

An Introduction to AQUACULTURE

**A primer on the industry
for B.C. First Nations**



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An Introduction to Aquaculture: A primer on the industry for B.C. First Nations
First Nations Fisheries Council

The First Nations Fisheries Council worked closely with both environmental organizations and industry specialists in order to obtain information for this document. In the end we were not able to satisfy everyone, but we have done our best to provide a fact-based, non-opinion overview of the aquaculture industry. Any errors or omissions are ours alone.

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The photo on the front cover is the reflection of a net from a salmon aquaculture farm in Quatsino Sound onto the surface of the water.

Where not otherwise noted, photos in the document are from the private collection of Brenda McCorquodale.



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Introduction

The First Nations Fisheries Council is a province-wide organization with a mandate to work with British Columbia First Nations to: 1) support the protection of First Nations' rights and title; 2) to help build capacity in First Nations' communities in the area of fisheries and fisheries management; and 3) to work with B.C. First Nations to examine opportunities for the development of co-management approaches.

The Fisheries Council was established in 2007 as an outcome of the *B.C. First Nations Fisheries Action Plan*. Since its establishment, the Council has worked to be responsive to issues and priorities brought forth by B.C. First Nations. The Fisheries Council became involved in aquaculture following the *Morton* case in 2009, when the current aquaculture management framework was declared by the courts to be "outside the law." Aquaculture was managed by the province of B.C. prior to the case, but upon being declared a fishery, the exclusive right to aquaculture management was transferred to the federal government. The Leadership Council's Aquaculture Working Group and the First Nations Fisheries Council undertook a workshop in the fall of 2009, and subsequently developed a Statement of Solidarity and a Statement of Jurisdiction on aquaculture. These were passed by the Union of B.C. Indian Chiefs, the First Nations Summit, and the B.C. Assembly of First Nations, giving the Council a mandate to work with Fisheries and Oceans Canada on the aquaculture issue.

In late 2009 the federal government announced its intent to develop a new regulatory framework for aquaculture, which would bring aquaculture management under federal jurisdiction. This move has created an opportunity for First Nations in British Columbia to look at all aspects of aquaculture, to understand what it involves, and the potential for the industry to infringe on aboriginal rights. As First Nations build capacity to develop their vision and expectations for aquaculture within their territories, they are better able to articulate to government where there are opportunities for collaborative management and joint decision-making.

The Fisheries Council has developed this primer as a tool for First Nations with varying degrees of experience with aquaculture. The intent of the document is to introduce information in a relatively simple way. If you have comments or input on this material, it is always welcome. First Nations in B.C. have varying views on the aquaculture industry in B.C.. The goal of this piece is to provide information to First Nations as they make their own decisions about if and how they want to engage in the management or practice of aquaculture.

For the purposes of this document, aquaculture is defined as the cultivation, breeding and rearing of species that are under the care or control of an operator for their entire lifespan, including both finfish and shellfish. This definition excludes hatcheries, 'ocean ranching' and the cultivation of aquatic plants. The Fisheries Council understands that during this regulatory



reform process DFO is seeking input into the scope of what aquaculture regulation should apply to, therefore the current definition of what DFO constitutes as being aquaculture is under review (for example, should aquaculture include hatchery programs and ocean ranching?).

The Aquaculture Industry in British Columbia

Aquaculture, in some form, has been practiced on the B.C. coast for as long as First Nations have lived here. Tended shellfish beds which were owned by specific families have been traced back thousands of years, and the resulting middens resulting from shellfish consumption are clear evidence of a long history of aquaculture in the province.

As of February 2010, in British Columbia there are approximately 128 finfish tenures (about 75 operating at a time) and 480 shellfish tenures. There are also approximately 180 freshwater aquaculture licenses. In the management of this industry, government currently collects about \$2.9 million per annum through a variety of licensing fees. These fees relate to tenure fees for the use of the space where aquaculture takes place (\$2M), fees relating to waste deposition (\$600K), and other fees (\$300K).

Today in B.C. the aquaculture industry includes the farming of salmon and shellfish, as well as other species such as sablefish, trout, sturgeon, tilapia, scallops and geoduck clams that are produced in limited or experimental quantities. In 2008, B.C. aquaculture produced 90,900 tonnes of fish and shellfish. In 2008 the finfish aquaculture industry in B.C. alone produced 73,600 dressed metric tonnes of product at a wholesale value of \$507 million. Finfish aquaculture is estimated to have contributed \$180M to B.C.'s gross domestic product, and to have directly created 2,800 jobs. B.C.'s share of the world market of farmed salmon was 5% in 2008.

What is Aquaculture?

The Food and Agriculture Organization of the United Nations broadly defines aquaculture as the farming of aquatic organisms: fish, mollusks, crustaceans, aquatic plants, crocodiles, alligators, turtles, and amphibians. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding or protection from predators, and implies individual or corporate ownership of the animals or plants being cultivated.

Over many thousands of years aquaculture systems have been developed for many aquatic species around the world. The number and scale of aquaculture systems has also increased dramatically, and aquaculture is now the fastest growing sector of the world food economy. Aquaculture can be an efficient way to produce fish, which are food sources high in protein. Aquaculture activities have grown as an industrial answer to meeting an increasing world demand for salmon, shellfish, and other species.



Aquaculture practices vary greatly with the species being cultivated. Practices can range from low impact to high intensity cultivation, with greatly varying levels of impact on the surrounding environment.

Shellfish Aquaculture

Shellfish aquaculture operations in B.C. are generally small scale operations carried out by owner-operators of farms, concentrated around Vancouver Island. A number of species of shellfish are cultivated, the most common being clams and oysters. Geoduck, mussels, scallops, abalone, and other shellfish are also farmed on the B.C. coast.

The majority of shellfish aquaculture operations in B.C. are modest in scope, with 87% of licenses grossing less than \$45,000 per year. Compared to the finfish industries in B.C., the shellfish aquaculture industry is much smaller in size. In 2005 there were 38,300 tonnes of farmed shellfish produced valued at \$67 million. Although many small scale shellfish aquaculture operations do exist, a United States based company, Taylor Shellfish, owns and controls a large market share of the current shellfish cultivation licenses and tenures.

Shellfish aquaculture can be composed of beach culture, floating lines or cages, or deep water culture. In most cases farmers do not 'feed' the shellfish they are growing. Shellfish generally grow well through filter-feeding, a process where they take nutrients directly out of the water. Due to the nature of shellfish, farms require areas with clean, unpolluted water.

Shellfish aquaculture involves the establishment of tenures, a privatization of marine space for the exclusive use of the farmer. In some cases people visiting a shellfish farm, specifically a beach tenure, may have no idea that the tenure is even there, as there may be no outward signs of the farm. For long-line or cage operations, a shellfish farm may look on the surface like a large collection of buoys in lines on the water. Suspended from these lines may be ropes, coil or cages, which contain various species of shellfish.

There are some concerns associated with shellfish aquaculture. One of the major concerns is the introduction of exotic species for cultivation purposes (such as the cultivation of the exotic Manila Clam and the Japanese Oyster). The introduction of exotic species can have unintended impacts on the native species populations. For example, the introduction of the Pacific Oyster (*Crassostrea gigas*) over 80 years ago, has now created a situation where the Pacific Oyster outnumbers the native Oysters (*Ostrea conchaphila*) in B.C. coastal waters.

Another concern associated with shellfish aquaculture is the alienation of people from traditional high value shellfish areas when a tenure is granted for an ocean-space. On the east coast



of Vancouver Island, some residents have also complained about the infrastructure associated with shellfish aquaculture negatively impacting their natural and pristine views of the ocean environment. The presence of farming activities on a beach in essence “privatizes” the area where farming is occurring, thus limiting access. This can have the effect of excluding First Nations from a part of their traditional territories, and excluding the public from access to a particular ocean/beach space. As well, the presence of shellfish operations near beaches can disrupt intertidal substrate movement, and create an impact to the habitats of organisms living in the adjacent tidal zones.

Freshwater Aquaculture

At present there are about 82 freshwater grow-out operations in B.C. Most of these operations exist in rural communities, and are small private land based operations. In B.C. a variety of freshwater species are cultivated, including Bass, Carp, various species of Trout, Crayfish, Sturgeon, freshwater shrimp, and tilapia. In most cases, the farming of these species is not occurring for commercial purposes. For example, in 2008 the trout U-fish industry (fee based recreational fishery in private ponds) generated about 7 tonnes of product, valued at \$113 thousand. At the other end of the spectrum, in 2008, B.C. produced 655 tonnes of farmed trout valued at \$2.762 million. As well, there are tilapia and freshwater shrimp operations, which are striving to compete at a commercial scale. In general, the freshwater industries face market challenges due to the large amount of freshwater product that is produced in the United States. Due to the colder temperatures in B.C., the added expense to heat the water for ideal cultivation temperatures is a barrier to market competitiveness when compared to the costs of cultivation in warmer climates further south.

Another facet of the freshwater aquaculture industry in B.C. is the grow-out of salmon smolt to stock marine aquaculture facilities. This is a relatively large industry in B.C., and in most cases, these salmon grow out facilities are on land closed containment operations. These operations are highly sophisticated, and in many cases utilize re-circulated water technologies to reduce the demand for continuous fresh water.

Freshwater aquaculture occurs across Canada, in varying scales and levels of intensification. There has been some interest in exploring large scale crayfish aquaculture in old mining facilities in B.C. While there has not been a big uptake on these types of aquaculture at this time, there is a possibility of expanding these types of operations in the future.

Salmon Aquaculture

Salmon farming is one of the most significant forms of aquaculture in British Columbia. Most commonly, salmon are hatched in a hatchery, grown out in tanks and/or lakes, and then trans-



ferred to the ocean where they are reared in floating net cages or mesh pens attached together into a farm, which is usually located in a sheltered bay or fjord. Typical net pens in B.C. are square or circular, cover about 225 to 900 m² of ocean surface, and are about 15 m deep.

B.C.'s farmed salmon begin their lives in privately owned land-based hatcheries. These eggs are usually from a foreign breeding stock, as Atlantic salmon are not a naturally occurring species on the Pacific coast. Eggs are fertilized and incubated, and young salmon are raised in hatcheries or freshwater pens for about one year until they are able to be moved into saltwater pens, where they remain for 16 to 22 months until harvested at a weight of about 5 kg.

Salmon farmers try to avoid holding too many fish in a net pen, as overcrowding may lead to poor health and growth. Atlantic salmon are the preferred species for salmon aquaculture. They are typically raised at densities of 15 to 25 kg/m³ in B.C.. Some 91% of salmon raised in B.C. are Atlantic salmon, and the remaining 9% are native chinook and coho.

The average commercial salmon farm in B.C. holds between 250,000 and 750,000 fish on a single "tenure", which is approximately the size of 2 football fields.

History of salmon farming outside of B.C.

The modern salmon farming industry began in the 1960s in Norway's sheltered fjords and inlets. Norway is currently the largest producer of farmed salmon (800,000 tonnes in 2008, which translates into about 220 million fish). In Scotland, the industry began in 1966 and production increased steadily to about 175,000 tonnes by 2004. Salmon sea culture began around 1975 in Ireland and production reached some 25,000 tonnes by 2002. In the southern ocean, farming began in Chile in the late 1970s, skyrocketing from the mid-1980s through the 1990s to a level approaching that of Norway at 570,000 tonnes by 2004. In 2007, infectious salmon anemia disease (ISA) appeared at several farms in Chile and outbreaks continued into 2008, devastating the industry. Production in 2009 was estimated at 220,000 tonnes—a drop of 61% from 2004 levels.

The first commercially viable farming operations on Canada's east coast began in the late 1970s in New Brunswick, and farms were subsequently established in Nova Scotia, with a total east coast production of 30,810 tonnes in 2008.

History of Salmon Farming in B.C.

Commercial finfish aquaculture in B.C. began in the mid-1950s when the provincial government first licensed rainbow trout farms. Modern salmon farming started in the early 1970s with small locally-owned farms, mainly on the Sunshine Coast. Growth in the salmon farming



industry in B.C. was stimulated by the government's 1987 decision to allow the switch from native coho and chinook salmon to imported Atlantic salmon.

Atlantic salmon have grown to be the preferred species for salmon farming in B.C. both due to the world-wide marketing effort geared toward Atlantics, and the fact that Atlantics are more-easily domesticated and faster growing than Pacific salmon. Additional investments in aquaculture, new research and development, and changes in legislation all contributed to significant development of the industry in the 1990s in B.C.

Though the industry eventually became more solid financially, public concern about the possible impacts of aquaculture resulted in the government imposing a nearly eight-year moratorium on new farms from 1995 to 2003. During this time, however, increased stocking densities and improved husbandry practices apparently allowed for increases in industry production (Figure 1), and farmed fish tonnage eventually surpassed that of wild salmon landings in 1997. By 2008 British Columbia's industry produced 73,260 tonnes of farmed salmon.

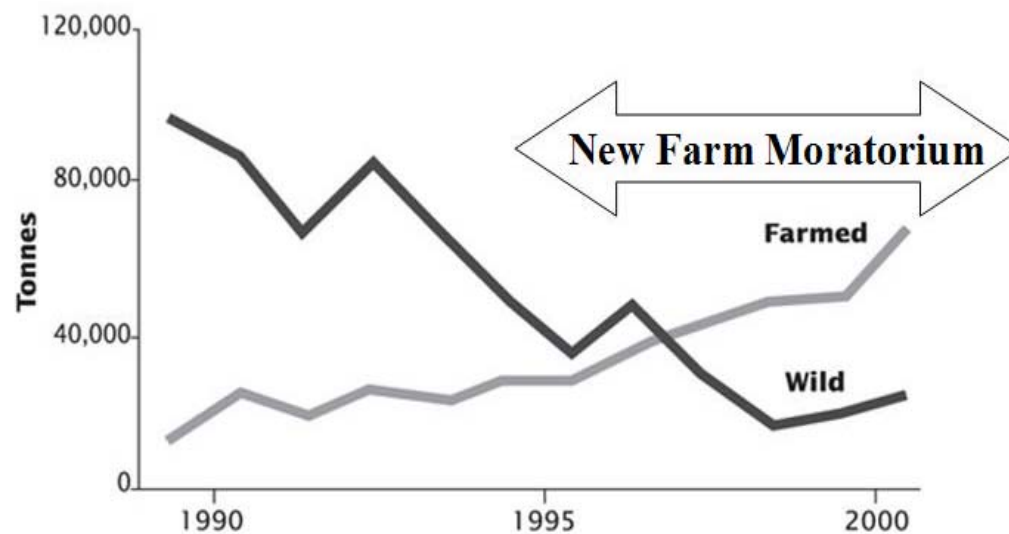
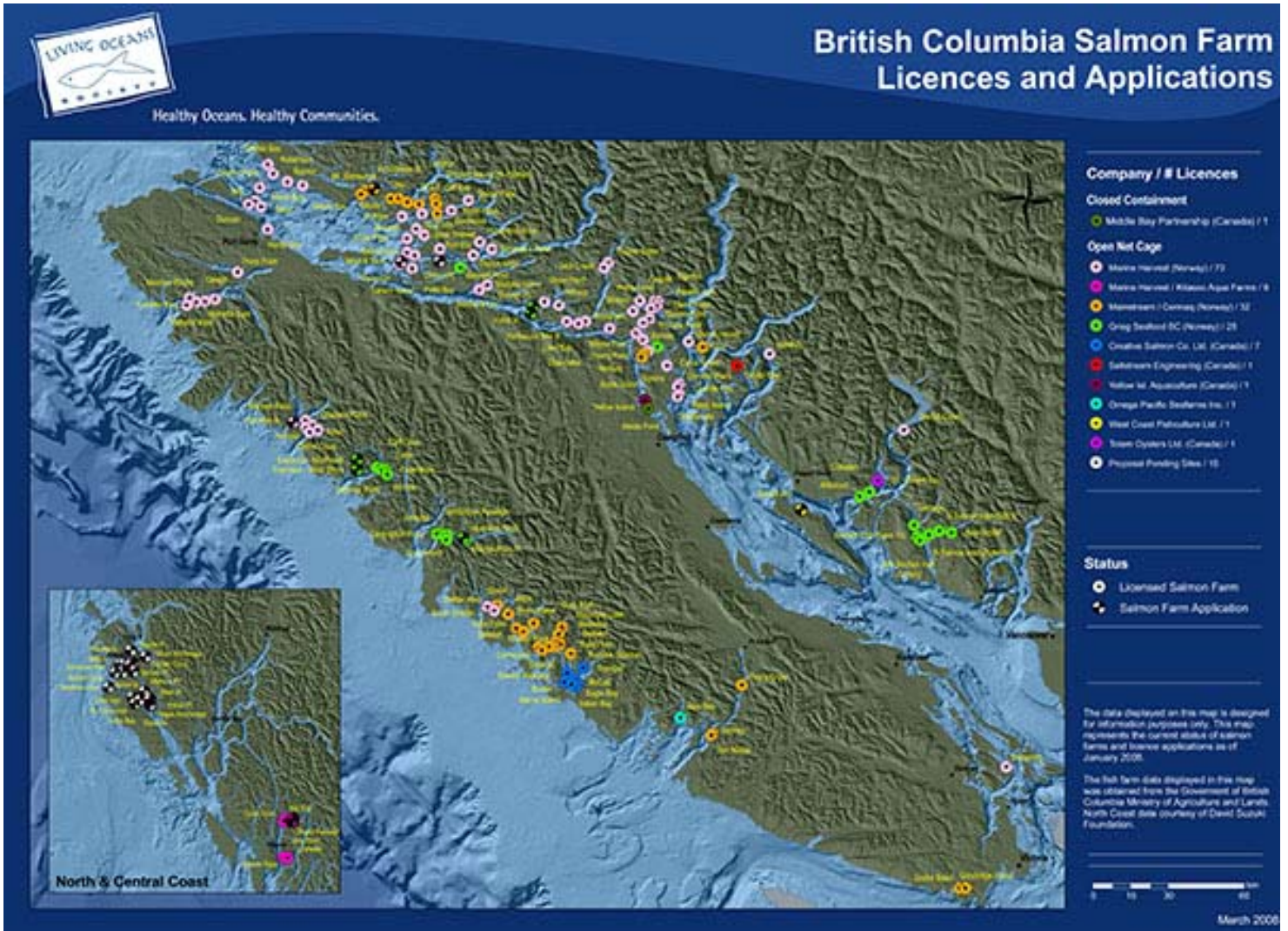


Figure 1: Farmed salmon production surpassed wild salmon landings circa 1997 courtesy watershed watch..

Figure 2: Map of B.C. salmon farm licenses and applications

The salmon aquaculture industry in B.C. is currently dominated by a few foreign-based players. The 2007 merger of Norwegian-owned PanFish with global giant Marine Harvest created the largest salmon aquaculture company in the world. Mainstream Salmon (formerly Heritage



Map courtesy of Living Oceans Society

Aquaculture) also operates in the Broughton and Strait of Georgia areas. In 2000 Mainstream/ Cermaq purchased B.C.'s Pacific National Group, and Prime Pacific Seafarms. In 2005 it bought out the Canadian-owned Heritage Salmon Farms. The third largest player, in terms of tenures and production, is Grieg Seafood, which bought out Canadian-owned Target Marine Group's coastal salmon farming sites and processing facility in 2007. Grieg operates open net-cage salmon farms on B.C.'s Sunshine Coast, on the west coast of Vancouver Island, and in the Discovery Islands.



As of April 2008, Norwegian-based companies own 92% of the B.C. salmon farm industry.

April 08 data	Country based-in	# Licenses	%
Marine Harvest	Norway	75	55%
Mainstream (Cermaq)	Norway	33	24%
Grieg Seafood	Norway	17	13%
Creative Salmon Company	Canada	6	4%

Figure 3: Four largest salmon farming companies

What’s the difference between a farm and a tenure?

A tenure is a location where it is legal to conduct aquaculture. The number of active salmon farms is always less than the number of tenures; some sites are used to grow smolts and others, adults; some occasionally sit fallow after harvest or because of annual variation in production; some have been abandoned due to poor environmental conditions; some have been harvested to facilitate wild smolt migration; and some tenures have been converted to other uses, such as staging facilities or shellfish culture.

Governance of the Industry

The governance of farming in B.C. is currently in flux due to a recent legal challenge, and will be shifting from provincial to federal jurisdiction. In response, Fisheries and Oceans Canada will assume governance of the majority of aquaculture related operations. Until recently the province of B.C. managed aquaculture through a memorandum of understanding with Canada. This created numerous concerns related to the responsibilities for monitoring and managing the potential impacts of the aquaculture industry.

At the same time the new B.C. regulatory framework is being developed, Canada is working on a new National Aquaculture Strategic Plan Initiative (NASAPI) . A goal of NASAPI is to increase production by all sectors by 6% per year. Canadian production projections for 2020 are 197,000 tonnes for salmon and 94,900 tonnes for shellfish, or “modest growth in B.C.”. Other goals include economic and social revitalization in coastal and rural communities, and enhanced participation in the aquaculture sector by First Nations. One of the NASAPI objectives is to “increase public confidence in the...environmental sustainability of aquaculture.”



There are concerns that this process is happening too quickly, and that the B.C. regulatory framework should be completed prior to the NASAPI going out for consultation in B.C.

General Ecological Concerns related to Salmon Farming

Organic Waste

Salmon farms use mesh nets to house the growing salmon. Mesh nets do allow organic waste to fall to the ocean bottom. Organic waste from farms is mainly salmon feces. Waste from several hundred thousand salmon raised in a confined area has the potential to impact the biological (benthic) community living in and on the ocean floor by smothering and/or reducing the available oxygen



Photo courtesy Marine Harvest

in the sediments. These impacts are localized and in a majority of cases are confined to the area beneath and in the immediate vicinity of the salmon farm, however in some cases the impacts are more widespread. Currently, the provincial Ministry of Environment monitors and enforces waste regulations governing aquaculture operations under the Finfish Aquaculture Waste Control Regulations (FAWCR). In part the regulation requires routine monitoring of benthic impacts, sets impact standards, and requires following of farms if these standards are not met. Following assists in the recovery of the impacted area.

Nutrients from finfish aquaculture can also have an effect on the receiving environment by stimulating or exacerbating toxic algal blooms, which can lead to a decrease in the amount of dissolved oxygen in the water (a condition which can be lethal to fish). The current regulations do not require monitoring of nutrient input and water quality around farms. The Ministry of Environment along with the Department of Fisheries and Oceans are considering the use of tracers to better understand the scope and fate of the organic waste being discharged from the fish farms.

Chemicals

Chemicals are required in the production process for farmed salmon. Some of the chemicals used include anti-fouling paints, antibiotics and disinfectants.



SLICE

Current methods of sea lice management on salmon farms in British Columbia requires the periodic use of the chemical emamectin benzoate, sold under the commercial name “SLICE.” Emamectin benzoate is a prescription drug that disrupts chloride ion channels, and hence neurotransmission, in arthropods (a phylum of which sea lice are a part).

Sea lice that feed on a host fish ingest emamectin benzoate from the tissues of the host, become paralyzed, die, and drop off. Emamectin affects all feeding stages of sea lice. SLICE, or emamectin benzoate, is milled into the feed of farmed fish and was first used on an “emergency basis” in B.C. until officially approved for use in July 2009. It has been criticized because of its “unknown fate” in the environment, due both to amounts of the chemical that might not be eaten by fish and may end up in other parts of the marine food chain, and due to concerns about the possible development of resistance to the chemical. In terms of application amounts, SLICE is applied at approximately 0.2 grams (emamectin benzoate) per 1000 kilograms of salmon harvested.

Disinfectants

Disinfectants may be regularly used on farms as “biosecurity measures” to limit the transfer of diseases from site to site. Many farms have protocols for the use of disinfectants on nets, boats, containers, raingear, boots, diving equipment, platforms and decking as well as the handling and disposal of them. It is inevitable that some amounts of these products will end up in the marine environment. The effects of these chemicals on the marine environment is not completely understood.

Heavy Metals

Copper-based antifouling paints are used on salmon cages and nets to kill attached marine organisms that may otherwise reduce the water flow through the cages and decrease the available dissolved oxygen to the salmon. Some of this copper ends up accumulating in the sediments beneath and in close proximity to the farms. The metal zinc, given to the fish as a nutritional supplement, can also accumulate in sediments near farm sites. The current management structures require the aquaculture industry to sample sediments on a routine basis to ensure metal concentrations do not exceed allotted standards. At present there are no requirements that aquaculture monitor for the bio-accumulation of heavy metals in wild fish adjacent to farms against the background levels of these materials found in the natural environment.

Vaccines and Antibiotics

The aquaculture industry routinely administer vaccines and antibiotics to salmon. Every salmon receives vaccinations prior to entering the ocean environment. Antibiotics are also used. Aquaculture has reduced their use of antibiotics over the past decade due to a number



of factors including improvements in fish husbandry and the availability of effective vaccines. Antibiotics are administered by a fish veterinarian. The use of antibiotics in medicated baths and medicated food has prompted concerns over bacteria developing resistance to the compounds, and the potential for resistance to transfer to other bacteria, including human pathogens. Though quantities of antibiotics used in salmon aquaculture are generally less than used for other forms of terrestrial food production, in Canada the amount of antibiotics prescribed are comparatively high relative to Norway and Scotland.

Far field effects

Far field effects are those effects that are witnessed at a significant distance from the source of pollution. While difficult to observe, far field effects from finfish aquaculture have been documented in B.C., and three types of impacts have been reported: nutrient overloading, deposition of sediment, and food web impacts. In B.C. First Nations and commercial fishers have expressed concern about far field effects. In response to these concerns, government, industry, and multi-stakeholder groups have attempted to measure these impacts so that solutions based on facts can be formulated.

Role of Traditional Ecological Knowledge in Identifying Concerns

First Nations have repeatedly raised concerns about the importance of protecting high value sites from potential aquaculture impacts. Many First Nations would like to see increased respect for the use of traditional or local knowledge in management. Some studies have shown that clam diggers may effectively monitor several qualitative indices to determine if farms are damaging traditional resources. For example, experienced clam diggers are able to observe overall environmental quality of beaches, such as the substrate hardness and color, and the presence or absence of other organisms, such as mussels and sea lettuce. Kwakwaka'wakw environmental monitoring methods, as documented by Heaslip (2008), include the use of different scales, numbers and specificity of indicators to assess impacts from fish farm wastes. Monitors also use a gradient of descriptions of color, size, strength, hardness, abundance, smell and taste of clams to measure environmental health. In addition to indicators related to individual clams, Kwakwaka'wakw clam diggers note population scale changes on clam beaches—for example, clam abundance as measured through both a visual survey of beaches and the amount of effort and time that is put in to digging clams. This analysis allows a useful comparison of the goals and characteristics of Kwakwaka'wakw monitoring to the current technical monitoring approach of government.

Management and transparency of information

In B.C., industry and government publicly report various types of aquaculture data, although not all of this data is reported to the public. Currently farm sea lice data, for example, is col-



lected by the industry and sent to a central database overseen by the B.C. Salmon Farmers Association (BCSFA). The BCSFA then provides monthly reports summarizing sea lice abundance information to the B.C. Ministry of Agriculture and Lands (BCMAL).

A common criticism of the industry is that information is not shared broadly enough to promote public confidence that the industry is operating in the best possible way. Increased information sharing would make the management of the industry more transparent. Some First Nations request more directed information sharing on a variety of areas, including— specifics on marine mammal deaths, pesticide uses, antibiotic uses sediment monitoring data, disinfectant use, anti-fouling use, escapees, and disease outbreaks. This would allow First Nations and the Canadian public to better formulate their own conclusions about the management of the aquaculture industry.

Diseases and Disease Control

There are four major naturally occurring infectious diseases that affect salmon in industrial farming operations globally:

- Infectious Salmon Anaemia (ISA) (*there have been no reported cases in B.C. to date*)
- Infectious Hematopoietic Necrosis (IHN)
- Furunculosis, and
- Bacterial Kidney Disease

Infectious Salmon Anaemia (ISA) was first detected in Norway in 1984. It has since spread to Canada's east coast, and has recently been found in Chilean salmon farming areas in the Pacific. The outbreak in Chile had significant ramifications on the entire salmon farming industry. ISA is usually transmitted via imported eggs, a practice which also occurs occasionally in B.C. but only from certified ISA-free countries. However, the occurrence of ISA in Chile has raised concerns that B.C. could be vulnerable to a similar outbreak of ISA that recently devastated Chile's farmed salmon industry.

Infectious Hematopoietic Necrosis (IHN) is a virus that affects both wild and farmed salmon and is commonly referred to as 'Sockeye disease'. Sockeye, chinook, coho, rainbow trout and Atlantic salmon may all contract the virus when they come into contact with wild fish in the marine environment, but Atlantic salmon are particularly susceptible. IHN is a virus and not a bacterial infection, and infected fish are not treated with antibiotics. IHN problems were reported in 1995, 1996, 1997 and 2001; between August 2001 and May 2002, 19 Atlantic salmon farms became infected with IHN. Since 2002, a vaccine has been available and administered to B.C. farmed salmon. This vaccine offers effective protection from exposure to IHN.



Furunculosis is an infectious bacterial disease. Caused by the bacterium *Aeromonas salmonicida*, both Atlantic and Pacific salmon are susceptible to this disease at all stages of their lives. Furunculosis causes boils under the surface of the skin. In 2005 it killed 1.8 million Atlantic salmon smolts at a single commercial salmon hatchery on Vancouver Island. The disease can occur in salmon farms throughout Scotland, Norway, and Canada but outbreaks worldwide have become uncommon since the widespread use of furunculosis injection vaccines.

Bacterial Kidney Disease is a chronic systemic bacterial condition of fish in the family Salmonidae caused by *Renibacterium salmoninarum*. Infection can result in significant mortalities in both wild and farmed salmon. Most age groups of fish can be affected, although the disease outbreaks are rare in very young fish. Losses are generally chronic, occurring over an extended period. It affects fish in freshwater and seawater environments, and can have a serious economic impact, particularly in seawater Pacific salmon farms. The first outbreak of bacterial kidney disease in farmed Atlantic salmon in Scotland was recorded in 1976, and has since been found in salmon farming operations around the world.

ISA and IHN are listed as Reportable diseases by the World Organization for Animal Health and the Canadian Food Inspection Agency (as of March 2010). This means that immediate notification to the world body is required within 24 hours if an outbreak occurs in a country or zone of the country that was previously considered to be free of that particular disease.

Escapes

Escapes from lake-based and marine net pens can occur either by “trickle” losses of relatively small numbers of fish (small numbers of fish getting through the cages, or being pulled out by predators), and through large-scale escapes (Table 1). From 1987 to 2008, the Ministry of Agriculture and Lands reported escapes totaling in excess of 1.5 million farmed salmonids. Wild fisheries at times report catches of farm origin salmon despite an absence of escape reports. There is concern that industry reporting may underestimate actual escape numbers.

At times mature escaped Atlantic salmon migrated to B.C. rivers. Concern has been expressed about the potential for these escaped salmon to colonize (reproduce) in the B.C. environment. Adult Atlantic salmon have been documented in some 80 B.C. rivers, and there is evidence that Atlantic salmon have reproduced naturally in at least three—the Tsitika, Adam, and Amor de Cosmos rivers—all near the western border of the Broughton Archipelago. Although reared on pellets, Atlantics have been reported to feed on native marine species in regions where they are exotic.



	Chinook	coho	Atlantic	steelhead	total
1987	22,422	0	0	32,576	54,998
1988	2,000	0	0	0	2,000
1989	390,165	0	0	0	390,165
1990	165,000	0	0	0	165,000
1991	229,500	0	6,650	0	236,150
1992	59,632	0	9,546	0	69,178
1993	12,113	0	9,000	0	21,113
1994	2,300	0	62,809	0	65,109
1995	5,000	1,000	51,883	0	57,883
1996	0	0	13,137	0	13,137
1997	38,956	0	7,472	0	46,428
1998	1,900	0	80,975	0	82,875
1999	0	0	35,954	0	35,954
2000	36,392	0	31,855	0	68,247
2001	0	0	55,414	0	55,414
2002	9,098	100	11,257	0	20,455
2003	9	1	30	0	40
2004	5	11	43,969	0	43,985
2005	2	41	21	0	64
2006	19,068	0	17	0	19,085
2007	11	12	19,223	0	19,246
2008	53	4	111,769	0	111,826
Total	993,626	1,169	550,981	32,576	1,578,352

Table 1. Number of farm salmon reported escaped into the marine environment from 1987 to 2008. Data compiled from B.C. Ministry of Agriculture and Lands.

Escaped Atlantics have dispersed widely in the North Pacific Ocean. Some scholars have questioned whether the probability of escaped Atlantic salmon establishing populations in B.C. may be a function of the state of declining native stocks, meaning Atlantic salmon may be able to better compete when native stocks are depressed. There have been over 170 historical attempts to introduce Atlantic Salmon to habitats in which they are non-native for recreational fishing purposes, all of which have failed, supporting the belief that escapee Atlantic salmon do not establish long-term viable populations in non-native waters.



Escaped Atlantic salmon have raised various concerns, including disease transmission from domesticated to wild species, genetic impacts resulting from interbreeding with wild fish, and resource competition with wild fish. Ultimately, the extent of impacts from escaped Atlantic and Pacific farm salmon on B.C.'s wild stocks is unknown.

Marine Mammals & Birds

Open net-cages attract marine mammals and birds that feed on fish. Nuisance animals (harbour seals, California and stellar sea lions) that threaten farm operations may be shot once the farm obtains the appropriate predator control permit. A review of the predator control data between 1989 and 2000 has not been updated in a decade, and little current information is publicly available on the number of marine mammals that might be impacted. The first predator control permits were issued in 1989, and by the year 2000, 116 permits had been issued. Between 1989 and 2000, an estimated 5,341 harbour seals had been shot. The number killed and the number that escaped (or that were injured) each year were relatively consistent, averaging 455 and 36, respectively. Over this period, 902 sea lions were shot (316 stellar sea lions, 565 California sea lions, and 21 unidentified). The number of sea lions killed per year increased between 1989 to 2000, to an estimated 267 in 2000.

Finfish and shellfish aquaculture operations attract a number of species of birds which can become entangled in nets and drown. Statistics on these events or occurrences where endangered bird species may have been killed are not available. The total impact of aquaculture on marine mammal and bird populations is unclear.

Sea Lice

The Pacific Salmon Forum (PSF) was formed in 2004 and mandated to explore the status of salmon in B.C. waters. The PSF released their final report in 2009, which contained numerous recommendations on how to improve the sustainability of B.C.'s wild and farmed salmon. One of the areas the Forum focused on was the debate and science on sea lice, and the possible threats that sea lice pose to the health of wild salmon. The final report noted "much of the public concern regarding salmon aquaculture has grown from the perception that sea lice generated from fish farms harm wild salmon populations." Public concern of the impacts of sea lice on salmon surfaced after pink salmon returns in the Broughton Archipelago crashed in 2002 following historically high returns. The Broughton is home to many salmon farms. The possibility of a correlation between the crash in Pink salmon returns and the growth of the salmon farming industry within the Broughton spurred a series of scientific endeavors over 7 years (and ongoing) to research whether the decline in wild pink salmon was a result of increased farming operations.



The PSF report notes that currently there is no scientific consensus on what the impact of sea lice is on wild salmon populations. There is a strong body of scientific evidence that has been able to link the presence of farms to an increase in local sea lice abundance (which are naturally occurring parasites) due to the presence of farmed salmon acting as an additional host for the sea lice. What follows is an introduction to this complex and charged discussion.

What is a sea louse?

Sea lice are naturally occurring small marine parasitic “copepods” that resemble tiny horse-shoe crabs. Lice thrive by feeding on the mucous, skin and blood of fish. Hundreds of species of sea lice are native to the marine waters of North America, three of which—*Caligus clemensi*, *Lepeophtheirus salmonis* and *Lepeophtheirus cuneifer*—rely on many types of wild and farmed fish as hosts; salmon being one of them. *Lepeophtheirus salmonis*, or “Leps”, the “salmon louse” are the most researched variety of sea lice in B.C. waters.

The presence, development and distribution of lice are influenced by a myriad of environmental factors including water temperature, water salinity, and host species. The warmer the water temperatures, the quicker sea lice mature and reproduce. Water salinity is also critical to lice survival. Previous research has shown that Leps cannot usually survive in freshwater for more than one week, yet recent research in B.C.’s Broughton Archipelago (Figure 5) determined that adult lice die quickly in fresh water. In terms of host species, evidence suggests that sea lice are able to produce more eggs on Atlantic salmon hosts versus Chinook salmon hosts (Johnson, 1993).

Figure 4: Picture of sea lice at various life stages courtesy Watershed Watch.



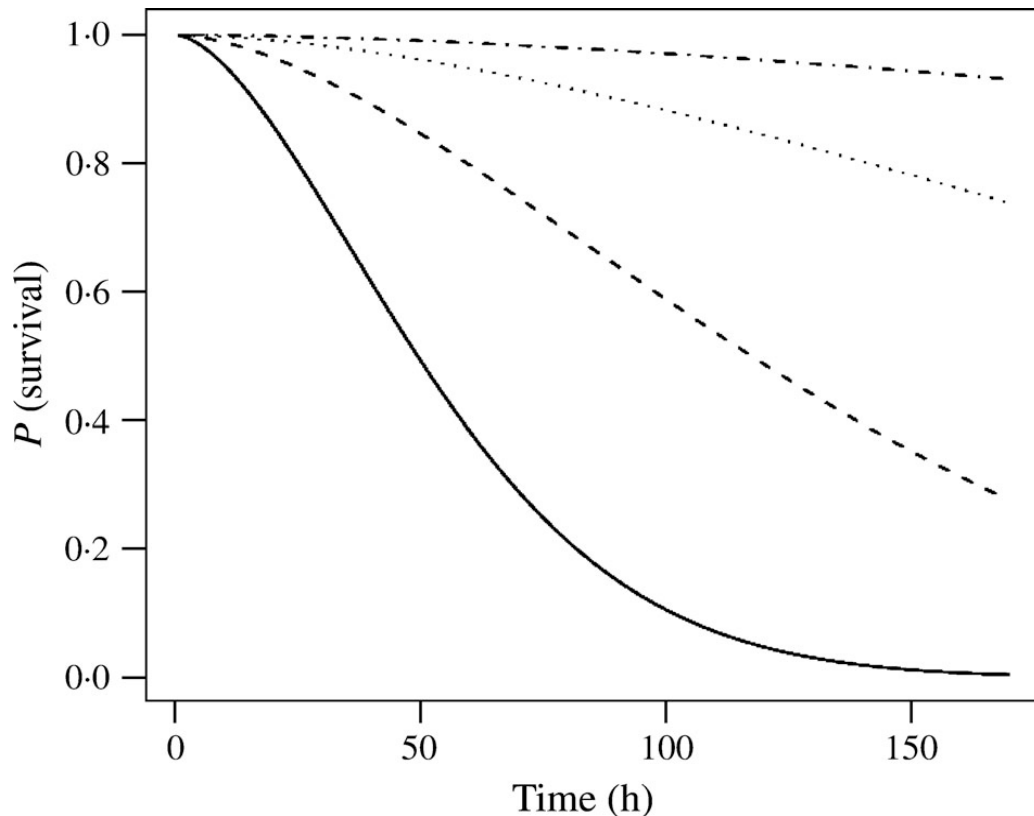


Figure 5: Predicted survival times for "motile" sea lice in four salinities (bottom to top) of 0, 7, 14 and 21 parts per thousand.. Connors et al, 2008

Planktonic life stages of sea lice are largely carried or pushed by water currents and waves. Current direction and speed are usually assumed to be principal influences on lice transport, but wind (i.e. wave action) may also concentrate microscopic lice into bays and other near shore areas (i.e. the same location of other fish, feed and fish farms). Lice detect their hosts from either mechanical stimuli (detection of water flow from swimming fish) or chemical stimuli.

Why the concerns about lice?

The presence of lice on adult wild salmon is not at issue, nor the subject of debate. Surveys along the central coast of British Columbia reveal that virtually all adult salmon are infected with sea lice and that pink, sockeye, and chum salmon host, on average, higher intensities (numbers of lice per infected fish) of lice than either Chinook or Coho salmon. Lice normally have little impact on adult salmon, and lice-related mortality of adult salmon in B.C. is rare. Genetically speaking, the Pacific salmon louse is substantially different than 'Leps' in other parts of the world.



The issue of key concern is the possibility of significant lice infections on wild juvenile salmon in areas adjacent to salmon farms. As millions of adult salmon are now cultured in coastal marine waters year-round, even with low abundance of lice present, high concentrations of caged salmon can act as unnatural “reservoirs” for lice. In areas without farms, uninfected juvenile wild salmon are separated from lice-bearing adult salmon because of the timing of wild migration. Juveniles salmon migrate in the spring, adults return from late autumn onward. Space and time therefore help to naturally separate adult and juvenile salmon, normally protecting juveniles from some of the parasites and diseases of adult salmon during early marine life. When adults and juveniles overlap in their distribution, usually in mid to late summer, there is greater opportunity for parasite and disease transfer from one generation to the next.

Today, juvenile fish in many areas of B.C. migrate past farmed salmon. A number of studies suggest that the small size of juvenile salmon makes them especially susceptible to negative consequences of parasite infestation. For example, a recent laboratory study on pink salmon found salmon fry greater than 0.7 grams are more able to cope with limited lice loads.

Why is there a debate about lice?

Lice on farmed salmon come from the natural marine environment. Atlantic salmon cultured in farms come from freshwater hatcheries and have no lice when stocked in marine net-cages. Evidence from farm records suggests that farmed salmon generally pick up lice mainly in the fall, coincident with the return of adult wild salmon.

The debate over the past several years has been whether salmon farms become the main source of wild lice affecting wild juvenile salmon, and to what degree those lice might affect the survival and populations of small juvenile wild salmon.

This debate exists because there is a lack of definitive evidence that lice overabundance on juvenile wild fish are lice from farmed fish. Several studies have looked without definitive conclusions for farm-specific molecular markers that would allow the path of transmission to and from wild fish to be traced. Since lice lay more eggs in the winter, the available farm lice data show that lice on farm salmon tends to peak in numbers in the winter. This peak of lice in the water may overlap with the arrival of juvenile salmon to coastal marine waters. This overlap may increase the likelihood of juvenile salmon coming into contact with sea lice.

In terms of support for the argument that salmon farms act as a reservoir for sea lice, and that juvenile wild salmon are challenged by sea lice more when in the proximity of farming operations, are the following associations:



- Lice are found in greater abundance on juvenile salmonids in areas where farms are also present;
- Number of wild juveniles infected with sea lice is correlated with the abundance of lice counted at nearby farms (i.e. increased abundance of sea lice on farms is associated with increased abundance on nearby wild juveniles) ;
- A comparative mathematical model of louse production suggests that farmed salmon could be a significant source of lice in the spring if lice abundance was not minimized on the farms; and
- Louse prevalence on wild fish may be reduced by fallowing farms (i.e. removing one of the potential ecological sources of lice: farmed salmon).

How do farms control sea lice?

Control of sea lice is a world-wide concern. Efforts to control lice on farmed salmon in B.C. and internationally include policies outlining legal limits on sea louse abundance on farmed fish in specific seasons, reporting of lice levels, and exploring the concept of “farm-free” areas to protect wild salmon (i.e. along known migration routes).

Salmon farmers can employ a number of tools to try to minimize sea lice levels on farmed salmon. These may include siting farms in areas with few natural hosts of sea lice or low salinity (sea lice thrive in high salinity water), reducing fish densities in the pens, and/or timing smolt entry and harvest to avoid wild migrations of young wild salmon.

Just like land-based farms, salmon farms can also be fallowed. Fallowing is the process of leaving a site void of fish for a few weeks to several months. Fallowing may be carried out as a means to break infectious life cycles, thus reducing the potential risk of infection to both wild and farmed juvenile salmon.

Fallowing is a standard management practice in Europe, and is most effective at reducing infection risk if all farms in an area are fallowed at the same time to avoid cross infections of farms (sometimes known as ‘whole-bay’ fallowing). In Laxford Bay, Scotland, the current practice is to fallow for a full year after harvesting, a practice that substantially reduced lice loads. “Whole bay fallowing” near Owen Gowla in Ireland has also resulted in increases in the marine survival of sea trout from around 2% to nearly 16%. Fallowing may also benefit salmon farmers by reducing the need for chemical treatments.



Photo courtesy Watershed Watch



Salmon farms in other countries have several options for treating sea lice, mostly chemical. In B.C., only one anti-lice drug is commercially approved and available. It is administered as an in-feed treatment (emamectin benzoate, also known as SLICE). Though chemicals tend to be effective (sometimes offering weeks of protection from lice), they are costly. It is also possible that treatments using a single chemical repeatedly over a long period has the potential to lead to drug resistance in lice. Other countries take an Integrated Pest Management (IPM) approach whereby managers are advised to use apply husbandry, fallowing, management and various chemical treatments to guard against the development of chemical resistance by the lice. Some research has been undertaken look at the unknown environmental fate of some of these chemicals released into marine environments.

Monitoring and reporting of sea lice

In B.C. sea lice policy developed by the provincial government is focused on monitoring lice on farmed salmon, not on wild salmon. The government of B.C. developed a sea lice action plan in 2003 which included a one-time “fallow” of Broughton farms in 2003 and required fish to be treated if, at any time throughout the year, more than 3 “motile” (mobile) lice per fish are recorded. Licensed veterinarians order and supervise treatments.

Public reporting of lice numbers is not mandatory in B.C., but beyond this difference, it is difficult to directly compare B.C.’s louse management to that of Europe’s, especially given the large differences in sizes and size-related vulnerabilities of juvenile salmonids in each region.

Closed Containment or Alternatives to Open Net Pen Farming

Closed System Aquaculture or “closed containment” is defined as “any system of fish production that creates a controlled interface between the culture (fish) and the natural environment.” In closed containment systems, there is a barrier between the farmed fish and the marine environment. This barrier helps protect the environment and its wild stocks from the wastes, disease, parasites, and other potential impacts of industrial salmon farming.

Closed containment is still a relatively new technology, and has not yet been widely adopted or embraced by industry due to potentially higher costs (for pumping of water, infrastructure, etc.) and the challenges of large-scale infrastructure change and innovation. Some companies, however, have piloted this technology, which may offer solutions to a number of the current challenges associated with salmon farming.

Lack of Response to First Nations Concerns

Some First Nations communities have repeatedly expressed concern with the siting, management, and monitoring of aquaculture in their territories. In some areas First Nations have had



significant challenges seeing their concerns addressed, and this has led some communities to undertake direct action and to challenge aquaculture management with government and in the courts.

Economic Impacts of Aquaculture

Some First Nation communities have chosen to get involved both directly and indirectly in aquaculture. Direct First Nations involvement in the aquaculture industry (ie. ownership and control), however, is a relatively small component of the overall sector. Aquaculture offers the opportunity for the development of spin-off businesses, and employment and income to communities, many of which are remote. The Komoks First Nation operates a successful shellfish farming operation under the name of Pentlatch Seafoods. Certain bands, such as the Kitasoo/Xaixais First Nation have been able to develop successful partnership arrangements with salmon aquaculture companies. Other First Nations have engaged in protocol agreements with aquaculture operators (such as Marine Harvest) when farming activities occur in their territories. These agreements have the potential to create financial benefit, to help build capacity in First Nations communities, and to create enhanced accountability frameworks for farming practices. First Nations can benefit economically from aquaculture operations in a more general sense as well. Some First Nations are able to benefit from employment associated with farming – for example in processing plants, transportation, and accommodation of employees. The presence of farming operations in/near communities can be a stimulus for other businesses as well (local shops, restaurants, etc).

Since the mid 1990s, the number of First Nation communities turning to finfish and shellfish aquaculture ventures has been steadily increasing, with more First Nations engaging in shellfish farming compared to finfish farming. In terms of involvement in shellfish farming, a report by Kingzett Professional Services (2002) discusses possible reasons for increasing interests of First Nations in becoming involved in shellfish cultivation for economic purposes. It is proposed that, “this interest arises not only because of the potential economic returns, but also because of the many compatibilities that exist between aboriginal communities and shellfish culture, including the cultural practice of shellfish harvest being deeply rooted in communities and the compatibility of shellfish farming with the environmental values held by many First Nations.”

One of the potential benefits of the aquaculture industry is the potential for employment to some coastal communities. The rural nature of aquaculture operations creates a potential for economic opportunities both on fish farms and in processing plants for employment. In Ahousaht for example, farms and the processing plants that handle the farmed fish employ over 60 people, and represent the second largest employer in the community, second to the band administration. Within Port Hardy and Campbell River many First Nations people are also employed in work related to the aquaculture industry.



In 2003, the Aboriginal Aquaculture Association (AAA) was established by six coastal First Nations to “promote and assist First Nations’ participation in the aquaculture industry in a manner that is respectful of First Nation communities, culture and values.” The AAA works with First Nations on finfish and shellfish aquaculture, providing a forum for discussion among First Nations. One of the products of the AAA is the publication of a handbook to assist First Nations in navigating the complex regulatory systems associated with opening new farms in B.C. This handbook also provides links and contact information for possible funding grants and subsidies for new ventures.

In the future there may be an opportunity for First Nations to negotiate a fee structure for aquaculture management which could be used to support a capacity within communities to engage in all aspects of aquaculture management.

First Nations representatives have voiced that one of the barriers to First Nations involvement in the finfish aquaculture industry is the initial investment of funds required, and the time-frame until products are available for market.

Conclusions

The current move for the jurisdiction of aquaculture from B.C. to Canada provides an opportunity for First Nations in B.C. to engage in a discussion about their vision for aquaculture. This discussion needs to consider issues related to First Nations’ rights and title issues, while taking into consideration the manner in which communities see themselves being engaged in aquaculture (including economic opportunities, siting, management, science, and monitoring and compliance activities). Broad First Nations input into these processes is key to developing sound legislation.

One of the important considerations will be how First Nations view their rights and title, and where/ to what extent they view aquaculture policy and management as potentially infringing upon those rights. New regulations could compel government to give First Nations greater decision-making in the siting of farms within their territories. The potential for an area-based management approach may create new opportunities for meaningful engagement First Nations in all aspects of the aquaculture industry.

Although outside of the scope of this discussion, it is clear that in order to participate effectively in the ongoing debate related to aquaculture First Nations communities need to build the capacity to understand the aquaculture industry and related policy, management and science. This is not something that will happen quickly, but needs to be a part of a plan which includes a vision for engagement and decision-making at the local and B.C.-wide scale in the overall area of aquaculture management.

