# Questions and Answers on Salmon Aquaculture in British Columbia


**Prepared By:**

**Dr. Tom Watson**
Senior Environmental Scientist, Triton Environmental Consultants Ltd.

**Research by:**

Erika Paradis, Senior Biologist, Triton Environmental Consultants Ltd.
Monica Stewardson, Senior Biologist, Mainstream Biological Consulting Inc.

**Comments provided by:**

Dr. Peter McKenzie, Fish Health Manager and Veterinarian, Mainstream Canada
Richard Opala, Regulatory Compliance Coordinator, Marine Harvest Canada
Mia Parker, Regulatory Affairs Manager, Grieg Seafood BC Ltd.
Mary Ellen Walling, President, BC Salmon Farmers Association
Dr. Brad Hicks, President, B. Hicks and Associates Inc.
Dr. Ron Lewis, Former Chief Veterinary Officer and Director of Animal Health Branch, B.C. Ministry of Agriculture and Lands
Sharon DeDominicis, Environmental Sustainability Manager, Marine Harvest Canada



Version 2, August 16, 2011

# Questions and Answers on Salmon Aquaculture in BC

## TABLE OF CONTENTS

## List of acronyms

| Acronym | Definition |
|---|---|
| AAA | Aboriginal Aquaculture Association |
| ACES | Aboriginal Certification of Environmental Sustainability |
| APF | Aquaculture Policy Framework |
| ASWP | Atlantic Salmon Watch Program |
| BAMP | Broughton Area Monitoring Program |
| BCARP | B.C. Aquaculture Regulatory Program |
| BCMAL | B.C. Ministry of Agriculture and Lands (now the B.C. Ministry of Agriculture) |
| BCMOE | B.C. Ministry of Environment |
| BCSFA | B.C. Salmon Farmers Association |
| BMP | Best Management Practices |
| *CEAA* | *Canadian Environmental Assessment Act* |
| CEDP | Community Economic Development Program |
| CFIA | Canadian Food Inspection Agency |
| CSAS | Canadian Science Advisory Secretariat |
| DFO | Fisheries and Oceans Canada (or, the Department of Fisheries and Oceans) |
| ENGO | Environmental Non-Governmental Organization |
| FADS | Federal Aquaculture Development Strategy |
| FAO | United Nations Food and Agriculture Organization |
| FHASP | Fish Health Audit and Surveillance Program |
| FHMP | Fish Health Management Plan |
| *FHPR* | *Fish Health Protection Regulations* |
| FTE | Full-time Equivalent (jobs) |
| *HAA* | *Health of Animals Act* (Canada) |
| *HAR* | *Health of Animals Regulations (Canada)* |
| HADD | Harmful Alteration, Disruption or Destruction |
| IHN | Infectious Hematopoietic Necrosis |
| ICES | International Council for the Exploration of the Seas |
| IMAPs | Integrated Management of Aquaculture Plans |
| ISA | Infectious Salmon Anemia |
| ITO Code | National Code on Introductions and Transfers of Aquatic Organisms |
| LFHO | Local Fish Health Officer |
| NAAHP | National Aquatic Animal Health Program |
| NASAPI | National Aquaculture Strategic Action Plan Initiative |
| OIE | World Organisation for Animal Health |
| *PAR* | *Pacific Aquaculture Regulations* |
| PWC | PricewaterhouseCoopers LLP |
| RAS | Recirculating Aquaculture Systems |
| ROE | Return on Equity |
| SEP | Salmon Enhancement Program |
| SOP | Standard Operating Procedure |
| SST | Sea Surface Temperature |
| WSP | Wild Salmon Policy |

## Introduction

This document has been created to provide a concise and comprehensive review of information relating to the salmon aquaculture industry in British Columbia (BC). The British Columbia Salmon Farmers Association (BCSFA) is dedicated to educating the general public about the salmon farming industry in the province. The material in this document has been summarized from a broad range of resources, including peer-reviewed scientific papers, books, government and industry publications, websites and media releases. Every attempt has been made to present a balanced description of all aspects of the industry, from regulation to the known and potential environmental impacts of salmon farm operations.

The purpose of such a document is to assist people outside of the industry, and those involved in the Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River, in developing a better understanding of salmon farming in BC. The BCSFA recognizes that some publications about salmon farming that are distributed to the general public by industry opponents are prepared to deliver a specific message. Intentionally or unintentionally, many of these publications do not always deliver a balanced message. It is hoped that the material in this document will educate readers and allow them to develop an informed opinion about the salmon farming industry in BC.

## Preamble

### 1. Why farm salmon in BC?

There are a number of reasons for farming salmon in BC. The sheltered, deep inlets, strong currents and cool temperatures characteristic of BC coastal waters provide ideal growing conditions and locations for fish farms. The proximity of farm sites to the market is favourable, allowing fresh prime product to reach the customer within 48 to 72 hours.[1] The worldwide demand for seafood, including salmon, is growing, and the commercial fishing industry is struggling to keep up.[2]

Currently, salmon aquaculture is BC's most important agricultural crop, supplying products to the rest of Canada, the United States and Asia. The aquaculture industry also provides employment for many individuals in remote coastal communities. A group of leading researchers have noted:

> "*Salmon farming provides employment in coastal communities and it reduces the pressure on Pacific salmon (Oncorhynchus spp.) stocks at a time when a warming climate is complicating the management of wild Pacific salmon stocks*."[3]

### 2. How long has salmon aquaculture been practiced in BC?

"Finfish aquaculture" began in the 1850s when governments engaged in the incubation and hatching of different species.[4] In the early 1900's the Canadian Fisheries Service developed a widespread hatchery program, but by the mid 1930's marginal success led to the closure of most of the hatcheries established in BC.[5] The modern salmon farming industry started commercial operations in Canada in the early 1970s.[6]

The first commercial salmon farms in BC were located on the Sunshine Coast, but the challenges of frequent algae blooms encouraged the industry to expand to more remote areas along the coast of Vancouver Island where conditions were more favourable. In conjunction with this move, farmers also began to farm Atlantic salmon (*Salmo salar*) in addition to the chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*) and sockeye (*O. nerka*) that were originally farmed.

The aquaculture industry in Canada has grown to be one of the top competitors in the world. In 2010, BC was responsible for over 50% of the nation's exports of farmed finfish (including both salmon and freshwater trout production).[7] The majority of the remaining finfish production occurred in eastern Canada (primarily New Brunswick, with lesser amounts in Nova Scotia, Newfoundland and Labrador, and Prince Edward Island) with a small amount of production occurring in Ontario and Quebec.[8]

## 3. Who farms in BC?

The consolidation of ownership of many smaller companies has transformed the industry in BC over the last two decades. The majority of farmed salmon production is now managed through four larger companies, three of which are listed on stock exchange(s) and are publicly traded. Marine Harvest Canada, Mainstream Canada, and Grieg Seafood BC Ltd. are all part of multinational businesses whose parent companies are public. Creative Salmon Company Ltd. is privately owned.

## 4. What benefits is this industry bringing to the people of BC?

In 2009, PricewaterhouseCoopers LLP (PWC) prepared an economic 'snapshot' of the entire industry based on 2008 financial results and previous work commissioned, at the time, by the BC Ministry of Agriculture, Food and Fisheries. The report found salmon farming in BC provides an estimated 6,000 direct and indirect full-time jobs. Direct employment of 2,800 person years occurs in hatcheries, farm sites, administration, and processing.[9]

Employment opportunities in the aquaculture industry vary from physically demanding field work to upper level management positions. Most positions require formal education in addition to on-the-job training and hands-on experience. Examples of positions within the aquaculture industry include: senior managers, scientists and technicians, veterinarians and fish health specialists, farm and hatchery workers, boat captains and deckhands, truck drivers, workers in manufacturing and processing facilities, administrators, sales and marketing staff, and transportation sector employees.[10]

In 2010, Fisheries and Oceans Canada (DFO) released a study entitled *Socio-Economic Impact of Aquaculture in Canada*.[11] The study indicated in 2007, the aquaculture industry in Canada created 14,500 full-time-equivalent (FTE) Canadian jobs. *Direct* employment in hatcheries, on farms, in processing plants and administration was estimated at 4,900 FTE. *Indirect employment* (includes impacts in the industries supplying goods and services to aquaculture activities) created 6,400 FTE, while *induced* activities (arising from spending of income earned by those employed in direct and indirect activities) added 3,200 FTE. In terms of income, *direct* labour income in

Canada in 2007 totalled $156.8 million, while *indirect* income for support industries totalled $241.2 million.

According to the DFO report, in BC in 2007, aquaculture generated about 6,000 FTE of employment: 2,220 FTE in *direct* activities, 2,330 FTE in *indirect* jobs and 1,410 FTE in *induced* activities, totalling $223.3 million in labour income.[12] Total *direct* labour income was $78.4 million (averaging $35,250 FTE), *indirec*t income totalled $95.1 million (averaging $40,900) and *induced* activities in the broader economy earned $50.4 million (averaging $35,700). The output value in 2007 was $559.7 million, resulting in gross value of economic activity generated of $946.1 million. The industry made an overall contribution to provincial GDP of $425.3 million. In comparison, commercial fisheries (including processing) employ approximately 1,600 people, many being seasonal workers only. By providing job security in coastal communities where other resource-based employment opportunities have been depressed, salmon farming also provides economic and social stability.

Another recent study commissioned by the Living Oceans Society and the Regional District of Mt. Waddington, examined the economic livelihoods of people, businesses and communities to the marine environment in that district in the Northern portion of Vancouver Island.[13] Having calculated aquaculture, commercial fisheries, marine recreation, and marine transport collectively it was determined these industries "generate $48 million in wages & benefits and 1,160 person-years of employment directly" to the area's residents, the study notes (as presented in Table 1) aquaculture represents the largest source of these direct benefits.[14] Worth $178.3 million in revenue, $19.2 million in wages and 400-person years of employment within the Regional District directly, aquaculture plays an important role in communities such as Port Hardy and Port McNeill.[15]

**Table 1. Economic importance of marine-based activities in Regional District of Mt. Waddington**[16]

| **Direct Industry Impacts** | **Wages & Benefits $ million** | **Employment per person-year or PYs** |
|---|---|---|
| Commercial Fisheries | 8.3 | 305 |
| Aquaculture | 19.2 | 400 |
| Marine Recreation - Sport Fishing | 5.0 | 120 |
| - Other | 8.0 | 225 |
| Marine Transportation | 7.5 | 110 |
| **Total** | **48.0** | **1,160** |

Note: Taken from GSGislason & Associates Ltd., 2011.

## 5. What species of salmon are farmed in BC?

In 2009, the three main species grown were Atlantic, chinook, and coho salmon; however, the vast majority (95%) of salmon grown is Atlantic salmon.[17]

## 6. Why farm Atlantic salmon in BC?

Atlantic salmon is the most commonly farmed salmonid species in BC due to the fact it is an efficient converter of feed to edible protein,[18] is easier to manage, has low mortality in sea cages, adapts well to being farmed and commands a high market value.[19]

## 7. What is the size of the BC salmon aquaculture industry?

There are 134 licensed salmon farms in BC, and this number can vary depending on the timing of renewals, amendments, and new applications. Roughly three quarters of the licensed farms are actively employed for scheduled production and of this number, approximately one third are fallow at any given time. In effect, there are 70 to 75 salmon farms operating at any given time in BC.

## 8. What is the size of a fish farm?

A typical salmon farm consists of two to 24 net pens of varying sizes from 15 metres by 15 metres to 30 metres by 30 metres. Some companies also use circular pens which have a circumference of 23 to 35 metres. Cage depth depends on the size and shape of the pen, and tends to be between 12 to 30 metres. The number of fish stocked into a net pen depends on its size and depth; however a 30 metre pen would usually be stocked with 35 – 60,000 fish for a stocking density at harvest of less than $15kg/m^3$.

## 9. How does the efficiency of aquatic farming compare to terrestrial farming?

Land-based agriculture accounts for 80% or more of the food we eat. Much of the world's arable land has been committed to the production of food, and few remaining areas are available for increasing production. Farming aquatic animal protein is generally more efficient and cost effective in terms of space and resource utilization compared with land-based animal proteins.[20] The Canadian Aquaculture Industry Alliance notes:

> "*Most aquaculture production methods rank on the lower end of the carbon footprint/output scale for food production when compared to industrial harvesting practices. When wastes from bycatch, fishery discards and processing by-products are factored into the equation, the differences are even greater.*"[21]

In terms of surface area, this means that much greater production per hectare can be achieved in general from aquaculture.[22] Based on statistics provided by the Ministry of Environment for the 2009 production year, 4,575 hectares (ha) of tenures produced 76,300 tonnes of salmon.[23] This gives a yield of 16.68 tonnes per hectare. The result is even more striking when one considers that less than 1.25 ha of a salmon farm tenure is used to grow fish and the remainder is used for storage and anchoring. In comparison, the amount of land required to raise cattle for the beef industry is larger: 6,982 ha of good pasture are needed to produce 1,250 kg of edible beef, compared to 1.6 ha, to produce the same amount of edible salmon. [24]

## 10. What is the production of farmed salmon in BC? How does this compare to the production of wild salmon at the same time?

While the production of farmed salmon has remained relatively consistent in recent years, the commercial harvest of wild salmon has been more variable from year to year. Table 2 (below) summarizes farmed salmon production in BC compared to the commercial salmon harvest for the period of 2006 to 2009.

**Table 2. Farmed salmon production compared to the commercial salmon harvest, BC, 2006-2009**

| Year | Farmed Salmon Production[25] | | Wild Salmon Harvest[26] | |
|---|---|---|---|---|
| | Tonnes | $ Value (millions) | Tonnes | $ Value (millions) |
| 2006 | 78,000 | 407.4 | 24,300 | 60.9 |
| 2007 | 78,900 | 384.1 | 20,200 | 31.6 |
| 2008 | 81,400 | 409.3 | 5,400 | 21.6 |
| 2009 | 76,300 | 394.2 | 18,500 | 23.7 |

## 11. What is the relationship between finfish aquaculture and First Nations in BC?

First Nations have a complex relationship with aquaculture, and they are neither universally opposed to aquaculture, nor universally in favour of it. A recent book by Nathan Young and Ralph Matthews, *The Aquaculture Controversy in Canada: Activism, Policy, and Contested Science* attempts to put these competing views of salmon farming by First Nations into context:

> "*While First Nations groups are adopting different and sometimes competing stances on aquaculture development, the issues of rights and self-governance are front and centre* both *in opposition to and in support of the industry*."[27]

As an example, in 2010 when environmental groups protested the Ahousaht First Nation involvement with aquaculture and copper mining companies, the Ahousaht hereditary chiefs issued a media release asking that external stakeholders recognize the Nation's sovereignty and cease in their efforts to impose their agendas on the Nation, its Leaders and its People.[28] In contrast, the Homalco First Nation openly opposed the production of farmed salmon in their traditional territory near the mouth of Bute Inlet and welcomed the support of environmental groups.[29] This position has since changed.[29a]

Authors Matthew and Young note that because aquaculture has been cast in the role of "an economic saviour and problem solver for troubled regions", it has unintentionally become "married… to the problem of coastal economic and environmental hardship".[30] The authors say the more realistic way to view the industry is as "*part* of a broader diversification of coastal economies."[31] As the Ahousaht press release suggests, whether aquaculture balances their traditional ways of life with economic, social and environmental sustainability is an issue that each First Nation must decide for itself.

There are other examples of positive relationships between the aquaculture industry and First Nations in BC. The Aboriginal Aquaculture Association (AAA) was established in 2003 by six Founding Members, representing a cross-section of aboriginal leaders in BC. Following a number of studies, these leaders "concluded that various forms of aquaculture may provide successful careers for their communities, especially among young aboriginal people."[32] The association has a mission to "promote and assist the development of First Nations' aquaculture that respects and supports First Nation communities, culture and values."[32a] The association has also taken the lead with the development of the Aboriginal Certification of Environmental Sustainability (ACES) Program for aquaculture.[33]

The salmon aquaculture industry in BC has developed partnerships with many First Nations people. For example, Marine Harvest Canada has been working together with the Kitasoo/Xai'xais people in Klemtu for over 10 years. The state-of-the-art aquaculture program developed with the Kitasoo processes 5,000 tonnes of salmon a year from local farms, while providing stable, long-term employment for members of the community.[34]

## Section 1. Does the regulatory regime for finfish aquaculture protect both farmed and wild salmon?

The regulatory regime that applies to salmon farming in BC is designed to protect both wild salmon and farmed salmon, as well as other marine life and habitats. Although exclusive jurisdiction over salmon farming in the province has only recently been given to the Federal Government of Canada, the new federal regulations and licences adopted many of the environmental monitoring and audit programs introduced by the Provincial government and included additional requirements to ensure the salmon aquaculture industry is in compliance with its obligations, provides for greater public reporting of compliance and environmental performance. By regulating the industry primarily through individualized licence conditions, the DFO (Department of Fisheries and Oceans, also known as Fisheries and Oceans Canada) also ensures that its management of salmon aquaculture is able to continuously adapt to current scientific knowledge to address potential impacts on wild salmon and the environment. [35]

## Regulatory backgrounder - context:

Apart from the regulatory framework, the DFO has numerous policies and programs that relate to aquaculture either directly by setting out the role of the Department with respect to aquaculture, or indirectly by establishing practices which touch upon aquaculture activities. A brief overview of several of these policies and programs is provided below.

### Federal Aquaculture Development Strategy (FADS)[36]

Aquaculture lies between fishing and farming, and developed in a complex jurisdictional context involving the participation of regional, provincial/territorial and federal governments. The Federal Aquaculture Development Strategy was developed to foster and guide the development of sustainable aquaculture in a manner consistent with the DFO's "responsibilities in such areas as habitat and biodiversity"[37] and the International Council for the Exploration of the Seas (ICES) position that "aquaculture, when properly managed, is an environmentally sound commercial activity."[38]

### Aquaculture Policy Framework (APF)[39]

Under the APF, aquaculture is a strategy that functions within DFO's management and conservation of wild salmon. It notes that aquaculture can reduce pressure on wild fish stocks, "*helping to sustain and enhance the wild fishery*".[40] The APF reports that "by 2025 annual demand for seafood will outstrip the capacity of wild fisheries by some 55 million tonnes".[41] Furthermore, it reads:

> *"With global demand increasing and natural stocks already largely at or exceeding their maximum capture potential, it is clear that aquaculture will play an important role in satisfying future global demand and in contributing to the security of the global food production system."*

The APF identifies numerous pressures on natural resources. These include population growth, the expansion of the world economy putting pressure on natural resources, climate change, air pollution, threats to water quality and availability, and declining biodiversity.[42] It recommends that governments and the private sector "take measures to ensure the long-term sustainability of the world's natural resources through responsible stewardship, sound environmental management and scientific innovation."[43]

The APF integrates consideration of sustainable development, adaptive management, and the precautionary approach into the development of the aquaculture industry.[44] Under the APF the DFO will, "where applicable, consider the social and economic benefits associated with aquaculture development in the course of its decisions."[45] This approach balances the risks of aquaculture to the environment with the social and economic benefits, and ensures that the risks are well-monitored, mitigated and offset wherever possible.

**Wild Salmon Policy (WSP)**[46]

The WSP explains that the DFO's conservation mandate and responsibilities under the WSP are consistent with the previously-published APF.[47] It notes that the DFO's role, "as the lead federal agency for aquaculture, is to manage aquaculture so that it is environmentally sustainable, socially responsible, and economically viable", and that the APF directs the DFO to "support aquaculture development in a manner consistent with its commitments to eco-system based and integrated management, as set out in departmental legislation, regulations and policies."[48]

The WSP says that aquaculture "will be regulated in a manner consistent with other human activities that may adversely affect salmon or their habitat" and provides:

> *"If specific Conservation Units of wild salmon are threatened by aquaculture operations, corrective actions will be taken under the Fisheries Act, or longer-term solutions will be pursued as part of an integrated planning process."*[49]

**B.C. Aquaculture Regulatory Program (BCARP)**[50]

BCARP is a new DFO program for managing, administering, and regulating aquaculture in BC and for governing the aquaculture industries now subject to federal regulation. Under this program, DFO will develop policies and Integrated Management of Aquaculture Plans (IMAPs), review licences and management plans, liaise with stakeholders, other governments and First Nations, and report publicly on the performance of the aquaculture industry.[51] In conjunction with the regular reporting obligations and approvals required under the new aquaculture licences, DFO may refuse to approve the transfer of new fish to sites before certain environmental thresholds are achieved, and may undertake prosecutions for breaches of the licence, and require "site observers" where other measures prove insufficient to achieve compliance.[52]

**Policy for the Management of Fish Habitat (No Net Loss)**

DFO defines "No Net Loss" to mean "A working principle by which the department strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis so that further reductions to Canada's fisheries resources due to habitat loss or damage may be prevented."[53] It is a flexible policy that operates through a hierarchy of preferences and other procedures to permit works or undertakings where "other techniques, including those used to restore and develop habitat, may be employed by proponents to achieve no net loss and the conservation goal."[54]

## 12. Are salmon aquaculture sites in BC regulated?

Canada's aquaculture industry operates under a comprehensive set of federal, provincial/territorial, and regional legislation and regulations.[55] Aquaculture in BC was regulated by both the federal and provincial governments until December 18, 2010. The Province of BC continues to issue tenures where operations take place on crown land in either the marine or freshwater environment, licence marine plant cultivation, license and inspect seafood processing plants and manage business aspects of aquaculture such as work place health and safety within the province.[56]

Formerly, aquaculture sites and farm siting were regulated by the Province of BC pursuant to numerous pieces of legislation.[57] The Federal Government of Canada regulated marine navigation and performed reviews and environmental assessments of aquaculture projects under the *Fisheries Act* (Canada),[58] the *Navigable Waters Protection Act* (Canada),[59] and the *Canadian Environmental Assessment Act* (*CEAA*).[60]

Following the decision of the B.C. Supreme Court in *Morton v. British Columbia (Ministry of Agriculture and Lands)* in 2009,[61] the Federal Government of Canada now regulates finfish aquaculture in BC, whereas the Province of BC regulates crown land tenures for aquaculture sites and the aforementioned additional processing and business aspects of aquaculture. Justice Hinkson in the *Morton v. British Columbia (Ministry of Agriculture and Lands)* decision held that the specific provisions of the B.C. legislation and regulations pertaining to finfish aquaculture were to be read down to only apply to the cultivation of marine plants.[62] Aquaculture in BC is now regulated under the *Fisheries Act* (Canada), the *Fishery (General) Regulations*, and the recently-enacted *Pacific Aquaculture Regulations* (*PAR*).[63]

## 13. How are farm sites regulated in BC?

The *PAR* sets out various conditions required in aquaculture licences including the waters in which aquaculture is permitted,[64] measures that must be taken to minimize the impact of the aquaculture facility's operations on fish and fish habitat,[65] and the measures that must be taken to monitor the environmental impact of the aquaculture facility's operations.[66] For example, the licence and conditions for finfish aquaculture under the *PAR* provides for the protection of fish habitat at section 13. Section 13 requires the industry to take numerous steps such as monitoring benthic impacts, fallowing farms, and in some cases providing habitat compensation and taking measures to mitigate the loss of productivity to the seabed.

## 14. Do aquaculture operations undergo an environmental assessment?

Environmental assessments of aquaculture sites under the *CEAA*[67] were performed to determine the significance of the potential adverse environmental effects that an aquaculture facility may have posed, including determining whether the site would impact fish and fish habitat under the

*Fisheries Act* (Canada).[68] However, the *Morton v. British Columbia (Ministry of Agriculture and Lands)*[69] decision introduced some uncertainty on whether *CEAA* continues to apply to aquaculture, as it ruled that aquaculture is a "fishery". There is case law that says fishing is not a "project" requiring environmental assessments under *CEAA*.[70]

Fisheries are not required to conduct environmental assessments. Nevertheless, a *CEAA* assessment is necessary for new or modified salmon farms if Transport Canada determines the project is likely to cause a substantial navigational interference when giving an approval under the *Navigable Water Protection Act*.[71]

## 15. What role does government play in aquaculture management?

As of December 18, 2010 the Federal Government of Canada is the regulator of the aquaculture industry in BC. Because of the substantial economic benefits of aquaculture, particularly to rural coastal areas,[72] in addition to regulating and enforcing compliance with the *PAR* and aquaculture licence conditions under the *Fisheries Act* (Canada), the Federal Government of Canada also supports the development of sustainable aquaculture.[73] There are 17 federal departments and agencies that have a direct influence on aquaculture development and management. Together, these departments cover issues such as research, environmental sustainability and interaction, and product safety inspections.[74] The *Fisheries Act* (Canada) does not directly reference Aquaculture activities and for this reason there is growing support across Canada within the salmon farming business for the development of an *Aquaculture Act* which would clearly define rights and responsibilities for this growing sector.[75]

## 16. Are aquaculture operations inspected on a regular basis?

Until December 18, 2010, DFO and the other federal departments and agencies, as well as the province of BC monitored aquaculture operations by reviewing monitoring data gathered by aquaculture operators as part of the requirements of their licence, lease or other approval, and by conducting periodic on-site audits of operations. Furthermore, BC Ministry of Agriculture and Lands (BCMAL) and the BC Ministry of Environment (BCMOE) conducted on-site audits to assess compliance, verify the accuracy of industry-reported information and to collect samples for disease testing.

The *Fisheries Act* (Canada) provides for inspectors to enter and inspect operations, including to check for deposition of deleterious substances by taking samples, tests and measurements, and requires every person in the place being inspected to give inspectors all reasonable assistance in carrying out their duties.[76] Under BCARP the DFO will conduct compliance evaluations for fish health and environmental protection, review and analyze environmental and compliance data, and evaluate the effectiveness of environmental protection.[77] A Conservation and Protection unit will now be enforcing compliance with the new *PAR* by inspecting and auditing sites, and undertaking investigations and enforcement actions.[78] According to the DFO, the new unit will create a substantial enforcement presence focused on aquaculture.[79]

## 17. What types of ongoing monitoring take place? Who does the monitoring?

Under BC's jurisdiction, compliance with regulatory requirements and the terms and conditions of Aquaculture Licences was determined by way of regular inspections of farm sites by provincial and federal inspectors. A comprehensive inspection of every active salmon farm was made once every year to measure compliance with the regulatory requirements of the BCMAL and the BCMOE, and terms and conditions of the Aquaculture Licences issued by BCMAL.[80] Provincial inspectors would interview company employees, review the farm's operational procedures and practices, inspect all aspects of the operational systems (cages, nets and ancillary infrastructure) and review maintenance records for completeness and compliance. On average, each operational finfish facility was visited several times each year by various government representatives other than the BCMAL inspectors, including BCMAL Fish Health Technicians, the BCMOE Environmental Protection Division staff, the DFO, and WorkSafeBC.[81]

Federal aquaculture licences granted under the *PAR* require licence holders to conduct ongoing monitoring themselves. The *PAR* requires additional information than was previously required by the Province's auditing process. Certain monitoring must also be accompanied by documented analysis. For example, fish health records must be "reviewed by the licence holder's veterinarian and/or fish health staff to look for patterns in fish health and disease", and these reviews must be documented and kept as part of the fish health records to be made available to the DFO upon request.[82] As formerly under the *Finfish Aquaculture Waste Control Regulation* (BC), aquaculture licence holders continue to be required to perform ongoing environmental monitoring of sediments below and in the vicinity of the farm site and to report results. They must collect raw benthic monitoring data and have analytical reports prepared and kept for a six year period.[83]

## 18. Does the DFO apply Sections 35 and 36 of the *Fisheries Act* (Canada) in consideration to aquaculture?

The DFO states that the *PAR* and the *Fishery (General) Regulations* apply to "individual Harmful Alteration, Disruption or Destruction (HADD) authorizations issued under Section 35 of the *Fisheries Act*."[84] Section 35(2) contemplates the authorization of HADDs by Ministerial authorization or regulations by the Governor in Council, whereas section 36(4) contemplates regulations prescribing the deposition of deleterious substances. Authorizations under section 35(2) of the *Fisheries Act* (Canada) permit aquaculture operations to create HADDs, and require them to exercise due diligence with respect to the deposition of deleterious substances under section 36(3) of the Act. However, at present there appears to be some uncertainty as to the application of sections 35 and 36 of the *Fisheries Act* (Canada)[85] to aquaculture.

For example, the National Aquaculture Strategic Action Plan Initiative (NASAPI) West Coast Marine Finfish Sector recommended in its Strategic Action Plan 2011–2015 there should be "regulations under the *Fisheries Act* to enable administration of drugs and pest control products in aquaculture for fish pathogen and pest treatment within the conservation and protection mandate of the Act (i.e. s.35)".[86] The plan recommends "a regulatory process by which drugs and pest control products, technologies and procedures can be used for fish health management without contravening s. 32 or s.36 of the *Fisheries Act* while ensuring that proper measures are in place to conserve and protect fish and fish habitat."[87]

For salmon farming operations in BC, DFO apparently intends to establish conditions of licence and a separate section 36 authorization to manage environmental impacts.[88] Conditions of the licence may include "setting limits on the extent of environmental impact, requiring compensatory measures for altered habitat, setting out monitoring and reporting requirements, and working with industry on aquaculture siting and assessment measures to ensure negative impacts to sensitive fish habitats are avoided".[89]

## 19. What has been the industry's level of compliance with the regulatory requirements in recent years?

The BCMAL and BCMOE joint report *Regulatory Compliance of British Columbia's Marine Finfish Aquaculture Facilities: 2008*, reports that in 2008 the salmon aquaculture industry had an average compliance level of 99% on both the BCMAL and the BCMOE inspection points.[90] The industry has demonstrated a high level of compliance since 2003.[91]

## 20. Are penalties given to aquaculture operators who break the rules? What kind?

The *Fisheries Act* (Canada) section 40 provides for criminal offences and penalties for the unauthorized HADDs under section 35(1) or deposition of deleterious substances under section 36(3) of that Act. The licences issued under the *PAR* provide that "Contravening a condition of this licence is an offence under the *Fisheries Act*."

Contravening sections 35(1) and 36(3) of the *Fisheries Act* (Canada) may result in an offence under the Act. Subsections 40(1) and 40(2) of the *Fisheries Act* (Canada) make it an offence to contravene subsections 35(1) and 36(1) of (3) respectively, and provide that a person may be guilty of either an offence punishable on summary conviction or an indictable offence. There are substantial fines of up to $300,000 for a summary conviction offence and up to $1,000,000 for indictable offences, as well as potential jail time of up to six months for a subsequent summary conviction, and up to three years for indictable offences under the Act. Section 40(3) also provides a list of other acts and omissions under the *Fisheries Act* for which, for a first offence a fine of up to $200,000 and for subsequent offences a fine up to the same amount or imprisonment of up to six months.

Both DFO and Environment Canada possess a suite of tools apart from prosecutions and convictions to encourage compliance with the *Fisheries Act* (Canada). The Compliance and Enforcement Policy for the Habitat Protection and Pollution Prevention Provisions of the *Fisheries Act* says that "warnings, directions by Fishery Inspectors, authorizations, and Ministerial orders" may be used to enforce the habitat protection and pollution prevention provisions.[92] Court actions other than prosecutions are also available, including injunctions and civil suits for recovery of costs.[93]

## 21. How do Canada's introductions and transfers regulations guard against introducing new pathogens/ diseases in the environment?

The movement of aquatic animals and eggs from other countries, and even within Canada, involves a risk of transferring fish pathogens or parasites. The introduction and transfer of eggs and aquatic animals in BC used to be governed by the Fishery (General) Regulations (Canada),[94] the Regulations Respecting the Protection of Health of Fish (Canada),[95] and the Introductions and Transfers Committee applying the National Code on Introductions and Transfers of Aquatic Organisms (ITO Code).[96] The purpose of the ITO Code was to reduce the risk of introducing new infectious agents that may cause disease outbreaks, in a manner "consistent with Canada's commitments under the 1992 Convention on Biological Diversity."[97]

The Canadian Food Inspection Agency (CFIA) is the federal agency now responsible for disease control and importation of fish and eggs, with the mandate to further reduce the risk to disease introduction and eradicate or control the disease if it occurs. The CFIA will administer the introduction of eggs through the recently-amended Health of Animals Act (Canada)[98] (*HAA*) and Health of Animals Regulations (Canada)[99] (*HAR*), and the National Aquatic Animal Health Program (NAAHP). These amendments were introduced to create a comprehensive national regulatory framework to protect against the introduction of diseases or spread of diseases within Canada, and to help Canada meet international standards for aquatic animal health control measures set by the World Organisation for Animal Health (OIE).[100]

As of December 2010, introductions and transfers are regulated by the CFIA applying the *HAA* and *HAR*, and in cooperation with DFO in delivering the NAAHP. Under the *HAA*, the CFIA must be informed of the presence of reportable and notifiable diseases, and must implement controls to prevent these diseases from being introduced into, or spread within, Canada. The parts of the *HAR* affecting movement of aquatic animals within Canada will come into effect once the health status of eradication areas have been declared.[101]

The *HAA* requires aquatic animals be presented for inspection when they are imported and requires a permit for importations of species susceptible to the diseases listed in the *HAR*.[102] Permits contain conditions which are designed to allow the importation of aquatic animals while minimizing the risk of introducing or spreading the listed diseases. Various risk factors are considered to determine the conditions of the import permit or whether a permit should be denied where the risk is too great. These factors include "species, life stage, disease agent, method of transmission and disease status of place of origin or specific uses such as bait, feeding to, or manufacturing feed for aquatic animals, research or diagnosis, or any other purpose that produce offal or effluent from those aquatic animals."[103] Although the government admits that "these amendments will not completely eliminate the risk of the introduction of the listed diseases", it says:

> "*However, it will constitute reasonable steps to control the preventable risk, and to harmonize Canadian requirements with international standards. As well, these amendments mirror the current provisions for land animals in that they include tools to help prevent the spread of disease as well as measures to prevent introduction*."[104]

A person who owns or has the possession, care or control of an animal must immediately notify the nearest veterinary inspector of the presence of a reportable disease or any fact indicating its presence.[105] A veterinarian or person who analyses animal specimens and who suspects a reportable disease must also immediately notify a veterinary inspector appointed under the Act of his or her suspicion.[106] Failure to notify is an offence under the Act, as is concealing a reportable disease.[107] The enforcement of permit conditions is achieved through the examination of animals and of records of hatcheries and other facilities that move aquatic animals.[108] Conviction of an offence under the *HAA* can result in a fine of up to $50,000 for a summary conviction or $250,000 for an indictable offence, and imprisonment of up to six months or two years respectively.[109]

Formerly, under the *Fisheries Act* (Canada) it was prohibited to release or transfer live fish into a rearing habitat except as authorized by a federal licence,[110] or to possess, transport, or traffic live fish unless authorized by a provincial licence.[111] Under the *Fishery (General) Regulations* (Canada), a licence could only be issued if the release or transfer of the fish would be in keeping with the proper management and control of fisheries, the fish did not have any disease or disease agent that may be harmful to the protection and conservation of fish, and the release or transfer of the fish did not have an adverse effect on the stock size of fish or the genetic characteristics of fish or fish stocks.[112] The *Regulations Respecting the Protection of Health of Fish* (Canada)[113] furthermore required a certificate that the eggs were inspected in the approved manner and were free from enumerated diseases before an import permit could be issued.

The safeguards implemented by DFO in its salmonid importation policies included:

- importation of eggs only (live fish are not permitted)
- certification of the exporting facility under the *Fish Health Protection Regulations* (*FHPR*) and inspection by a Canadian Fish Health Officer (or competent authority of the exporting country)
- surface-disinfection of eggs prior to shipping
- rearing of eggs and fry in a DFO-approved quarantine facility within the Pacific Region until the fish are at least 3 grams. During this time monthly health monitoring must be done to test for infectious agents.[114]

The certified exporting facility approved by the DFO is located in Stofnfiskur, Iceland, where Infectious Salmon Anemia (ISA), the primary pathogen of concern, has never been detected.

The ITO Code, which is still listed on the DFO's website discussing the CFIA's delivery of the new NAAHP, required proponents to provide detailed information relating to the transfer, and a risk assessment is then carried out to determine whether the introduction poses a low, medium or high risk on the basis of international models, processes, and scientific knowledge and expertise.

Introductions and transfers to which the ITO Code applied occurred for a variety of reasons such as to create or improve new recreational fisheries and expand enhancement programs,[115] aquaculture, increase fish stocks, biocontrol, or fill perceived gaps in certain aquatic communities is permitted under certain conditions.[116] It is also important to note the ITO Code never applied to numerous other human activities which posed significant threats of disease transfer to wild salmon in the marine environment.[117] In particular, ballast water used in the shipping industry is considered "the largest single source of new aquatic invasive species … ranging from bacteria to larger organisms."[118] When processing wild fish, processing plants may also harbour substantial concentrations of viable pathogens from distant locations.[119]

## 22. Does the DFO have a conflict with its mandate(s)?

Some ENGOs claim that the DFO is in a conflict of interest with respect to its mandates to conserve wild salmon and to regulate and promote aquaculture. The Living Oceans Society credits this notion to the "Federal Auditor General's audit" in 2000 which it says "identifies a conflict of interest between the Department of Fisheries and Oceans' (DFO) promotion of salmon farming and its mandate to protect wild fish and wild fish habitat".[120] The audit's purpose was to determine "whether the Department, as the agency responsible for the conservation and protection of wild salmon stocks, is meeting its obligations under the *Fisheries Act* and the *Oceans Act*, while participating in the regulation of the salmon farming industry in B.C. …"

However, the Report of the Auditor General of Canada[121] (December 2000) does not say DFO's conservation mandate and its commitment to develop sustainable aquaculture are in a clear conflict, only that DFO was not adequately meeting its obligations. The potential conflict noted by the Report was between federal and provincial legislation.[122] The Report in fact says:

> "…*It is in the Department [of Fisheries and Ocean]'s and B.C.'s mutual interest to create an environment in which wild salmon and the farming industry can co-exist, thus maximizing sustainable economic benefits*."[123]

The Report noted a number of areas in which DFO needed to improve, such as in monitoring habitat and enforcing compliance under the *Fisheries Act*, using scientific criteria for siting farms, assessing cumulative effects as required by CEAA, and monitoring impacts on wild fish by farms, including by escaped Atlantic salmon. The Auditor General noted 69% public support of expanding the BC salmon aquaculture industry in 1999 "assuming the guidelines in the B.C. Salmon Aquaculture Review are turned into workable regulations".[124]

Now that BC no longer has jurisdiction over salmon aquaculture in the Province, the possibility of conflict with provincial laws is minimized. Moreover, DFO is seeking to implement more rigorous monitoring and reporting requirements than what was mandated by BC. It is possible that many of the concerns expressed in the Auditor General's report are now being addressed or will be addressed by the DFO's new regulation of the industry.

The future development of an *Aquaculture Act* would also assist in clarifying governments roles and responsibilities.[125]

## Section 2a. Can diseases of farmed fish be managed to minimize or eliminate risk to wild stocks?

Concerns raised about the potential fish health impacts of salmon aquaculture on wild populations relate to the amplification of endemic pathogens, the introduction of new diseases, and use of antibiotics.[126] The BC salmon aquaculture industry is a strictly regulated food production industry, and one that strives to continuously improve its practices to prevent and control disease.

### 23. Why are diseases found in farmed fish?

Diseases have been found on salmon farms because fish can become infected by endemic pathogens in the marine environment. Farmed fish are free of marine pathogens when they are introduced to net pens – juveniles are routinely monitored while being raised in hatcheries, and any health issues are addressed immediately. The development of vaccines has provided a valuable tool to protect farmed salmon from endemic diseases found in the marine environment. In addition, farmed fish are monitored by trained personnel and fish health professionals for any sign of stress or disease:

> "*In BC, fish health management on salmon farms is overseen by an aquaculture veterinarian and involves continuous monitoring and assessment of mortalities and underperforming fish by trained site and fish health personnel.*"[127]

### 24. Why are we looking for pathogens/diseases in farmed fish?

In food production industries, the health performance of crops or stocks is key to profitability: therefore most effort is directed at establishing and maintaining the best possible conditions for these to remain healthy. Fish health monitoring on salmon farms, in concert with rigorous biosecurity measures and proven husbandry practices (discussed below), help to maintain healthy stocks by tracking performance (*i.e.*, growth) and survival, along with the occurrence of pathogens and/or diseases. Fish health monitoring and reporting have been required under both federal and provincial legislation, and they are also essential to ensure profitable farming. Farm operators have been reporting monitoring results to the BC Salmon Farmers Association (BCSFA) database, on a monthly basis and to BCMAL – now the BC Ministry of Agriculture - on a quarterly basis.

### 25. How is this different from wild fish?

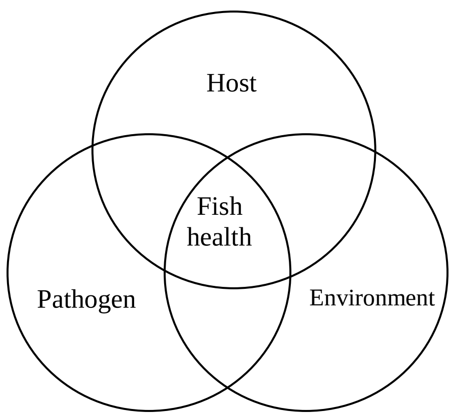
Fish health in wild populations has not received the same attention as in farmed stocks. Aquaculture provides captive populations that can be scrutinized throughout the production cycle in a controlled environment, leading to a better knowledge of the diseases of captive fish. This control also allows for the investigation of the roles of pathogens and the environment in these fish diseases.[128] As reported by Kent in 2011,[129] "the state of the science for understanding the impacts of pathogens on wild salmon in British Columbia is minimal". There is no provincial or federal fish health (disease) monitoring program for wild stocks, and periodic field surveys have provided only snapshots of the state of wild salmon health. The study of fish health in wild salmonid population is complicated by their large migratory distribution and complex interactions with their environment. As a result, even though pathogens and diseases are most likely common and persistent in wild populations, they are rarely documented and therefore it is difficult to demonstrate changes in the patterns of disease in wild stocks.[130]

## 26. How is fish health managed on finfish aquaculture facilities?

Since 2004, salmon farmers have been required to develop and maintain an up-to-date, government-approved Fish Health Management Plan (FHMP) as a condition of licence. A FHMP is a document that encompasses all aspects of growing salmon on the farm, including biosecurity measures, proper fish handling (to reduce stress), standardized record keeping, as well as monitoring and reporting.[130a] In addition to the FHMP, aquaculture operations have Best Management Practices (BMPs) and Standard Operating Procedures (SOPs), which complement the FHMP and, in some cases, exceed the requirements set in the regulations.

To maintain fish health, farmers appreciate the interactions between the fish (host), the environment and pathogens (Figure 1).

**Figure 1. Elements involved in fish health.**




Some have speculated farmed salmon are more stressed than wild salmon since they are caged and kept at higher densities. However, fish densities in net pens are maintained to optimize growth and minimize stress: stocking densities are kept at approximately 15 kg/cubic meter (equivalent to, just prior to harvest, 3 fully grown fish / 1000 litres) of water meaning the fish occupy a small percentage (less than 5%) of the pen volume.

> "*There is certainly no evidence to support the assertion that farmed fish are more stressed than the 'fight or flee' world of wild salmon. St. Hilaire et al. (1999) compared stressors affecting wild and farmed fish, and concluded that wild fishes are not necessarily subjected to fewer stressors.*"[131]

Since the inception of salmon aquaculture in BC, improvements in husbandry, along with advances in disease prevention and control measures (*e.g.*, vaccines) have increased the efficacy of fish health management. Practices which may have contributed to disease outbreaks on farms in the past are no longer used, such as: the movement of juvenile fish between hatcheries; growing multiple brood years, simultaneously, at one site; and live hauling (*i.e.*, transporting live fish from the farms to the processing facilities).

The health of farmed salmon, unlike wild and enhanced salmon, is subject to routine and frequent scrutiny by the aquaculture industry. Farmers undertake many preventative measures to ensure the health of the fish at every step of the process:

a) Parent fish (to the next generation), at company hatcheries, are screened to ensure that they are healthy before they are used as a source of eggs;

b) Eggs are disinfected (with an iodine solution) and reared in facilities where contact with fish pathogens (found in the natural environment) is limited. Water coming into hatcheries is disinfected, and treated according to Ministry of Environment regulations prior to being discharged;

c) Smolts are routinely screened for disease while being raised at hatcheries, until they are released in the net pens; and,

d) Fish in net pens are monitored along with their environment (*i.e.*, water quality), until harvested.

At farm sites, biosecurity activities include: strict sanitary measures (*e.g.*, foot bath before entering site and regular equipment disinfection), traffic/close contact restrictions (*e.g.*, no/limited traffic between sites), containment and/or treatment of effluent and organic waste, pest management protocols. Water quality at the farms (*e.g.*, temperature, salinity and the presence of algae blooms) is also monitored on a daily basis to ensure good conditions for the fish. When natural algae blooms occur near farms, various actions can be taken to maintain fish health (*e.g.*, the use of bubble curtains to disperse the algae). Sanitary measures are also taken during harvest and transport of fish to the processing facilities (*e.g.*, equipment used for the transfer of the fish and the transport vessels are disinfected).

Blood-water as a result of on-site harvesting of farmed fish is collected into secure containers or well boat holds using suitable methods to avoid spillage into the marine environment and transported to the processing plant for disposal. Effluents from processing plants are screened and tested regularly. Walcan, a seafood processing facility located on Quadra Island, for example, hires a third-party environmental company to sample and test effluent, including liquid coming from the outfall. Effluent levels are kept under minimum guidelines approved by the BCMOE[132]. For example, water quality parameters which may be monitored at processing plants include: flow rates, total suspended solids, 5-day biological oxygen demand, total oil and grease, nitrite, nitrate, nitrate plus nitrite, ammonia, total nitrogen, orthophosphate, total phosphate, total residual chlorine and fecal coliform. Testing may be done at a reference station, the output terminus and 100 metres downstream of the terminus on an annual basis. Industry is also working with government to further increase treatment standards with newly-developed ultraviolet systems. This treatment will kill pathogens and is a much more environmentally-friendly alternative to chemical use.

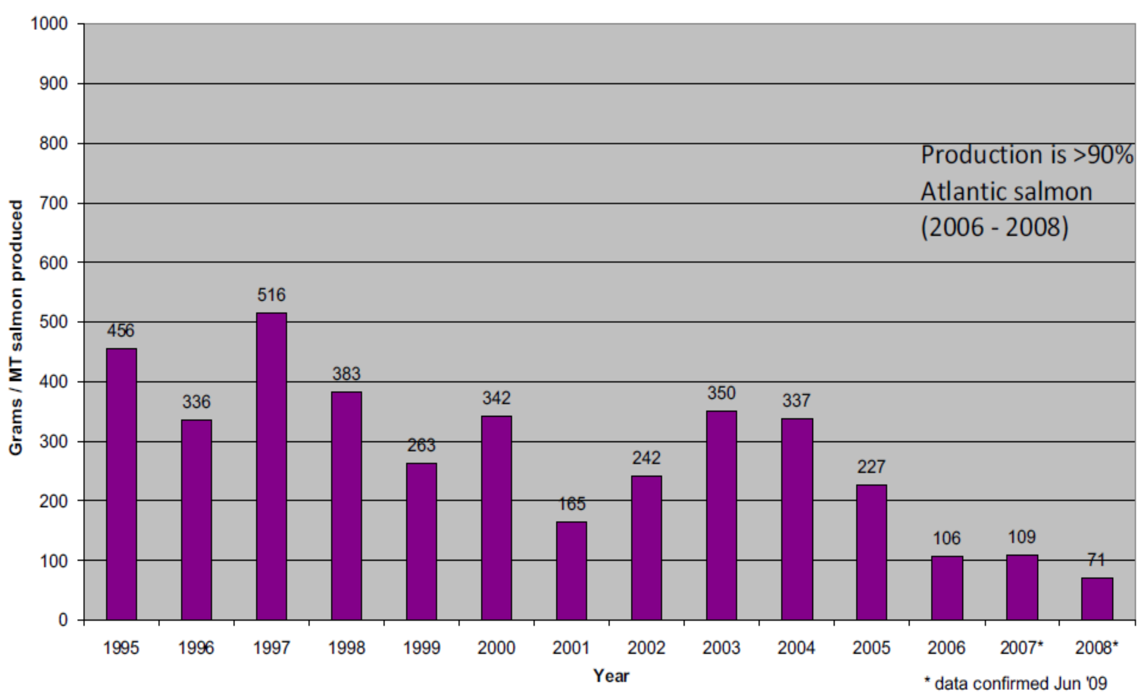
## 27. What is the role of the fish health veterinarian?

The company veterinarian, in conjunction with fish health staff, is responsible for overall fish health management for the operator. BC is the only jurisdiction in Canada where every company either has a full-time aquatic animal veterinarian on staff or immediate access to one. Veterinarians are responsible for broodstock management, fish welfare, international export requirements, developing biosecurity measures and disease outbreak management. They also review practices and procedures with facility managers to identify and rectify any gaps in fish health sampling. If, despite all of the preventative measures, some salmon become ill, the veterinarian will examine the fish and determine the appropriate action that must be taken.

## 28. Are antibiotics used on salmon farms?

In Canada, antibiotics are regulated by the CFIA and each therapeutic product used by the BC aquaculture industry is approved by Health Canada. In addition, the Ministry of Agriculture maintains a database of antibiotic usage for the industry. Antibiotics are used in the salmon aquaculture industry to treat bacterial diseases (not prophylactic, nor to promote fish growth). All antibiotics are prescribed by a licensed veterinarian: this makes salmon farming unique amongst the food-producing industries, which are not bound by the same strict regulation. Antibiotics used on fish farms are recorded and reported. Furthermore, the development of vaccines, along with improvement in fish health management and husbandry practices, has reduced the need for antibiotics over the last decade (Figure 2) with the end result that salmon farming is the protein producer that uses the least amount of antibiotics (with on average only 2.5% of all milled feeds being medicated each year).[133]

**Figure 2. Antibiotics use in BC aquaculture 1995-2008[134]**



## 29. Are the fish health measures in place effective?

The measures in place to prevent and control disease have been successful, as the BC salmon aquaculture industry now experiences only low occurrence of disease and very low mortality rates. BCMAL has reported in the 2009 Annual Fish Health Report, "less than 1.0% (and in many cases less than 0.5%) of the Atlantic salmon died of possible infectious disease each quarter."[135]

> "*The development of effective vaccines in the fish farming industry has significantly reduced the problems associated with some of the serious diseases (Youngson et al., 1998). Where vaccines are not available, alternative disease management approaches have proved to be successful in reducing disease incidents on farms (McVicar 2004). Such approaches include, removing all fish from a farm facility to break disease cycles, area or bay management, and use of single generations and targeted administration of chemotherapeutants at critical times in the disease development cycle (e.g., of lice).*"[136]

Results from the Provincial Fish Health Audit and Surveillance Program (FHASP), a provincial initiative started in 2000 aimed at improving understanding of fish health at aquaculture facilities by monitoring disease and pathogen (*i.e.,* sea lice) occurrences, have shown the same endemic diseases were found during the audits as those reported by industry. The strong agreement between audit results and Fish Health Event reports from the BCSFA has demonstrated the efficacy of farm-level diagnosis of disease and reporting system. DFO will from now on be carrying out similar monitoring and audits in the future in the context of the new BCARP.

## 30. What happens if disease is detected on a fish farm?

In any suspected disease outbreak, a fish veterinarian is contacted to determine, in consultation with government veterinarians, the best course of action. If a farm is affected by a disease of concern (*e.g.*, Infectious Hematopoietic Necrosis; IHN), procedures are in place to prevent it from spreading. These include: disinfection procedures, limited movement of all personnel, equipment and boats, special procedures for removal and disposal of dead fish, as well as for harvesting. When necessary, the stocks are removed from the environment and disposed of.

## 31. How is the risk of introduction of exotic pathogens being managed?

Salmon aquaculture has been practiced for over 30 years in BC and no exotic pathogen has been introduced. In his review of fish health data (produced by the BCMAL and BCSFA), Korman (2011) reported "[t]*hese records do not show the presence of new or novel high risk pathogens to wild salmon*".[137] The regulations and measures in place to prevent the introduction of exotic diseases are rigorous and strictly implemented. DFO was formerly responsible for enforcing importation requirements under the *Fish Health Protection Regulations*. Now, the CFIA enforces importation and national disease reporting requirements under the *HAA*, which provides inspection powers and enforcement by way of prosecution for offences.

In BC, only milt and surface-disinfected eggs are allowed for importation by the salmon aquaculture industry. The importation of eggs requires permits, which also requires the originating facility obtain a certificate through a local fish health officer (LFHO). Imported eggs are disinfected and held in quarantine for up to one year. The resulting progeny are subjected to regular disease testing before introduction to net pens; results have been reported to the LFHO on a monthly basis. Fish are only released from quarantine if all reports from screening come back as satisfactory.[138]

The industry in BC produces the great majority of its stocks through its own hatcheries (thus only a limited amount of eggs are imported each year). Through selective breeding, salmon farmers have succeeded in improving stock resistance to endemic diseases. Since 2004, only eggs from a certified (pathogen free), land-based facility in Iceland have been imported into the province.[139]

## 32. Can farmed fish pass diseases to wild populations?

Diseases found on BC farms have been shown to originate in wild populations. The transfer of infection, however, is not unidirectional,[140] and although the risk of disease transmission from farmed salmon to wild fish exists, the likelihood is small as "surveys of pathogens in wild and hatchery fish show no patterns that could be attributed to salmon farming." [141] Furthermore, there has been no evidence of an impact at a population level:

> "*Over the last 20 years, several reviews have already comprehensively assessed the available scientific literature on the potential for disease interchange between wild and farmed fish (Hastein and Lindstad 1991; Brackett 1991; McVicar et al. 1993; McVicar 1997a, b; Hedrick 1998; Reno 1998; Amos et al. 2000; Amos and Thomas 2002; Olivier 2002). Notably, none of these reviews has found irrevocable evidence that fish farming has contributed to detectable adverse changes in wild fish populations, yet the topic remains one of the most controversial in the media and scientific community."*[142]

Pathogens and diseases are common among fish populations. For example, the IHN virus has been found to be prevalent in wild BC and Alaska sockeye salmon.[143] In fact, Traxler *et al.* (1997) reported:

> "*All sockeye salmon populations along the Pacific coast of North America examined to date are infected with IHN virus*". [144]

The IHN virus is contracted by juvenile sockeye in freshwater; they can be carriers of the virus and are suspected to be one of the sources of infection for farmed fish, instead of the other way around.[145].

> "*It is unlikely that the Atlantic salmon smolts are infected with the virus while in fresh water because the hatcheries that produce smolts do not use surface water or are located on streams not accessible to anadromous fish. Also, IHN virus has not been detected in routine viral monitoring of Atlantic salmon pre-smolts*."[146]

The sources of the 1992-1994 and 2001-2003 IHN outbreaks in BC are unknown, however wild sockeye are suspected. Furthermore, Saksida (2003)[147] has shown the impacted farmed fish during the 2001-2003 outbreak were infected with different "isolates", meaning there had been more than one single source of infection. The 2001-2003 event was the last IHN outbreak in BC salmon farms; also confirmed by Korman (2011) in his review of the last 10 years of fish health records.[148]

As more studies are conducted on fish health - in the province and around the world - and new tools are being utilized to investigate, "novel" pathogens and diseases (whether newly present in the environment or never observed or described before) may emerge. This may be the case with the findings of a study conducted in recent years, using biotelemetry (radio tracking) and genomics to investigate Fraser River sockeye en-route mortality.[149] The study found a correlation between the occurrences of premature mortalities and a certain gene expression profile in sockeye salmon. The authors of the study hypothesized the genomic profile could be associated with a viral infection. Although the limitations of the study were made clear by the authors (*i.e.*, no disease agent was identified) and they made no association between this gene expression profile (or "signature") and farmed salmon, unfounded speculations were made linking the emergence of a "new virus" to salmon aquaculture.[150] Dr. Kristina Miller, the primary author of the study, recently provided clarification of the research results and significance. [151] In this document, Dr. Miller stated:

> *"First of all, the involvement of a virus in eliciting the mortality-related signature (MRS) was only a hypothesis, as no specific disease agent was identified in this study. Second, this study was based solely on wild sockeye salmon returning to spawn in the Fraser River, not farmed salmon. Importantly, the MRS was observed in fish tagged both in Johnstone Strait and in Juan de Fuca Strait, and unpublished data shows the signature is also present in salmon migrating through the Haida Gwaii, before they would have encountered salmon farms."*[152]

Furthermore, Miller reported the mortality-related signature was also found in Cultus Lake sockeye leaving the hatchery[153], as well as in other Fraser River sockeye smolts: 90% of tested smolts in 2007, and 82% in 2008. [154]

Concerns raised about the potential for fish farms to act as an amplifier for pathogens have not been supported by scientific knowledge.[155] Whereas diseases on salmon farms in BC are quickly detected and dealt with by professionally trained staff, this may not be the case for all enhancement facilities: a review of the Salmon Enhancement Program (SEP) by DFO (2009) concluded reduced funding for Community Economic Development Program (CEDP) hatcheries has, in some cases, resulted in lack of training and problems with diagnosing and treating fish diseases.[156] Internationally, hatchery fish (from BC, Washington, Alaska and Japan) with no visible sign of disease at release may still carry pathogens and infect other fish during migration.

In his review, Korman (2011) stated:

> *"Reliable information on pathogens in salmon farms that could potentially infect wild salmon is available for the period 2002/2004-2010. This information includes data from statistically representative audit samples from provincial salmon farm regulators (BCMAL), and data from all farms sampled on a more frequent basis provided by the industry. The combined government-industry monitoring program is impressive in terms of the fraction of farms that are audited, the number of pathogens that are tested for, the intensity of*

> *industry-based sampling and reporting, and the annual reporting and comparison of audit and industry-based results by regulators."* [157]

The author also reported a statistically significant decline in the number of high risk diseases reported by industry between 2003 and 2010. Furthermore, "[i]*n the vast majority of audit cases where* […] *dead fish from salmon farms were tested, bacterial and viral infections were not found and no sign of disease was observed."* Korman (2011) concluded negative impacts of salmon farms on Fraser River sockeye returns (2002-2010) *"were not apparent based on a qualitative comparison with salmon farming data"*. [158]

## Section 2b. Can sea lice on fish farms be managed to minimize or eliminate the risk of transfer to wild stocks?

> "*The fact that sea lice infestations pass to and from wild salmon is agreed by scientists and environmental groups alike. However, it is debatable whether the transfer of sea lice from the farmed salmon to the wild salmon is on a sufficient scale to have an impact.*"[159]

When considering the risk and potential impacts of sea lice to wild and farmed fish, it is important to remember that not all fish species are the same, and not all sea lice species are the same. Variability exists in both host susceptibility and pathogenicity of the parasites.

The monitoring and management of sea lice associated with salmon farms in BC is currently required by sections 4(f), 4(g) and 4(j) of the *PAR* under the *Fisheries Act* (Canada).[160] Specific monitoring and management requirements are stated in Part B (6) and Appendix VII of the Finfish Aquaculture Licence issued to active salmon farms in BC.[161]

Prior to December 2010, aquaculture companies were required to produce a Fish Health Management Plan (FHMP) as a condition of their operating license issued by the Provincial government (BCMAL). The FHMP included the sea lice monitoring practices and management strategies that were implemented by the companies to control lice production on the farmed fish. Industry was required to report the results of their internal monitoring and compliance monitoring and reporting was conducted by government representatives. Overall, industry compliance with the monitoring and management requirements was high under the Provincial licensing system.[162]

Currently, industry is required to have FHMPs under the new federal regulation, and these must be submitted to DFO by March 31, 2011. The required content of the FHMPs is very similar to the previous documents; therefore industry should be able to easily transition to the new regulatory requirement.

The relationship between sea lice, farmed salmon and wild salmon is one of the most widely discussed topics relating to the finfish aquaculture industry in BC (and around the world). Several publications have been produced that express concern about the impacts of sea lice transferring from farmed to wild salmon in BC.[163] Others have shown that farmed salmon represent only one potential host of sea lice in the nearshore environment[164] and that other mechanisms for infection of wild salmon must be considered. While some researchers report that even one motile lice will kill a young juvenile pink and chum salmon,[165] others have reported that motile lice are very rare on juvenile salmon in nearshore habitats[166] and that some species (for example, pink and coho salmon) have an innate resistance to sea lice.[167]

While the base of knowledge relating to sea lice in coastal waters off of BC is growing, a direct cause-effect relationship between the contribution of sea lice from farmed salmon and recent fluctuations in salmon populations has not been demonstrated.[168]

## 33. What are sea lice?

Sea lice are small, salt water crustaceans. These ectoparasitic copepods are common on wild marine fish. Species reported on salmon belong to the Caligidae family. These parasites generally develop through 10 life stages, including two non-infective planktonic larval stages (*nauplii*), an infective planktonic copepodid stage, infectious non-motile chalimus stages and motile pre-adult and adult stages. When attached, the lice feed on the mucus, scales and blood of the host. While some level of infection is natural and tolerated by the host, excessive infestation can result in severe lesions that may lead to osmoregulatory failure, blood loss and / or the development of secondary diseases.

## 34. Are sea lice endemic in BC?

Sea lice are present in all areas of the BC coast, whether or not salmon farms are present.[169] In BC, 12 species of sea lice belonging to two genera (*Caligus and Lepeophtheirus*) parasitize many different species of marine fish.[170] Two species, *Caligus clemensi* and *Lepeophtheirus salmonis*, are the most commonly reported on wild and farmed salmon in BC.

*C. clemensi* are found on a wide range of fish and are reported to be common on herring, juvenile salmon and stickleback. An analysis of sea lice infection on farmed salmon in BC between 2004 and 2010 found that this species was the most prevalent.[171] Parker and Margolis (1964) note that this species of parasite seems to be more specific to environment (found primarily on hosts captured in the surface layer of sheltered coastal waters) than to host species.[172] This species is very mobile and will abandon their host very quickly if they are handled.[173] In at least two regions of BC (Gulf Islands and North Coast), *C. clemensi* has been reported on juvenile sockeye at significantly higher levels of abundance than *L. salmonis* leading to the perception that this is the species most commonly found infecting juvenile sockeye.[174] Numbers of juvenile sockeye captured in other regions have been very low and infection rates reported are a combination of both *L. salmonis* and *C. clemensi*, therefore it has not been confirmed that the high rates of *C. clemensi* infection among juveniles occurs coastwide.[175]

*L. salmonis*, commonly referred to as the salmon louse, is the species of sea lice most frequently reported on wild and farmed salmon in BC.[176] Jones *et al*. (2006) noted that while the species has been considered specific to salmonids, it has also been reported on white sturgeon, sand lance and saithe (pollock).[177] This 2006 Jones study in the Broughton Archipelago also reported three-spine stickleback as a newly discovered host population for *L. salmonis* in BC.[178]

While *L. salmonis* is reported on farmed salmon around the world, the population in BC has recently been found to be genetically distinct from the population in the Atlantic Ocean.[179] This is significant as the degree of infection, and the physical damage experienced by salmonid populations infected with *L. salmonis* in the Atlantic Ocean, has not been documented in BC, and is likely related to the genetic variation between these species, and the host species.[180]

## 35. How do levels of sea lice vary in the environment?

In addition to requiring a host population, sea lice also require specific environmental conditions to successfully mature and reproduce. In particular, water temperature and salinity are reported to play an important role in regulating sea lice in the marine environment.[181] Ocean currents have also been considered by researchers evaluating the mechanisms of sea lice dispersal from host to host.

While correlations between sea lice abundances and water temperature in BC have not been conclusively shown, conflicting studies exist relating salinity to abundance of sea lice. While a number of studies find no relationship between the prevalence and abundance of sea lice on juvenile salmon, others do note a relationship between these two factors.

In a 2005 paper, Dr. Kenneth Brooks summarizes a number of studies relating to the influence of the environment on sea lice development.[182] For example, the generation time of *L. salmonis* has been estimated to require 106 days at 7.5 degrees Celsius and 32 days at 14 – 15 degrees Celsius. Tucker et al. also reports that fewer infectious copepodids establish themselves on hosts at lower temperatures (7°C versus 12°C).[183] Brooks states that “sea lice larvae do not consistently develop to an infectious stage at salinities <30 ‰”.[184] As surface water salinity typically ranges between 15 – 25 ‰ from June through November in the Broughton Archipelago due to estuarine currents, this results in a natural control mechanism for sea lice infection in that region. Other findings reported by Brooks include results of net current speeds measured at salmon farms in the Broughton, which when used to predict the transport of larval sea lice, indicate that the larva could be transported distances of 7.3 to 10 km in the time it requires for them to develop to their infectious stage. Other studies found that *nauplii* released in the vicinity of two farms in the Broughton travelled 10 – 40 km before becoming infective. While these findings are contradicted by reports of increased prevalence and abundance of lice on juvenile pink and chum in the immediate vicinity of salmon farms[185] independent of temperature or salinity levels, other researchers have observed gradients of sea lice infection corresponding to salinity changes (or distance from freshwater sources) that suggest at least some level of natural lice control related to environmental conditions.[186]

Saksida *et al*., (2007) note that a relationship between surface water temperature and sea lice infection levels on salmon farms has not been shown in BC, and that this may be due to the fact that the range of temperatures experienced around farms is not great enough to have a significant effect on the abundance levels of sea lice.[187] Attempts to correlate sea lice infection with salinity measured at farms have also been unsuccessful, but this could be attributed to limitations associated with the measurement equipment frequently used by salmon farmers.

### 36. How do sea lice impact fish health?

Under natural conditions, salmon and sea lice co-exist with minimal impact to the host, as evidenced by the continual return of sea lice infected adult salmon to BC rivers. When extreme infestations (epizootics) occur, and if fish health is compromised for other reasons, such as reduced food supply or fish are small (*i.e*., juvenile pink salmon less than 0.7g)[188] there is increased potential for impacts to fish survival. Regulated fish health management practices on BC salmon farms control lice levels on farms with the ultimate goal of protecting the health of all fish.[189]

Sea lice feed predominantly on host mucus, skin and blood.[190] They can be found on the skin, fins and, less frequently, gills of their hosts. The only reported incidence of wild fish mortality in BC relating to sea lice infection occurred in 1990 on the west coast of Vancouver Island, when returning adult sockeye salmon were forced to delay their migration into the rivers (due to low river flows and high river temperatures) and developed *L. salmonis* infestations.[191] These infestations by *L. salmonis* resulted in skin lesions that altered osmoregulatory processes and permitted secondary infections to develop that lead to mortality of the mature fish. It was noted that the extreme environmental conditions at the time led to the adult fish to become more susceptible to infection, and also more conducive to rapid reproduction of the lice, leading to the atypical infestation levels. This outbreak was not linked to the production of farmed salmon, but represented a natural epizootic induced by extreme environmental conditions.

Laboratory studies conducted by Webster *et al*. (2007) found that sea lice infestation results in an alteration of behaviour in juvenile pink salmon.[192] More research is required to determine if the benefit of the behaviour (loss of parasite) outweighs the potential negative effects associated with the behaviour (increased energy expenditure, increased susceptibility to predation). A study of the impacts of sea lice infection on the swimming endurance of juvenile pink salmon showed reduced swimming endurance only when the fish were infected with mature female *L. salmonis* (no change in endurance if infected with adult male or pre-adult lice).[193] The authors of this study note the reduced swimming endurance could increase the possibility of predation on the infected individuals, or could slow seaward migration. Work by Nendick *et al*. (2011) reported effects of infection on swimming performance and post-exercise ion balance of juvenile pink salmon were detected on small fish (0.34 g) and when lice were larger (stage 3 chalimus or greater).[194] Both of these studies suggest the energetic cost of sea lice infection is most significant when large (motile) lice infect very small pink salmon that have not yet developed their natural resistivity to infection.[195]

Another concern associated with sea lice infection of salmon is the potential for the lice to act as a vector for pathogen transmission. For example, researchers in Norway have isolated the Infectious Salmon Anemia (ISA) virus from *L. salmonis* collected from diseased fish, implying that the sea lice could transmit the virus between hosts.[196] Locally, researchers have isolated three species of bacteria on the external surfaces and stomach contents of sea lice collected from farmed Atlantic salmon (*Tenacibaculum maritimum, Pseudomonas fluorescens and Vibrio spp*.).[197] Further study is being undertaken to attempt to determine if lice can transfer these bacteria between hosts, and what the significance of this transmission is. While studies like these indicate the potential for transmission of pathogens by sea lice moving between hosts, more information is required before it can be confirmed fish will develop diseases from this mode of transfer, what the incidence of this type of transmission is and what impact it could have on wild salmon populations. Fortunately, fish health management on salmon farms in BC is successful in controlling pathogens on the farmed fish, further reducing the potential this mode of pathogen transmission as a significant concern for wild salmon in BC.

A high prevalence of IHN virus has been found in ectoparasitic leeches (*Piscicola salmositica*) and copepods (*Salmincola* sp.).[198] It has been speculated that sea lice may also act as a vector to transmit the virus to farmed fish from persistently infected or carrier wild marine salmonids.[199] In 2009, Dr. Duane Barker from Vancouver Island University (VIU) was granted $413,000 in NSERC grants to undertake a 3 year study examining the potential role of sea lice as pathogen (bacteria and virus) vectors to salmon.[200]

Sockeye salmon populations along the Pacific coast of North America have been shown to be infected with IHN virus although the source of the virus is unresolved.[201] Persistent infection of wild marine salmonids can be a source of infection for farmed fish. Direct horizontal transmission is the most important route of spread and IHN-infected fish are known to shed the virus in feces, urine, sexual fluids, and external mucus. Since the virus is directly transmitted in the absence of any parasitic vector, sea lice are unlikely to play any significant role in the epidemiology of IHN. Although IHN has been demonstrated in sockeye populations, the enhanced susceptibility of Atlantic salmon suggests that infection in farmed fish will be recognized. The last occurrence of IHN in farmed salmon was in 2003.

Fortunately, sea lice in BC do not affect wild and farmed salmon as significantly as in other areas of the world. In fact, treatment of farmed salmon for sea lice infection (for the purpose of protecting the health of the farmed fish) was rare in BC prior to the implementation of the Provincial Fish Health Management protocols designed to protect outmigrating juvenile salmon in 2003. In addition, the data collected on farmed salmon during required fish health inspections in 2003 and 2004 "confirmed scientific reports that farmed Pacific salmon harbour very few lice."[202]

### 37. Do sea lice "originate" from salmon farms?

Farmed salmon from freshwater hatcheries enter the marine environment free of lice. Over time, sea lice from wild fish infect the farmed salmon. Industry monitoring programs have shown that, without efforts to control lice, the infection level on farmed salmon increases with the amount of time the fish are in the marine environment.[203] A review of the relationship between farm salmon, sea lice and wild salmon in the Broughton Archipelago found that a relationship could be shown between the natural seasonal increase in lice load on wild salmon and the subsequent increase on farmed salmon in the same area. This study also showed that the farmed fish were then the main source of salmon lice (*L. salmonis*) infecting juvenile pink salmon in the area .[204] Therefore, the original source of the sea lice could be directly linked to the lice load on the returning wild fish the previous fall.

As lice reproduce on the farmed salmon, their offspring can be released to the environment. Industry implements management practices to effectively reduce the sea lice load on salmon farms, and ultimately minimize the release of the offspring into the surrounding areas.

At this time, there is no way to conclusively determine the origin of sea lice found on wild salmon.[205] Recent analysis of DNA collected from sea lice obtained from three geographically separated wild and farmed salmon populations found notable variability in genetic structure not only between the geographically separated wild populations (Barkley Sound and Broughton Archipelago), but also between farmed and wild populations within one region (Broughton Archipelago).[206] The latter observation indicates sea lice migration between farmed and wild populations in the Broughton Archipelago was low enough for the two populations to remain genetically distinct. The authors note this observation must be considered preliminary due to the small sample size and should not be used "to make conclusive statements about the frequency of transmission of lice from wild fish to farm fish".[207]

## 38. Can sea lice be spread by salmon farms?

Salmon farms can act as a static host population for sea lice, as can other non-migratory fish populations.[208] Due to the possibility of host to host transmission when fish are in close proximity to each other, sea lice infection can spread between individuals on a salmon farm, in the same way that infections would spread within a schooling population of wild fish. As the sea lice mature on the farmed salmon, their eggs are released into the environment, potentially infecting other host populations (within 7.4 to 26.8 days under laboratory conditions, at temperatures ranging from 15 degrees to 5 degrees Celsius)[209] as the larval lice mature to the first infectious state (copepodid). There is also the possibility of direct host to host transmission between the farmed and wild salmon, but the low number of motile lice reported on juvenile pink and chum salmon suggests that this mechanism is not a significant source of infection on wild fish.

In their review of the relationship between farm salmon, sea lice and wild salmon populations, Marty *et al*. (2010) note their analysis of sea lice infection on wild and farmed fish in BC supports the hypothesis reported in earlier studies that farm fish are the primary source of *L. salmonis* infesting juvenile pink salmon in the Broughton Archipelago.[210] Recent work by Price *et al*. (2010, 2011) indicates lice from farmed salmon appears to be related to the levels of sea lice on juvenile pink, chum and sockeye salmon in the Discovery Islands region.[211] However, the results in this area differ from the Broughton in that the abundance of *C. clemensi* (the species of lice known to infect several species of fish in the region) was significantly higher than the abundance of *L. salmonis* (the species of lice most frequently associated with farmed salmon) on the captured fish. The prevalence of *C. clemensi* on juvenile salmon varied by year (study was conducted in 2007 and 2008), and their analysis of sea lice data collected on at least three active salmon farms in the study area (there are 18 farms total in the area) indicated that the pattern of infection seen on the wild fish could be similar to the pattern seen on the farmed salmon.

What is not clear from any of the studies conducted in BC is how the level of sea lice infection impacts the populations of wild salmon. While the juvenile sockeye present in the Discovery Islands survey area were theoretically exposed to a higher proportion of *L. salmonis* (the species of lice thought to pose a higher risk to juvenile wild salmon) originating from salmon farms in 2008 than in 2007, the return of adult sockeye resulting from those outmigrations was higher in 2010 (2008 outmigration) than in 2009 (2007 outmigration). Korman (2011) also noted this discrepancy, finding that the salmon lice infection levels on farmed salmon was "40% below the 2004 – 2010 average" in spring 2007, while the infection level in the spring of 2008 "was very close to the multi-year average rate."[212]

Sea lice levels are managed on salmon farms according to practices established by the Provincial government in 2003, thereby reducing the potential for transmission of juvenile and mature lice from farmed to wild fish. Management options such as single-year class stocking, fallowing and therapeutant treatment have been effective in maintaining low levels of sea lice on farmed salmon in BC.[213] When lice are managed on salmon farms, researchers have reported a corresponding reduction in sea lice infection in wild juvenile salmon.

## 39. How is industry controlling sea lice on farms?

The BC salmon farming industry has implemented management practices aimed at controlling the levels of motile sea lice on farmed salmon. These practices include the following:

- Single age class stocking
- Area management planning, including strategic fallowing
- Treatment
- Harvest

These measures are implemented (when necessary) with the specific goal of reducing the potential exposure of outmigrating juvenile salmon to sea lice that may be released from farmed salmon, and also to protect the health of fish being raised on the salmon farms.

A recent review of sea lice levels on farmed salmon in BC found that "the effects of Slice treatments last up to 5 months following treatment".[214] The treatment efficacy in Europe and Eastern North America has been reported to last between 43 days and 14 weeks, indicating that this method of sea lice management is very effective for the species of lice present in BC.[215]

## 40. Does farm fallowing reduce sea lice abundance?

While fallowing is primarily used as mitigation for managing salmon farm impacts on the seafloor, it also has the secondary effect of removing a static host population for a period of time. By removing the mature (Year 2) fish, which typically carry the heaviest sea load (compared to smolts, or Year 1 fish) and the higher proportion of reproductive lice, there will be an immediate reduction in the production of lice in the area. However, as the natural (baseline) lice load has not yet been determined in the established salmon farming regions in BC, it is not possible to conclusively determine the significance of the removal of this portion of the lice load.

Reports have been published that attribute a decline in sea lice infection on juvenile salmon in an area of fallowed farms in the Broughton Archipelago in 2003, suggesting that fallowing is an effective action to reduce impacts to wild fish.[216] However, some research has also shown a significant reduction in sea lice abundance regardless of whether farms were held fallow or not. Beamish *et al*. (2006) note that salmon farm production in the entire Broughton Archipelago remained the same in that year compared to 2001 and 2002 (years of extremely high lice infection and poor pink salmon production in the region). They note, "This is a significant finding because active and viable salmon farming continued even as wild salmon showed high marine survival", referring to the 2003 outmigrating pink salmon population.[217]

## 41. Has there been a decline in SLICE® efficacy in BC?

The use of SLICE® had been regulated by the Provincial government in the past, and currently is regulated under the *PAR*. When required to treat farmed salmon, SLICE® must be prescribed by a licensed veterinarian. Use of SLICE® in BC was rare prior to the implementation of the Provincial Fish Health Program in 2003, as infestations of sea lice were not significant enough to farmed fish health to warrant treatment.

Saksida *et al*. (2010) considered sea lice infection levels on salmon farms in BC that were treated with SLICE® in 2003, 2007 and 2008. The results of their analysis showed that "unlike most other salmon farming regions, a decline in efficacy of SLICE® is not evident on salmon farms in British Columbia".[218] It was hypothesized that the difference may be because of the larger number of wild salmon and the fact that sea lice in the Pacific appear to be less pathogenic than those in the Atlantic. Messmer *et al*. (2010) have also found through genetic comparisons of several populations of *L. salmonis* in the Pacific Ocean there is little genetic variability between lice from wild and farmed salmon in this region. This suggests sufficient mixing between treated and untreated populations to reduce the potential for the species to develop resistance to SLICE®.[218a]

Fish health professionals associated with salmon farming on both coasts of Canada have expressed a desire to develop Integrated Pest Management plans in order to control levels of sea lice on farmed salmon.[219] However, this strategy requires Industry to have access to multiple treatment options to help reduce the potential for resistance to treatment. At this time, SLICE® is the only treatment permitted for use in BC.[220]

**42. What sea lice research is being carried out?**

Monitoring programs aimed at collecting data related to sea lice have been running continuously in various locations on the coast of BC since 2003. Initially, the research and monitoring programs were primarily run independently by salmon farm opponents and DFO researchers. Recently, these programs have evolved into collaborative projects involving multiple parties (environmental non-government organizations (ENGOs), industry and government) in an attempt to increase the consistency between data collection methodologies[221] and reduce the disagreement in findings between research programs. The current monitoring programs include:

(a) Broughton Area Monitoring Program (BAMP) – Collaborative sea lice research program in the Broughton Archipelago, involving ENGOs, DFO researchers and three aquaculture companies. The sea lice monitoring program began in 2010, taking over for the program previously managed by DFO (2003 – 2009) and involving other independent researchers that had previously been working in the area.

(b) Clayoquot Sound Sea Lice Working Group – Collaborative monitoring program being conducted by two local First Nations and two aquaculture companies operating in Clayoquot Sound, on the west coast of Vancouver Island. This group has been collecting data since 2004.

(c) Klemtu Monitoring Program – A First Nations led sea lice monitoring program that has been monitoring sea lice in the Finlayson / Mathieson Channel areas since 2005. It was funded by the Pacific Salmon Forum from 2005 to 2008, and by Marine Harvest Canada from 2009 to the present.

(d) Nootka Sound Monitoring Program – Initiated by DFO in 2003 (prior to the start of finfish aquaculture in the region), monitoring of sea lice abundance and prevalence on juvenile salmon has been conducted by Industry since 2004.

(e) North Coast Sea Lice Research Program – This program is unique in that it operates in a region that does not have any established finfish aquaculture farms. Partners in this program, designed to collect baseline sea lice data on salmon populations in the region, have included the Skeena Fisheries Commission and local First Nations.[222] It has received funds from a number of sources including the Pacific Salmon Forum.

### 43. Are sea lice from fish farms contributing to salmon mortality?

Despite some publications suggesting a link between sea lice from farms and declining pink salmon abundance,[223] there has been no direct cause and effect relationship shown between lice presence on farmed salmon and fluctuating salmon populations in BC.[224] While current research suggests a regional relationship between sea lice levels on farmed and wild salmon, there has been no confirmation to date that the degree of infection on wild salmon has resulted in sufficient mortality that results in impacts at the population level.

In 2005, Morton and Routledge reported that juvenile pink and chum infected with only a single motile sea lice were more likely to die than uninfected fish.[225] However, there have been questions raised about the statistical validity of this study, and whether the earlier research correlating sea lice infestation to salmon mortality considered other possible sources of mortality while the fish were being held in artificial enclosures.[226] Contrary to Morton's report, recent laboratory studies lead by Jones *et al*. (2009) on juvenile pink salmon in BC have shown mortality will typically only occur if individuals are infected by *L. salmonis* when the fish are less than 0.7 g.[227]

As noted above, in 1990, an epizootic of *L. salmonis* on adult sockeye returning to two rivers on the west coast of Vancouver Island was caused by extreme environmental conditions, and was linked to higher than normal pre-spawning mortality.[228] Evidence of this type of mass mortality of wild salmon linked to sea lice has not since been recorded in BC.

Jones (2007) has also shown juvenile pink salmon develop an immune response to infection by *L. salmonis* that is superior to the response of chum salmon.[229] This immune response develops as the pink fry reach a weight of 0.7 g, defining a very brief period of vulnerability of these species when they first enter the marine environment, as the weight of pink fry when they first enter the marine environment is approximately 0.3 g. As the small fish develop scales, they become less susceptible to infection, as noted by Morton:

> "*...there's a great deal of literature already on the existence of sea lice on larger salmon. Once the fish are larger, they're considered a benign parasite*."[230]

In comparison, juvenile sockeye salmon, which rear in freshwater lakes for one year prior to migrating to the marine environment (compared to pink and chum salmon fry that outmigrate immediately after emergence) are significantly larger when they first become exposed to potential sea lice infection (approximately 2 to 8 g in BC).[231] Fast *et al*. (2002) also noted that coho salmon demonstrated an increased resistance to infection to multiple species of sea lice, compared to rainbow trout and Atlantic salmon.[232]

While it is apparent that infection of salmon by sea lice has the potential to impact fish health, and cause mortality under certain conditions, the significance of this type of mortality compared to other natural causes of mortality is very difficult to define. For example, the mortality rate of juvenile pink salmon has been reported in the range of 55% to 77% within the first 40 days of sea life, with much of this mortality attributed to predation by juvenile coho salmon.[233] The results of exposure studies under laboratory controls suggests juvenile salmon can tolerate exposure to high levels of potential infection, and in some cases, develop resistance as they grow. This ability to avoid the effects of infection, as well as the documented ability of mature salmon to "live" with lice, all suggests that sea lice infection (regardless of the source of the parasite) does not unequivocally result in fish mortality.

## Section 2c. Are escaped farmed salmon a threat to wild salmon stocks?

### 44. What are the main causes of escapes on BC salmon farms?

In the early 1990s, system failure (most often attributed to extreme weather or ecological events) was the main cause for escapes. Improvements to system design and infrastructures have since reduced the occurrence of system failure, thus decreasing escape events. Handling (generally attributed to human error) is believed to be the main cause of escapes in recent years. Boat operations (e.g., collisions and propeller damage) and net failure (due to predators, poor maintenance or vandalism) have also been identified as causes for escapes. [234]

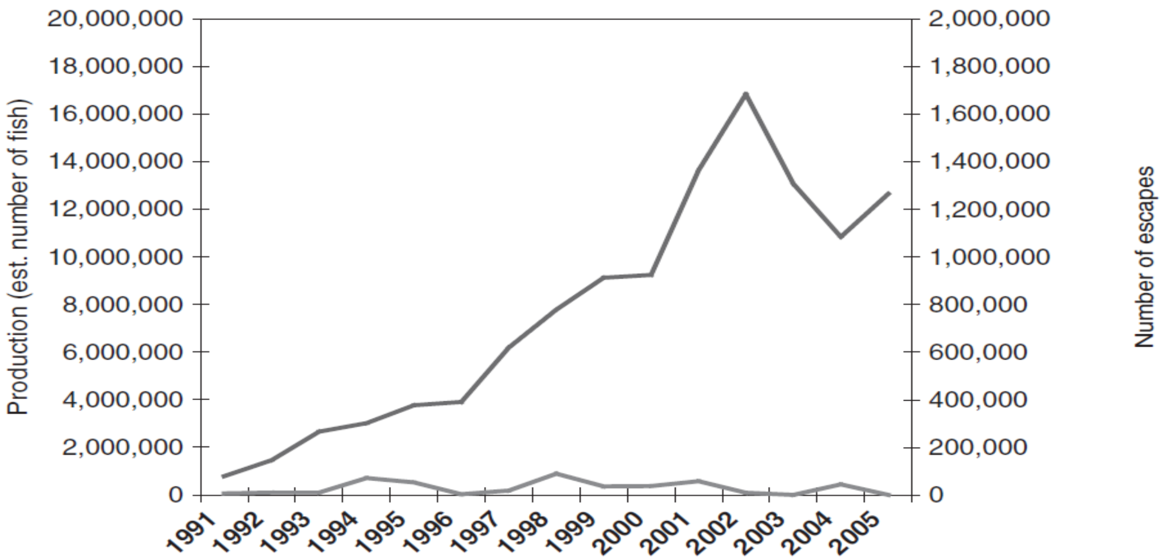
### 45. How is the risk of escapes being managed on farms?

Improved net-pen technology, farm siting and farming techniques have reduced escape events dramatically. Comprehensive Best Management Practices (BMPs) and Standard Operating Procedures (SOPs), along with proper staff training (which may include periodic Escape Response Drills) greatly reduce the risk of escapes due to human error. Preventive measures include, but are not limited to: redundant containment systems at hatcheries, escape prevention procedures while transferring fish between hatcheries and grow out sites, regular inspection and maintenance of nets and cage support system and strict guidelines for boat operation near farms. In addition, the BC Salmon Farmers Association has developed its own Code of Practice[235] with respect to escape prevention, setting out standards for minimum net strength, net testing, and escape-response plans.

Prior to 2000, aquaculture licence holders in BC were only required to “take reasonable precautions to prevent escapes”. Since, the regulations and standards for escapes prevention in BC have developed to become the most rigorous among other salmon aquaculture regions - including the United States, Chile and Europe.[236] Escapes prevention was, until recently, regulated under the BCMAL Aquaculture Regulation and the Escapes Prevention Policy.

Regulatory compliance reports (publicly available since 2000) have shown the industry’s high level of compliance in regards to escapes prevention. Compliance with BCMAL requirements averaged 99% in both 2007,[237] and 2008,[238] Despite a significant increase in production, escapes have not increased since 1991 (Figure 3 below), further demonstrating that efforts by industry to improve infrastructures and practices are effective.

**Figure 3. Atlantic salmon production (top line) and reported escapes (bottom line) in BC, 1991 to 2005.**[239]




## 46. Do escaped Atlantic salmon compete with native Pacific salmon stocks for habitat and food?

Escaped Atlantic salmon represent a small fraction of the enhanced and wild salmon production in BC. Furthermore, the domesticated Atlantic salmon has been shown to be "less environmentally aggressive than Pacific salmonids"[240], making it an under-matched competitor. Studies have found that the majority of escaped Atlantic salmon have nothing in their stomachs and only a very small percentage have wild prey.[241]

> "*Atlantic salmon are fed large pellets in the marine net pens so it is not within their normal behaviour pattern to capture and feed on live prey*."[242]

The Atlantic Salmon Watch Program (ASWP) is a cooperative research program initiated in 1991-92 and operated by DFO. The purpose of the program is to study the abundance, distribution and biology of Atlantic salmon in BC and adjacent waters. The ASWP monitors commercial and sport catches and relies on fishers, fish processors, government field staff and hatchery workers to report observations of Atlantic salmon.

> *"Over a span of 10 years, limited numbers (in some cases 1 or 2 fish) were observed in approximately 80 different streams, but not in the same year."*[243]

In a 2001 coast-wide study under the First Nation Atlantic Watch Program, 103 surveys were carried on 49 river systems: out of more than 350,000 salmonids counted, only two (adult) Atlantic salmon were observed.[244]

## 47. Can Atlantic salmon mate with Pacific salmon?

The likelihood of escaped Atlantic salmon successfully mating with Pacific salmon is extremely low as these fish belong to two separate genera: *Salmo* and *Oncorhynchus*, respectively.

Hybridization between Atlantic and Pacific salmon has been attempted repeatedly in laboratory conditions, but none of the experiments generated offspring that would have been expected to survive in the wild, much less reproduce. [245]

## 48. Have Atlantic salmon colonized streams on the West Coast (*i.e.* is there evidence they are established)?

There is no evidence Atlantic salmon are becoming established in BC. In his review of the ASWP data, Korman (2011) reported *"an average of 30,000 Atlantic salmon have escaped from salmon farms or juvenile production facilities annually between 1991 and 2008."*[246] The author reported a decline in the average number of escapees (with the average for 2003-2008 being less than half that of the 1992-2002 period), along with a decline in the number of captures or sightings of Atlantic salmon in BC waters (over the same periods). The author also reported only *"33 adult Atlantic salmon have been caught or sighted in the Fraser River drainage since 1991, and reproduction of Atlantic salmon (based on capture of juveniles) in the Fraser River drainage has never been documented."* In fact, the BC Environmental Assessment Office, the Department of Fisheries and Oceans Canada, the US National Marine Fisheries Service, and the Washington Department of Fisheries and Wildlife agree the likelihood of Atlantic salmon colonizing habitat occupied by Pacific salmon is very small:[247]

> "*Escaped farmed salmonids generally have lower survival in both freshwater and marine systems compared to wild conspecifics, due to both genetic effects of domestication and environmental effects of rearing in culture*."[248]

The recovery of a small number feral juvenile Atlantic salmon in 3 BC streams does not constitute evidence that a self-sustaining population has developed.[249] To become permanently established, not only would Atlantic salmon need to successfully complete all stages of their life history (i.e., from egg to spawning), but they would have to do so in numbers sufficient to perpetuate the population.[250]

> *"Given the unfavourable marine survival conditions for Pacific salmon including steelhead trout, it is unreasonable to assume that progeny from Atlantic salmon would fare any better than Pacific salmon in the foreseeable future*."[251]

Since the early 1900's there have been repeated and intensive attempts, both in Canada and the US, to introduce Atlantic salmon on the West Coast for recreational and commercial fisheries: all have failed. Atlantic salmon have had over 100 years to colonize the Pacific Ocean, but have simply been unable to do so. Even in their natural home range Atlantic salmon have shown poor capacity to compete against introduced Pacific salmon species (as demonstrated by failed attempts at reintroducing Atlantic salmon in Ontario Lake, where chinook salmon has become established).[252] Thus, the likelihood of escaped Atlantic salmon becoming established on the BC coast is extremely small.

## Section 2d. Can the benthic impacts associated with salmon farming be managed to minimize or eliminate risk to fish habitat?

Benthic impacts associated with finfish aquaculture occur as a result of the intentional or unintentional discharge of organic and inorganic wastes from the farm. Many studies have examined the benthic impacts of aquaculture to determine the spatial and temporal scale of effects.

### 49. What kind of waste comes from salmon farms?

As the DFO notes: "All fish, whether wild or farmed, produce waste." [253] There are different types of wastes that are associated with salmon farms. These include uneaten fish feed (including trace amounts of zinc, copper and antibiotics sometimes added to feed), fish feces, fish carcasses, net-washing debris, farm litter and facility effluent.

### 50. Do farms dump waste directly into the ocean?

It is inevitable that some waste material (biological and anthropogenic) is released to the environment through the net pens. Regulations have been and continue to be in place, which control the volume and composition of salmon farm waste that is released Under the *PAR*, licence holders are required to prepare and implement a Chemical and Other Substances Management Plan as well as a Mortality Management Plan. The former was implemented on March 31, 2011 and includes plans to manage and control therapeutants, disinfectants, pesticides, anti-fouling agents, hydrocarbons and bloodwater. The Mortality Management Plan addresses the appropriate storage and disposal of regular fish mortalities.

Industry managers and staff hold annual reviews to identify products, methods or practices which may assist in reducing potential wastes or pollutants discharged from farms. Currently, industry BMP's and SOP's are in place to help achieve this goal. For example, Industry SOP's include directions on removing and disposing of all mortalities on all farms and all associated material according to existing regulatory standards. Reducing the use of anti-foulants on nets is a key measure for farm companies, however ensuring that nets are clean to support water flows is also a key consideration for fish health.

Licence holders are required, under the *PAR*, to maintain on-site records of the *in situ* removal of biofouling, which should include: the date of cleaning, equipment or procedure used, the number and type of nets, the cumulative net area cleaned and if applicable the type of anti-foulant and the date of application. In an effort to reduce the environmental impacts associated with large inputs of organic material from the nets, *in-situ* maintenance is conducted regularly. Companies practice *in situ* net washing which must be done according to regulations and in a manner to reduce the amount of waste material released. Whenever possible, net washing is done on land.

The amount of waste released to the environment as a result of fish carcasses is minimized through management practices on the farms. Net pens are inspected daily and fish carcasses are removed on a routine basis before they begin to decompose and fall through the nets and deposit on the benthic environment below the cages. Any carcasses removed from the net pens are stored in secure totes and transported to composting facilities or land-based disposal sites. No fish carcasses are intentionally dumped into the ocean. Historically, dumping fish carcasses in the ocean was allowed with a federal permit, however this practice has been discontinued and industry BMPs and SOPs now outline requirements, in accordance with the regulations, to appropriately dispose of any fish carcasses.

Until December 2010, domestic sewage associated with finfish aquaculture operations was regulated under Section 7 of the Provincial *Finfish Aquaculture Waste Control Regulations*. Guidelines remained the same when the current *PAR* came into effect. All sewage must be treated according to standards outlined in the regulations.

Waste associated with finfish aquaculture disperses into the marine environment through hydrological processes. The amount of operational waste being produced at a salmon farm has been reduced through industry best management practices and technological advances in feed composition.[254] Waste generated on the facility not directly associated with the production of fish (household/ commercial garbage) is stored on the facility until it can be taken to a landfill.

### 51. Are chemicals released to the environment through feed or through the use of antifoulants regulated?

The use and release of these chemicals is controlled by provincial and federal regulations. For example, active salmon farms are required to conduct routine sediment sampling at and near net pens to evaluate concentrations of metals in the sediments that may have originated from excess fish feed or antifoulants.[255] The results of metals testing is compared against the federal standards for the protection of marine aquatic life, and if the standards are exceeded, additional monitoring is then required.[256] Only chemotherapeutants and antibiotics which have been approved by Health Canada and prescribed by a veterinarian can be used.

Under the *PAR*, finfish aquaculture companies are required to prepare and implement a "Chemical and Other Substances Management Plan". The purpose of this plan is to detail the management and control of "therapeutants, disinfectant, pesticides, anti-fouling agents, hydrocarbons and bloodwater".[257] The DFO required aquaculture companies to submit these plans by March 31, 2011.

### 52. Do leftover food or feces from farmed fish affect wild fish or pollute the marine environment?

Uneaten fish feed has the potential to fall through the net pens and settle on the ocean floor beneath the cages. Over the last decade, industry best management practices and standard operating procedures, along with advancements in feed technology, have reduced the amount of feed that actually reaches the benthic environment. The use of underwater cameras for example has improved feed practices significantly. Improved feed formulas have been developed which result in higher digestibility[258] (reducing the amount of solid waste discharged to the environment) and contain the minimum levels of zinc necessary for salmon health.[259]

Leftover food and feces have the potential to alter the natural composition of the benthic ecosystem through prolonged or excessive exposure, however many studies argue that benthic changes are usually limited to the near-field environment[260] and that these changes can be reversed if the input of material is stopped.[261]

For example, when a salmon farm is at "peak production" (*i.e.*, the fish are at their largest size just prior to being harvested), it is typical that the deposition of fish waste (feed and feces) is the most significant. The deposition of waste at this time can act to alter the physical and chemical properties of the sediments directly below the farm, and result in an alteration in the biological community in that location. Fortunately, once the fish are harvested and the site is able to fallow, the recovery of the habitat, and the associated biological community, typically follows quickly (within weeks to months).[262]

BMP's, farm siting protocols and the *PAR* also work to avoid or minimize the severity of these impacts. For example, at sites with strong current flows residual food or feces is dispersed over a greater distance, reducing the degree of impact.[263] It has never been shown that waste from salmon farms has a measurable impact on wild salmon populations.

### 53. What are the potential impacts of waste deposition on the benthic environment?

The potential benthic impacts of waste deposition are highly site specific and are affected by a number of factors including community structure, site history, hydrodynamics, water chemistry, topography, farm size and intensity and management practices.[264] Wastes associated with farms are deposited in minimal amounts which do not have a significant impact unless they continuously accumulate and remain in one location over time.[265]

#### (a) Potential impacts associated with deposition of organic waste

The benthic environment has the ability to naturally absorb organic waste associated with finfish aquaculture.[266] However, when this natural capacity to absorb waste is overloaded a number of potential impacts can occur, including:

(i) Changes in substrate composition and bottom type, changes in benthic macrofauna species composition and abundance, decreased diversity, with increased abundance of opportunistic species, organic enrichment and eutrophication.[267]

(ii) Changes in faunal structure in sediments beneath fish farms toward smaller opportunistic species results in slower mineralization rates and increased accumulation of organic wastes. [268]

(iii) Continuous inputs of organic matter can cause sediments to become anoxic or hypoxic resulting in the death of sensitive organisms and a shift in benthic pelagic coupling.[269]

Brooks (2001) noted "[t]he degree and distance at which negative effects are observed are sensitive to farm management practices and can be controlled." [270]

(b) **Potential impacts associated with the deposition of chemicals and other substances.**

Organic matter particles and chemicals added to feed or used as antifoulants can accumulate on or in sediments and have the potential to be re-released into the environment through re-suspension processes. However most of the chemicals deposited on the sea bed are bound in the sediments which helps to decrease their toxicity. [271]

In aquatic environments the toxicity of both copper and zinc are affected by a number of variables including, water hardness, salinity, temperature, alkalinity and the presence of other contaminants. Sediment quality criteria has been established at the lowest observed effect level to ensure impacts associated with these chemicals are kept at a minimum.[272] Studies have also shown that the toxicity of heavy metals is much higher in freshwater than in marine ecosystems.[273]

Fallowing and site selection prevent potential long term impacts associated with the release of these substances.[274] "*In general, measurable (benthic) effects have extended to between 145 and 165 m from netpen perimeters*."[275]

Proper siting plays a key role in reducing or eliminating the potential impacts of waste deposition on the benthic environment. Modelling systems are used as a management and planning tool by the industry to assist with siting farms in areas which will experience the least environmental impact from an operating farm. DEPOMOD is used in BC to create a theoretical footprint of the potential area of impact associated with a farm based on site specific characteristics including hydrographic data, benthic characteristics, cage layout, feed characteristics and specific seasonal characteristics.[276]

(c) **How long before any impacts are reverted?**

There is no specified time limit on how long it will take the benthic ecosystem to recover from impacts associated with finfish farms. Numerous studies have shown that recovery time is site specific and depends on a number of factors, including current speed, bottom type, production levels, operating procedures and management practices. [277]

For example, studies have shown that recovery times can vary from weeks to years.[278] Sites which displayed longer recovery times were sites located in shallow, depositional environments, with weak current flows. In contrast, sites that showed signs of recovery within weeks to months were located in areas with strong bottom currents and are at depths greater than 30 m. Conclusions from these studies support the assertion that benthic impacts can be reversed but the spatial and temporal extent of the benthic recovery will vary from site to site.

(d) **What are the benthic impacts associated with SLICE®?**

Some argue that there is the potential for SLICE® to accumulate in sediments (through repeated application) and enter the food chain through organisms like crabs, mussels and oysters. However, one study reported that SLICE® was not detected in sediment samples collected near a fish farm for 10 weeks after treatment and no positive results were measured in mussels after 4 months. [279] Additional studies conducted at active sites did not find a relationship between levels of SLICE® in sediments and benthic community changes.[280]

To prevent the development of SLICE® resistant sea lice, Canada has limited the number of SLICE® treatments during a fish grow out cycle to three. Under the *PAR*, licence holders are required to report the use and amount of any medicated feed administered. In addition, Industry BMP's and SOP's outline medicated feed protocols which include safe storage and handling of medicated feed. All medicated feed is administered under prescription and supervision of a veterinarian.

**54. How are the potential impacts from waste deposition mitigated?**

Potential impacts caused by waste deposition associated with finfish aquaculture are prevented or mitigated through a number of options, including Federal legislation, Industry Best Management Practices and Standard Operating Procedures, appropriate siting, fallowing of sites and through ongoing research to better understand benthic impacts.

Under the *PAR*, specific licence conditions are outlined to reduce potential impacts to the environment and protect fish and fish habitat.[281] This section of the licence requires completion of a Benthic Monitoring Program to ensure compliance standards are attained at peak biomass and prior to re-stocking. Licence holders are required to submit annual reports on the monthly amount of feed purchased and used including therapeutants, pigments, pesticides and zinc and copper formulations, the names of all materials released into the water during the reporting period including anesthetics, anti-fouling agents and other substances, and the monthly weight of mortalities and the disposal method.

(a) **Siting**

Proper siting has become recognized as an important part of the regulation and management process. There are numerous standards for new sites that have been developed to reduce environmental impacts. These standards outline minimum distance requirements from salmonid bearing streams, sensitive fish habitat, pre-existing aquaculture sites, shellfish beds and kelp beds.

As previously mentioned farms that are located in well-flushed environments will have faster remediation times and the effects on the benthic environment will be greatly reduced. As Dr. Brooks (2001) explains:

> "*Salmon farms located in well flushed environments frequently increase both the abundance and taxa richness of infaunal communities, even at high levels of salmon production.*"[282]

Annex 1 of the Finfish Aquaculture Licence recognizes DEPOMOD as a useful tool to predict the potential carbon footprint of an aquaculture facility, to appropriately site the containment structure array, and to locate appropriate compliance monitoring stations.

(b) **Fallowing**

Temporary impacts associated with waste deposition from finfish aquaculture are inevitable, however fallowing of farms assists in reversing these impacts. Studies have shown changes to the benthic environment revert during fallow periods.[283] Post-production fallow periods at fish farm locations have shown a reduction in the concentration of chemicals in sediment.[284] It has been suggested that even in poorly flushed environments benthic recovery will occur naturally during a fallow period.[285]

### (c) Feeding practices

There are a number of feeding guidelines outlined in Industry Standard Operating Procedures which help to reduce the amount of feed reaching and accumulating on the benthic environment. These include: 1) The use of underwater cameras placed in net pens during feeding to minimize feed wastage; 2) defined feed application rates based on fish weight and water temperatures; 3) correct feed size pellets. If the pellets are too big fish will be unable to ingest the pellets and they will settle on the benthos below the cages; 4) site managers are required to sample all feed deliveries for dust, floatation, fungus/mould and free oil, to determine feed quality. If the quality of the feed is below standards it will not be used; and, 5) weekly system calibrations to confirm if feeding is optimal for fish species, age and water quality conditions.

In compliance with the *PAR*, licence holders are required to submit annual reports showing monthly quantities of antibiotics used, as well as any amounts of therapeutants released to the environment. Licence holders must ensure therapeutants used in feed are prepared at the feed mill and not on-site.

Industry is careful to ensure that appropriate medication is safely administered to the target population. Only antibiotics which are licenced and approved for use are administered. All antibiotics and therapeutants are used "judiciously" and only used for treatment or control of disease. Medicated feeds are fed first followed by unmedicated feeds to prevent loss of medicated feed to the environment. SOP's clearly state that no spillage or discharge of antibiotics to the natural environment is allowed. Literature shows that there has been a steady decline in the amount of antibiotics used in Canada.[286]

### (d) Net cleaning protocols

Licence holders are required (under the *PAR*), to maintain on-site records of the *in-situ* removal of biofouling. In an effort to reduce the environmental impacts associated with large inputs of organic material from the nets, in-situ maintenance is conducted regularly. Industry also aims to reduce the release of fouling materials to the environment when washing nets. To mitigate impacts associated with the use of antifoulants, nets are treated at the beginning of each production cycle and are not re-treated until after harvest occurs.

### (e) Benthic Monitoring

Licence holders are required to comply with Benthic Monitoring requirements set out in Appendix XVI of the licence conditions. During peak biomass and prior to re-entry licence holders are required to ensure compliance standards are met.

Monitoring is conducted in accordance to the regulations to assess chemical triggers and pre-stocking requirements and standards. Farm management confirms waste control and pre-stocking compliance before entering fish at a facility.

### 55. Do farms cause *Heterosigma* blooms?

Studies have stated that the potential for finfish aquaculture to cause enhancements in phytoplankton populations is "remote or non-existent".[287] *Heterosigma* blooms occur naturally in shallow bays with significant freshwater inputs and minimal flushing. These sites are considered poor locations for fish farms.

However, in very rare cases where a farm is sited at a location as described above, some argue that there is the potential for nutrient input from salmon farms to further stimulate plant growth (under the right conditions).[288] Once again, this possibility can be avoided by strategic siting of aquaculture operations:

> "…*it has been suggested that salmon farms have little or no effect on ambient levels of either nutrients or phytoplankton density*".[289]

## Section 3. Why is science in a war of words over this industry?

Salmon is an iconic symbol in BC and a topic of popular and often emotional discussions. There are many voices "speaking for the salmon": government, academia, First Nations, ENGOs, as well as many other concerned groups and individuals. Because of the biological and ecological complexities associated with salmonids, there are still many unknowns about the factors influencing their productivity. There is general agreement that overfishing and habitat loss have contributed to the decline of Pacific salmon, and that Climate Change will have important effects on salmon productivity in the future. However, there is still much debate regarding the effects of salmon aquaculture on wild stocks, largely driven by polarized opinions on how to interpret existing knowledge as well as gaps in knowledge, and different scientific approaches. As stated by Dr. Noakes and Dr. Beamish in 2011:

> *"There continues to be no shortage of questions about this industry, and while it is important to at least better understand if not resolve some of the issues for the benefit of all involved, that has not always been the goal of everyone involved in the process. The lack of or selective use of data (such as excluding large proportions of the data) ignoring potentially important contributing factors and the selective use of reference points and modeling is not uncommon. The result is too often conclusions that are neither rational nor scientifically defensible (see, for example, Krkosek et al. 2007; Riddell et al. 2008)."* [290]

Science has often been portrayed as the objective, non-biased voice among all others: it poses questions, tests hypotheses and reports facts, and it has traditionally done so primarily within the scientific community. However, it is now accepted that science is not the only source of knowledge nor the only factor or voice guiding environmental policy and management decisions. Robust, unbiased science works mainly by process of elimination, revealing one tiny piece of the puzzle at the time, and often generating even more questions along the way.

Where scientists generally seek to communicate their findings within the scientific community to increase knowledge, activists have a different audience in the public, and a different purpose in their communications. The answers to scientific questions are often not black and white and scientists have a responsibility to report their findings truthfully including communicating both the significance and limitations of their work. Activists are increasingly including goal-based science in their messaging and they have been effective in having their voices rise well beyond the scientific community, reaching both the public and government. However, can and should research conducted with the precise objective to support one's point of view be referred to as *scientific research*? Can the resulting knowledge be trusted as *unbiased*? The results of this sort of research often claim to provide answers to public concerns and are usually presented in a way this is easy for the concerned layperson to grasp. It then becomes difficult to judge whether the source is reliable or not. As noted by Young and Matthews,[291] the media play an important role in the controversy around aquaculture. *What* is reported (*i.e.*, knowledge claims) in the media, and *who* is chosen to make those claims has a significant impact on risk perception. With so many voices making claims, how does one chose which to listen to?

The weight of evidence may provide the answer. Not who speaks loudest, but where does most scientific agreement lie? This is not based on the number of papers published claiming one truth, but in terms of the likelihood of a knowledge claim, as presented by a large number of scientific experts rather than a small number multiple times. A large number of scientists have demonstrated through multiple robust studies that the impacts of fish farms on the environment are predictable to a large extent and can therefore be managed. They have also concluded that the likelihood of salmon aquaculture impacting wild salmon at the population level is *very small*.

## Section 4. Why does the industry worldwide have impacts that the BC industry says can't happen here? How's the BC industry different?

Impacts related to finfish aquaculture vary around the world. Each country and its oceans have different ecosystems composed of different species, different topography and oceanography and different legislation regulating the potential impacts to these environments.

### 56. How is BC model different from the Norwegian (and Chilean) model?

The aquaculture industry in BC is subject to some of the most stringent regulations around the world. BC aquaculture is regulated by the *PAR*. Licenses granted under the *PAR* outline conditions which must be followed to control and monitor pathogens, minimize fish escapes, and minimize and monitor the impact on fish and fish habitat. Regulations in BC also outline specific environmental standards which must be met prior to entering fish into a netpen site and at peak biomass. New licenses or amendments to existing licences must meet specific site guidelines and require that a detailed application be submitted to DFO for approval.

Aquaculture operations in BC are required to keep and submit records on fish biomass, treatment or diagnosis of disease, amounts of antibiotics used, total number of mortalities, inspection and maintenance of equipment, escapes or suspected escapes and benthic monitoring results. Auditing of this information is currently conducted by DFO, but was performed by Provincial government staff prior to December 2010.

The aquaculture industry in Norway is regulated similar to the BC industry with individual licenses being granted under the *Aquaculture Act* (2005). Legislation in Norway also requires site specific information be collected and submitted with applications for new licences, however Norway has less stringent standards in regards to siting near existing finfish aquaculture sites, within marine protected areas and near areas used extensively by marine mammals.[292]

Norway requires additional nets be deployed 20 m from farms to continuosly monitor for escapes (from Oct-April).[293] Farms are also required to report escapes to the government, however there is no specified time limit for when this report should be submitted, whereas in BC all escapes must be reported within 24 hours. BC and Norway are the only jurisdictions with mandatory sea lice monitoring, reporting and auditing and both have mandatory net strength guidelines which must be met. [294] In Norway, regulations require mandatory fallowing of sites after each production cycle and unlike BC, aquaculture companies must post a public notice of any antibiotics used.[295]

Chile, the second largest farmed salmon producer in the world, is not as strictly regulated as BC and Norway. An authorization or licence is not required in Chile for aquaculture activities carried out on private property.[296] It has been suggested that "the regulatory structure in Chile is outdated and based on insufficient science". [297] For example, escapes in Chile are prohibited and any escape event is published online or in newspapers;[298] however regulations do not specify escape prevention practices as implemented in BC.[299] There are no single age class stocking requirements outlined in Chilean legislation or Industry BMPs. In BC and Norway this is a requirement and the BC industry has adopted it into BMP's and SOP's.[300] Furthermore, siting guidelines require farms to be separated by 2.78 km; they do not establish siting distances in relation to any other important environmental factors (*i.e.*, marine protected areas, shellfish or kelp beds, etc.). Fallowing (at the regional level) is not practiced in Chile.[301] Legislation instead requires environmental monitoring and mandatory decrease in production if aerobic conditions in the vicinity of the farm are not maintained.[302]

Farmers in Chile are only required to report specific diseases to the authorities and there is no specific threshold provided by law to define what encompasses a disease outbreak. In BC, all diseases, even suspected diseases must be reported. Salmon farms in Chile, like BC and Norway, are required to provide annual reports on the amounts of any antibiotics used, however in Chile this data is not available to the public and it has been suggested that the reported amounts are only estimates generated by researchers, not by regulatory agencies. [303] In contrast, in BC, all antibiotics used in salmon farming have to be prescribed by veterinarians, as well as recorded and reported to government.

### 57. Why do these countries have impacts that the BC industry says can't happen here?

In addition to strict industry regulations and best management practices, there are a number of reasons why impacts seen in other countries may not occur in BC. The industry in BC produces significantly less farmed salmon than Norway or Chile.[304] As less fish are being produced in BC this would decrease the probability of escapes and reduce the total amount of feed being discharged to the environment.

Chilean studies have shown that escaped farmed salmon have successfully reproduced in Chilean rivers.[305] Escaped Atlantic salmon have been found in BC rivers, although some of these escaped fish are suspected to come from farms in Washington. To date, there are no reports of Atlantic salmon establishing self-sustaining populations outside of their home range. In addition, there is no evidence that Pacific salmon are being displaced or taken-over by Atlantic salmon.[306] Agriculture and Agri-Food Canada reports that "…[Atlantic salmon] cannot produce viable off-spring from mating with local, Pacific Salmon".[307]

Fish diseases seen in BC are different from those seen in Chile and Norway, which are difficult to control or eradicate. Rickettsia, a bacterial disease in Chile, lacks an effective vaccine. In addition, BC was the first jurisdiction to require comprehensive Fish Health Management Plans.[308]

Regulations in each country limit the number of sea lice treatments that can be administered. In Canada this is restricted to three treatments per grow out cycle. In Norway up to five treatments per grow out cycle may be administered and in Chile up to eight treatments per grow out cycle are allowed.[309]

All three countries have different ecosystem structures which have varying levels of carrying capacity. The west coast of BC is highly diverse and productive, which increases the ecosystems ability to take up and process organic inputs associated with aquaculture. Furthermore, BC salmon farms are located in deep waters with strong currents to aid in the dispersal of substances that can be released from farms. Chile and Norway have only recently begun to locate farms in deeper inshore waters,[310] however surface currents (at farm locations) are still relatively low and residence times (of deposited materials) are generally longer.[311]

> "*BC centred studies are important because differences in oceanographic conditions, seasonal and annual environmental changes and the presence and distribution of other fish and shellfish species can make meaningful statistical comparisons between regions highly variable.*"[312]

BC also has the advantage that it is a relatively young industry and can learn from well established jurisdictions like Norway, Scotland and Chile. BC has the opportunity to examine past and current practices from other countries and compare what works and what doesn't work and apply that knowledge here.

**58. Is it useful to compare sea lice in BC to other salmon farming regions?**

Variability in environmental conditions, host fish species and sea lice species limits the direct transferability of information from other salmon farming regions in the world to BC. However, the experiences of other regions can be used to help predict potential evolutions in the management of sea lice, and allow the industry in BC to more quickly respond to potential impacts of this parasite to both the farmed and wild salmon.

In Chile, salmonids are an introduced species unlike BC or Norway where they exist naturally.[313] Because salmon do not exist naturally in Chile, the species of sea lice associated with their farmed fish represent a concern for the endemic species of fish. The lack of historical exposure has prevented wild fish stocks from evolving a tolerance to these species of lice. In BC fish populations have naturally co-existed with the species of lice present on wild and farmed fish for centuries and it has been suggested that Pacific salmon have developed an innate resistance to species of sea lice. For example, coho salmon and Atlantic salmon appear resistant to *Caligus flexispina*.[314]

In addition, studies suggest that "Pacific and Atlantic populations of *L. salmonis* are genetically distinct and may have different evolutionary adaptations" and that the Caligus species more commonly found in Chile can be more difficult to control.[315]

> "*…research done on environmental effects in other parts of the world can only be applied to BC with great care.*"[316]

In a rebuttal to comments made by Morton and Routledge on a previous publication, Butterworth *et al*. (2008) explain that European literature is of limited applicability in BC for a number of reasons, including differences in host salmonid species, the relative numbers of wild and farmed salmon in BC and Europe, and the presence of alternate potential hosts.[317]

## Section 5. Why doesn't industry embrace closed containment as an ideal option in BC?

The BC salmon aquaculture industry has been - and continues to be - a leader in improving practices and reducing effects on the environment. If closed containment was "the perfect solution" as claimed by certain groups, it is likely the industry would transition to it. As the Pacific Salmon Forum noted in its *Final Report & Recommendations to the Government of BC*, "[t]here is a high degree of public misinformation on closed containment and many questions to be answered before it can be considered viable."[318]

### 59. What is closed containment?

As the BC Pacific Salmon Forum explained, closed containment involves "a range of technologies that attempt to restrict and control interactions between farmed fish and the external aquatic environment with the goal of minimizing impacts and creating greater control over factors in aquaculture production."[319]

### 60. How would closed containment affect the industry?

The BC salmon aquaculture industry understands closed containment technologies well. Farmed salmon are currently raised in land-based recirculating systems for one-third of their life. The industry supports continued efforts in developing new and improved technologies, and acknowledges closed containment could provide some advantages. However, it also recognises that, currently, it is not a sustainable option to grow salmon commercially and that a shift from net pen systems would bring significant challenges:

Financially – In a recent study assessing the economic feasibility of 10 proposed salmon-rearing technologies, only net pens and recirculating aquaculture systems (RAS) showed "potential for financial feasibility."[320] However, RAS technologies were found to be only "marginally viable from a financial perspective."[321]

Should net pen farm operators attempt to convert to RAS, an initial investment of $22 million would be required, whereas capital expense for a net pen system is approximately $5 million. Third-year income for RAS was estimated at $381,467, producing a marginal return on equity (ROE) of 4%. In comparison, third-year income for a net pen system was calculated at $2,641,147, with a ROE of 52%. [322]

In addition to raising capital cost from around $2,000 per tonne of product to over $9,000/t (with no increase in return), conversion to land-based closed containment systems would also translate into increased energy costs and labour requirements, which could significantly impact overall profitability.[323] The analysis also showed RAS facilities could prove would be much more susceptible to pressures which had already been experienced by the industry.

Based on the assessment of 10 proposed salmon-rearing technologies, only two (net pens and RAS) showed potential for financial feasibility, warranting a more in-depth financial and sensitivity analysis. The results of this subsequent analysis have shown that while both technologies are profitable on a pro-forma basis, with returns significantly higher for net pen, RAS technologies are projected to be considerably more sensitive to market forces (*e.g.*, exchange rate and market price) beyond the operator's control, and may likely prove non-profitable within a range of variability that has actually been experienced by the Canadian salmon aquaculture industry in the past. These sensitivities are due largely to the high initial capital investment and subsequent costs associated with it.[324]

The systems, once employed, would also have little flexibility to natural fluctuations in the price of salmon – with small variations putting businesses in the red. This could result in lower wages and reduced job security.

Technically – A report by the Canadian Science Advisory Secretariat (CSAS) showed, in order to transition to land-based systems, the net pen aquaculture industry would have several technical challenges to overcome. These include: $CO_2$ build up, waste management, siting and installation and energy requirements.[325] The greater complexity of closed containment systems would result in important changes to management and operational requirements: system maintenance to prevent mechanical failure would require a different set of skills than that found in the industry at the moment.

Animal welfare – Various changes would have to be made concerning animal husbandry in the event of a shift to closed containment. The industry would have to find ways to maximize production, without compromising animal health. Higher fish densities could lead to greater risk of disease.

Changes to the husbandry environment involving closed-containment technologies, including increases in fish densities and hydraulic retention times, could increase the risk of pathogen exposure and horizontal transmission, relative to current systems.[326]

### 61. Are there any closed containment systems for salmon aquaculture?

Land-based flow-through systems are used to commercially grow juvenile salmon, trout and tilapia.[327] As mentioned, the salmon aquaculture industry in BC also uses land-base systems to grow fish to smolt stage. China, experimented with RAS technology for the rearing of Atlantic salmon, but discontinued its efforts in 2007. Thus, there have been no successful attempts at growing Atlantic salmon commercially, through its entire production cycle.

The 2008 CSAS report concluded:

> "*A review of over 40 closed-containment systems from around the world found that none was producing exclusively adult Atlantic salmon and that many previous attempts to do so had failed. Reasons for failure [...] included, but were not limited to mechanical breakdown, poor fish performance, management failure, declines in market price and inadequate financing.*"[328]

More recently, Trevor Swerdfager, former Director General of the Aquaculture Management Directorate at DFO said:

> "*We're not aware of anywhere in the world that produces salmon at a commercial scale or even close to a commercial scale, both from a technological point of view and from a financial point of view. We're not aware of that being done anywhere today*."[329]

**62. Is closed-containment technology, as it is currently, an economically viable alternative to net pens?**

Results from the latest feasibility study were clear; RAS technology is the only alternative to net-pen systems, which could be economically viable. However, the report also stated "higher capital costs, energy costs and labour requirements considerably affected its overall profitability".[330] In addition, because RAS technologies may be more sensitive to market forces and considering the Canadian aquaculture industry has proven variable, the report concludes:

> "*Overall, the analyses showed that RAS technology is marginally viable from a financial perspective, but that it presents a higher level of risk compared to net-pen systems*".[331]

**63. What are the environmental impacts associated with closed containment? How does the severity of these impacts compare with net pen aquaculture?**

In a study which compared the potential environmental impacts of rearing salmonids in a net pen system with those of three reportedly environmentally-friendly alternatives, the authors concluded closed containment is not the perfect solution some have claimed it to be:

> "*The implementation of closed-containment salmonid farming technologies would appear to represent a classic case of environmental problem shifting*." [332]

The study reported:

> "*…while the use of these closed-containment systems may reduce the local ecological impacts typically associated with net-pen salmon farming, the increase in material and energy demands associated with their use may result in significantly increased contributions to several environmental impacts of global concern, including global warming, non-renewable resource depletion, and acidification*."
>
> "*In order for these systems to have the capacity to be economically competitive with net-pen farming systems and other well-established seafood production seafood production systems, they will need to produce a large volume of fish. This will require the construction of larger closed-containment systems, or alternatively the construction of a greater number of small systems. In either case, the increase in material and energy demand involved with this expansion would be substantial, as would the associated life cycle impacts*." [333]

The 2008 CSAS report identified similar environmental costs associated with closed containment systems, including lower energetic efficiency compared to net pen.[334] Not only have studies on closed containment been unable to show economic feasibility, but they have not produced evidence of greater environmental sustainability.

## Section 6. Is the quality of our ocean habitat being sacrificed for private industry?

Some have argued farmed salmon is a "luxury" food, which does not contribute to feeding the world population, but rather to enrich private industry. Not only is this argument incorrect, but it shows a clear lack of understanding of the importance of salmon as a food source (today and into the future). It is well known salmon is an important traditional food for First Nations (and coastal communities in general). However, its importance has yet to be fully recognized as an emerging cultural staple in modern society. Fish has become a symbol of "healthy eating", not only for its beneficial properties, but also as it is perceived by many as one of the more environmentally sustainable sources of protein. In recent years, sushi (a traditional food from Japan) has become a major item in the North American diet and "a global food commodity".[335] One only needs to look at the growing number of sushi bars in Vancouver to understand the magnitude of this phenomenon.[336]

The FAO (United Nations Food and Agriculture Organization) reported the contribution of fish to global diets has reached an all-time high.[337] The same report concluded the "..proportion of overexploited, depleted or recovering stocks increased from 10 percent in 1974 to 32 percent in 2008".[338]

Salmon aquaculture is an economic activity to the same extent as commercial fishing; both are utilizing resources from ocean to provide a commodity, for which the demand is growing. Fishers remove their product from wild stocks, while farmers grow it. However, the uncertainties related with commercial fisheries are much greater than those associated with aquaculture. Fishers obtain their product from populations which have been difficult to assess and which, without increased enhancement efforts, are likely to become depleted over time (as a result of overexploitation, habitat destruction and climate change). Experts agree, in the course of this century, great changes can be expected as a result of climate change.

> "*Pacific salmon from the Fraser River stocks will suffer major impacts in fresh water and in the ocean. Sockeye, pink and chum from the Fraser River will be reduced in abundance as a consequence of reduced freshwater survival as juveniles and spawning adults. The production of wild coho and chinook will also be reduced, but the reduction will be less than for the other species. Pacific salmon stocks from the Skeena and Nass rivers and to the north will increase in abundance as a result of improved ocean productivity. Pacific salmon will begin to reproduce in Arctic rivers. Pink salmon will be excellent indicators of climate-related change. Basin-scale changes in growth, survival, and straying rates will all indicate when large-scale changes occur.*" [339]

The effectiveness of enhancement efforts will likely be greatly reduced. With both wild and enhanced stocks in decline, how will commercial fisheries meet the ever-growing demand without further depleting Pacific salmon stocks? Already, the global demand for seafood has surpassed "capture" fisheries:

> "*Globally, demand for finfish and shellfish is growing by 9 percent a year and*

> *conventional "capture" fisheries can meet less than half the current and anticipated demand. Canadian aquaculture is uniquely positioned to capitalize on that growing demand."*[340]

Fish farmers obtain from the ocean only what they have put in. Aquaculture provides a predictable and stable source of food. It is also a very efficient food production system: with a feed to growth ratio of approximately 1:1 to 1.2:1 (i.e., 1 – 1.2kg of feed for 1kg of fish produced), it is more efficient than any other farmed food source.[341] Wild-caught salmon has an estimated food conversion ratio of 10:1. Furthermore, it is a system which deals with fewer variables than fishing does, and which can control many of these variables to reduce uncertainties. Climate change may not have the same impacts on farmed fish, than it does on wild stocks:

- Changes in the freshwater environment, likely to impact early life stages of wild salmon, would not affect farmed salmon produced in hatcheries.
- Increased sea surface temperatures (SST) may have a lesser affect on farmed salmon (which have lower somatic energy requirements), or greater tolerance could be bred into farmed stocks.
- Any decline in ocean food production (*i.e.*, ocean productivity) is less likely to affect farmed fish.

Aquaculture has already taken an important place, alongside commercial fisheries, in feeding the world. In BC, salmon farming has emerged as a sustainable strategy to help fisheries meet the growing demand for fish. And with the increasing threat of continuous freshwater habitat loss (caused by population growth) and of changing ocean conditions (due to climate change), aquaculture may become even more important in the future, as a dependable food production system.

**64. What kind of environmental impacts (*actual* not *perceived*) are associated with salmon aquaculture?**

All human activities have an effect on the environment. As one DFO paper explains:

> "*Whenever there is a new use of the natural resources of an area, there is an inevitable alteration to that part of the environment being used."* [342]

Activities for which the impacts are well understood, manageable and reversible are more readily accepted for their benefits. Salmon farming may still be a relatively new activity in BC, but it has been practiced in Europe for approximately half a century and, during this time, much has been learned about the interactions between fish farms and the environment. Although there are many differences between environmental conditions in BC and those found in other aquaculture regions, the industry in this province (because of its late coming) has benefited greatly from the knowledge gained elsewhere in the world and has built upon that knowledge to ensure its success. Today, the BC salmon aquaculture industry is a sophisticated and efficient food production system, well-adapted to the environment it operates within, and controlled by strict regulations that have been successful at making this industry sustainable.

The *actual* (as opposed to *perceived*) impacts associated with salmon aquaculture operations in BC today are ***quantifiable, predictable*** and ***transient***. Furthermore, these impacts are ***regulated, monitored*** and ***mitigated***.

Diseases: Salmon farming in BC is regulated under the most stringent fish health policies in the world, and the most rigorous in the Canadian food production industry. Farmed fish are grown in controlled conditions to reduce the risk of disease. The fish are monitored daily for any sign of stress or infection. Diseases are rapidly identified and controlled by highly trained fish health personnel and veterinarians. Strict biosecurity measures are implemented to prevent the spread of infections.

Of all the possible invasion pathways in BC for exotic pathogens, aquaculture is certainly the most regulated and least likely. Other pathways include pathogens in the ballast waters of cargo ships or shed from barnacles or mussels attached to cruise ships and sailboats, introduction through invasive host species (such as lionfish) which are extending their range across the oceans as a result of climate change,[343] or through fish species introduced from the aquarium trade such as oriental weatherfish.[344]

What is *not* well known is the status of fish health in wild populations. As the source of infectious diseases for farmed salmon are likely to be wild fish, information about diseases in wild populations could be useful to farm operators for preventative measures.

Sea Lice: The BC aquaculture industry has implemented comprehensive management practices aimed at controlling the levels of motile sea lice on farmed salmon. These measures have been shown to be effective.[345] Industry compliance with the monitoring and management requirements under the Provincial licensing system was very high.[346]

There has been no direct cause and effect relationship shown between lice presence on farmed salmon and fluctuating salmon populations in BC.[347]

Sea lice are present in all areas of the BC coast, whether or not salmon farms are present.[348] Farmed salmon represent only one potential host of sea lice in the nearshore environment[349] and other mechanisms for infection of wild salmon must be considered. More research could be done on how levels of sea lice vary naturally, in relation to environmental conditions.

Escapes: The regulations and standards for escapes prevention in BC have developed to become the most rigorous among other salmon aquaculture regions - including the United States, Chile and Europe.[350] Compliance reports (MAL/MOE) have shown the industry's high level of compliance in regards to escapes prevention. Improvements to system design and infrastructures have since significantly reduced the occurrence of system failure, thus decreasing escape events.

There is no evidence Atlantic salmon are becoming established in BC.[351] Atlantic salmon is a poor colonizer: despite sustained efforts in the early part the 20th century and some opportunities since, it has been unable to compete with wild stocks and establish itself in an environment which is simply not suitable to this species.[352] The likelihood of escaped Atlantic salmon producing viable offspring with Pacific salmon is negligible.[353]

The risk of introduction of other invasive fish species in BC and their impacts on endemic populations are, however, very real. Exotic fishes can be (and have been) introduced through several pathways:[354] shipping and ballast water, aquarium trade and illegal introduction for recreational fisheries. Good colonizers, such as various species of bass and carp, have rapidly become established in BC and are a real threat to endemic populations.[355] The likelihood of introduction of alien, invasive fish species – and subsequent impacts on native stocks – is much greater from the above-mentioned activities (and related species), than from farmed Atlantic salmon.

Benthic Impacts: Beginning March 31, 2011 licence holders are required to prepare and implement a Chemical and Other Substances Management Plan including the management and control of therapeutants, disinfectants, pesticides, anti-fouling agents, hydrocarbons and bloodwater. It is inevitable that some waste material is released to the environment through the net pens. Farmed fish are grown in sites specifically selected to minimize impacts on benthic communities. DEPOMOD has been recognised as a useful tool to predict the potential carbon footprint of an aquaculture facility, to appropriately site the containment structure array, and to locate appropriate compliance monitoring stations. Industry BMP's are continuously working to reduce the discharge or potential discharge of wastes or pollutants to the surrounding environment.

Numerous studies have examined the benthic impacts associated with aquaculture to determine the spatial and temporal scale of effects. The potential benthic impacts of waste deposition are highly site specific.[356] Wastes associated with farms are typically deposited in minimal amounts. Studies have shown when most sites are left to fallow the potential for impact is reduced because this allows for waste to be dispersed away from the farm rather than continuously accumulating over time..[357] Once the fish are harvested and the site is able to fallow, the recovery of the habitat, and the associated biological community, typically follows within weeks, to a few months. [358]

## Section 7. Can salmon farms and wild salmon co-exist?

**65. How do the environmental impacts of aquaculture compare to impacts from other anthropogenic activities?**

Aquaculture has been proposed as a sustainable strategy - one that complements fisheries - to help meet the growing international (as well as local) demand for fish.[359]

All human activities have an effect on the environment. For centuries, we have cleared large portions of forested areas, for lumber, to construct dwellings, commercial and industrial centres and to make room for agricultural operations. We have also fished the ocean with methods that sometimes remove significant volumes of by-catch or leave the seafloor barren. Ranched fisheries are currently releasing between 4 to 6 billion smolts annually into the North Pacific to support commercial fisheries (Alaska alone produces 1.5 billion smolts each year).[360] However, there is growing evidence this might precipitate the decline of wild populations.

> *"Large-scale salmon enhancement projects have also resulted in significant ecological and genetic interactions with wild salmon, particularly for coho and chinook stocks."*[361]

We have accepted a certain level of impact from agriculture and from fisheries, because we believe the benefits (*i.e.*, being able to maintain beef or halibut in our diet), outweigh the risks associated with these activities.

Despite not fully understanding the risks involved, society is willing to accept them, as long as measures are in place to mitigate impacts and improve our practices. It may have been no different for salmon aquaculture, except for the fact that it is a relatively new industry in Canada, one that strives to become established in a much changed societal and regulatory context.

> "*Aquaculture is unlike any other resource or agricultural sector in Canada simply because of its novelty. As a new industry, it has been formed in a unique crucible, shaped by structural and cultural forces that differ significantly from the circumstances that shaped Canada's more established primary sector economies*."[362]

When put into context and compared to other industries and anthropogenic impacts, salmon aquaculture, as conducted in BC today, represents a very small environmental footprint:

(a) Physical footprint:

There are currently 134 licensed salmon farms in BC, occupying an estimated area of approximately 46 $km^2$ or 11,367 acres. In comparison, agriculture has a much greater footprint. The 2006 census of agriculture reported 19, 844 farms in BC, occupying 7,006,569 acres, or approximately 30% of the province:[363] "BC's Fraser Valley has the highest concentration of very large farms in Canada, with 30 large farms for every square km of farmland available."[364]

Other developments and human activities have created more significant marine footprints than aquaculture. For example, the BC Nearshore Habitat Loss Working Group reported, in 2001, that 23% (60 km) of estuarine and other nearshore habitat in the Georgia Basin had been urbanized and altered by dykes, seawalls, docks, and other uses.[365] Fisheries, such as trawling, have a direct footprint on the ocean floor:

> "*From 1996 to 2005, the Pacific groundfish bottom trawl fleet fished over 38,000 km$^2$ of Canada's Pacific Ocean floor. During this time, there was a general decline in the area trawled annually*."[366]

Trawling may have also had significant unreported impacts on benthic habitat.

(b) Nutrient loading:

The production of waste is an inevitable result of farmed salmon production, as it is with the production of all food sources. Fortunately, the potential impacts of waste released from salmon farms can largely be mitigated through regulatory requirements, proper siting, and industry best management practices. When these practices are implemented, it has been repeatedly shown that the marine environment has the capacity to recover from the near-field impact associated with salmon farm operations very rapidly due to the flushing and dispersal associated with the ocean currents and tides (with total recovery of the seabed within a few weeks to a few months).

> "*It is difficult to compare nutrient loads coming from fish farms with other human and natural sources of nutrients because individual finfish sites are relatively small point sources (as opposed to sewage outfalls) and are located where there is little additional loading from human sources and where there is relatively little information on natural loadings. Compared to such sources as the Fraser River, which contributes an estimated 171,000 tonnes of particulate organic carbon per year…, the annual loads from BC finfish farms are small. Increased nutrient loads from finfish farms in areas that are already experiencing large nutrient loads from natural and human sources (e.g., Georgia Basin) may have little additional cumulative effect.*"[367]

Impacts to aquatic and terrestrial ecosystems associated with nutrient loading and release of containments from agricultural operations are well documented. Concerns have arisen relating to nutrient loading (and contamination) of watercourses, either resulting from the use of fertilizer to promote crop growth, or as waste products from farmed animals. Nutrient loading of aquatic habitats can dramatically alter the biological community due to changes in species composition and abundance, and in extreme cases result in eutrophication.[368] Nutrient loading of terrestrial soils can also result in alterations to the vegetation community, and ultimately drive changes to all levels of the terrestrial ecosystems. The United Nations Food and Agriculture Organization (FAO) has said:

> "*The livestock sector emerges as one of the top two or three most significant contributors to the most serious environmental problems, at every scale from local to global*."[369]

Furthermore in Canada, Statistics Canada reports:

“*Few farms in Canada have nutrient management plans. Concerns for the environment is the single largest reason for having a nutrient plan*.”[370]

Sewage discharge from various origins (such as municipal sewage systems, industries and shipping) is a significant source of nutrient loading in the aquatic environment.

“*The highest volume of sewage discharge [in BC] is in the Georgia Basin… Volume has been increasing due to population growth and the addition of new areas to municipal sewage systems (i.e., converted to septic systems).”*

“*Cruise ships carry an average of 2,000 crew and passengers and generate more waste and sewage than a small town… Little documentation exists on cruise ship impacts in British Columbia*.”[371]

(c) Antibiotics:

The use of antibiotics in the salmon aquaculture industry is very limited and more closely controlled than in other livestock industries.[372] Antibiotics are used treat bacterial diseases (not prophylactic, nor to promote fish growth) and are prescribed by a licensed veterinarian: this makes salmon farming unique amongst the animal protein-producing industries, which are not bound by the same strict regulation. Furthermore, antibiotics used on fish farms are recorded and reported.

In the agriculture industry, antibiotics are routinely added to feed and their use has increased over time:

“*About 90% of the antibiotics used in agriculture are given as growth-promoting and prophylactic agents, rather than to treat infection. The recommended levels of antibiotics for feeds were just 510 ppm in the 1950s but have increased by 10 –to-20 fold since then*.”[373]

(d) Genetic impacts on wild stocks:

Whereas the impacts from aquaculture are likely very limited as the farmed Pacific salmon industry is quite small and the likelihood of farmed Atlantics interbreeding with wild Pacific salmon is almost non-existent, there is a real risk that hatchery fish may spawn with wild salmon and impact genetic diversity and wild salmon’s ability to adapt to changing environmental conditions, or compete for limited food resources.[374]

“*Large-scale salmon enhancement projects have also resulted in significant ecological and genetic interactions with wild salmon, particularly for coho and chinook stocks. These interactions have tended to reduce genetic diversity and result in the replacement of wild salmon by hatchery fish*.”[375]

(e) By-catch:

By-catch in the salmon aquaculture industry is very limited in comparison with capture fisheries. For example, by-catch in groundfish trawling is a significant proportion of the total catch:

*"Based on government data, we determined that the Pacific groundfish bottom trawl fleet discarded nearly 100,000 metric tonnes of bycatch from 1996 through 2006. This amounts to 20% of all the biomass caught in this fishery during this time. While the majority of this bycatch was composed of commercial species, approximately 30% of the bycatch biomass was made of non-commercial species, for which there are currently no management measures in place*." [376]

**66. Has salmon farming contributed to the decline of wild salmon stocks?**

Historically, the abundance of salmon has always been variable**.** BC Pacific salmon have been in decline over the last several decades, and this trend seems to have been precipitated since the early 1990's. Regarding the decline of the Fraser River sockeye salmon in BC, what the weight of evidence does indicate is that there is no single cause, but rather, several factors are involved.

"*Shifts in climate in 1977 and 1989 resulted in significant changes in production for a number of marine fish species including Pacific salmon. These climate-related changes, combined with local overfishing and the loss of freshwater habitat, have left some salmon stocks at very low levels*."[377]

There has also been growing evidence indicating climate-related changes have been a major factor in the decline of wild Pacific salmon.

*"In recent years, production of Fraser sockeye has declined precipitously [...] Global climate change is likely playing a large role in this decline. Various authors have examined the potential impact of global climate change on particular life stages of sockeye salmon, with many of the analyses done on Fraser sockeye stocks (e.g., Henderson et al., 1992; Hinch et al., 1995a, 1995b; Swansburg et al., 2002; Rand et al., 2006; Farrell et al., 2008; Hague et al., in press; Martins et al., in press), as well as on overall production rates (e.g., Klyashtorin, 1998; Levin, 2003), and concluded that Fraser sockeye salmon would experience declining production based on recent changes in climate, and production would continue to decline as climates continue to change."*[378]

It has been suggested that the growth of fish farm production in the 1990s may have contributed to the decline of wild salmon populations. Although industry opponents maintain the correlation exists, *causation* has never been established. For example, the decline of pink and chum salmon populations in the Broughton Archipelago was hypothesized to have been related to sea lice from farms in the area.[379] This suggested correlation was extensively studied. However, the hypothesis has since been rejected by several scientists, some of whom have also identified concerns with the underlying science of that study.[380] In fact, the authors themselves have recalibrated the model and found a very different conclusion to their original study:

*"The survival of the pink salmon cohort was not statistically different from a reference region without salmon farms."*[380a]

Correlations can be seen among many things and new hypotheses are constantly formulated: this is how we come to understand the world around us. Conclusions, however, should only be drawn from the weight of evidence, based on credible and reliable science.

> "*... as wild salmon productivity has been reduced by habitat loss and the effects of climate change on watersheds and oceans, public concern about the potential impacts of salmon farms on wild fish has increased. Some of this public concern has been fuelled by a lack of information or by misinformation about current operational practices as well as by conflicting scientific research and scientific commentary about the impacts of fish farming on wild fish and the environment*."[381]

Several reviews and studies of the environmental impacts of salmon aquaculture in BC have concluded the industry represents a low risk to wild salmon stocks. The *Salmon Aquaculture Review,* completed in 1997, concluded: "salmon farming in BC, as presently practiced and at current production levels, presents a low overall risk to the environment."[382] Other studies have come to the same conclusions:

> "*The combined evidence indicates that salmon farming, as currently practiced in British Columbia, poses a low risk to wild salmon stocks particularly when compared to other potential factors*."[383]

Put into context, salmon aquaculture impacts are limited both temporally and spatially, and the likelihood of an effect on wild salmon at the population level is very small. Furthermore, there has been no evidence impacts from salmon aquaculture have contributed to the decline of Fraser River sockeye. The risks related to fish health, escapes and wastes are being managed through stringent regulations, and are mitigated by strict industry implemented protocols and practices.

## Endnotes

[1] Agriculture and Agri-Food Canada, "The Canadian Farmed Salmon Industry - Benchmark Analysis for the US Market" (2006), accessed March 22, 2011, http://www.ats.agr.gc.ca/can/4220-eng.htm (AAC, "The Canadian").

[2] Food and Agriculture Organization of the United Nations (FAO). 2010. "The State of World Fisheries and Aquaculture 2010", Rome 2010 (FAO, "State of World Fisheries").

[3] Beamish, R., E Gordon, J Wade, B Pennell, C Neville, K Lange, R Sweetting and S Jones. "The Winter Infection of Sea Lice on Salmon in Farms in a Coastal Inlet in British Columbia and Possible Causes". *J Aquac Res Development* Vol 2 Issue 1. (2011):1 – 11. (Beamish et al, "The Winter Infection")

[4] Fisheries and Oceans Canada, "Frequently Asked Questions – How long has aquaculture been practiced in Canada," accessed March 21, 2011, http://www.dfo-mpo.gc.ca/aquaculture/faq-eng.htm#n1f. (DFO, "FAQ Aqua in Canada").

[5] The Canadian Encyclopedia, 2011, s.v. "Fisheries History". Accessed August 16, 2011, http://www.thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Params=A1ARTA0002833

[6] DFO," FAQ Aqua in Canada" *supra* note 4 at 2.

[7] Fisheries and Oceans Canada, "Socio-Economic Impact of Aquaculture in Canada", Published by Fisheries and Aquaculture Management Ottawa. (2010). (DFO, "p-Economic Impact").

[8] *Ibid.*

[9] BC Salmon Farmers Association, "Profile of the BC Farmed Salmon Industry in 2008", accessed March 21, 2011, http://salmonfarmers.khamiahosting.com/sites/default/files/2008_IndustryProfile_PWC.pdf.

[10] BC Salmon Farmers Association,"Working in the BC Salmon Farming Industry", accessed March 21, 2011, http://salmonfarmers.khamiahosting.com/careers.php.

[11] DFO, "Socio-Economic Impact" *supra* note 7.

[12] *Ibid*.

[13] GSGislason & Associates Ltd. "The Marine Economy & the Regional District of Mt. Waddington in BC". Prepared for Living Oceans Society and the Regional District of Mt. Waddington, 2011.

[14]*Ibid*.

[15] *Ibid*.

[16] *Ibid.*

[17] British Columbia, Ministry of Environment, "Salmon Aquaculture in British Columbia", accessed March 22, 2011, http://www.env.gov.bc.ca/omfd/fishstats/aqua/salmon.html. (BCMOE, Salmon Aquaculture).

[18] Marine Harvest Canada, "Fish Farming Facts", accessed March 21, 2011, http://www.marineharvestcanada.com/farming_did_you_know.php.

[19] Knapp Gunnar, Cathy A. Roheim and James L. Anderson, "The Great Salmon Run: Competition Between Wild And Farmed Salmon," (TRAFFIC North America. Washington D.C.: World Wildlife Fund, 2007).

[20] Canadian Aquaculture Industry Alliance. "Aquaculture Benefits to the Environment". Prepared in collaboration with *Aquaculture Collaborative Research & Development Program*, Fisheries and Oceans Canada. 2009. (CAIA, "Aquaculture").

[21] I*bid.*, 10.

[22] Brooks, K. *British Columbia Ministry of Environment - Soft Bottom Database Evaluation*, (Presentation on report, 2006). (Brooks, "Soft Bottom").

[23] BCMOE, Salmon Aquaculture, *supra* note 17.

[24] Brooks, "Soft Bottom", *supra* note 22.

[25] BCMOE, Salmon Aquaculture, *supra* note 17.

[26] BC Ministry of Environment, "Capture Fisheries Statistics", accessed March 22, 2011, http://www.env.gov.bc.ca/omfd/fishstats/capture/index.html.

[27] Young, Nathan & Ralph Matthews, *The Aquaculture Controversy in Canada: Activism, Policy, and Contested Science* (Vancouver, BC: UBC, 2010) at 47, (Young and Matthews, " Aquaculture Controversy").

[28] Ahousaht First Nation, "Ahousaht First Nation Demands Respect for its Sovereignty and Decision-Making Process", Press Release (May 19, 2010), accessed April 14, 2011, http://www.marketwire.com/press-release/Ahousaht-First-Nation-Demands-Respect-its-Sovereignty-Decision-Making-Process-1263559.htm. (Ahousaht First nation, "Ahousaht First Nation").

[29] Georgia Strait Alliance. "Holmaco First Nation Win Historic Court Case". Media Release March 3, 2005 accessed April 29, 2011 http://www.georgiastrait.org/?q=node/249.

[29a] Naut'sa mawt Tribal Council. "Strong Future in Aquaculture says Chief Harry". (February 8, 2011) accessed May 31, 2011 at http://klahowya.nautsamawt.org/Environment/Resources/strong-future-in-aquaculture-says-chief-harry.html.

[30] Young and Matthews, "Aquaculture Controversy" *supra* note 27 at 54.

[31] Young and Matthews, "Aquaculture Controversy" *supra* note 27 at 55.

[32] Aboriginal Aquaculture Association, "Welcome", accessed April 19, 2011, http://www.aboriginalaquaculture.com/

[32a] *Ibid*

[33]Cross, S.F. and J. Brackett, *Aboriginal Certification of Environmental Sustainability in Aquaculture (ACES Program) Proposed Operational Framework*, Aboriginal Aquaculture Association, 2006.

[34] Marine Harvest Canada, "Aboriginal Peoples and Marine Harvest Canada Working together", accessed April 19, 2011, http://www.marineharvestcanada.com/people_first_nations.php.

[35] Fisheries and Oceans Canada. "Federal BC Aquaculture Regulation and Strategic Action Plan Initiative Discussion Document" (2009), accessed May 3, 2011, http://www.dfo-mpo.gc.ca/aquaculture/lib-bib/nasapi-inpasa/nasapi-inpasa-nov2009-eng.pdf. (DFO, "Strategic Action Plan")

[36] Fisheries and Oceans Canada, "Federal Aquaculture Development Strategy", (Ottawa, Ontario: DFO 1995), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/aquaculture/ref/FADS_e.pdf.

[37] *Ibid*., 8.

[38] *Ibid*., 2.

[39] Fisheries and Oceans Canada, "Aquaculture Policy Framework" (Ottawa, ON: DFO, 2005), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/aquaculture/ref/APF_e.pdf.

[40] *Ibid*.,12.

[41] *Ibid.*, 11.

[42] *Ibid*.

[43] *Ibid*.

[44] *Ibid*., 23.

[45] *Ibid*., 21.

[46] Fisheries and Oceans Canada, "Wild Salmon Policy", (Ottawa, Ontario: DFO, 2005), at 31, accessed March 22, 2011, http://www.dfo-mpo.gc.ca/Library/315577.pdf.

[47] *Ibid*., 31.

[48] *Ibid*.

[49] *Ibid.*, 36.

[50] Fisheries and Oceans Canada, "B.C. Aquaculture Regulatory Program" (December 10, 2010) accessed March 20, 2011, (DFO, "Regulatory Program")

[51] *Ibid*.

[52] Fisheries and Oceans Canada, "Aquaculture in the Pacific Region - Frequently Asked Questions" (December 16, 2010), accessed March 22, 2011, http://www.pac.dfo-mpo.gc.ca/aquaculture/FAQ-eng.htm (DFO, "PAR-FAQ")

[53] Fisheries and Oceans Canada, 'The Department of Fisheries and Oceans Policy for the Management of Fish Habitat", (9 January, 2001) at 27, accessed March 21, 2011, http://www.dfo-mpo.gc.ca/habitat/role/141/1415/14155/fhm-policy/index-eng.asp

[54] *Ibid*.

[55] Fisheries and Oceans Canada, Aquaculture - Frequently Asked Questions", 2010 http://www.dfo-mpo.gc.ca/aquaculture/faq-eng.htm#n3 (DFO, Aqua-FAQ)

[56] DFO, "PAR-FAQ", *supra* note 52.

[57] *Fisheries Act*, RSBC 1996, c. 149; *Aquaculture Regulation*, BC Reg. 78/2002; *Columbia Fire Code Regulation*, B.C. Reg. 175/2006*; Contaminated Sites Regulation*, B.C. Reg. 375/96; *Environmental Management Act*, SBC 2003, c.53; *Farm Practices Protection (Right to Farm) Act*, RSBC 1996, c. 131; *Finfish Aquaculture Waste Control Regulation*, BC Reg. 256/2002; *Land Act*, RSBC 1996, c.245; *Municipal Sewage Regulation*, B.C. Reg. 129/99; *Water Act*, RSBC 1996, c.483; and the *Wildlife Act*, RSBC 1996, c.488.

[58] *Fisheries Act,* RS, 1985, c. F-14 (*Fisheries Act* (Canada))

[59] *Navigable Waters Protection Act*, RS, 1985, c. N-22

[60] *Canadian Environmental Assessment Act*, 1992, c. 37(CEAA)

[61] *Morton v. British Columbia (Ministry of Agriculture and Lands)* (2009), 2009 BCSC 136. 92 B.C.L.R. (4th) 314, 2009 CarswellBC 282 (WLeC) at para. 156 (BCMAL, "Morton v. BC".)

[62] *Ibid*. at paras. 194-200

[63] *Pacific Aquaculture Regulations* SOR/2010-270 (*PAR*)

[64] *Ibid.* at s. 4(c)

[65] *Ibid*. at s. 4(j)

[66] *Ibid*. at s. 4(k)

[67] CEAA, *supra* note 60

[68] DFO, 'FAQ Legislation", *supra* note 55.

[69] BCMAL, "Morton v. BC", *supra* note 61

[70] *Kwicksutaineuk/Ah-Kwa-mish Tribes v. Canada (Minister of Fisheries and Oceans)* (2003), 227 F.T.R. 96, aff'd. (2003), 313 N.R. 394 (F.C.A.)

[71] National Aquaculture Strategic Action Plan Initiative, 'West Coast Marine Finfish Sector, Strategic Action Plan 2011–2015" (November 1, 2010), Accessed March 22, 2011, http://www.dfo-mpo.gc.ca/aquaculture/lib-bib/nasapi-inpasa/index-eng.htm. (NASPI, "West Coast")

[72] *Supra* note 13 at 2

[73] DFO, "Aquaculture FAQs", *supra* note52.

[74] Fisheries and Oceans Canada, "Roles and Responsibilities" (September 1, 2005), accessed March 19, 2011, http://www.dfo-mpo.gc.ca/aquaculture/gov-gouv/role-eng.htm.

[75] Canadian Aquaculture Industry Alliance, "Canadians Overwhelmingly Support a National Aquaculture Act," by Abacus Data Inc., April 20 2011, accessed April 21, 2011, http://aquaculture.ca/files/CAIA_-_April_20,_2011_FINAL.pdf (CAIA, "Aquaculture Act Poll 2011").

[76] *Fisheries Act* (Canada), *supra* note 58 at s. 38.

[77] DFO, "Regulatory Program", *supra* note 50

[78] *Ibid*.

[79] DFO, "Aquaculture FAQs" *supra* note 52

[80] BC, Ministry of Agriculture and Lands and Ministry of the Environment, *Regulatory Compliance of British Columbia's Marine Finfish Aquaculture Facilities: 2008* (Victoria: BCMAL & BCMOE, 2009) at 16. (BCMAL "Regulatory: 2008").

[81] *Ibid*. at 6.

[82] *Finfish Aquaculture Licence 2010 under the Pacific Aquaculture Regulations*, s. 7.4 – 7.5 (Finfish Aquaculture Licence 2010)

[83] *Ibid.* at s. 13.9

[84] Fisheries and Oceans Canada, "*Pacific Aquaculture Regulations* Now Come Into Force" (December 2010), accessed March 21, 2011, http://www.dfo-mpo.gc.ca/aquaculture/bcr-rcb/index-eng.htm.

[85] *Fisheries Act* (Canada), *supra* note *58*

[86] NASPI, "West Coast", *supra* note 71, at FH-3.

[87] *Ibid*.

[88]. Fisheries and Oceans Canada, "Aquaculture – Frequently Asked Questions – Legislation and Regulation", 2005 http://www.dfo-mpo.gc.ca/aquaculture/bcr-rcb/index2-eng.htm (DFO, PAR-FAQ)

[89] *Ibid.*

[90] BCMAL "Regulatory: 2008", *supra* note 80 at 6-7.

[91] Ministry of Agriculture, Food and Fisheries, "Fish Farmers Score High in Compliance Report", Information Bulletin 2004AGF0018-000755, (2004).; Ministry of Agriculture and Lands, "Aquaculture Industry in High Compliance", News Release 2006AL0029-001007 (2006).; Ministry of Agriculture and Lands, "Aquaculture Reports Show High Level of Compliance", News Release 2008ALOOOl-000008, (2008).; BCMAL "Regulatory: 2008" *supra* note 80.

[92] Environment Canada, *Compliance and Enforcement Policy for the Habitat Protection and Pollution Prevention Provisions of the Fisheries Act* (Environment Canada, November 2001) at 3.

[93] *Ibid.*

[94] *Regulations Respecting Fishing and Fish Habitat in General and the Payment of Penalty and Forfeiture Proceeds Under the Fisheries Act* (SOR/93-53) at s. 56 (*Fishery (General) Regulations*)

[95] *Regulations Respecting the Protection of Health of Fish* (C.R.C., c. 812) (Regulations Respecting Protection)

[96] Fisheries and Oceans Canada, "National Code on Introductions and Transfers of Aquatic Organisms 2003",accessed at http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/code/Code2003-eng.pdf (ITO Code).

[97] Fisheries and Oceans Canada, National Code on Introductions and Transfers of Aquatic Organisms - Preliminary Information (modified March 7, 2011), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/code/prelim-eng.htm.

[98] *Health of Animals Act*, SC 1990, c. 21 (*HAA*)

[99] *Health of Animals Regulations*, CRC, c. 296 (*HAR*)f

[100] *Regulations Amending the Health of Animals Regulations*, SOR/2010-296, Canada Gazette Part II: Official Regulations, Vol. 144, No. 26, December 22, 2010 "Regulatory Impact Analysis Statement" (*HAR* Impact Analysis Statement).

[101] *Ibid.*

[102] *Ibid*.

[103] *Ibid.*

[104] *Ibid.*

[105] *HAA*, *supra* note 98 at s. 5(1)

[106] *Ibid.* at s. 5(2)

[107] *Ibid.* at s. 8

[108] *HAR* Impact Analysis Statement, *supra* note 100.

[109] *HAA* supra note 1 at s. 98

[110] *Fishery (General)* Regulations, supra note 94 at s. 55 (1)

[111] *Freshwater Fish Regulation*, BC Reg. 261/83 at s. 110(2)(h)(aa)

[112] Fisheries and Oceans Canada, "Fishery (General) Regulations", accessed March 23, 2011, http://laws.justice.gc.ca/eng/regulations/SOR-93-53/index.html.

[113] Regulations Respecting Protection, *supra* note 95.

[114] Fisheries and Oceans Canada, "Fish Health Protection and the National Aquatic Animal Health Program", accessed March 23, 2011, http://www.pac.dfo-mpo.gc.ca/science/species-especes/aq-health-sante/naahp-pnsaa-eng.htm.

[115] ITO Code *supra* note 96

[116] Fisheries and Oceans Canada, "A Canadian Action Plan to Address the Threat of Aquatic Invasive Species: Canadian Council of Fisheries and Aquaculture Ministers Aquatic Invasive Species Task Group" (modified March 7, 2011), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/plan/plan-eng.htm. (Fisheries and Oceans Canada, "Action Plan to Address Aquatic Invasive Species")

[117] ITO Code, *supra* note 96 at 1.1.4; Fisheries and Oceans Canada, "State-of-Knowledge Presentation for the Special Committee on Sustainable Aquaculture of the British Columbia Legislature " (presented Thursday, November 30, 2006, 1088 Burrard Street, Vancouver, BC) at 3.2, http://www.dfo-mpo.gc.ca/Library/327248.pdf. (DFO, "State-of Knowledge")

[118] Fisheries and Oceans Canada, "Action Plan to Address Aquatic Invasive Species" *supra* note 116

[119] Fisheries and Oceans Canada, State of Knowledge, *supra* note 117 at 3.2.

[120] Living Oceans Society, "History of Salmon Farming in B.C." accessed March 11, 2011, http://www.livingoceans.org/programs/fishfarms/history.html.

[121] Auditor General of Canada, Chapter 30 "Fisheries and Oceans—The Effects of Salmon Farming in British Columbia on the Management of Wild Salmon Stocks" in *Report of the Auditor General to the House of Commons for December 2000*, http://www.oag-bvg.gc.ca/internet/English/parl_oag_200012_30_e_11217.html.

[122] *Ibid*. at 30.76.

[123] *Ibid*. [emphasis added].

[124] *Ibid*. at section 30.8.

[125] CAIA, "Aquaculture Act Poll 2011", *supra* note 75.

[126]Noakes, D.J., R. J. Beamish, M. L. Kent, "On the Decline of Pacific Salmon and Speculative Links to Salmon Farming in British Columbia," *Aquaculture* 183 (2000): 363–386 (Noakes, *et al*., "On the Decline").

[127] BC Centre for Aquatic Health Sciences (BC CAHS), "Fish Health Audits," accessed March 29, 2011, http://www.cahs-bc.ca/fish-health-audits.php.

[128] Hedrick, R.P. "Relationships of the Host, Pathogen, and Environment: Implications for Diseases of Cultured and Wild Fish Populations," *Journal of Aquatic Animal Health* 10 (1998):107–111.

[129] Kent, M. "Infectious Diseases and Potential Impacts on Survival of Fraser River Sockeye Salmon - Technical Report 1". The Cohen Commission of Inquiry in to the Decline of Sockeye Salmon in the Fraser River, (2011).

[130] McVicar. G. Olivier, G.S Traxler, S. Jones, D. Kieser, and A-M MacKinnon. "Cultured and Wild Fish Disease Interactions in the Canadian Marine Environment". A Scientific Review of the Potential Environmental Effects of Aquaculture in Aquatic Ecosystems - Volume 4, 2006, Fisheries and Oceans Canada. (McVicar, *et al*., "Cultured and Wild,")

[130a] Province of British Columbia. "Template for Development of Facility – Specific Fish Health Management Plans". (2006)

[131] Noakes, *et al*., "On the Decline", *supra* note 126 at 380.

[132] BC Ministry of Environment. *Water Quality Guidelines (Criteria) Reports.* Accessed March 8, 2011. http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html.

[133]Cubitt, F., Butterworth, K., McKinley, S. R. "A Synopsis of Environmental Issues Associated with Salmon Aquaculture in Canada." Chapter 9. West Vancouver, BC: UBC-DFO (2008), (Cubitt et al, "A Synopsis").; BC Ministry of Agriculture and Land, "Therapeutant (Antibiotic) Use in Aquaculture", accessed April 28, 2011, http://www.agf.gov.bc.ca/ahc/fish_health/ antibiotics.htm.

[134]BC Ministry of Agriculture and Land, "Therapeutant (Antibiotic) Use in Aquaculture", (August 24, 2009.), accessed May 18, 2011, http://www.agf.gov.bc.ca/ahc/fish_health/Antibiotic_Graphs_1995-2008.pdf. (BCMAL, "Therapeutant")

[135] BC Ministry of Agriculture and Lands, 2009 Annual Report Fish Health Program. (BCMAL, "FHP 2009").

[136] McVicar, *et al*., "Cultured and Wild," *supra* note 130.

[137] Korman, J. 2011. "Summary of information for evaluating impacts of salmon farms on survival of Fraser River sockeye salmon". Cohen Commission Tech. Rep. 5A. 65p. Vancouver, B.C. www.cohencommission.ca (Korman, "Summary of information").

[138] Fisheries and Oceans Canada, *Policy for the Importation of Atlantic Salmon* (Ottawa, Ontario: DFO, 1992).

[139] Fisheries and Oceans Canada "Salmon Egg Imports" (modified February 24, 2011), accessed May 18, 2011, <http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/egg-oeuf-eng.htm>.

[140] McVicar, *et al*., "Cultured and Wild," *supra* note 130 at 2.

[141] Noakes, *et al*., "On the Decline", *supra* note 126.

[142] McVicar, *et al*., "Cultured and Wild," *supra* note 130 at 1.

[143] Traxler, G.S., J.R. Roome, K.A. Lauda, S. LaPatra. "Appearance of infectious hematopoietic necrosis virus (IHNV) and neutralizing antibodies in sockeye salmon *Onchorynchus nerka* during their migration and maturation period," *Diseases of Aquatic Organisms* 28 (1997): 31-38. (Traxler, *et al*., "Appearance of IHNV")

[144] *Ibid.*, 36.

[145] *Ibid.*

[146] *Ibid.*, 36.

[147] Saksida, S. *Investigation of the 2001-2003 IHN epizootic in farmed Atlantic salmon in British Columbia.*

[148] Korman, "Summary of information", *supra* note 137.

[149] Miller, KM., S Li, K H. Kaukinen, N Ginther, E Hammill, J M. R. Curtis, D A. Patterson, T Sierocinski, L Donnison, P Pavlidis, S G. Hinch, K A. Hruska, S J. Cooke, K K. English, A P. Farrell. "Genomic Signatures Predict Migration and Spawning Failure in Wild Canadian Salmon", *Science* 331 (2011): 214-217.

[150] Morton, A. in T. Jean. *Salmon Farm Disease and Sockeye*, accessed May 18, 2011 http://www.thecanadian.org/k2/item/343-twyla-roscovich.

[151] BC Centre for Aquatic Health Sciences. Questions and answers regarding the paper "Genomic Signatures Predict Migration and Spawning Failure in Wild Canadian Salmon" published in *Science*, January 2011.

[152] *Ibid* at 1.

[153] *Ibid* at 2.

[154] Miller, K. “Hypothesis: Genomic data indicate that a potentially novel disease, possibly viral in origin, has been affecting a high proportion of juvenile and adult Fraser River sockeye salmon.” (circa 2009).

[155] Noakes, *et al*., “On the Decline”, *supra* note 126.

[156] Fisheries and Oceans Canada, *Evaluation Directorate - Salmonid Enhancement Program - Project Number 6B105 - Final Evaluation Report.* (September 22, 2009),accessed May 18, 2011, http://www.dfo-mpo.gc.ca/ae-ve/evaluations/09-10/6b105-eng.htm.

[157] Korman, “Summary of information”, *supra* note 137 at 9.

[158] Korman, “Summary of information”, *supra* note 137 at 10.

[159] Aquaculture Association of Canada. “Sea Lice Fact Sheet Brief Version”, accessed February 21, 2011. www.aquacultureassociation.ca/sites/default/files/sea%20lice%20fact%20sheet.pdf

[160] *PAR*, *supra* note 63.

[161] Finfish Aquaculture Licence 2010, *supra* note 82.

[162] BCMAL, “FHP 2009”, *supra* note 135.

[163] Krkosek, M, M Lewis, and J Volpe. "Transmission dynamics of sea lice from farmed to wild salmon." *Proceedings of the Royal Society B*, 2005: 689-696.; Krkosek, M., MA Lewis: A Morton, N Frase, and JP Volpe. "Epizootics of wild fish induced by farm fish." *PNAS Vol. 103 No. 42; DOI:10.1073/pnas.0603525103*, 2006: 15506-15510.; Krkosek, M., J.S. Ford, A. Morton, S. Lele, R.A. Myers, and M.A. Lewis. "Declining Wild Salmon Populations in Relation to Parasites from Farm Salmon." *Science Vol 318; DOI: 10.1126/science.1148744*, 2007: 1772-1775.; Morton, A, R Routledge, Corey Peet, and A Ladwig. "Sea Lice (Lepeophtheirus Salmonis) Infection Rates on Juvenile Pink (Oncorhynchus Gorbuscha) and Chum (Oncorhynchus Keta) Salmon in the Nearshore Marine Environment of British Columbia Canada." *Canadian Journal of Fisheries and Aquatic Sciences 61;DOI: 10.1139/F04-016*, 2004: 147-157. (Morton et al, “Sea Lice Infection Rates”); Morton, A., R Routledge, and M. Krkosek. "Sea Louse Infestation in Wild Juvenile Salmon and Pacific Herring Associated with Fish Farms off the East-Central Coast of Vancouver Island, British Columbia." *North American Journal of Fisheries Management 28*, 2008: 523-532. (Morton, *et al*., “Sea Louse Infestation”); Price, MHH, A Morton, and JD Reynolds. "Evidence of farm-induced parasite infestations on wild juvenile salmon in multiple regions of coastal British Columbia, Canada." *Canadian Journal of Fisheries and Aquatic Sciences 67; DOI;10.1139/F10-105*, 2010: 1925-1932. (Price *et al*., “Evidence of farm-induced parasite infestations”); Price, MHH, SL Proboszcz, RD Routledge, AS Gottesfeld, C Orr, and JD. Reynolds. "Sea Louse Infection of Juvenile Sockeye Salmon in Relation to Marine Farms on Canada's West Coast." *PLoS ONE 6(2):e16851. DOI:10.1371/journal.pone.0016851*, 2011: 1-9. (Price *et al.*, “Sea Louse Infection of Juvenile Sockeye.”).

[164] Beamish, RJ., et al. "A proposed life history strategy for the salmon louse, *Lepeophtheirus salmonis* in the subarctic Pacific." *Aquaculture 264 (2007) . doi:10.1016/j.aquaculture.2006.12.039*, 2007: 428-440;(Beamish *et al*, “Proposed life history”) Beamish, R., Wade, J., Pennell, W., Gordon, E., Jones, S., Neville, C., Lange, K. and R. Sweeting. "A large, natural infection of sea lice on juvenile Pacific salmon in the Gulf Island area of British Columbia, Canada." *Aquaculture 297; doi:10.1016/j.aquaculture.2009.09.001* 9 (2009): 31-37, (Beamish *et al*., “Large natural infection”);. Beamish et al, “The Winter Infection”, *supra* note 3.; ; Gottesfeld, AS, B Proctor, LD Rolston, and C Carr-Harris. "Sea lice, *Lepeophtheirus salmonis*, transfer between wild sympatric adult and juvenile salmon on the north coast of British Columbia, Canada." *Journal of Fish Diseases 32; doi:10.1111/j.1365-2761.2008.01003.x*, 2009: 48-57. (Gottesfeld, *et al*., “Sea lice transfer”) ; Jones, Simon, Gina Prosperi-Porta, Eliah Kim, Paul Callow, and Brent Hargreaves. "The occurance of *Lepeophtheirus salmonis* and *Caligus clemensi* on three-spine stickleback Gasterosteus aculeatus in coastal British Columbia." *Journal of Parasitology 92(3)*, 2006: 473-480. (Jones, *et al.*, “The Occurance of *Lepeophtheirus salmonis*”) ; Trudel, M., et al. "Infestations of Motile Salmon Lice on Pacific Salmon along the West Coast of North America." *American Fisheries Society Symposium 57* , 2007: 157-182. (Trudel, *et al*., “Infestations of Motile Salmon Lice”).

[165] Morton, A. and R.Routledge. "Mortality Rates for Juvenile Pink *Oncorhynchus gorbuscha* and Chum *O. keta* Salmon Infested with Sea Lice *Lepeophtherius salmonis* in the Broughton Archipelago." *Alaska Fishery Research Bulletin 11(2)*, 2005: 146-152. (Morton and Routledge, “Mortality Rates”).

[166] Beamish *et al*, “Proposed life history*supra* note 164

[167] Fast, MD, NW Ross, A Mustafa, DE Sims, and SC Johnson and 5 others. "Susceptibility of rainbow trout *Oncorhynchus mykiss*, Atlantic salmon *Salmo salar* and coho salmon *Oncorhynchus kisutch* to experimental infection with sea lice *Lepeophtheirus*." *Diseases of Aquatic Organisms Vol 52*, 2002: 57-68. (Fast, *et al*., "Susceptibility"); Jones, S., E. Kim, and W. and Bennett. "Early development of resistance to the salmon louse, *Lepeoptheirus salmonis* (Kroyer), in juvenile pink salmon, *Oncorhynchus gorbuscha* (Walbaum)." *Journal of Fish Diseases; doi:10.1111/j.1365-2761.2008.00933.x* 31: 591-600 (2008): 1-10. (Jones, *et al*., "Early development of resistance").

[168] DFO, "State-of Knowledge" *supra* note 117 at 3.5.4

[169] Beamish et al, "A large, natural infection", *supra* note 164; Beamish, et al. "The Winter Infection", *supra* note 3; Butterworth, KG., KF Cubitt and RS McKinley. "The prevalence, density and impact of *Lepeoptherius salmonis* infestation on juvenile pink salmon from the central coast of British Columbia, Canada." *Fisheries Research 91*, 2008: 35-41. (Butterworth *et al*., "The prevalence"); Clayoquot Sound Sea Lice Working Group. "Prevalence and Intensity of sea louse (*L.salmonis and C.clemensi*) infections in juvenile chum salmon (*Oncorhynchus keta*) in Clayoquot Sound 2004-2007." 2009. (Clayoquot Sound Sea Lice Working Group, "Prevealence and Intensity of Sea Louse"); Gottesfeld, *et al*., "Sea lice transfer" *supra* note164; Jones, S. and A Nemec. "Sea Lice on Juvenile Salmon and on Some Non-Salmonid Species Caught in the Broughton Archipelago in 2003 DRAFT." PSARC Working Paper H2004-01, 2004. (Jones and Nemec, "Sea Lice on Juvenile Salmon"); Kabata, Z. "The Species of *Lepeophtherious* (Copepoda:Caligidae) from Fishes of British Columbia." *Journal of the Fisheries Research Board of Canada 30*, 1973: 729-759.; Morton et al,"Sea Lice Infection Rates", *supra* note163.

[170] Jones, *et al.*, "The Occurance of *Lepeophtheirus salmonis*" *supra* note 164 at 473.

[171] Korman, "Summary of information" *supra* note 137 at 9.

[172] Parker, RR and L. Margolis. "A New Species of Parasitic Copepod, Caligus clemensi sp.nov. (Caligoda:Caligidae) from Pelagic Fishes in the Coastal Waters of British Columbia'. *J. Fish. Res. BD. Canada* 21(5), 1964.

[173] Butterworth, Kevin, Fiona Cubitt, Bengt Finstad, and Scott McKinley. "Sea Lice: The Science Behind the Hype". *Fraser Institute Digital Publication*, 2006.

[174] Beamish *et al*., "Large natural infection" *supra* note 164; Price *et al.,* "Sea Louse Infection of Juvenile Sockeye." *supra* note 163.

[175] Clayoquot Sound Sea Lice Working Group, "Prevealence and Intensity of Sea Louse" *supra* note 169; Morton, *et al*., "Sea Louse Infestation"; *supra* note 163.

[176] Johnson, SC and LJ Albright. "Development, Growth and Survival of *Lepeophtherius salmonis* (Copepoda:Caligidae) under laboratory conditions." *Journal of the Marine Biological Association of the United Kingdom 71*, 1991: 425-436. (Johnson and Albright, "Development"); Saksida, S., J Constantine, GA Karreman, and A. Donald. "Evaluation of sea lice abundance levels on farmed Atlantic salmon (*Salmo salar* L.) located in the Broughton Archipelago of British Columbia from 2003 to 2005." *Aquaculture Research. 38*, 2007: 219-231. At 228 (Saksida, *et al*., "Evaluation of sea lice abundance").

[177] Jones, *et al.*, "The Occurance of *Lepeophtheirus salmonis*" *supra* note 164 at 473.

[178] *Ibid.* at 479.

[179] Yazawa, R, M Yusuike, J Leong, KR van Schalburg, GA Cooper, M Beetz-Sargent, A Robb, WS Davidson, SRM Jones and BF Koop. "EST and Mitochondrial DNA Sequences Support a Distinct Pacific Form of Salmon Louse, *Lepeoptheirus salmonis*". *Mar Biotechnical. doi; 10.1007/s10126-008-9112-y*, 2008.; Boulding, EG, JR deWaard, KP Ang and PDN Hebert. "Population genetic structure of the salmon louse, *Lepeoptheirus salmonis* (Kroyer) on wild and farmed salmonids around the Pacific Coast of Canada". *Aquaculture Research* 40, 2009: 973 – 979. (Boulding *et al*., Population genetic structure").

[180] Saksida, *et al*., "Evaluation of sea lice abundance" supra note 176 at 228.

[181] Tucker, CS, C Sommerville, and R. Wootten. "The effect of temperature and salinity on the settlement and survival of copepodids of Lepeophtherius salmonis (Kroyer, 1837) on Atlantic salmon, Salmon salar." *Journal of Fish Diseases 23*, 2000: 308-320. (Tucker, *et al*., "The effect of temperature and salinity").

[182] Brooks, K. "The Effects of Water Temperature, Salinity, and Currents on the Survival and Distribution of the Incfective Copepodid Stage of Sea Lice (Lepeoptheirus salmonis) Originating on Atlantic Salmon Farms in the Broughton Archipelago of British Columbia, Canada." *Reviews in Fisheries Science 13*, 2005: 177-204. (Brooks, "The Effects of Water Temperature, Salinity and Currents").

[183] Tucker, *et al*., "The effect of temperature and salinity" *supra* note 181 at 309.

[184] Brooks, "The Effects of Water Temperature, Salinity and Currents" *supra* note 182 at 177.

[185] Morton, *et al*., "Sea Lice Infection Rates" *supra* note 163; Morton, *et al*., "Sea Louse Infestation" *supra* note 163.

[186] Jones and Nemec, "Sea Lice on Juvenile Salmon", *supra* note 169; Jones, *et al.*, "The Occurance of *Lepeophtheirus salmonis*" *supra* note 164; Clayoquot Sound Sea Lice Working Group, "Prevealence and Intensity of Sea Louse" *supra* note 169; Gottesfeld, A., D Rolston, B Proctor, and and T. Ryan. "2004-2005 North Coast Marine Baseline Survey and Sea Lice Research Program." 2006. (Gottesfeld et al, "2004-2005"); Gottesfeld, *et al*., "Sea lice transfer" *supra* note 164.

[187] Saksida, S, GA Karreman, J Constantine and A Donald. "Differences in Lepeophtheirus salmonis abundance levels on Atlantic salmon farms in the Broughton Archipelago, British Columbia, Canada". *Journal of Fish Diseases* 30, 2007. 357-366.(Saksida, et al., "Differences in *L. Salmonis* abundance").

[188] Jones, *et al*., "Early development of resistance" *supra* note 167.; Sutherland, BJG, SG Jantzen, DS Sanderson, BF Koop and SRM Jones. "Differentiating size-dependant responses of juvenile pink salmon (*Oncoryhnchus gorbuscha*) to sea lice (*Lepeoptheius salmonis*) infections". *Comparitive Biochemistry and Physiology*, Part D 6 (2011):213-223 at 221.

[189] Saksida, *et al*., "Evaluation of sea lice abundance" *supra* note 176.

[190] Johnson, SC, RB Blaylock, J Elphick and KD Hyatt. "Disease induced by the sea louse (Lepeophtherius salmonis) (Copepoda: Caligidae) in wild sockeye salmon (Oncorhynchus nerka) stocks of Alberni Inlet, British Columbia." *Canadian Journal of Fisheries and Aquatic Sciences 53*, 1996: 2888-2897. (Johnson, *et al*., "Disease induced by the sea louse").

[191] *Ibid.*

[192] Webster, SJ., LM Dill, and K. Butterworth. "The effect of sea lice infestation on the salinity preference and energetic expenditure of juvenile pink salmon (Oncorhynchus gorbuscha)." *Canadian Journal of Fisheries and Aquatic Sciences 64*, 2007: 672-680.

[193] Mages, PA and LM Dill. "The effect of sea lice (*Lepeoptheirus salmonis*) on juvenile pink salmon (*Oncorhynchus gorbuscha*) swimming endurance." *Can. J. Fish. Aquatic. Sci.* 67 (2010): 2045 – 2051.

[194] Nendick, L, M Sackville, S Tang, CJ Brauner and AP Farrell. "Sea lice infection of juvenile pink salmon (*Oncorhyncus gorbuscha*): effects on swimming performance and postexercise ion balance". Can. J. Fish. Aquat. Sci. 68 (2011): 241 – 249.

[195] Jones, *et al*., "Early development of resistance" *supra* note 167.

[196] Nylund, A, T Hovland, K Hodneland, F Nilsen and P Lovik. "Mechanisms for transmission of infectious salmon anemia (ISA)". *Diseases of Aquatic Organisms* vol 19, 1994: 95 – 100.

[197] Barker, DE, LM Braden, MP Coombs and B Boyce. "Preliminary studies on the isolation of bacteria from sea lice, *Lepeoptheirus salmonis*, infecting farmed salmon in British Columbia, Canada". Parasitol Res 105 (2009): 1173 – 1177. DOI: 10.1007/s00436-009-1523-9.

[198] European Food Safety Authority (EFSA). "Possible Vector Species and Life Stages of Susceptible Species Not Transmitting Disease as Regards Certain Fish Diseases" - Scientific Opinion of the Panel on Animal Health and Welfare. s.l. : The EFSA Journal (2007) 584 1-163, 2007. http://www.efsa.europa.eu/en/efsajournal/doc/ahaw_op_ej584_fishdiseasevectors_en.pdf .

[199] Traxler et al, "Appearance of IHNV", *supra* note 143.

[200] A Point of VIU, “VIU researcher wins major grant to study sea lice,” accessed May 12, 2011, http://www.viu.ca/mainly/page.asp?ID=1646.

[201] Traxler *et al.*, “Appearance of IHNV”, *supra* note 143.

[202] Korman, “Summary of information” *supra* note 137 at 5

[203] Saksida, *et al*., “Evaluation of sea lice abundance” *supra* note 176

[204] Marty, GD, SM Saksida, and TJ Quinn. "Relationship of farm salmon, sea lice, and wild salmon populations." *PNAS doi:10.1073/pnas.1009573108*, 2010: 1-6. At 4 (Marty, et al., “Relationship of farm salmon”).

[205] Jones, S. "Controlling salmon lice on farmed salmon and implications for wild salmon." *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 4 No. 048. Doi: 10.1079/PAVSNNR20094048.* 2009. (Jones, “Controlling Lice”)

[206] Boulding *et al*., Population genetic structure” *supra* note 179.

[207] *Ibid.* at 977.

[208] Beamish, R., C. Neville, R. Sweeting, and N. Ambers. "Sea lice on adult Pacific salmon in the coastal waters of central British Columbia, Canada." *Fisheries Research 76*, 2005: 198-208.; Jones, *et al.*, “The Occurance of *Lepeophtheirus salmonis*” *supra* note 164; Trudel, *et al*., “Infestations of Motile Salmon Lice” *supra* note 164

[209] Johnson and Albright, “Development”, *supra* note 176.

[210] Marty, et al., “Relationship of” *supra* note 204.

[211] Price *et al*., “Evidence of farm-induced parasite infestations” *supra* note 163; Price *et al.*, “Sea Louse Infection of Juvenile Sockeye” *supra* note 163.

[212] Korman, “Summary of information” *supra* note 137 at 10.

[213] BCMAL, “FHP 2009” *supra* note 135; Saksida, SM, D Morrison and CW Revie. "The efficacy of emamectin benzoate against infestations of sea lice, Lepeophtheirus salmonis, on farmed Atlantic salmon, Salmo salar, in British Columbia." *Journal of Fish Diseases 33, doi: 10.1111/j.1365-2761.2010.01192x*, 2010: 913-917. at 916 (Saksida, *et al*., “The efficacy of emamectin benzoate”)

[214] Saksida, *et al*., “Evaluation of sea lice abundance” *supra* note 176 at 228.

[215] *Ibid*

[216] Morton, Alexandra, Richard Routledge, and Rob Williams. "Temporal patterns of sea louse infestation on wild Pacific salmon in relation to the fallowing of salmon farms." *North American Journal of Fisheries Management 25*, 2005: 811-821.; Orr, C. "Estimated Sea Louse Egg Production from Marine Harvest Canada Farmed Atlantic Salmon in the Broughton Archipelago, British Columbia, 2003-2004." *North American Journal of Fisheries Management 27*, 2007: 187-197.

[217] Beamish, RJ, S Jones, CE Neville, R Sweeting, G Karreman, S Saksida, and E Gordon. "Exceptional marine survival of pink salmon that entered the marine environment in 2003 suggests that farmed Atlantic salmon and Pacific salmon can coexist successfully in a marine ecosystem on the Pacific coast of Canada." *ICES Journal of Marine Science 63*, 2006: 1326-1337. at 1335. (Beamish, *et al*., “Exceptional marine survival”)

[218] Saksida, *et al*., “The efficacy of emamectin benzoate *supra* note 213

[218a] Messmer, AM, EB Rondeau, SG Jantzen, KP Lubieniecki, WS Davidson and BF Koop. “Assessment of population structure in Pacific *Lepeophtheirus salmonis* (Kroyer) using single nucleotide polymorphism and microsatellite genetic markers.” *Aquaculture* (2010) doi:10.1016/j.aquaculture.2010.09.033. at 10.

[219] Sams, Saksida, McClure and Hammell. "Canadian Sea Lice Therapeutant Availability: Jurisdictional Considerations." (2008). BC Center for Aquatic Health Sciences and Atlantic Veterinary College – Centre for Aquatic Health Sciences.

[220] Saksida, *et al*., "The efficacy of emamectin benzoate" *supra* note213; DFO. "Treatment of sea lice" accessed March 21, 2011 online at http://www.dfo-mpo.gc.ca/aquaculture/lice-pou/lice-pou03-eng.htm.

[221] The Centre for Aquaculture and Environmental Research (UBC) produced "A Reference Manual for Research Involving Wild / Cultured Fish Interactions with Sea Lice" in 2006, which describes study design, methods of collecting specimens and analyzing results. While the specific projects develop their own sampling programs, many of the common practices are described in this protocols and guidelines document.

[222] Gottesfeld et al, "2004 – 2005", *supra* note 186; Gottesfeld, AS, C Carr-Harris, B Proctor and D Rolston. "Sockeye salmon juveniles in Chatham Sound 2007". Report to the *Pacific Salmon Forum*. (2008).

[223] Krkosek "Declining Wild Salmon", *supra* note 163.

[224] Beamish, *et al*., "Exceptional marine survival" *supra* note 217; Marty, *et al*., "Relationship of". *supra* note204.

[225] Morton and Routledge, "Mortality Rates" *supra* note 165.

[226] Jones, "Controlling Lice", *supra* note 205; Marty, et al., "Relationship of farm salmon", *supra* note 204.

[227] Jones, S and NB. Hargreaves. "Infection Threshold to estimate Lepeophtherius salmonis-associated mortality amoung juvenile pink salmon." *Diseases of Aquatic Organisms Vol 84*, 2009: 131-137.; Jones, et al., "Early development of resistance" *supra* note 167.

[228] Johnson, *et al*., "Disease induced by the sea louse" *supra* note 190.

[229] Jones, SRM., MD Fast, SC Johnson and DB Groman. "Differential rejection of salmon lice by pink and chum salmon: disease consequences and expression of proinflammatory genes." *Diseases of Aquatic Organisms Vol. 75*, 2007: 229-238.

[230] 2006 Legislative Session: Second Session, 38th Parliament SPECIAL COMMITTEE ON SUSTAINABLE AQUACULTURE accessed April 12, 2011 http://www.leg.bc.ca/cmt/38thparl/session-2/aquaculture/hansard/W61205a.htm at 995.

[231] Burgner, RL. "Life History of Sockeye Salmon", in *Pacific Salmon Life Histories* eds C. Groot and L. Margolis. (UBC Press, Vancouver, 1991), 45.

[232] Fast, *et al*., "Susceptibility" *supra* note 167

[233] Heard, WR., "Life History of Pink Salmon". *In Pacific Salmon Life Histories* eds C. Groot and L. Margolis (UBC Press, Vancouver, 1991), 180.

[234]BCMAL. "2010 Escapes Statistics". http://www.agf.gov.bc.ca/fisheries/escape/escape_reports.htm.

[235] BCSFA, "Code of Practice" 2005

[236] BC Ministry of Agriculture, Food and Fisheries. 2005. Salmon Aquaculture – Comparison of Regulations. 2005, (BCMAFF, "Comparison").

[237] BCMAL/ BC Ministry of Environment. *Regulatory Compliance of British Columbia's Marine Finfish Aquaculture Facilities: 2007*. (2007).

[238] BCMAL, "Regulatory 2008", *supra* note 80.

[239] Cubitt et al, "A Synopsis", *supra* note 133.

[240] Ginetz, R.M.J. "On the risk of colonization by Atlantic salmon in BC waters," (on special assignment to the BCSFA from DFO, 2002). (Ginetz."On the risk").

[241] Amos, K.H. and A. Appleby. "Atlantic Salmon in Washington State: A Fish Management Perspective," *Washington Department of Fish and Wildlife* (1999). (Amos and Appleby. "Atlantic Salmon"); Atlantic Salmon Watch Program. *Atlantic*

*Salmon Watch Program 1996 Review*. (1997); Morton, A. and Volpe, J. "A description of escaped farmed Atlantic salmon *Salmo salar* captures and their characteristics in one Pacific salmon fishery area in British Columbia, Canada, in 2000." Alaska Fisheries Research Bulletin 9(2), (2002):102-110.

[242] Amos and Appleby. "Atlantic Salmon" *supra* note 241 at 8.

[243] Ginetz."On the risk"*supra* note 240 at 27.

[244] *Ibid* at 28

[245] Blanc, J.M. and Chevassus B. "Hybridization in salmonids: results and perspectives". *Aquaculture* 17 (1979): 113-128; Loginova GA, and Krasnoperova SV. "An attempt at crossbreeding Atlantic salmon and pink salmon (preliminary report)". *Aquaculture* 27(1982):329-337.; Gray AK, Evans MA, Thorgaard GH. "Viability and development of diploid and triploid salmonid hybrids," *Aquaculture* 122 (1993):125-142.; Noakes *et al*., "On the Decline" *supra* note 126

[246] Korman, "Summary of information", *supra* note 137 at 9.

[247] Ginetz."On the risk". *supra* note 240

[248] Leggatt, R.A., P.T. O'Reilly, P.J. Blanchfield, R. Devlin. "Pathway of effects of escaped aquaculture organisms or their reproductive material on natural ecosystems in Canada," *Canadian Science Advisory Secretariat, Research Document*, (2009) at 16(Leggatt et al, "Pathway")

[249] Ginetz."On the risk". *supra* note 240

[250] Amos and Appleby. "Atlantic Salmon". *supra* note 241.

[251] Noakes *et al*., "On the Decline" *supra* note 126 at 14.

[252] Scott, R.J., D.L.G. Noakes, F.W.H. Beamish, L.M. Carl. "Chinook salmon impede Atlantic salmon conservation in Lake Ontario," *Ecology of Freshwater Fish* 12(2003):66-73.

[253] DFO, "Aquaculture - FAQ", *supra* note.55.

[254] Burridge L.E. et al., "Pathway of Effects of chemical inputs from the aquaculture activities in Canada", (unknown):1-95.(Burridge, LE *et al*., "Pathway of Effects"); Author Unknown, "Terms of Reference for a National Advisory Workshop on Potential Technologies for Closed-containment Saltwater Salmon Aquaculture." Paper presented at the IOS-DFO workshop, Sydney, BC, January-February,2008.

[255] Finfish Aquaculture Licence 2010, *supra* note 82 at Appendix XVI.

[256] Canadian Council of Ministers of the Environment. 2002. "Canadian sediment quality guidelines for the protection of aquatic life: Summary tables". Updated. In: *Canadian environmental quality guidelines, 1999*, Canadian Council of Ministers of the Environment, Winnipeg. (CCME, "Sediment Guidelines")

[257] Finfish Aquaculture Licence 2010, *supra* note 82 at s. 13.1 – 13.26

[258] Canadian Aquaculture Systems Inc. *Solid Waste Management in Enclosed Marine Aquaculture Systems: Scoping Document* (Coberg, ON, 2007).

[259] Burridge L., J. Weis, F. Cabello and J. Pizarro. *"Chemical Use In Salmon Aquaculture: A Review of Current Practices and Possible Environmental Effects"*2008 (Burridge et al, "Chemicals").

[260] Black, Kenneth, D., Pi Kupka Hansen and Marianne Holmer. *Salmon Aquaculture Dialogue: Working Group Report on Benthic Impacts and Farm Siting.* (2008) (Black, Kenny, *et al*. "Case Study 6.1"); "Case Study 6.1 Fish Farming Effects on Benthic Community Changes Due to Sedimentation" in *GESAMP Reports and Studies No. 76: Assessment and Communication of Environmental Risks in Coastal Aquaculture,* Chapter 6. Rome: Food and Agriculture Organization of the United Nations, 2008, (Black et al, "Salmon Aquaculture Dialogue").

[261] Brooks, KM "Seven Year remediation study at the Carrie Bay Atlantic salmon (Salmo salar) farm in the Broughton Archipelago, British Columbia, Canada," *Aquaculture* 239 (2004) 81-123 (Brooks, "Seven year remediation"); Brooks, KM "An Evaluation of the Relationship between Salmon Farm Biomass Organic Inputs to Sediments Physiochemical Changes Associated

With Those Inputs and the Infaunal Response - with Emphasis on Total Sediment Sulfides Total Volatile Solids and Oxidation-Reduction potential as surrogate endpoints for biological monitoring-Final Report" paper produced for The Technical Advisory Group, Care of the BC Ministry of Environment, Nanaimo, BC, September 21, 2001. (Brooks, "An Evaluation").

[262] *Ibid.* See also Brooks, KM "Chemical and biological remediation of the benthos near Atlantic salmon farms," *Aquaculture* 219 (2003):355-377 (Brooks, "Chemical and biological remediation")

[263] Wildish, D.J., Dowd. M., Sutherland. T.F., Levings.C.D., "Near-field Organic Enrichment from Marine Finfish Aquaculture" in A Scientific Review of the Potential Environmental Effects of Aquaculture in Aquatic Ecosystems Fisheries and Oceans Canada. Vol III (2004). Originally published in Can.Tech.Rep.Fish.Aquat.Sci.2450:ix+117p. (Wildish et al, Near-field").

[264] Klaver, Marjories, "Benthic Community Systems and Threshold Levels Associated with Organic Enrichment from Finfish Aquaculture Facilities", MSc Thesis, Royal Roads University, 2004, (Klaver, "Benthic").

[265] Brooks, "Chemical and biological remediation" *supra* note 262.

[266] Brooks, Kenneth. "Stolt Canada Arrow Pass Salmon Farm Benthic and Shellfish Effects Study 1996-1997." (2001). (Brooks, "Stolt Canada Arrow Pass'); Burridge et al., "Chemicals" *supra* note 259

[267] Wildish et al, Near-field, *supra* note263.

[268] Wildish et al, "Near-field", *supra* note 263.

[269] *Ibid.*

[270] Brooks, "Stolt Canada Arrow *supra* note 266

[271] Brooks, "Chemical and biological remediation", *supra* note 262.

[272] CCME, "Sediment Guidelines", *supra* note 256

[273] Kautsky Lena, "Monitoring eutrophication and pollution in estuarine environments-focusing on the use of benthic communities" *Pure &App. Chem.,* Vol. 70, No. 12 (1998). 2313-2318.

[274] Environment Canada, Environmental Assessment of Marine Finfish Aquaculture Projects: Guidelines for consideration of Environment Canada Expertise. Environmental Protection Branch, (2001).

[275] Brooks, *Soft Bottom*, *supra* note 22 .

[276] Stucchi, Dario, Leavings, Colin and Chamberlain, Jon. "Working Paper: DEPOMOD Modeling of Particle Deposition Rates and Benthic Impacts" (Presentation at the National Advice for Finfish Cage Aquaculture in the Marine Environment, Institute of Ocean Sciences, 2005); Chamberlain, Jon, *et al*., "The suitability of DEPOMOD for use in management of finfish aquaculture sites with specific reference to Pacific region," Canadian Science Advisory Secretariat Research Document (2005).

[277] Brooks, "Stolt Canada Arrow *supra* note 266; Brooks, "Seven year remediation", *supra* note 261; Brooks, "An Evaluation"*supra* note 261.

[278] Brooks, "Stolt Canada Arrow *supra* note 266; see also Levings, Colin and Terri Sutherland, "Effects of aquaculture operations on fish habitat at an abandoned salmon net pen operation in the Broughton Archipelago, BC," (Report prepared for DFO, 1999).

[279] Burridge et al., "Chemicals" *supra* note 259.

[280] Black, Kenny, *et al*. "Case Study 6.1 *supra* note 260

[281] Finfish Aquaculture Licence 2010, supra note 82 at s. 13.1 – 13.26

[282] Brooks, "Stolt Canada Arrow *supra* note 266

[283] *Ibid*.

[284] Burridge, LE *et al*., "Pathway of Effects"*supra* note 254.

[285] Brooks, "Stolt Canada Arrow *supra* note 266

[286] Burridge et al., "Chemicals" *supra* note 259

[287] Brooks, "Stolt Canada Arrow *supra* note 266

[288] *Ibid*.

[289] Pearsall, Isabelle. "Broughton Archipelago: A State of Knowledge". Pearsall Ecological Consulting, 2008: 315

[290] Noakes, D.J. and R.J. Beamish. "Shifting the Balance: Toward Sustainable Salmon Populations and Fisheries of the Future," in *Sustainable Fisheries: Multi-Level approaches to a Global Problem*, American Fisheries Society, 2011, 23-50.

[291] Young and Matthews, "Aquaculture Controversy", *supra* note 27.

[292] Dow, Aaron. *Norway vs. British Columbia: A comparison of Aquaculture Regulatory Regimes.* Victoria, BC: Environmental Law Centre (2004). (Dow, '*Norway"*); Food and Agriculture Organization of the United Nations-Fisheries and Aquaculture Department. '"National Legislation Overview- Norway". Accessed March 14, 2011. 03 11. Online http://www.fao.org/fishery/legalframework/nalo_norway/en

[293] *Ibid*

[294] BCMAFF, "Comparison", *supra* note 236.

[295] Dow, "Norway" *supra* note 292.

[296] Food and Agriculture Organization of the United Nations-Fisheries and Aquaculture Department. '"National Legislation Overview- Chile". Accessed March 11, 2011. 03 11. Online http://www.fao.org/fishery/legalframework/nalo_chile/en (FAO, "National Legislation Overview – Chile").

[297] Buschmann, AH, F Cabello, K Young, J Carvaja, DA Varela and L Henriquez. "Salmon aquaculture and coastal ecosystem health in Chile: Analysis of regulations, environmental impacts and bioremediation systems". *Ocean and Coastal Management* (2009), doi:10.1016/j.ocecoaman.2009.03.002., at 1 (Buschmann, *et al*., "Salmon aquaculture – Chile").

[298] Hammel, L, C. Stephen, I Bricknell and O Evensen. "Salmon Aquaculture Dialogue Working Group Report on Salmon Disease". (2009 DRAFT) Online http://wwf.worldwildlife.org/site/PageNavigator/SalmonSOIForm. (Hammel, *et al*., "Salmon Aquaculture Dialogue").

[299] BCMAFF, "Comparison", *supra* note 236.

[300] AAC, "The Canadian", *supra* note 1.

[301] Hammel, *et al*., "Salmon Aquaculture Dialogue" *supra* note 298.

[302] Wilson, A, S Magill and KD Black. "Review of environmental impact assessment and monitoring in salmon aquaculture". In FAO. Environmental Impact assessment and monitoring in aquaculture. *FAO Fisheries and Aquaculture Tehcnical Paper*. No 527, Rome FAO. (2009): 455-535.

[303] Burridge et al, "Chemical", *supra* note 259.

[304] AAC, "The Canadian", *supra* note 1.

[305] Buschmann, *et al*., "Salmon aquaculture – Chile" *supra* note 297.

[306] Ginetz, "On the risk", *supra* note 240; Noakes et al,"On the decline", *supra* note 126; Leggatt et al, "Pathway", *supra* note 248.

[307] AAC, "The Canadian", *supra* note 1.

[308] BCMAFF, "Comparison", *supra* note 236.

[309] Burridge *et al*., "Chemical", *supra* note 259.

[310] Black et al, "*Salmon Aquaculture Dialogue*", supra note 260.

[311] *Ibid*.

[312] Wagner, G. "Aquaculture in British Columbia. Putting the Regulatory Situation into Perspective". (2010) *EDI Whitepaper* No 1 Rev 2.1. online at http://edynamics.com/uploads/documents/factsheets/Aquaculture%20White%20Paper_Formated_Draft%202%201%20cm.pdf.

[313] Soto, D, F Jara and C Moreno. "Escaped salmon in the inner seas, southern Chile: Facing Ecological and Social Conflicts". *Ecological Applications* 11(6) (2001): 1750-1762.

[314] Jones, *et al*., "Early development of resistance", *supra* note 167; Brooks, KM and SRM Jones. "Perspectives on Pink Salmon and Sea Lice: Scientific Evidence Fails to Support the Extinction Hypothesis". *Reviews in Fisheries Science* 16(4) (2008): 403-412; Carvajal, J., L. Gonzalez and M. George-Nascimento. "Native sea lice (*Copepoda: Caligidae*) infestation of salmonids reared in netpen systems in southern Chile". *Aquaculture* 166 (1998). 241 – 246.

[315] Costello, MJ. "How sea lice from salmon farms may cause wild salmonid declines in Europe and North America and be a threat to fishes elsewhere". *Proceedings of the Royal Society B* 276 (2009): 3385-3394.

[316] Burd Brenda, "Review and prioritizing of benthic invertebrate indicator species, species assemblages and chemical characteristics that could be used in assessing effects of marine finfish farms on fish habitat." Report to Habitat and Enhancement Branch, Fisheries and Oceans Canada, Vancouver, British Columbia, June 1, 2003.

[317] Butterworth, K, KF Cubitt and RS McKinley. "Response to "Comment on Butterworth, Cubitt and McKinley (2008)". *Fisheries Research* Vol 92 Issues 2 – 3 (2008): 347-349.

[318] BC Pacific Salmon Forum. *Final Report & Recommendations to the Government of BC*, (2009) at 9. (PSF, "Final Report")

[319] Canada, Department of Fisheries and Oceans, *Assessing Potential Technologies for Closed-Containment Saltwater Aquaculture* (Ottawa: Canadian Science Advisory Secretariat Science Advisory Report, 2008) at 1.(DFO, "Assessing Potential Technologies").

[320] Fisheries and Oceans Canada, *Feasibility Study of Closed-Containment Options for the British Columbia Aquaculture Industry* by D Boulet, A Struthers and E Gilbert, (Ottawa: Innovation and Sector Strategies Aquaculture Management Directorate, 2010). (DFO, "Feasibility Study").

[321] *Ibid.* at pvii

[322] *Ibid.*

[323] *Ibid.*

[324] *Ibid* at 55.

[325] Fisheries and Oceans Canada, "Assessing Potential Technologies" *supra* note 319.

[326] *Ibid.* at 2.

[327] *Ibid* at 4

[328] *Ibid.* at 2.

[329] Canada, House of Commons, Evidence - Standing Committee on Fisheries and Oceans, 40th Parl, 3rd Sess, No 3 (22/03/2010) at 12 (Trevor Swerdfager).

[330] Fisheries and Oceans Canada, "Feasibility Study" *supra* note 320.

[331] *Ibid*. at 8.

[332] Ayer, N.W. and P. H. Tyedmers, "Assessing alternative aquaculture technologies: life cycle assessment of salmonid salmonid culture systems in Canada" Journal of Cleaner Production 17(2009): 371.

[333] *Ibid*. at 362, 370.

[334] Fisheries and Oceans Canada, "Assessing Potential Technologies", *supra* note 319.

[335] Carroll, W.F., SUSHI: Globalization through Food Culture: Towards a Study of Global Food Networks. www.icis.kansai-u.ac.jp/data/journal02-v1/31_Carroll.pdf

[336] DineHere lists 583 sushi restaurants in Metro Vancouver. http://dinehere.ca

[337] FAO, "The State of World Fisheries", *supra* note 2.

[338] *Ibid*.

[339] Beamish, R.J., ed. *Impacts of Climate and Climate Change on the Key Species in the Fisheries in the North Pacific*, (PICES Scientific Report No. 35, 2008) at 48.

[340] DFO, "Strategic Action Plan", *supra* note 35.

[341] Pamela D. Tom, Paul G. Olin. *Farmed Or Wild? Both Types Of Salmon Taste Good And Are Good For You.* Global Aquaculture Advocate, May/June 2010: 58-60; International Fishmeal and Fish Oil Organisation,;. "IFFO Briefing - Fishmeal and Fish Oil Issues raised by Hugh Fearnley Whittingstall on UK television between 11 - 13 January" accessed August 15, 2011 at http://www.iffo.net/default.asp?contentID=730

[342] McVicar *et al*., "Cultured and Wild", *supra* note 130.

[343] ScienceDaily, (15/03/2011) "Extent and Speed of Lionfish Spread Unprecedented; Invasive Marine Fish May Stress Reefs". http://www.sciencedaily.com/releases/2011/03/110314141606.htm

[344] American Fisheries Society. "The aquarium trade as an invasion pathway in the Pacific Northwest." *Fisheries*, Feb 2011 Vol 36 No 2. p74-85.

[345] Saksida, *et al*., "Differences in *L. salmonis* abundance" *supra* note 187 at 363.

[346] BCMAL, *2009 Annual Report Fish Health Program*. (Animal Health Branch – Fish Health, 2009). BCMAL, "FHP 2009", *supra* note 135.

[347] Beamish *et al.*, "Exceptional marine survival", *supra* note 217; Marty et al, "Relationship of farm salmon", *supra* note 204

[348] Clayoquot Sound Sea Lice Working Group, "Prevalence and Intensity of sea louse", *supra* note 169.

[349] Beamish *et al*., "The Winter Infection", *supra* note 3.

[350] BCMAFF, "Comparison", , *supra* note 236

[351] Ginetz, ”On the risk”, *supra* note240.

[352] Amos and Appleby. “Atlantic Salmon” *supra* note 241.

[353] Noakes, *et al*., “On the Decline”, *supra* note 126.

[354] Fisheries and Oceans Canada, “STOP The Spread of Invasive Species”. (2009), http://www.pac.dfo-mpo.gc.ca/publications/docs/invasives-envahissantes-eng.htm

[355] BC Ministry of Water, Land and Air Protection (2004). *Invasive Alien Species Framework for BC: Identifying and Addressing Threats to Biodiversity.* Online http://www.env.gov.bc.ca/wld/documents/alien_species_framework_BC_0205.pdf

[356] Klaver, “Benthic”, *supra* note 264.

[357] Burridge *et al*., “Chemical”, *supra* note 259.

[358] Brooks, “An Evaluation”, *supra* note 261.

[359] FAO Committee on Fisheries: http://www.fao.org/focus/e/fisheries/sustaq.htm

[360] Vernon, B. Salmon Ranching Examined. s.l.: Northern Aquaculture, September/October, 2007. http://www.certifiedorganic.bc.ca/rcbtoa/services/NAsept-oct-pgs14-15c.pdf.

[361] Noakes *et al*., “On the Decline”, *supra* note 126.

[362] Young and Matthews, “Aquaculture Controversy, *supra* note 27.

[363] Statistics Canada, *Snapshot of Canadian Agriculture,* (Ottawa, ON: Agriculture Division, 2006). http://www.statcan.gc.ca/ca-ra2006/articles/snapshot-portrait-t2-eng.htm

[364] The Vancouver Humane Society, *Meat and the Environment.* http://www.vancouverhumanesociety.bc.ca/campaigns/eat-less-meat/meat-and-the-environment/ at para. 1. (VHS, “Meat and the Environment”)

[365] BC Nearshore Habitat Loss Working Group, *British Columbia Coast and Marine Environment Project.* (2006). 20. (BCNHLWG, “Marine Project”)

[366] Driscoll, J., C. Robb and K. Bodtker. Bycatch in Canada's Pacific Groundfish Bottom Trawl Fishery – Trend and Ecosystem Perspective. 2009.. Living Oceans Society, at 6.

[367] BCNHLWG, “Marine Project”, *supra* note 365 at 47.

[368] Smith, VH, Samamtha B. Joye, and Rovert W. Howarth “Eutrophication of freshwater and marine ecosystems,” Limnol. Oceanogr., 51(1, part 2) (2006):361-355

[369] VHS, “Meat and the Environment”, *supra* note 364.

[370] Statistics Canada, *Fertilizer and Pesticide management in Canada*. http://www.statcan.gc.ca/pub/21-021-m/2004002/4144650-eng.htm#10. At para. 45.

[371] BCNHLWG, “Marine Project”, *supra* note 365

[372] British Columbia Salmon Farmers Association, *FAQ - About Salmon Farming.* (British Columbia, 2010) http://www.salmonfarmers.org/faqs_about_salmon_farming.php at 1.

[373] Khachatourians, G.G. “Agricultural use of antibiotics and the evolution and transfer of antibiotic resistant bacteria,” *Canadian Medical Association Journal* 159 (1998): 1.

[374] Noakes *et al.*, “On the Decline”, *supra* note 126.

[375] *Ibid.*

[376] Driscoll *et al.*, "Bycatch in Canada's", *supra* note 366 at 5.

[377] Noakes *et al.*, "On the Decline", *supra* note 126 at 363.

[378] McDaniels, T. *et al*. "Vulnerability of Fraser River sockeye salmon to climate change: A life cycle perspective using expert judgment" (2010).

[379] Morton *et al*., "Sea Lice Infection Rates", *supra* note 163.

[380] Brooks, "The Effects of Water Temperature, Salinity and Currents", *supra* note 182; Beamish et al., "Exceptional marine survival", *supra* note 217: Marty et al, "Relationship", *supra* note 204.

[380a] Morton, A, R. Routledge, A McConnell and M Krkosek. "Sea lice dispersion and salmon survival in relation to salmon farm activity in the Broughton Archipelago". *ICES Journal of Marine Science* 68(1) (2011): 144 – 156 at 1.

[381] PSF, "Final Report", *supra* note 318 at 37.

[382] British Columbia Environmental Assessment Office. *Salmon Aquaculutre Review.* (British Columbia, 1997).

[383] Noakes *et al.*, "On the Decline", *supra* note *126* at 363.

# Bibliography

2006 Legislative Session: Second Session, 38th Parliament SPECIAL COMMITTEE ON SUSTAINABLE AQUACULTURE.

A Point of VIU, “VIU researcher wins major grant to study sea lice,” accessed May 12, 2011, http://www.viu.ca/mainly/page.asp?ID=1646.

Aboriginal Aquaculture Association, “Welcome”, accessed April 19, 2011, http://www.aboriginalaquaculture.com/.

Agriculture and Agri-Food Canada. “The Canadian Farmed Salmon Industry- Benchmark analysis for the US Market.” (2006), Accessed March 22, 2011, http://www.ats.agr.gc.ca/can/4220-eng.htm.

Ahousaht First Nation, “Ahousaht First Nation Demands Respect for its Sovereignty and Decision-Making Process”, Press Release (May 19, 2010), online: marketwire http://www.marketwire.com/press-release/Ahousaht-First-Nation-Demands-Respect-its-Sovereignty-Decision-Making-Process-1263559.htm.

American Fisheries Society. “The aquarium trade as an invasion pathway in the Pacific Northwest”. *Fisheries* 36 No 2. (2011):74-85.

Amos, K.H. and A. Appleby. “Atlantic Salmon in Washington State: A Fish Management Perspective,” *Washington Department of Fish and Wildlife* (1999).

Aquaculture Association of Canada, “Sea Lice Fact Sheet Brief Version”, accessed February 21, 2011, www.aquacultureassociation.ca/sites/default/files/sea%20lice%20fact%20sheet.pdf.

Atlantic Salmon Watch Program. “Atlantic Salmon Watch Program 1996 Review”. (1997).

Auditor General of Canada, Chapter 30 “Fisheries and Oceans—The Effects of Salmon Farming in British Columbia on the Management of Wild Salmon Stocks” in *Report of the Auditor General to the House of Commons for December 2000*, http://www.oag-bvg.gc.ca/internet/English/parl_oag_200012_30_e_11217.html

Ayer, N.W. and Peter H. Tyedmers, “Assessing alternative aquaculture technologies: life cycle assessment of salmonid salmonid culture systems in Canada” *Journal of Cleaner Production* 17(2009): 371. EV.CAN.0014.005000.CAN068584.

Barker, DE, LM Braden, MP Coombs and B Boyce. “Preliminary studies on the isolation of bacteria from sea lice, *Lepeoptheirus salmonis*, infecting farmed salmon in British Columbia, Canada”. *Parasitol Res* 105 (2009): 1173 – 1177. doi: 10.1007/s00436-009-1523-9.

BC Centre for Aquatic Health Sciences (BC CAHS), “Fish Health Audits,” accessed March 29, 2011, http://www.cahs-bc.ca/fish-health-audits.php.

BC Centre for Aquatic Health Sciences. Questions and answers regarding the paper "Genomic Signatures Predict Migration and Spawning Failure in Wild Canadian Salmon" published in *Science*, January 2011.

BC Environmental Assessment Office. "Salmon Aquaculture Review". (British Columbia, 1997).

BC Ministry of Agriculture and Land, "2009 Annual Report Fish Health Program". BCP001641.

BC Ministry of Agriculture and Land. "2010 Escapes Statistics." Accessed April 26, 2011 http://www.agf.gov.bc.ca/fisheries/escape/escape_reports.htm.

BC Ministry of Agriculture and Land. "Therapeutant (Antibiotic) Use in Aquaculture," accessed August 24, 2009, http://www.al.gov.bc.ca/ahc/fish_health/antibiotics.htm.

BC Ministry of Agriculture and Land, "Therapeutant (Antibiotic) Use in Aquaculture" GRAPH, (August 24, 2009.), online: BCMAL http://www.agf.gov.bc.ca/ahc/fish_health/Antibiotic_Graphs_1995-2008.pdf.

BC Ministry of Agriculture and Land / BC Ministry of Environment.. "Regulatory Compliance of British Columbia's Marine Finfish Aquaculture Facilities: 2007". (2007)EV.CAN.0005.000000.CAN005264.

BC Ministry of Agriculture and Land / BC Ministry of Environment. 'Regulatory Compliance of British Columbia's Marine Finfish Aquaculture Facilities: 2008". (2008). EV.CAN.0005.000000.CAN005265.

BC Ministry of Agriculture, Food and Fisheries.. "Salmon Aquaculture – Comparison of Regulations".

BC Ministry of Environment, "Capture Fisheries Statistics", Accessed March 22, 2011, http://www.env.gov.bc.ca/omfd/fishstats/capture/index.html.

BC Ministry of Environment, "Salmon Aquaculture in British Columbia", Accessed March 22, 2011. http://www.env.gov.bc.ca/omfd/fishstats/aqua/salmon.html.

BC Ministry of Environment. *Water Quality Guidelines (Criteria) Reports.* Accessed March 8, 2011. http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html.

BC Ministry of Water, Land and Air Protection, 'Invasive Alien Species Framework for BC: Identifying and Addressing Threats to Biodiversity". (2004) Accessed April 26, 2011 http://www.env.gov.bc.ca/wld/documents/alien_species_framework_BC_0205.pdf

BC Nearshore Habitat Loss Working Group. "British Columbia Coast and Marine Environment Project 2006, http://www.env.gov.bc.ca/soe/bcce/05_biodiversity/technical_paper/biodiversity.pdf.

BC Pacific Salmon Forum. "Final Report & Recommendations to the Government of BC". (2009).

BC Salmon Farmers Association, "Code of Practice" 2005

BC Salmon Farmers Association, "FAQ - About Salmon Farming". (British Columbia, 2010) Accessed April 25, 2011 at http://www.salmonfarmers.org/faqs_about_salmon_farming.php

BC Salmon Farmers Association, "Profile of the BC Farmed Salmon Industry in 2008", Accessed March 21, 2011. http://salmonfarmers.khamiahosting.com/sites/default/files/2008_IndustryProfile_PWC.pdf.

BC Salmon Farmers Association, "Working in the BC Salmon Farming Industry", Accessed March 21, 2011. http://salmonfarmers.khamiahosting.com/careers.php.

Beamish, R., Wade, J., Pennell, W., Gordon, E., Jones, S., Neville, C., Lange, K. and R. Sweeting. "A large, natural infection of sea lice on juvenile Pacific salmon in the Gulf Island area of British Columbia,Canada." *J. Aquaculture*, (2009). EV.CAN.0032.002000.CAN256667.

Beamish, RJ., CM Neville, RM Sweeting, SRM Jones, N Ambers, EK Gordon, KL Hunter and TE McDonald. 2007. "A proposed life history strategy for the salmon louse, Lepeophtheirus salmonis in the subarctic Pacific". *Aquaculture* 264 (2007) 428-440. doi:10.1016/j.aquaculture.2006.12.039, 2007. EV.CAN.0023.021000.CAN185235 .

Beamish, R.J., S. Jones, C. Neville, R. Sweeting, G. Karreman, S. Saksida, and E. Gordon, "Exceptional marine survival of pink salmon that entered the marine environment in 2003 suggests that farmed Atlantic salmon and Pacific salmon can coexist successfully in a marine ecosystem on the Pacific coast of Canada," *ICES Journal of Marine Science* 63 (2006): 1326-1337.

Beamish, R.J., ed. "Impacts of Climate and Climate Change on the Key Species in the Fisheries in the North Pacific.", PICES Scientific Report No. 35, (2008).

Beamish, R., C. Neville, R. Sweeting, and N. Ambers. "Sea lice on adult Pacific salmon in the coastal waters of central British Columbia, Canada." *Fisheries Research 76*, 2005: 198-208

Beamish, RJ, E. Gordon1, J. Wade, B. Pennell, C. Neville, K. Lange, R. Sweeting and S. Jones, "The Winter Infection of Sea Lice on Salmon in Farms in a Coastal Inlet in British Columbia and Possible Causes,". *Journal of Aquaculture Research & Development*, 2 (2011). http://dx.doi.org/10.4172/2155-9546.1000107.

Black, Kenny and Chris Cromey., "Case Study 6.1 Fish Farming Effects on Benthic Community Changes Due to Sedimentation" in *GESAMP Reports and Studies No. 76: Assessment and Communication of Environmental Risks in Coastal Aquaculture, Chapter 6*. Rome: Food and Agriculture Organization of the United Nations, (2008).

Black, K.D., P.K. Hansen and M. Holmer, “Salmon Aquaculture Dialogue: Working Group Report on Benthic Impacts and Farm Siting”, (2008).

Blanc, J.M. and Chevassus, B., “Hybridization in salmonids: results and perspectives.” *Aquaculture* 17, (1979):113-128.

Boulding, EG, JR deWaard, KP Ang and PDN Hebert. “Population genetic structure of the salmon louse, *Lepeoptheirus salmonis* (Kroyer) on wild and farmed salmonids around the Pacific Coast of Canada”. *Aquaculture Research* 40, (2009): 973 – 979

Brooks, K. M. “An Evaluation of the Relationship between Salmon Farm Biomass Organic Inputs to Sediments Physiochemical Changes Associated With Those Inputs and the Infaunal Response - with Emphasis on Total Sediment Sulfides Total Volatile Solids and Oxidation-Reduction potential as surrogate endpoints for biological monitoring.” Report prepared for The Technical Advisory Group, Care of the British Columbia Ministry of Environment, (2001). EV.CAN.0028.000000.CAN217008.

Brooks, Kenneth M. “British Columbia Ministry of Environment - Soft Bottom Database Evaluation”, (Presentation on report, 2006)EV.CAN.0011.008000.CAN044462.

Brooks, Kenneth M. “Chemical and biological remediation of the benthos near Atlantic salmon farms,” *Aquaculture* 219 (2003):355-377.

Brooks, KM and SRM Jones. ”Perspectives on Pink Salmon and Sea Lice: Scientific Evidence Fails to Support the Extinction Hypothesis”. *Reviews in Fisheries Science* 16(4) (2008): 403-412.

Brooks, Kenneth M, Annette R Stierns and Clare Backman, “Seven Year remediation study at the Carrie Bay Atlantic salmon (Salmo salar) farm in the Broughton Archipelago, British Columbia, Canada,” Aquaculture 239 (2004):81-123..

Brooks, Kenneth. 2001. “Stolt Canada Arrow Pass Salmon Farm Benthic and Shellfish Effects Study 1996-1997.”2001. EV.CAN.0033.002000.CAN266732

Brooks, K. "The Effects of Water Temperature, Salinity, and Currents on the Survival and Distribution of the Incfective Copepodid Stage of Sea Lice (Lepeoptheirus salmonis) Originating on Atlantic Salmon Farms in the Broughton Archipelago of British Columbia, Canada." *Reviews in Fisheries Science 13*, (2005): 177-204. EV.CAN.0012.007000.CAN054267 .

Burd, Brenda, “Review and prioritizing of benthic invertebrate indicator species, species assemblages and chemical characteristics that could be used in assessing effects of marine finfish farms on fish habitat.” Report to Habitat and Enhancement Branch, Fisheries and Oceans Canada, Vancouver, British Columbia, June 1, 2003.

Burgner, RL. “Life History of Sockeye Salmon”, in *Pacific Salmon Life Histories* eds C. Groot and L. Margolis. (UBC Press, Vancouver, 1991)

Burridge, L., J. Weis, F. Cabello and J. Pizarro. "Chemical Use In Salmon Aquaculture: A Review of Current Practices and Possible Environmental Effects." (2008). EV.CAN.0023.011000.CAN174378.

Burridge, L.E., Doe, K.G. and Ernst, W. "Pathway of Effects of chemical inputs from the aquaculture activities in Canada." EV.CAN.0008.002000.CAN014410.

Buschmann, AH, F Cabello, K Young, J Carvaja, DA Varela and L Henriquez. "Salmon aquaculture and coastal ecosystem health in Chile: Analysis of regulations, environmental impacts and bioremediation systems". *Ocean and Coastal Management* (2009), doi:10.1016/j.ocecoaman.2009.03.002.

Butterworth, K, Cubitt, K and McKinley, R. 2008. *Response to "Comment on Butterworth, Cubitt and McKinley (2008)" by Morton and Routeldge [Fish. Res. (2008)]*. 2008. EV.CAN.0023.021000.CAN185247

Butterworth, K., F. Cubitt, B. Finstad, S. McKinley. "Sea Lice: The Science Behind the Hype". *Fraser Institute Digital Publication*, (2006). EV.CAN.0006.000000.CAN008608.

Butterworth, KG., KF Cubitt and RS McKinley. "The prevalence, density and impact of *Lepeoptherius salmonis* infestation on juvenile pink salmon from the central coast of British Columbia, Canada." *Fisheries Research 91*, 2008: 35-41.

Canada, House of Commons, Evidence - Standing Committee on Fisheries and Oceans, 40th Parl, 3rd Sess, No 3 (22/03/2010) at 12 (Trevor Swerdfager). EV.CAN.0034.002000.CAN276801.

Canadian Aquaculture Industry Alliance, "Aquaculture Benefits to the Environment", (Prepared in collaboration with Aquaculture Collaborative Research & Development Program, Fisheries and Oceans Canada, 2009). EV.CAN.0028.000000.CAN216845

Canadian Aquaculture Industry Alliance, "Canadians Overwhelmingly Support a National Aquaculture Act", by Abacus Data Inc., April 20, 2011, accessed April 21, 2011, http://aquaculture.ca/files/CAIA_-_April_20,_2011_FINAL.pdf

Canadian Aquaculture Systems Inc. Solid Waste Management in Enclosed Marine Aquaculture Systems: Scoping Document (Coberg, ON, 2007). EV.CAN.0026.009000.CAN205537

Canadian Council of Ministers of the Environment. "Canadian sediment quality guidelines for the protection of aquatic life: Summary tables". Updated. In: *Canadian environmental quality guidelines, 1999*, Canadian Council of Ministers of the Environment, Winnipeg. 2002.

*Canadian Environmental Assessment Act*, 1992, c. 37 (CEAA)

Carroll, W.F., SUSHI: Globalization through Food Culture: Towards a Study of Global Food Networks. www.icis.kansai-u.ac.jp/data/journal02-v1/31_Carroll.pdf.

Carvajal, J., L. Gonzalez and M. George-Nascimento. "Native sea lice (Copepoda: Caligidae) infestation of salmonids reared in netpen systems in southern Chile". *Aquaculture* 166 (1998). 241 – 246.

The Centre for Aquaculture and Environmental Research (UBC) produced "A Reference Manual for Research Involving Wild / Cultured Fish Interactions with Sea Lice" in 2006, which describes study design, methods of collecting specimens and analyzing results. While the specific projects develop their own sampling programs, many of the common practices are described in this protocols and guidelines document.

Chamberlain, Jon, et al., "The suitability of DEPOMOD for use in management of finfish aquaculture sites with specific reference to Pacific region," Canadian Science Advisory Secretariat Research Document (2005). EV.CAN.0007.000000.CAN010686.

Clayoquot Sound Sea Lice Working Group, "Prevalence and Intensity of sea louse (*L.salmonis and C.clemensi*) infections in juvenile chum salmon (*Oncorhynchus keta*) in Clayoquot Sound 2004-2007", 2009.

Costello, MJ. "How sea lice from salmon farms may cause wild salmonid declines in Europe and North America and be a threat to fishes elsewhere". *Proceedings of the Royal Society B* 276 (2009): 3385-3394.

Cross, S.F. and J. Brackett, *Aboriginal Certification of Environmental Sustainability in Aquaculture (ACES Program) Proposed Operational Framework*, Aboriginal Aquaculture Association, 2006.

Cubitt, F., Butterworth, K., McKinley, S. R. "A Synopsis of Environmental Issues Associated with Salmon Aquaculture in Canada." Chapter 9. West Vancouver, BC: UBC-DFO (2008).

Dow, Aaron. Norway vs. British Columbia: A comparison of Aquaculture Regulatory Regimes. Victoria, BC: Environmental Law Centre (2004).

Driscoll, J., C. Robb and K. Bodtker. *Bycatch in Canada's Pacific Groundfish Bottom Trawl Fishery – Trend and Ecosystem Perspective*. 2009. Living Oceans Society.

Environment Canada, "Compliance and Enforcement Policy for the Habitat Protection and Pollution Prevention Provisions of the *Fisheries Act*" (2001) accessed April 26, 2011 at http://www.ec.gc.ca/alef-ewe/default.asp?lang=En&n=D6B74D58-1

Environment Canada, Environmental Assessment of Marine Finfish Aquaculture Projects: Guidelines for consideration of Environment Canada Expertise. Environmental Protection Branch, (2001).

European Food Safety Authority. Possible Vector Species and Life Stages of Susceptible Species Not Transmitting Disease as Regards Certain Fish Diseases - Scientific Opinion of the Panel on Animal Health and Welfare. s.l. : The EFSA Journal (2007) 584 1-163, 2007. http://www.efsa.europa.eu/en/efsajournal/doc/ahaw_op_ej584_fishdiseasevectors_en.pdf

Food and Agriculture Organization of the United Nations, “Sustainable Aquaculture Development”. Committee on Fisheries: http://www.fao.org/focus/e/fisheries/sustaq.htm

Fast, MD, NW Ross, A Mustafa, DE Sims, SC Johnson, GA Conboy, DJ Speare, G Johnson and JF Burka. "Susceptibility of rainbow trout *Oncorhynchus mykiss*, Atlantic salmon *Salmo salar* and coho salmon *Oncorhynchus kisutch* to experimental infection with sea lice *Lepeophtheirus*." *Diseases of Aquatic Organisms Vol 52*, (2002): 57-68.

*Freshwater Fish Regulation*, BC Reg. 261/83

*Finfish Aquaculture Licence 2010 under the Pacific Aquaculture Regulations*, s. 7.4 – 7.5

*Fisheries Act*, RS, 1985, c. F-14 (*Fisheries Act* (Canada))

Fisheries and Oceans Canada, “A Canadian Action Plan to Address the Threat of Aquatic Invasive Species: Canadian Council of Fisheries and Aquaculture Ministers Aquatic Invasive Species Task Group” (modified March 7, 2011), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/plan/plan-eng.htm

Fisheries and Oceans Canada, “Assessing Potential Technologies for Closed-Containment Saltwater Aquaculture” (*Canadian Science Advisory Secretariat Science Advisory Report,* (2008). EV.CAN.0005.000000.CAN005358.

Fisheries and Oceans Canada, “Aquaculture – Frequently Asked Questions – Legislation and Regulation”, 2005 http://www.dfo-mpo.gc.ca/aquaculture/bcr-rcb/index2-eng.htm

Fisheries and Oceans Canada, “Aquaculture in the Pacific Region - Frequently Asked Questions” (December 16, 2010), accessed March 22, 2011, http://www.pac.dfo-mpo.gc.ca/aquaculture/FAQ-eng.htm.

Fisheries and Oceans Canada, “Aquaculture Policy Framework” (Ottawa, ON: DFO, 2005), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/aquaculture/ref/APF_e.pdf

Fisheries and Oceans Canada, “B.C. Aquaculture Regulatory Program” (December 10, 2010) accessed March 20, 2011 http://www.dfo-mpo.gc.ca

Fisheries and Oceans Canada, *Evaluation Directorate - Salmonid Enhancement Program - Project Number 6B105 - Final Evaluation Report.* 2009. http://www.dfo-mpo.gc.ca/ae-ve/evaluations/09-10/6b105-eng.htm EV.CAN.0010.006000.CAN027637.

Fisheries and Oceans Canada (Boulet, A. Struthers and E. Gilbert), “Feasibility Study of Closed-Containment Options for the British Columbia Aquaculture Industry” Ottawa: Innovation and Sector Strategies Aquaculture Management Directorate, 2010.

Fisheries and Oceans Canada, “Federal Aquaculture Development Strategy”, (Ottawa, Ontario: DFO 1995), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/aquaculture/ref/FADS_e.pdf

Fisheries and Oceans Canada, “Federal BC Aquaculture Regulation and Strategic Action Plan Initiative Discussion Document” (2009), accessed May 3, 2011, http://www.dfo-mpo.gc.ca/aquaculture/lib-bib/nasapi-inpasa/nasapi-inpasa-nov2009-eng.pdf.

Fisheries and Oceans Canada, “Fish Health Protection and the National Aquatic Animal Health Program” (March 31, 2010) accessed March 23, 2011, http://www.pac.dfo-mpo.gc.ca/science/species-especes/aq-health-sante/naahp-pnsaa-eng.htm.

Fisheries and Oceans Canada, “Frequently Asked Questions – How long has aquaculture been practiced in Canada,” accessed March 21, 2011, http://www.dfo-mpo.gc.ca/aquaculture/faq-eng.htm#n1f.

Fisheries and Oceans Canada, “National Code on Introductions and Transfers of Aquatic Organisms 2003”,accessed April 25, 2011 at http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/code/Code2003-eng.pdf

Fisheries and Oceans Canada, National Code on Introductions and Transfers of Aquatic Organisms - Preliminary Information (modified March 7, 2011), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/code/prelim-eng.htm.

Fisheries and Oceans Canada, Aquaculture - Frequently Asked Questions”, 2010 http://www.dfo-mpo.gc.ca/aquaculture/faq-eng.htm#n3

Fisheries and Oceans Canada, “Pacific Aquaculture Regulations Now Come Into Force” (December 2010), accessed March 21, 2011, http://www.dfo-mpo.gc.ca/aquaculture/bcr-rcb/index-eng.htm.

Fisheries and Oceans Canada, *Policy for the Importation of Atlantic Salmon* (Ottawa, Ontario: DFO, 1992).

Fisheries and Oceans Canada, “Roles and Responsibilities” (September 1, 2005), accessed March 19, 2011, http://www.dfo-mpo.gc.ca/aquaculture/gov-gouv/role-eng.htm.

Fisheries and Oceans Canada, “Salmon Egg Imports” (modified February 24, 2011), accessed online: DFO: http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/egg-oeuf-eng.htm.

Fisheries and Oceans Canada. “Socio-Economic Impact of Aquaculture in Canada”, Published by Fisheries and Aquaculture Management Ottawa, 2010.

Fisheries and Oceans Canada, “State of Knowledge Presentation for the Special Committee on Sustainable Aquaculture of the British Columbia Legislature “(presented Thursday, November 30, 2006, 1088 Burrard Street, Vancouver, BC) at http://www.dfo-mpo.gc.ca/Library/327248.pdf

Fisheries and Oceans Canada (2009). “STOP The Spread of Invasive Species”. Accessed http://www.pac.dfo-mpo.gc.ca/publications/docs/invasives-envahissantes-eng.htm.

Fisheries and Oceans Canada, ‘The Department of Fisheries and Oceans Policy for the Management of Fish Habitat”, (9 January, 2001) at 27, accessed March 21, 2011, http://www.dfo-mpo.gc.ca/habitat/role/141/1415/14155/fhm-policy/index-eng.asp

Fisheries and Oceans Canada, “Treatment of sea lice” accessed March 21, 2011 http://www.dfo-mpo.gc.ca/aquaculture/lice-pou/lice-pou03-eng.htm.

Fisheries and Oceans Canada, “Wild Salmon Policy”, (Ottawa, Ontario: DFO, 2005), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/Library/315577.pdf

Food and Agriculture Organization of the United Nations-Fisheries and Aquaculture Department. ‘”National Legislation Overview- Chile”. Accessed March 11, 2011. 03 11. Online http://www.fao.org/fishery/legalframework/nalo_chile/en.

Food and Agriculture Organization of the United Nations (FAO), *The State of World Fisheries and Aquaculture 2010*, Rome 2010.

Georgia Strait Alliance. “Holmaco First Nation Win Historic Court Case”. Media Release March 3, 2005 accessed April 29, 2011 http://www.georgiastrait.org/?q=node/249.

Ginetz, R.M.J.”On the risk of colonization by Atlantic salmon in BC waters,” on special assignment to the BCSFA from DFO, 2002.

Gottesfeld, AS, D Rolston, B Proctor and T Ryan. “2004 – 2005 North Coast Marine Baseline Survey and Sea Lice Research Program”. Report prepared for the *Northern Boundary and Transboundary Rivers Restoration and Enhancement Fund* and the *British Columbia Aquaculture Research and Development Committee*. (2006).

Gottesfeld, AS, B Proctor, LD Rolston, and C Carr-Harris. "Sea lice, *Lepeophtheirus salmonis*, transfer between wild sympatric adult and juvenile salmon on the north coast of British Columbia, Canada." *Journal of Fish Diseases 32; doi:10.1111/j.1365-2761.2008.01003.x*, (2009): 48-57.

Gottesfeld, AS, C Carr-Harris, B Proctor and D Rolston. “Sockeye salmon juveniles in Chatham Sound 2007”. Report to the *Pacific Salmon Forum*. (2008).

Gray, A.K., M.A. Evans and G.H. Thorgaard, “Viability and development of diploid and triploid salmonid hybrids,” *Aquaculture* 112; (1993): 125–142.

Hammel, L, C. Stephen, I Bricknell and O Evensen. “Salmon Aquaculture Dialogue Working Group Report on Salmon Disease”. (2009 DRAFT) Online http://wwf.worldwildlife.org/site/PageNavigator/SalmonSOIForm.

*Health of Animals Act*, SC 1990, c. 21 *(HAA)*

*Health of Animals Regulations*, CRC, c. 296 (*HAR*)f

Heard, WR. “Life History of Pink Salmon”. *In Pacific Salmon Life Histories* eds C. Groot and L. Margolis (UBC Press, Vancouver, 1991)

Hedrick, R.P. “Relationships of the Host, Pathogen, and Environment: Implications for Diseases of Cultured and Wild Fish Populations,” *Journal of Aquatic Animal Health* 10 (1998):107–111.

International Fishmeal and Fish Oil Organisation, . “IFFO Briefing - Fishmeal and Fish Oil Issues raised by Hugh Fearnley Whittingstall on UK television between 11 - 13 January” accessed August 15, 2011 at http://www.iffo.net/default.asp?contentID=730

Johnson, SC and LJ Albright. "Development, Growth and Survival of *Lepeophtherius salmonis* (Copepoda:Caligidae) under laboratory conditions." *Journal of the Marine Biological Association of the United Kingdom 71*, (1991):: 425-436

Johnson, SC, RB Blaylock, J Elphick and KD Hyatt. "Disease induced by the sea louse (Lepeophtherius salmonis) (Copepoda: Caligidae) in wild sockeye salmon (Oncorhynchus nerka) stocks of Alberni Inlet, British Columbia." *Canadian Journal of Fisheries and Aquatic Sciences 53*, (1996): 2888-2897.

Jones, S. "Controlling salmon lice on farmed salmon and implications for wild salmon." *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 4 No. 048. Doi: 10.1079/PAVSNNR20094048.* (2009).

Jones, SRM., MD Fast, SC Johnson and DB Groman. "Differential rejection of salmon lice by pink and chum salmon: disease consequences and expression of proinflammatory genes." *Diseases of Aquatic Organisms Vol. 75*, (2007): 229-238

Jones, S., Kim, E. and and Bennett, W., “Early development of resistance to the salmon louse, *Lepeoptheirus salmonis* (Kroyer), in juvenile pink salmon, *Oncorhynchus gorbuscha* (Walbaum),” *Journal of Fish Diseases* 8 (2008): 591-600. EV.CAN.0023.012000.CAN175651.

Jones, S and NB. Hargreaves. "Infection Threshold to estimate Lepeophtherius salmonis-associated mortality amoung juvenile pink salmon." *Diseases of Aquatic Organisms Vol 84*, (2009): 131-137.

Jones, S. and A Nemec. "Sea Lice on Juvenile Salmon and on Some Non-Salmonid Species Caught in the Broughton Archipelago in 2003 DRAFT." PSARC Working Paper H2004-01, (2004).

Jones, Simon, Gina Prosperi-Porta, Eliah Kim, Paul Callow, and Brent Hargreaves. "The occurance of Lepeophtheirus salmonis and Caligus clemensi on three-spine stickleback Gasterosteus aculeatus in coastal British Columbia." Journal of Parasitology 92(3) (2006): 473-480.

Kabata, Z. "The Species of *Lepeophtherious* (Copepoda:Caligidae) from Fishes of British Columbia." *Journal of the Fisheries Research Board of Canada 30*, (1973): 729-759

Kautsky, Lena, “Monitoring eutrophication and pollution in estuarine environments-focusing on the use of benthic communities” Pure &App. Chem., Vol. 70, No. 12 (1998). 2313-2318.

Kent, M. “Infectious Diseases and Potential Impacts on Survival of Fraser River Sockeye Salmon - Technical Report 1”. The Cohen Commission of Inquiry in to the Decline of Sockeye Salmon in the Fraser River, (2011).

Khachatourians, G.G. “Agricultural use of antibiotics and the evolution and transfer of antibiotic resistant bacteria,” *Canadian Medical Association Journal* 159 (1998).

Klaver, Marjorie, “Benthic Community Systems and Threshold Levels Associated with Organic Enrichment from Finfish Aquaculture Facilities” (MSc Thesis, Royal Roads University, 2004). EV.CAN.0013.001000.CAN057473.

Knapp Gunnar, Cathy A. Roheim and James L. Anderson, “The Great Salmon Run: Competition Between Wild And Farmed Salmon,” (TRAFFIC North America. Washington D.C.: World Wildlife Fund, 2007).

Korman, J. 2011. “Summary of information for evaluating impacts of salmon farms on survival of Fraser River sockeye salmon”. Cohen Commission Tech. Rep. 5A. 65p. Vancouver, B.C. www.cohencommission.ca.

Krkosek, M., J.S. Ford, A. Morton, S. Lele, R.A. Myers, and M.A. Lewis. "Declining Wild Salmon Populations in Relation to Parasites from Farm Salmon." *Science Vol 318; DOI: 10.1126/science.1148744*, (2007): 1772-1775

Krkosek, M., MA Lewis: A Morton, N Frase, and JP Volpe. "Epizootics of wild fish induced by farm fish." *PNAS Vol. 103 No. 42; DOI:10.1073/pnas.0603525103*, (2006): 15506-15510

Krkosek, M, M Lewis, and J Volpe. "Transmission dynamics of sea lice from farmed to wild salmon." *Proceedings of the Royal Society B*, (2005): 689-696EV.CAN.0012.007000.CAN054257.

*Kwicksutaineuk/Ah-Kwa-mish Tribes v. Canada (Minister of Fisheries and Oceans)* (2003), 227 F.T.R. 96, aff’d. (2003), 313 N.R. 394 (F.C.A.)

Leggatt, R.A., P.T. O’Reilly, P.J. Blanchfield, R. Devlin. “Pathway of effects of escaped aquaculture organisms or their reproductive material on natural ecosystems in Canada,” *Canadian Science Advisory Secretariat, Research Document*, (2009). EV.CAN.0008.002000.CAN014411.

Levings, Colin and Terri Sutherland, “Effects of aquaculture operations on fish habitat at an abandoned salmon net pen operation in the Broughton Archipelago, BC,” Report prepared for DFO. (1999).

Living Oceans Society & Regional District of Mt. Waddington, *The Marine Economy & the Regional District of Mt. Waddington in BC, Quantifying Nature’s Bounty: The Contribution of Marine Ecosystems to Local Communities, prepared by GSGislason & Associates Ltd.* (Vancouver, BC: March 2011), accessed March 20, 2011, http://www.salmonfarmers.org

Living Oceans Society, “History of Salmon Farming in B.C.” accessed March 11, 2011, http://www.livingoceans.org/programs/fishfarms/history.html

Loginova, G.A. and S.V. Krasnoperova. “An attempt at crossbreeding Atlantic salmon and pink salmon (preliminary report)”. *Aquaculture* 27 (1982): 329–337.

Mages, PA and LM Dill. “The effect of sea lice (*Lepeoptheirus salmonis*) on juvenile pink salmon (*Oncorhynchus gorbuscha*) swimming endurance.” *Can. J. Fish. Aquatic. Sci.* 67 (2010): 2045 – 2051

Marine Harvest Canada, “Fish Farming Facts”, Accessed March 21, 2011, http://www.marineharvestcanada.com/farming_did_you_know.php.

Marine Harvest Canada, “Aboriginal Peoples and Marine Harvest Canada Working together”, accessed April 19, 2011, http://www.marineharvestcanada.com/people_first_nations.php

Marty, GD, Saksida, SM and Quinn, TJ., “Relationship of farm salmon, sea lice, and wild salmon populations” *Proceedings of the National Academy of Science of the United States of America*”, (2010) . PNAS doi/10.1073/pnas.1009573108.

Messmer, AM, EB Rondeau, SG Jantzen, KP Lubieniecki, WS Davidson and BF Koop. “Assessment of population structure in Pacific *Lepeophtheirus salmonis* (Kroyer) using single nucleotide polymorphism and microsatellite genetic markers.” *Aquaculture* (2010) doi:10.1016/j.aquaculture.2010.09.033

Miller, KM., S Li, K H. Kaukinen, N Ginther, E Hammill, J M. R. Curtis, D A. Patterson, T Sierocinski, L Donnison, P Pavlidis, S G. Hinch, K A. Hruska, S J. Cooke, K K. English, A P. Farrell. “Genomic Signatures Predict Migration and Spawning Failure in Wild Canadian Salmon.” 2011. *Science* Vol 331:214-217.

Miller, K. “Hypothesis: Genomic data indicate that a potentially novel disease, possibly viral in origin, has been affecting a high proportion of juvenile and adult Fraser River sockeye salmon.” (circa 2009). AQU000230

Morton, A. and Volpe, J. “A description of escaped farmed Atlantic salmon *Salmo salar* captures and their characteristics in one Pacific salmon fishery area in British Columbia, Canada, in 2000.” *Alaska Fisheries Research Bulletin* 9(2), (2002):102-110.

Morton, A. and R.Routledge. "Mortality Rates for Juvenile Pink *Oncorhynchus gorbuscha* and Chum *O. keta* Salmon Infested with Sea Lice *Lepeophtherius salmonis* in the Broughton Archipelago." *Alaska Fishery Research Bulletin 11(2)*, (2005): 146-152

Morton, A. in T. Jean. *Salmon Farm Disease and Sockeye*, accessed May 18, 2011 http://www.thecanadian.org/k2/item/343-twyla-roscovich.

Morton, A, R. Routledge, A McConnell and M Krkosek. “Sea lice dispersion and salmon survival in relation to salmon farm activity in the Broughton Archipelago”. *ICES Journal of Marine Science* 68(1) (2011): 144 – 156.

Morton, Alexandra, Richard Routledge, and Rob Williams. "Temporal patterns of sea louse infestation on wild Pacific salmon in relation to the fallowing of salmon farms." *North American Journal of Fisheries Management 25*, (2005): 811-821.;

Morton, A, R Routledge, Corey Peet, and A Ladwig. "Sea Lice (Lepeophtheirus Salmonis) Infection Rates on Juvenile Pink (Oncorhynchus Gorbuscha) and Chum (Oncorhynchus Keta) Salmon in the Nearshore Marine Environment of British Columbia Canada." *Can. J. Fish. Aquat. Sci* 61;DOI: 10.1139/F04-016, (2004): 147-157.

Morton, A., R Routledge, and M. Krkosek. "Sea Louse Infestation in Wild Juvenile Salmon and Pacific Herring Associated with Fish Farms off the East-Central Coast of Vancouver Island, British Columbia." *North American Journal of Fisheries Managemen*t 28, (2008): 523-532.

*Morton v. British Columbia (Ministry of Agriculture and Lands)* (2009), 2009 BCSC 136. 92 B.C.L.R. (4th) 314, 2009 CarswellBC 282 (WLeC)

McDaniels, T., S. Wilmot, M. Healey, S.Hinch. “Vulnerability of Fraser River sockeye salmon to climate change: A life cycle perspective using expert judgments,” *Journal of Environmental Management* 91 Issue 12, (2010): 2771-2780.

McVicar. G. Olivier, G.S Traxler, S. Jones, D. Kieser, and A-M MacKinnon. “Cultured and Wild Fish Disease Interactions in the Canadian Marine Environment”. *A Scientific Review of the Potential Environmental Effects of Aquaculture in Aquatic Ecosystems* - Volume 4(2006), Fisheries and Oceans Canada.

National Aquaculture Strategic Action Plan Initiative, West Coast Marine Finfish Sector, Strategic Action Plan 2011–2015 (November 1, 2010), accessed March 22, 2011, http://www.dfo-mpo.gc.ca/aquaculture/lib-bib/nasapi-inpasa/index-eng.htm

Naut’sa mawt Tribal Council. “Strong Future in Aquaculture says Chief Harry”. (February 8, 2011) accessed May 31, 2011 at http://klahowya.nautsamawt.org/Environment/Resources/strong-future-in-aquaculture-says-chief-harry.html.

*Navigable Waters Protection Act*, RS, 1985, c. N-22

Nendick, L, M Sackville, S Tang, CJ Brauner and AP Farrell. “Sea lice infection of juvenile pink salmon (*Oncorhyncus gorbuscha*): effects on swimming performance and postexercise ion balance”. *Can. J. Fish. Aquat. Sci*. 68 (2011): 241 – 249

Noakes, Donald .J., Richard J. Beamish, and Michael L. Kent. “On the Decline of Pacific Salmon and Speculative Links to Salmon Farming in British Columbia” *Aquaculture* 183 (2000).

Noakes, D.J. and R.J. Beamish. “Shifting the Balance: Toward Sustainable Salmon Populations and Fisheries of the Future,” in *Sustainable Fisheries: Multi-Level approaches to a Global Problem*, American Fisheries Society, (2011), 23-50.

Nylund, A, T Hovland, K Hodneland, F Nilsen and P Lovik. “Mechanisms for transmission of infectious salmon anemia (ISA)”. *Diseases of Aquatic Organisms* vol 19, (1994): 95 – 100

Orr, C. "Estimated Sea Louse Egg Production from Marine Harvest Canada Farmed Atlantic Salmon in the Broughton Archipelago, British Columbia, 2003-2004." *North American Journal of Fisheries Management 27*, (2007): 187-197

*Pacific Aquaculture Regulations* SOR/2010-270 (*PAR*)

Pamela D. Tom, Paul G. Olin. *Farmed Or Wild? Both Types Of Salmon Taste Good And Are Good For You*. Global Aquaculture Advocate, May/June 2010: 58-60; International Fishmeal and Fish Oil Organisation

Parker, RR and L. Margolis. “A New Species of Parasitic Copepod, Caligus clemensi sp.nov. (Caligoda:Caligidae) from Pelagic Fishes in the Coastal Waters of British Columbia’. *J. Fish. Res. BD. Canada* 21(5), (1964).

Pearsall, Isabelle. “Broughton Archipelago: A State of Knowledge”. Pearsall Ecological Consulting, 2008.

Price, MHH, A Morton, and JD Reynolds. "Evidence of farm-induced parasite infestations on wild juvenile salmon in multiple regions of coastal British Columbia, Canada." *Can. J. Fish. Aquat. Sci. 67; DOI;10.1139/F10-105*, (2010): 1925-1932.

Price, MHH, SL Proboszcz, RD Routledge, AS Gottesfeld, C Orr, and JD. Reynolds. "Sea Louse Infection of Juvenile Sockeye Salmon in Relation to Marine Farms on Canada's West Coast." *PLoS ONE 6(2):e16851. DOI:10.1371/journal.pone.0016851*, (2011): 1-9.

Province of British Columbia. “Template for Development of Facility – Specific Fish Health Management Plans”. (2006).

*Regulations Amending the Health of Animals Regulations*, SOR/2010-296, Canada Gazette Part II: Official Regulations, Vol. 144, No. 26, December 22, 2010 “Regulatory Impact Analysis Statement”.

*Regulations Respecting Fishing and Fish Habitat in General and the Payment of Penalty and Forfeiture Proceeds Under the Fisheries Act* (SOR/93-53) at s. 56 (*Fishery (General) Regulations*)

*Regulations Respecting the Protection of Health of Fish* (C.R.C., c. 812)

Saksida, S, GA Karreman, J Constantine and A Donald. "Differences in Lepeophtheirus salmonis abundance levels on Atlantic salmon farms in the Broughton Archipelago, British Columbia, Canada". *Journal of Fish Diseases* 30, (2007): 357-366.

Saksida, S., J Constantine, GA Karreman, and A. Donald. "Evaluation of sea lice abundance levels on farmed Atlantic salmon (*Salmo salar* L.) located in the Broughton Archipelago of British Columbia from 2003 to 2005." *Aquaculture Research. 38,* (2007): 219-231

Saksida, S. Investigation of the 2001-2003 IHN epizootic in farmed Atlantic salmon in British Columbia.

Saksida, SM, D Morrison and CW Revie. "The efficacy of emamectin benzoate against infestations of sea lice, Lepeophtheirus salmonis, on farmed Atlantic salmon, Salmo salar, in British Columbia." *Journal of Fish Diseases 33,* (2010):: 913-917

Sams, Saksida, McClure and Hammell. "Canadian Sea Lice Therapeutant Availability: Jurisdictional Considerations." (2008). BC Center for Aquatic Health Sciences and Atlantic Veterinary College – Centre for Aquatic Health Sciences.

ScienceDaily, (15/03/2011) Extent and Speed of Lionfish Spread Unprecedented; Invasive Marine Fish May Stress Reefs. online: http://www.sciencedaily.com/releases/2011/03/110314141606.htm.

Scott, R.J., D.L.G. Noakes, F.W.H. Beamish, L.M. Carl. "Chinook salmon impede Atlantic salmon conservation in Lake Ontario," *Ecology of Freshwater Fish* 12(2003):66-73.

Smith, V.H., Joye, S.B., and Howarth, R.H. "Eutrophication of freshwater and marine ecosystems," *Limnol. Oceanogr.*, 51(1, part 2) (2006):361-355

Soto, D, F Jara and C Moreno. "Escaped salmon in the inner seas, southern Chile: Facing Ecological and Social Conflicts". *Ecological Applications* 11(6) (2001): 1750-1762.

Statistics Canada, 'Fertilizer and Pesticide management in Canada. Accessed "http://www.statcan.gc.ca/pub/21-021-m/2004002/4144650-eng.htm#10.

Statistics Canada, *Snapshot of Canadian Agriculture,* (Ottawa, ON: Agriculture Division, 2006). http://www.statcan.gc.ca/ca-ra2006/articles/snapshot-portrait-t2-eng.htm.

Stucchi, Dario, Leavings, Colin and Chamberlain, Jon. "Working Paper: DEPOMOD Modeling of Particle Deposition Rates and Benthic Impacts" (Presentation at the National Advice for Finfish Cage Aquaculture in the Marine Environment, Institute of Ocean Sciences, 2005). EV.CAN.0011.007000.CAN043781.

Subasinghe, R.P, M.G. Bondad-Reantaso, and S.E. McGladdery,. "Aquaculture development, health and wealth" in R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. *Technical Proceedings of the Conference on Aquaculture in the Third Millennium*, Bangkok, Thailand, 20-25 February 2000: (2001)167-

191. NACA, Bangkok and FAO, Rome, http://www.fao.org/docrep/003/ab412e/ab412e09.htm.

Sutherland, BJG, SG Jantzen, DS Sanderson, BF Koop and SRM Jones. "Differentiating size-dependant responses of juvenile pink salmon (*Oncoryhnchus gorbuscha*) to sea lice (*Lepeoptheius salmonis*) infections". *Comparitive Biochemistry and Physiology*, Part D 6 (2011):213-223.

The Canadian Encyclopedia, 2011, s.v. *Fisheries History. Accessed August 16. 2011. http://www.thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Params=A1ARTA0002833.*

The Vancouver Humane Society, *Meat and the Environment*. http://www.vancouverhumanesociety.bc.ca/campaigns/eat-less-meat/meat-and-the-environment/

Traxler, G.S., J.R. Roome, K.A. Lauda, S. LaPatra. "Appearance of infectious hematopoietic necrosis virus (IHNV) and neutralizing antibodies in sockeye salmon *Onchorynchus nerka* during their migration and maturation period," *Diseases of Aquatic Organisms* 28 (1997):31-38. AQU000050.

Trudel, M., et al. "Infestations of Motile Salmon Lice on Pacific Salmon along the West Coast of North America." *American Fisheries Society Symposium 57* , (2007): 157-182.

Tucker, CS, C Sommerville, and R. Wootten. "The effect of temperature and salinity on the settlement and survival of copepodids of Lepeophtherius salmonis (Kroyer, 1837) on Atlantic salmon, Salmon salar." *Journal of Fish Diseases 23*, (2000): 308-320

Unknown, "Terms of Reference for a National Advisory Workshop on Potential Technologies for Closed-containment Saltwater Salmon Aquaculture." Paper presented at the IOS-DFO workshop, Sydney, BC, January-February,2008.

Vernon, B. *Salmon Ranching Examined.* s.l.: Northern Aquaculture, September/October, 2007. http://www.certifiedorganic.bc.ca/rcbtoa/services/NAsept-oct-pgs14-15c.pdf.

Wagner, G. "Aquaculture in British Columbia. Putting the Regulatory Situation into Perspective". (2010) *EDI Whitepaper* No 1 Rev 2.1. online at http://edynamics.com/uploads/documents/factsheets/Aquaculture%20White%20Paper_Formated_Draft%202%201%20cm.pdf.

Webster, SJ., LM Dill, and K. Butterworth. "The effect of sea lice infestation on the salinity preference and energetic expenditure of juvenile pink salmon (Oncorhynchus gorbuscha)." *Can. J. Fish. Aquat. Sci*. *64*, (2007): 672-680

Wildish, D.J., Dowd. M., Sutherland. T.F., Levings.C.D., "Near-field Organic Enrichment from Marine Finfish Aquaculture"in A Scientific Review of the Potential Environmental Effects of Aquaculture in Aquatic Ecosystems Fisheries and Oceans Canada. Vol III (2004). Originally published in *Can.Tech.Rep.Fish.Aquat.Sci*.2450:ix+117p.

Wilson, A, S Magill and KD Black. "Review of environmental impact assessment and monitoring in salmon aquaculture". In FAO, Environmental Impact assessment and monitoring in aquaculture. FAO Fisheries and Aquaculture Technical Paper. No 527, Rome FAO (2009): 455-535

Yazawa, R, M Yusuike, J Leong, KR van Schalburg, GA Cooper, M Beetz-Sargent, A Robb, WS Davidson, SRM Jones and BF Koop. "EST and Mitochondrial DNA Sequences Support a Distinct Pacific Form of Salmon Louse, *Lepeoptheirus salmonis*". *Mar Biotechnical. doi; 10.1007/s10126-008-9112-y*, (2008).

Young, N. and R. Matthews, *The Aquaculture Controversy in Canada: Activism, Policy, and Contested Science,* UBC Press, Vancouver, BC, 2010.