there, as are sea-run cutthroat trout and steelhead. Though juvenile pink salmon are the most susceptible to sea lice, [43, 57, 58] other salmon are also at risk of infestations, especially outmigrating juveniles. [36] A recent study in the Broughton Archipelago found that 90% of juvenile pink and chum salmon near salmon farms were infected at or above lice loads considered to be lethal. [110] Other recent research in the area found that 28% of the area's juvenile pink and chum salmon were infected with lice. [109]

Experts believe that the Broughton Archipelago's wild salmon are at great risk.

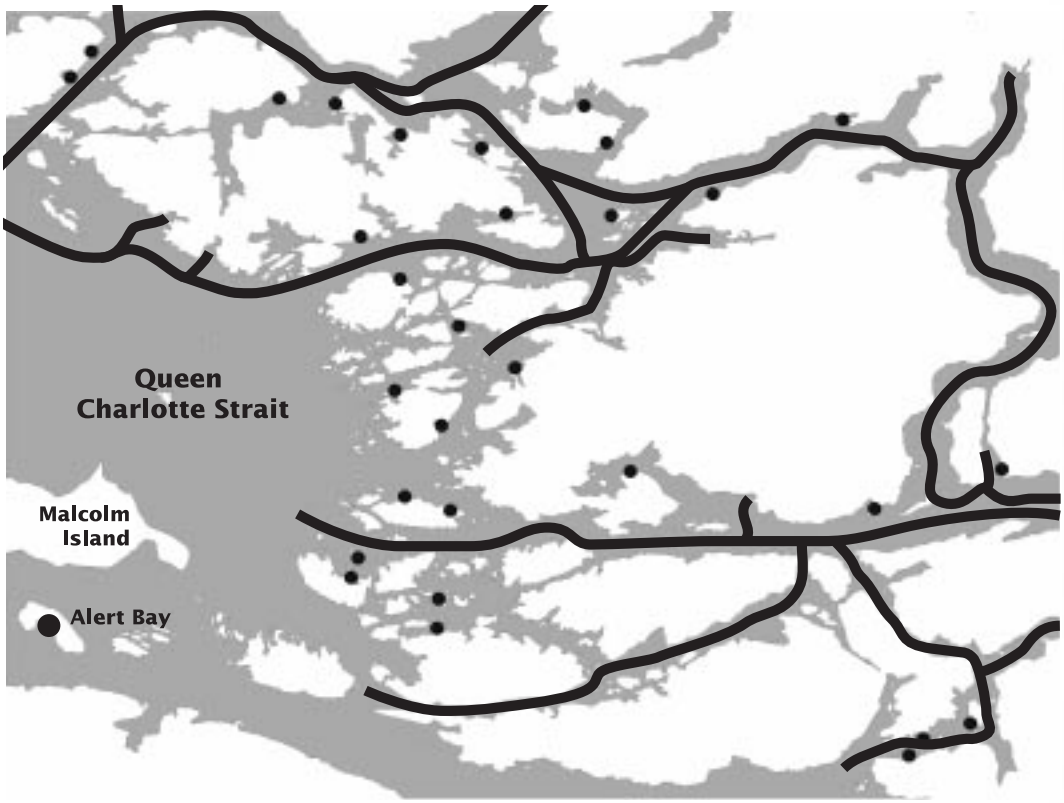


FIGURE 8
Pink salmon migration routes and salmon farm tenures in the Broughton Archipelago.

Modified from Living Oceans Society map

Treatment

There is no known 'silver bullet' for permanently stopping sea lice infestations on fish farms.

1. HOW DO SALMON FARMERS TREAT FARMED SALMON FOR SEA LICE?

In order to avoid costly losses, salmon farmers have developed a variety of methods to prevent and treat sea lice outbreaks. Good farm maintenance and husbandry can help prevent outbreaks, and chemicals and drugs can help treat salmon after an outbreak occurs. There is no known 'silver bullet' for permanently stopping sea lice infestations on fish farms. Most salmon farmers use a combination of treatments, depending on the severity of the infestation and the stage in the sea louse development cycle. [78]

Various measures can be used either before a sea lice outbreak, or as part of a continuous management regime. They include the following: [79]

- **Proper site location** —which maximizes the chances that farmed salmon will be healthy by ensuring that farms are not located near potential sources of infection, such as salmon-bearing streams and other salmon farms;
- **Adequate tidal current** —which minimizes dangers associated with accumulation of sea-lice larvae;
- **Separating year classes** —which prevents smolts (i.e. the lice-free, freshwater juveniles) from contacting the older and already lice-infested farm fish;
- **Fallowing** —which breaks the reproductive cycle of sea lice, thereby reducing the risk of outbreaks;
- **Minimizing crowding** —which decreases host density and stress, and thereby reduces infection rates;
- **Good husbandry** —which contributes to the health of fish. Cleaning and caring of nets is one example;
- **Cleaner fish (wrasse)** —which eat parasites carried by other fish, and feed on algae and sessile animals, such as mussels (common on nets) are a less-expensive and non-chemical means of controlling sea lice currently being used on some European salmon farms. [64] Unfortunately, there are no native wrasse in BC. Nor is it advisable to introduce non-native species into any environment—including introducing Atlantic salmon to the Pacific coast;
- **Reactive treatments** —which are usually a chemotherapeutant given to farm fish either in food or as a bath, after a sea-lice infestation has occurred. Bath treatments are difficult to administer and are not effective against all life stages of sea lice. Feed treatments are more effective, and farmers can treat many cages quickly. Although diluted by surrounding water, the chemicals used may affect non-target wild crustaceans and may remain in the environment from ten days to six months. [78, 80-89] The ability of sea lice to quickly develop resistances to chemical treatments is also a major issue. [111]

2. WHAT IS FALLOWING?

Just like farms on dry land, fish farms can be fallowed. By taking all of the farmed salmon out of a farm and leaving it empty for one production cycle (two years), the seabed may recover from damage caused by the farm above it. It also breaks the cycle of sea lice and other disease infestation in that farm. Fallowing is most effective if all the farms in an entire bay or fjord are emptied, because it is much less likely that farms will be reinfected by their neighbours. To be effective, fallowing must be done in conjunction with a separation of year classes to ensure that smolts are not infected by adult fish in the same farm.

3. WHAT IS SLICE?

SLICE is the commercial name for emamectin benzoate, a chemical used to kill sea lice. It has mostly replaced its more costly and less effective predecessor, Ivermectin. [41] Although SLICE is currently undergoing clinical trials in Norway, Scotland, and Chile, [78] in Canada, in

2004, it has yet to be tested for food safety by the Canadian Food Inspection Agency, [90] to be licensed by the Bureau of Veterinary Drugs (Health Canada), or to be permitted for use through the Pesticide Control Act. So how is it that salmon farmers in BC are able to use SLICE to control sea lice? They gained the go-ahead through the Emergency Drug Release Program (EDR) which approves the use of non-approved drugs when recommended by veterinarians for emergency situations. [91]

Emamectin benzoate belongs to a class of chemicals called avermectins, which are produced by the actinomycete *Streptomyces avermictilis*. [92] Avermectins are axonic poisons which affect nerve cells causing hyper-excitedness leading to loss of nerve control. [82]

Farm fish ingest SLICE as a coating on commercial food pellets. Digestion releases the drug to pass through the lining of the fish's gut and into the fish's tissues, from where it takes about a week to be eliminated. [93] Although SLICE contains emamectin benzoate (0.2%), an active ingredient in pesticides, it is classified as a drug because it is fed to the fish rather than applied externally. Drugs are regulated by the Food and Drugs Act, whereas pesticides are regulated by the Pest Control Products Act. [112] Whether emamectin benzoate is considered to be a drug or a pesticide, however, it is the same chemical. Because of its ability to accumulate in sediments, SLICE could become toxic to marine life. In fact, the label of the pesticide 'Proclaim', in which emamectin benzoate is the only active ingredient, clearly warns that "This pesticide is toxic to fish, birds, mammals, and aquatic invertebrates. Do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not contaminate water when cleaning equipment or disposing of equipment wash water." [94]

Though SLICE effectively controls all life stages of sea lice, [95] and appears to have no negative effects on farmed salmon, it is not known how long SLICE might remain effective before sea lice develop a resistance to the treatment.

4. DOES SLICE AFFECT ANY OTHER MARINE ANIMALS?

Whether or not SLICE affects animals other than sea lice is the cause of much argument. Industry [93] and government agencies [91] claim that SLICE is quite safe, but recent science warns that SLICE may harm non-target animals. SLICE has been found to induce premature molting in lobsters (a crustacean), and to have caused female lobsters to lose their eggs prematurely. [96] Scientists in Scotland have shown that mysid shrimp are highly sensitive to emamectin benzoate; [97] the equivalent of half a drop in an Olympic-sized swimming pool is enough to poison these small planktonic animals. Because of its low solubility in water, SLICE is very likely to bioaccumulate in marine sediments, [98] possibly to levels toxic to nearby marine animals.

There are, as yet, no rules governing how BC fish farmers treat lice.

5. WHO WINS AND WHO LOSES BY GOVERNMENT IMPATIENCE?

Because SLICE is classified as a drug, and has not been approved through the provincial Pesticide Control Act, the government can delay the filing and/or enforcing of management plans. Fish farms get a reprieve. The public loses an opportunity to appeal government decisions through the Environmental Appeal Board. The public also loses a guarantee that it will even be informed when SLICE is being used. Fish farmers gain the opportunity to avoid advertising their intention to use SLICE until government adopts the permitting procedure. [114]

6. HOW DOES GOVERNMENT REGULATE SEA-LICE TREATMENTS?

There are, as yet, no rules governing how BC fish farmers treat lice. In Europe, protocols are precise, even to identifying the number of sea lice allowed per fish before sea-lice treatment becomes obligatory. In Norway, the threshold is an average of 0.5 gravid (pregnant) female lice/fish, [17] but even this seemingly low number may be excessive. [59] In BC, the usual practice is for fish farmers to call a veterinarian when they become concerned about sea-lice numbers. The veterinarian

prescribes either Ivermectin or emamectin benzoate, the only two treatments used in BC. SLICE has become the preferred choice because it has a shorter withdrawal period (as low as 7 days) than Ivermectin (3 months), [9] meaning fish can be harvested and sold sooner after treatment. [99] The BC Ministry of Agriculture, Food and Fisheries (MAFF) has a voluntary Sea Lice Monitoring Program. [100] Since it is a volunteer measure only, the data gathered are of limited value.

7. TO SLICE, OR NOT TO SLICE?

Closed containment salmon farming may be one way to eliminate the lice, chemical, and other problems associated with salmon farming. Critics claim that closed containment is too costly—while ignoring the environmental costs of open net cage technology. For more information on the potential merits of closed containment salmon farming, visit: www.sargo.net.

The conflict between provincial and federal legislation is a potential excuse to ignore the public interest and the needs of wild salmon.

The Role of Governments

1. WHOSE RESPONSIBILITY IS IT TO PROTECT WILD SALMON?

The protection of wild salmon is primarily the responsibility of the Department of Fisheries and Oceans Canada (DFO). DFO's mandate to manage and protect fisheries resources includes responsibility for marine and freshwater environments. The federal Fisheries Act clearly states that no one is to harmfully alter, disrupt or destroy fish habitat without authorization. Unfortunately, DFO has also been mandated to promote aquaculture in Canada, which undermines its ability to protect wild salmon resources. A further complication stems from the fact that DFO is not the primary agency responsible for the aquaculture industry. Largely because aquaculture is viewed as being more similar to farming than to fisheries, it is the provinces that assume responsibility for the aquaculture industry. The provincial government creates the plans and policies under which the industry operates in British Columbia. The conflict between provincial and federal legislation is a potential excuse to ignore the public interest and the needs of wild salmon. Although federal legislation is supposed to take precedence in these situations, DFO appears to be unwilling and unable to enforce the Fisheries Act.

2. WHAT IS DFO'S POSITION ON SALMON FARMING? CONSERVATION?

Although DFO is legally responsible both for protecting wild salmon and for developing Canada's aquaculture industry, it has determined that it must be neutral, and refuses to take sides in the salmon farming versus wild salmon dispute. Can DFO favour aquaculture when fish farms pose such a threat to wild salmon? Can DFO favour salmon conservation and yet allow fish farms to operate where they endanger juvenile wild salmon? And, most importantly, why are the federal and provincial governments acting as agents for the salmon farming industry? What is their excuse for putting a special interest ahead of the public interest? In short, because of its conflicting directions and political pressure, DFO appears unable to uphold its legal responsibility to protect wild salmon as long as it continues to promote fish farming. [6]

3. DOES THE PROVINCE HAVE A PLAN FOR DEALING WITH SEA LICE?

In February 2003, British Columbia's provincial government announced the creation of the Broughton Archipelago Action Plan, ostensibly to study and control sea lice in the Broughton Archipelago. Key components of the action plan are to: [100]

- Create a pink salmon migration corridor by fallowing specific farms;
- Better monitor both farmed and wild salmon, and to coordinate sea lice treatment efforts;
- Review fish health policy;
- Improve research;
- Improve communication.

The government's pink salmon corridor called for fallowing 11 farms during the spring migration of pink salmon juveniles that begins at Thompson Sound, passes through Tribune Channel, Fife Sound, and reaches into Queen Charlotte Strait. [101] However, Tribune channel splits into two arms at Gilford Island, the north arm of which continues under the same name and the south arm of which goes around the south of Gilford Island, and into Knight Inlet. Pink salmon smolts use both arms. [72] Fallowing only the north arm was a practical compromise between economics and biological effectiveness. Likewise, the government selected only 16 farms for routine sea lice monitoring, to be conducted every two to four weeks from January to March. The farms conducted the reported counts themselves and reported only to the BC Ministry of Agriculture, Food and Fisheries (MAFF). [102] Proper statistical sampling procedures seem not to have been used. A small number of farms was sampled, and the data MAFF made public seem to confuse lice load per fish with lice load per farm. The number of fish sampled at each remains unknown. In short, the data lack needed transparency.

In respect of its research and policy activities, MAFF sponsored a Science Forum at the University of British Columbia in February 2003. Eminent fisheries scientists from around the world reviewed and discussed sea lice research priorities.

As for the aim to improve communication, what the First Nations in the Broughton Archipelago experienced is instructive. Despite repeatedly telling federal and provincial ministers that they don't want fish farms on their traditional territory largely because of the threat to wild salmon, and despite provincial government assurances that fish farms would be removed from their territory, the Gilford Island First Nations were not even told of a Stolt Sea Farm application for a new fish farm near Humphrey Rock. The provincial government approved the Stolt application, and another fish farm will soon appear in the Broughton Archipelago. [103]

4. ARE THERE ANY OTHER PLANS FOR DEALING WITH SEA LICE ON FARMS?

The BC government is not the only agency implementing or recommending plans for controlling sea lice in the Broughton Archipelago. DFO, the Pacific Fisheries Resource Conservation Council (PFRCC), and gatherings of academic and governmental scientists have also addressed the problem.

DFO appears to be unwilling and unable to enforce the Fisheries Act.

In 2003, DFO developed a $700,000 Pink Salmon Action Plan to determine exactly why 2002's pink salmon returns were so low. DFO's five key recommendations are that:

- A freshwater monitoring program be conducted in addition to DFO's usual assessment of salmon stock abundance in the Broughton Archipelago;
- A marine monitoring program determine where and how badly sea lice infect juvenile salmon in the Broughton Archipelago, and identify migration corridors more clearly;
- A strategic fallowing plan create a juvenile pink salmon migratory corridor;
- A long-term research plan, to set priorities for research, be developed with input from First Nations, environmental organizations, the aquaculture industry, academic institutions, and different levels of government;
- A public consultation process enable First Nations, environmental organizations, the aquaculture industry, academic institutions, and different levels of government to discuss science, policy, and regulatory issues (both DFO and the provincial government have agreed to co-chair a committee that will oversee this process).

The PFRCC, an independent, government appointed advisory council, recommended that:

- The precautionary principle be applied more rigorously in the evaluation of risks;
- The aquaculture industry and governments undertake a wide-ranging research and monitoring program on wild/farmed salmon interaction, and develop better management

practices to decrease the environmental impacts of salmon farms;

- The Government of Canada immediately create and implement a comprehensive wild salmon policy that clearly gives wild salmon priority in government decision-making;
- Government supervision and regulation of wild and farmed salmon, especially for health and disease monitoring, be centered on whole bays or large areas of coastline, not on individual farms;
- A Salmon Aquaculture Forum, including a multi-stakeholder scientific panel, be established to identify public consensus about the future direction of the industry, and to identify ways to reduce risks to wild salmon from net-cage aquaculture.

The overwhelming consensus is that, at present, far too little is known about environmental impacts of aquaculture to permit full-scale expansion of BC's aquaculture industry.

Many meetings of experts occurred in 2003/04 (e.g. SFU Sea Lice Summit, SFU Sea Lice Action Plan Meeting, UBC Sea Lice Summit). All made recommendations concerning the management of sea lice. The overwhelming consensus is that, at present, far too little is known about environmental impacts of aquaculture to permit full-scale expansion of BC's aquaculture industry. Specific research priorities must be identified and carried out, all steps taken by regulatory agencies must rigorously apply the precautionary principle, and there must be improved communication for all interested and affected groups.

5. WHAT RESEARCH IS CURRENTLY BEING CONDUCTED ON SEA LICE?

A broad cross-section of scientists from government agencies, industry, academic institutions, and environmental organizations in Europe, the UK, and North America is still studying the impacts of sea lice and fish farming on wild fish and the environment.

In Europe and the UK, where the link between sea lice, salmon farms, and wild salmon is more commonly accepted,[108] research is strongly focused on finding ways to protect the last remaining wild salmon from problems originating in fish farms.

Unfortunately, North American regulatory agencies still refuse to recognize what ever-growing evidence and expert opinion throughout the world indicates—that sea lice from fish farms are a serious danger to wild salmon. In any event, much of the research being conducted by government agencies such as DFO or MAFF remains bogged down trying to determine whether sea lice from fish farms actually do infect wild salmon, or did cause the unnaturally low pink salmon returns to the Broughton Archipelago.

On the positive side, MAFF and DFO now seem to be encouraging academics to address other concerns—such as the need for coast-wide planning and management of fish farm sites with their surrounding environment[104, 105] (especially the benthos),[106] the advantages of improving monitoring and operating technologies, addressing socio-economic concerns, and learning more about the biology of cultured animals. The BC Aquaculture Research and Development Committee was established in 2001 to identify and help fund research opportunities.[107]

Results from research conducted in 2003 in the Broughton Archipelago were recently discussed at a workshop in Alert Bay. The workshop was hosted by the Inner Coast Natural Resource Centre (ICNRC) and the Centre for Coastal Studies, Simon Fraser University. Academics, conservationists, First Nations, government representatives, and local community members attended.[109]

People

1. WHAT IS CAAR?

CAAR is the Coastal Alliance for Aquaculture Reform, a coalition of local groups concerned about how fish farming is practiced in BC and about the health of wild salmon, coastal ecosystems, and coastal people. Member groups include First Nations, commercial fishermen, and conservationists. Watershed Watch Salmon Society is a member of CAAR. For more about CAAR, visit www.farmedanddangerous.org.

2. DOES CAAR OPPOSE FISH FARMS?

CAAR does not oppose salmon farming, only salmon farming as currently conducted. CAAR supports aquaculture operated in a sustainable, environmentally-conscious manner, and with the support of local communities and First Nations.

3. WHAT IS THE PFRCC?

The Pacific Fisheries Resource Conservation Council (PFRCC) is a government appointed, semi-independent organization created to advise the governments and citizens of Canada and British Columbia on conserving and sustaining Pacific salmon stocks and their habitat. Council members include experts from the scientific and academic community, the commercial fishing industry, the conservation community, and First Nations. The PFRCC publishes annual reports on the status of wild salmon, and recommends how to better protect wild salmon. For more information, visit the PFRCC website at www.fish.bc.ca.

4. WHAT IS THE BCSFA?

The BC Salmon Farmers' Association (BCSFA) is an organization representing those who work in the salmon farming industry, and includes salmon farmers and service and supply companies. The BCFSA works to protect the BC salmon farming industry's market share and international reputation. For more information: www.salmonfarmers.org.

5. HOW DO FIRST NATIONS FEEL ABOUT SALMON FARMING?

Many of BC's First Nations believe salmon farms infringe on aboriginal rights, and oppose fish farms being established in their traditional territories. [5] Though a handful of individuals have benefited from fish farms, First Nations communities as a whole have not. Coastal First Nations are dependent on salmon both as a food source and a livelihood, and are understandably concerned that salmon farming might threaten their lifestyle, and wild salmon. Some First Nations communities, such as the Heiltsuk Tribal Council and the Musgamagw Tsawataineuk Tribal Council, have a zero tolerance policy towards fish farms. Though other First Nations are less strict, most feel that fish farming is destructive to wild salmon and the environment. First Nations that do participate in the salmon farming industry do so out of a desperate need of employment.

Many of BC's First Nations believe salmon farms infringe on aboriginal rights.

Academic, conservation, government, First Nation and community reps at a workshop in Alert Bay.

Craig Orr photo

Sources for More Information

1. WHERE CAN I LEARN MORE?

GENERAL AQUACULTURE INFORMATION:

- **Watershed Watch—Salmon Farming**
  www.watershed-watch.org/ww/salmon_farming.html
- **Coastal Alliance for Aquaculture Reform**
  www.farmedanddangerous.org
- **Aquanic** www.aquanic.org/
  Gateway site to electronic aquaculture resources
- **Seaweb Aquaculture Clearinghouse**
  www.seaweb.org/resources/sac/
  Independent, not-for-profit ocean info center

SEA LICE AND SALMON:

- **Simon Fraser University Speaking for the Salmon Series**
  www.sfu.ca/cstudies/science/salmon.htm
- **University of Maine - Sea Lice and Salmon**
  www.umaine.edu/livestock/Publications/sea_lice_bullets.htm
  General sea lice information
- **Fisheries Research Services – Environmental Impact of Fish Farms**
  www.frs-scotland.gov.uk/FRS.Web/Delivery/display_standalone_with_child_menu.aspx?contentid=522
  Information and research from the Fisheries Research Service, an agency of Scotland's Environment and Rural Affairs Department
- **Health Canada Pest Management Regulatory Agency**
  www.hc-sc.gc.ca/pmra-arla/english/pdf/fact/fs_ipmsealice-e.pdf
  Fact Sheet on Integrated Pest Management and the control sea lice on salmon farms
- **DFO Sea Lice/Pink Salmon Monitoring Programme**
  www-sci.pac.dfo-mpo.gc.ca/mehsd/sea_lice/pink_salmon_e.htm
  Progress updates & raw data from DFO's sea lice monitoring efforts in the Broughton Archipelago

2. WHAT CAN BE DONE TO HELP?

You can do many things to help.

- Foremost, you can remember that the aquaculture industry is driven by consumer demand, and that customer choices, count. The less demand, the less production, and less marketing in stores and restaurants;
- You can stop buying and eating farmed salmon;
- You can tell others why you won't buy or eat farmed salmon;
- You can ask whether unidentified fish—in stores and restaurants—are wild or farmed, and;
- You can write to your Federal Member of Parliament or Provincial Member of the Legislative Assembly, the Provincial Minister of Agriculture, Food and Fisheries, or the Federal Minister of Fisheries explaining that the salmon farming industry should not be permitted to operate in BC unless it is run in a sustainable manner, and unless it poses no threat to wild salmon.
- Find your Federal Member of Parliament here or check your local library:
  www.canada.gc.ca/directories/direct_e.html
- Find your Provincial Member of the Legislative Assembly here or check your local library:
  www.legis.gov.bc.ca/mla/3-1-1.htm
- To contact the Hon. John van Dongen:
  Phone: 250.387.1023 Fax: 250.387.1522
  Email: John.vanDongen@gems4.gov.bc.ca
  Mail: The Honourable John van Dongen, P.O. Box 9058, Stn Prv Govt, Victoria, BC Canada, V8W 9E2
- To contact the Hon. Geoff Regan:
  Email: Min@dfo-mpo.gc.ca (remember to include your postal and email address)
  Mail (no stamp required): The Honourable Geoff Regan, House of Commons, Minister, Fisheries and Oceans Canada, Parliament Buildings, Wellington St. Ottawa, Ontario, Canada, K1A 0A6

Why conserve the diversity of wild salmon?

Conservationists frequently extol the importance of conserving biodiversity—but rarely explain why. Most of the arguments have to do with ethics (it is the right thing to do). Only recently, however, have we begun understanding the biological merits of biodiversity. A study of Alaskan sockeye sheds new light on how "biocomplexity" (or biodiversity) in salmon helps generate sustainability. (1)

Sockeye have colonized numerous rivers in Bristol Bay, and over time, these populations have developed a 'suite of adaptations to the diversity of spawning and incubation environments'. In certain years, environmental conditions appear to favor some populations over others. Rivers that were once productive have declined, while others that were once small producers are now major ones. In a broad sense (the scale of Bristol Bay, at least), the resilience of salmon is linked to the maintenance of "all the diverse life history and geographic locations that comprise the stock." The biocomplexity now recognized as being so important could easily have been lost, had earlier managers focused too much on the then most productive runs, and neglected the less productive ones. (1)

Conservation biologists have recently said that by conserving biodiversity we are in fact conserving important "redundancies" and "reinforcement of function". (2) In this case, redundancy is not used in the way an engineer might explain how to achieve engineering reliability, but rather, how each species (or population, or stock) has a "similar scale of function" through "different responses to unanticipated environmental change." Put another way, this 'within-scale and between-scale diversity' produces an overlapping reinforcement of function that is remarkably robust. (2)

The importance of overlapping reinforcement of function is shown in the simple example of roofing shingles. (2) We can also liken wild salmon to the cast of an "ecosystem theater" in which certain populations serve as "stand-in actors" waiting in the wings to replace regular performers who fall. (2) Without such stand-ins, a loss of function might cascade across a broader geographic area, thus reducing the continuous (sustainable) supply of salmon for catching, for cultural and social needs, for biological perpetuation (through both natal stream spawning, and straying and replacement of lost stocks), and for supplying critical marine-derived nutrients to terrestrial habitats.

This overlapping function has been termed "imbricated (overlapping) redundancy". (2) In the case of salmon, the greater the number of locally adapted salmon populations in a given area, the greater the overlap in function, and the more likely that wild salmon will collectively persist and adapt in the face of changing environmental conditions. Thus, any threats to local populations of wild salmon—including those posed by open net-cage salmon farming—have coastwide implications to the adaptability, productivity and persistence of wild salmon.

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