The Benefits and Impacts of Net-cage Salmon Farming:

An internet literature review

Jody Cox
Research Northwest
P.O. Box 1237
Marsh Lake, Yukon
Ph: (867) 660-5347
jodycox@northwestel.net

Executive Summary

The purpose of this review is to provide a broad overview of the benefits and negative impacts of net-cage salmon aquaculture in British Columbia. The Yukon Salmon Committee has an interest in BC's net-cage salmon farms based on annual permits that allow the export of Yukon River chinook salmon milt to a BC aquaculture operation. The YSC will be holding public consultations on this issue in 2004 and this review will help provide background information for the Committee and the general public on the issues.

Economic and social impacts

The economic benefits — and especially jobs — created by net-cage salmon farming in rural coastal areas where economic opportunities are few are the industry's greatest attraction for governments and communities.

In BC net-cage salmon farming supports 900 direct jobs (about 7.5 jobs per farm). Industry proponents claim that an additional 2,600 or more indirect jobs are supported by the industry; skeptics suggest that about 1,000 indirect jobs are supported by industry operations.

The massive increase in salmon farming worldwide over the past 20 years has pushed down the price of all salmon — farmed and wild — by approximately two thirds. The dropping prices have had a large negative impact on the economics of the wild salmon fishery.

Industry proponents argue that salmon farming (and other aquaculture) has the important worldwide social benefit of helping to reduce hunger. Skeptics point out that salmon is marketed as a luxury good, not a basic foodstuff, and that the industry relies on 4 pounds of other wild fish (anchovies, mackerel etc.) as feed to produce 1 pound of salmon.

Eight BC coastal First Nations are involved in salmon farming while other First Nations have opposed the industry due to fears of its negative environmental impacts.

Environmental impacts

There has been surprisingly little long-term scientific research done on many of the environmental issues around net-cage salmon farming. These issues will only be resolved satisfactorily when the research is done.

Industry advocates acknowledge some negative environmental impacts but question the level of long-term risk. They also argue that the effects of fish farms on wild salmon are no different from hatcheries and salmon-enhancement programs.

Parasites and disease
The diseases and parasites found on fish farms also occur in many — usually most — wild populations and are considered enzootic (indigenous) to BC. Fish farms do not create the diseases and parasites found at them. But high-density net-cage salmon farming likely creates conditions that amplify the risk of infection. Sea lice infestations have recently been a contentious topic in BC and illustrate the difficulty in proving direct links between salmon farming and outbreaks of parasites and disease in wild salmon stocks.

Exotic species: Atlantic salmon in fish farms
Net-cage salmon farming in BC began in the early 1970s with operations that farmed Pacific salmon, first coho and then chinook. But by the late 1980s, Atlantic salmon had displaced the Pacific as the most commonly farmed fish in BC because they have been selected and bred to be more docile, they grow faster, and they spawn over a

longer period. Pacific salmon now make up approximately 14% of farmed salmon in BC with chinook salmon alone totalling about 12% of all farmed salmon and coho totalling about 2%.

Escapes of Atlantic salmon and the possible implications for wild Pacific salmon have long been a concern in BC. Industry proponents have argued that escaped Atlantic salmon are unable to survive long in the wild, compete successfully against their wild Pacific cousins, or successfully spawn. However, the discovery of juvenile Atlantic salmon in the wild demonstrates that farmed salmon can escape and survive in salt water, migrate to fresh water and spawn successfully, and that their offspring can also survive in fresh water.

Escapes of farmed Pacific salmon and genetic diversity
Unlike farmed Atlantic salmon, farmed Pacific salmon can interbreed with wild Pacific salmon. Many believe this threat to the genetic integrity of wild Pacific salmon stocks is far greater than the threats associated with escaped Atlantic salmon, particularly as interest in chinook salmon farming is increasing in BC.

The long-term viability of mixed wild and escaped farm salmon populations is unknown but the risk of hybridization is extreme: the fish are increasingly homogenized as the natural variations among the wild populations are lost, and the hybrids are ill-adapted to local conditions. However, some researchers have argued that Pacific salmon hatchery programs pose a greater risk to genetic adaptation than fish farms due to the sheer numbers of cultured fish released into the wild and the transfer of hatchery fish throughout the Pacific Northwest over many years.

Environmental impact of fish farm wastes
Waste from fish farms includes fecal material, urine, uneaten feed, chemical residues (from antibiotics, pesticides, net-cleaning agents) and marine organisms falling off the nets. The decomposition of the waste causes chemical changes in the sediments under the pens and can result in oxygen reduction or depletion. These changes in the seabed may affect the marine organisms naturally occurring in the area.

There is no consensus on how much impact fish farm waste has on the farm's local environment and how widespread or long-lasting that impact is. Some studies show that the seabed under the pens returns to its natural state within weeks of a halt in production. Others show it takes much longer. Most studies demonstrate that the impacts on the seabed do not extend more that a few hundred metres from the pens. Much appears to depend on the location of the pens and on their maintenance.

Table of Contents

1 Introduction

The purpose of this review is to provide a broad overview of the benefits and negative impacts of net-cage salmon aquaculture in British Columbia. The overview is based on a review of literature available on the internet and includes economic, social, and environmental impacts. A further purpose is to provide the links to research and opinion for those who wish to explore the issues in more depth.

The Yukon Salmon Committee has an interest in BC's net-cage salmon farms based on annual permits that allow the export of Yukon River chinook salmon milt to a BC aquaculture operation. The YSC will be holding public consultations on this issue in 2004 and this review will help provide background information for the Committee and the general public on the issues.

The review focused on finding the most recent (all of the literature consulted was published after 2000) and most credible research available. However, there are two general caveats that must be emphasized:

1. There has been surprisingly little long-term scientific research done on many of the environmental issues around net-cage salmon farming. These issues will only be resolved satisfactorily when the research is done.
2. There are often strongly conflicting points of view on many issues, and often insufficient data is available to make definitive judgments on which view is correct.

Throughout the review every effort has been made to present both sides of the argument where there is disagreement on an issue. And where there is an obvious bias or flaw in logic or data evident, that bias or flaw is pointed out but making definitive judgments on these issues is beyond the scope of the review.

A significant amount of discussion and research in the literature focuses on the introduction and propagation of Atlantic salmon in the Pacific Northwest. To assist the Yukon Salmon Committee in discussions on continued support of sending wild Yukon River salmon milt to fish farms, this review presents findings on the overall impact of salmon farming as well as the farming specifically of Pacific salmon.

1.1 Background: Salmon Aquaculture

Net-cage salmon farming in BC began in the early 1970s with operations that farmed Pacific salmon, first coho and then chinook. But by the late 1980s, Atlantic salmon had displaced the Pacific as the most commonly farmed fish in BC. The reasons for the increasing use of the non-native species include:

- Atlantic salmon have been selected and bred for decades to do well in captivity,
- they are less aggressive and so can be farmed more intensely with lower mortality,
- Atlantic salmon convert feed to meat more efficiently, reaching market size in 30 months; and
- because they spawn over a long period of time, they are available almost year-round.[1]

Because of the advantages of using Atlantic salmon, Pacific salmon fell out of favour with fish farmers. However, in the past few years Pacific salmon have garnered renewed interest in part because of their greater resistance to disease. Pacific salmon now make up approximately 14% of farmed salmon in BC with chinook salmon alone totalling about 12% of all farmed salmon and coho totaling about 2%.

The growth of the salmon aquaculture industry in BC (and worldwide) has been phenomenal. In BC, production

[1] David Suzuki Foundation. http://www.davidsuzuki.org/Oceans/Fish_Farming/Salmon/ and Gross, Mart R. 2002. "Net Risk: Assessing potential impacts of fish farming on BC's Wild Salmon", in: Ghost Runs: The Future of Wild Salmon on the North and Central Coasts of British Columbia, p. 139. http://www.raincoast.org/files/ghost_runs/chapter5.pdf

has increased from roughly 100 tonnes in 1980 to 85,400 tonnes in 2002. The industry developed from 10 operating farms in 1984 to a peak of 135 farms in 1989. Much of the initial growth of the industry was created by smaller, often local firms with 50 companies operating in 1989. Through the 1990s, however, there has been considerable consolidation with large, often multinational companies taking over much of the industry. Companies have become increasingly integrated with hatcheries, grow-out, processing and marketing operations, and all of BC's 121 farm sites are now owned and operated by 12 firms.[2]

[2] British Columbia. Ministry of Agriculture, Food, and Fisheries. http://www.agf.gov.bc.ca/fish_stats/aqua-salmon.htm

2 Economic and social impacts

As with any industry, net-cage salmon farming can have both positive and negative economic and social impacts. For example, when an industry creates jobs there are both positive economic impacts and positive social impacts as more jobs are viewed as a social good.

2.1 Does the net-cage salmon industry have positive effects on the economy?

The net-cage salmon farming industry does have positive effects on the economies in which it operates. Not surprisingly, industry groups emphasize the economic benefits that the industry brings to the areas it operates in, along with its promotion of the farmed salmon product itself. An industry lobby group called Salmon of the Americas is typical in stating:

> "Salmon farming plays an important role in the economies of many areas. Jobs and other economic benefits contribute to the value of salmon as much as its role in good nutrition."[3]

These positive economic impacts are the industry's greatest attraction and are the reason for the high level of support and encouragement given to the industry by the BC government. The location of fish farms in largely rural coastal areas — where economic opportunities are few — adds to the attraction of the industry for governments and communities.

The production and value of BC's net-cage salmon farm industry from 1998 to 2002 is summed up in Table 1 below.

Table 1: BC production and value of farm salmon: 1998 to 2002

Year	Production (thousands of tonnes)	Farm-gate value ($millions)
1998	42.3	229.0
1999	49.6	290.5
2000	49.4	281.7
2001	68.0	270.9
2002	85.4	288.9

Source: Government of British Columbia[4]
Note: In 2002 approximately 12% of farm production is chinook salmon.

The production of farmed salmon more than doubled from 1998 to 2002 in British Columbia. The increase has been achieved without increasing the number of farm locations (which remained at 121 crown tenures) and only a minimal increase in the area covered by the net-cages (from 1,000 hectares to 1,191 hectares).[5] This indicates that existing operations have become much more intensive, producing more fish without greatly increasing their area of operation.

[3] Salmon of the Americas. http://www.salmonoftheamericas.com/enviro.html
[4] British Columbia. Ministry of Agriculture, Food, and Fisheries. http://www.agf.gov.bc.ca/fish_stats/aqua-salmon.htm
[5] British Columbia. Ministry of Agriculture, Food, and Fisheries. http://www.agf.gov.bc.ca/fish_stats/aqua-salmon.htm

Unfortunately, the overall value of the total production increased by only 25% as production went up by 102%. This clearly shows that the value of the farmed fish has been dropping sharply on a per-pound basis. Farmed salmon is now a standard commodity and production has been increasing rapidly in many areas of the world, including Chile, which is now among the world's top producers. As with almost all commodities, prices have been dropping as more and more is produced (see section 2.2 below).

The entry of developing countries such as Chile into the industry puts further downward pressure on prices as costs tend to be substantially lower. In a survey of the competitiveness of the BC aquaculture industry, PriceWaterhouseCoopers states:

> "Producers with operations in Chile have the lowest production cost by a wide margin, on average 13% lower than BC. Chile ranked the lowest in all major cost categories except for transport to market. In particular, Chile has the lowest smolt, feed, labour, and depreciation costs."[6]

2.1.1 Does the net-cage salmon industry provide many jobs?

The number of jobs created by the net-cage salmon industry in BC appears to be the subject of some debate. The BC government offers the following in support of the industry:

> "Salmon aquaculture contributes enormously to our British Columbia economy – more than 3,500 direct and indirect jobs. Ninety percent of those jobs are in coastal communities, and 50 percent of those jobs are for women and First Nations. These are full-time, year-round jobs."[7]

But the same government department also states that the industry supports 900 direct jobs[8] while not providing its rationale for estimating an additional 2,600 indirect jobs, and not defining what those indirect jobs consist of.

In contrast, a paper by Dale Marshall on the economics of BC's salmon farming industry uses statistics from the BC government and Statistics Canada to estimate that the industry accounts for 1,936 direct and indirect jobs in the province.[9] The paper defines the salmon aquaculture industry to include: farmed salmon production, production of fishmeal and related products, and the processing of farmed salmon. Further, Marshall states that increasing production further will show greatly diminishing returns in job creation:

> "In the 1990s, BC's salmon farming industry tripled production while adding no new jobs. Fish farms in BC are following the trend set in Norway by becoming increasingly mechanized and thus needing fewer workers."[10]

It is interesting to note (using the BC government's figures of 900 direct jobs and 121 sites) that net-cage salmon farms provide an average of 7.5 direct jobs per farm.

---

[6] PriceWaterhouseCoopers. May 2003. "A Competitiveness Survey of the British Columbia Salmon Farming Industry," p. 5 http://www.agf.gov.bc.ca/fisheries/reports/Competitiveness_Survey.pdf
[7] British Columbia. Ministry of Agriculture, Food, and Fisheries. http://www.agf.gov.bc.ca/fisheries/faq.htm#contribute
[8] British Columbia. Ministry of Agriculture, Food, and Fisheries. http://www.agf.gov.bc.ca/fish_stats/aqua-salmon.htm
[9] Marshall, Dale. July 2003. "Fishy Business: The economics of salmon farming in BC," p.5 http://www.policyalternatives.ca/bc/fish-farms.pdf
[10] Marshall, Dale. July 2003. "Fishy Business: The economics of salmon farming in BC," p.4 http://www.policyalternatives.ca/bc/fish-farms.pdf

2.2 Do net-cage salmon farms have negative effects on the economy?

The major potential negative effect that net-cage salmon farms may have on the BC economy is through any environmental damage they may do to other fisheries — and particularly the wild salmon fishery. Those potential effects are discussed at length in the environmental sections below.

Apart from potential environmental damage, it is argued that net-cage salmon farms produce negative economic effects by:

1. forcing down the price of wild salmon; and
2. making coastal areas less attractive to ecotourism.

As worldwide farmed salmon production increased throughout the 1980s and 1990s, the price of salmon, both farmed and wild, fell by approximately two thirds.[11] Colin Nash writes:

> "Salmon farmers and traditional Pacific salmon fishermen sell the same generic product, and therefore compete in the marketplace… In terms of price and availability, Atlantic salmon has an all-year round advantage and therefore a competitive edge over Pacific salmon harvested in the commercial fisheries. They are also relatively cheap to produce for the market. Per harvested fish, the cost to the private producer of farmed Atlantic salmon is currently about US $1 per pound, head on, gutted weight."[12]

There are other factors that affect the price of salmon, including the attempts to create niche markets and price premiums for wild salmon, but the overall price trends are inescapable. The reaction of traditional fishers to falling prices is not necessarily to decrease their fishing effort; indeed it is often the reverse as they try to compensate for lower prices by catching more. A further impact of falling prices is the simultaneous decline in the value of commercial fishing permits, which have long acted as a form of pension for commercial fishers.[13]

The impact of net-cage salmon farms on coastal ecotourism is difficult to measure and largely anecdotal. Wilderness guides and ecotourism operators claim that the salmon farming industry has a negative effect on their operations as clients do not wish to tour areas containing fish farms and this reduces the areas available for ecotourism.[14]

2.3 What are the social impacts of net-cage salmon farms?

Two social impacts of net-cage salmon farms are considered here. The first is the argument that salmon farming has an important worldwide role to play in preventing hunger and that it decreases fishing pressure on wild stocks. The second is the impact the industry has on First Nation people and communities in coastal British Columbia.

---

[11] Marshall, Dale. July 2003. "Fishy Business: The economics of salmon farming in BC," p.25 http://www.policyalternatives.ca/bc/fish-farms.pdf

[12] Nash, Colin E. June 2003. "Interactions of Atlantic salmon in the Pacific Northwest. VI. A synopsis of the risk and uncertainty" in *Fisheries Research*, Vol. 62, Issue 3, pp. 339-347.

[13] Marshall, Dale. July 2003. "Fishy Business: The economics of salmon farming in BC," p.25 http://www.policyalternatives.ca/bc/fish-farms.pdf

[14] Marshall, Dale. July 2003. "Fishy Business: The economics of salmon farming in BC," p.25 http://www.policyalternatives.ca/bc/fish-farms.pdf

The salmon farming industry makes sweeping claims on the social need the industry fills:

> "We need to farm fish to feed people. Farm-raised salmon is now part of the answer to preventing hunger."[15]

How the production of what is largely marketed as a high-end luxury good will help prevent hunger is not made clear.

Critics of the salmon farming industry argue that — like the beef industry — salmon farming uses far more food energy to feed the salmon than the salmon provide to consumers. Farmed salmon are fed with fish meal made from anchovies, mackerel, and other fish harvested in the wild. The David Suzuki Foundation argues that the demand for feed by salmon farms is playing a role in depleting global fish stocks.[16] Further arguments that the fish farm industry increases rather than reduces pressure on wild stocks of fish are made by the World Wildlife Fund's *Food for Thought* report, which states that 4 pounds of fish are required to produce each pound of farmed salmon.[17]

The industry responds to such criticism by arguing that the fish used in fishmeal would not be used directly for human consumption and that salmon farming is far more ecologically efficient than harvesting wild salmon:

> "The fishmeal used in salmon farming feed is composed primarily of fish, commonly called forage fish, that are fast-growing, short-lived, and not generally used for human consumption… Salmon farming produces about one pound of salmon for every one and a half of feed consumed…Specifically, with regard to forage fish, it takes about three pounds to produce one pound of farmed salmon…As a comparison with wild salmon production efficiency, farmed salmon efficiencies represent a significant ecological advantage because it takes between 10 and 15 pounds of wild forage fish to produce one pound of wild salmon."[18]

As with most other aspects of the net-cage salmon farms, the industries impact on BC's coastal First Nations is disputed. The BC government writes:

> "Eight First Nations on the coast of British Columbia are involved in salmon aquaculture. The unemployment rate in Klemtu, a First Nations community on BC's central coast, has been reduced from 90 percent to 30 percent since aquaculture came to the community."[19]

But some First Nations and First Nation people are on record as being totally opposed to salmon farms because of the perceived threats the farms pose to wild salmon stocks.[20]

---

[15] Salmon of the Americas. http://www.salmonoftheamericas.com/env_aqua.html
[16] David Suzuki Foundation. http://www.davidsuzuki.org/Oceans/Fish_Farming/Salmon/Net_Loss.asp
[17] Tuominen, Taija-Riitta and Esmark, Maren. February 2003. "Food For Thought: The Use of Marine Resources in Fish Feed." http://www.panda.org/downloads/marine/foodforthoug.pdf
[18] Salmon of the Americas. http://www.salmonoftheamericas.com/env_food.html
[19] British Columbia. Ministry of Agriculture, Food, and Fisheries. http://www.agf.gov.bc.ca/fisheries/faq.htm#contribute.
[20] Marshall, Dale. July 2003. "Fishy Business: The economics of salmon farming in BC," p.26 http://www.policyalternatives.ca/bc/fish-farms.pdf

3 Environmental impacts

Net-cage salmon farming clearly does have impacts – on the marine environment at and near the farms, and on farmed and wild salmon. Are these impacts negative in the long term? Are fish farms being unfairly targeted as responsible for observed changes in the marine environment? Industry advocates acknowledge impacts but question the long-term risks. They also argue that the effects of fish farms on wild salmon are no different from hatcheries and salmon-enhancement programs.[21] Most sources, however, emphasize the need for long-term research to provide conclusive evidence one way or the other.

The sections below summarize some of the relevant issues about environmental impacts of net-cage farming. The reader is often directed to other reports and articles for detailed information on certain subjects. A particularly useful analysis of the environmental issues, both because of its thoroughness and recent completion, was prepared for the Pacific Fisheries Resource Council.[22]

3.1 Do fish farms increase the risk of diseases and parasites in wild salmon populations?

The diseases and parasites found on fish farms also occur in many, usually most, wild populations and are considered enzootic (indigenous) to BC.[23] Fish farms do not create the diseases and parasites found at them. But high-density net-cage salmon farming likely creates conditions that amplify the risk of infection.

The health of any fish stock is determined by:

1. the general health of the fish;
2. the quality of the environment the fish are in; and
3. the nature and concentration of the pathogen in contact with the fish.[24]

Stress is identified as a key factor in fish health and is significant in determining whether or not a fish that has come into contact with a pathogen (bacterium, virus or parasite) will show clinical signs of disease, die or survive.[25] Stress occurs for a number of reasons in wild fish (e.g. climatic conditions) and in farmed fish (e.g. overcrowded conditions). Furthermore, among the fish species, there are differences in susceptibility to diseases and parasites. For example, Atlantic salmon are particularly susceptible to sea lice, while coho and chinook are shown to be more resistant. These differences are attributed to innate immunological defence mechanisms. Factors that increase the stress or reduce the immune system predispose fish to sea lice and other diseases.[26]

---

[21] Nash, Colin E. June 2003. "Interactions of Atlantic salmon in the Pacific Northwest. VI. A synopsis of the risk and uncertainty" in *Fisheries Research*, Vol. 62, Issue 3, pp. 339-347.

[22] Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia." http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf

[23] Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf p. 55. For an excellent discussion of a range of diseases associated with salmon, see Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia." http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf See also David Suzuki Foundation. http://www.davidsuzuki.org/Oceans/Fish_Farming/Salmon/Diseases.asp

[24] Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf p. 53.

[25] Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf p. 53

[26] Canada. Health Canada. 2003. "Overview: Integrated Pest Management of Sea Lice in Salmon Aquaculture." http:

While it is known that diseases transfer from wild to farmed salmon, there appears to be no proof that diseases transfer from farmed to wild salmon. Some researchers have stated that while there is no evidence in British Columbia that this occurs, the transfer is likely a two-way street and the fact that the diseases are enzootic makes detection of the farm-to-wild movement difficult.[27] Others have concluded that fish farms do indeed create a reservoir of pathogens, increasing the challenges for wild salmon when they migrate past or are otherwise near fish farms.[28] (The word "challenges" is important because it goes back to the health, or vulnerability, of the fish stock in question.) Supporters of the aquaculture industry may acknowledge the high level of diseases on the fish farms but consider the risk of increased incidences of disease in wild fish to be "low risk". For example, a series of articles in the journal *Fisheries Research* downplay the role of fish farms in spreading diseases:

> "The specific diseases and their prevalence in Atlantic salmon stocks cultured in net-pens in Puget Sound are not shown to be any different than those of the more numerous cultured stocks of Pacific salmon in hatcheries, which in turn are not known to have a high risk for infecting wild salmonids. All Pacific and Atlantic salmon stocks currently cultured in Washington are inspected annually for bacterial and viral pathogens, and the movement of fish from place to place is regulated by permit."[29]

3.1.1 Is there a connection between sea lice outbreaks in the wild and on fish farms?

A highly topical issue in British Columbia over the last few years is the relationship between fish farms and the outbreaks of sea lice. Juvenile salmon are particularly vulnerable to the sea louse (*Lepeophtheirus salmonis*), a copepod parasite native to British Columbia. While the BC Ministry of Agriculture, Food and Fisheries states that they usually have "little impact on their health and survival", studies have shown that five lice can debilitate a fish 15 grams or less, 11 can kill it.[30] As noted above, coho and chinook salmon are more resistant to sea lice.

Research in Scotland, Ireland and Norway discusses the link between fish farms and the infestation of sea lice on wild Atlantic salmon and salmon trout.[31] There appears to be no doubt that wild Atlantic salmon contract the parasites to a higher degree when passing through farm areas – e.g. more than100 sea lice per Atlantic salmon near farms in Scotland.[32]

---

www.hc-sc.gc.ca/pmra-arla/english/pdf/spm/spm2003-e.pdf p. 8

[27] Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf p. 53-55.

28 Gross, Mart R. 2002. "Net Risk: Assessing potential impacts of fish farming on BC's Wild Salmon", in: Ghost Runs: The Future of Wild Salmon on the North and Central Coasts of British Columbia. http://www.raincoast.org/files/ghost_runs/chapter5.pdf p. 145; and David Suzuki Foundation. http://www.davidsuzuki.org/Oceans/Fish_Farming/Salmon/Diseases.asp

[29] Nash, Colin E. June 2003. "Interactions of Atlantic salmon in the Pacific Northwest. VI. A synopsis of the risk and uncertainty" in *Fisheries Research*, Vol. 62, Issue 3, pp. 339-347.

[30] British Columbia. Ministry of Agriculture, Food and Fisheries. April 28, 2004. http://www.agf.gov.bc.ca/fisheries/health/sealice.htm; and Watershed Watch Salmon Society. December 2001. "Salmon Farms, Sea Lice and Wild Salmon: a Watershed Watch Report on Risk, Responsibility and the Public Interest," p. 7. http://www.watershed-watch.org/ww/publications/SeaLice/WWSS_Sea_Lice_Report.pdf

[31] See Gargan, Patrick. 2000. "The Impact of the Salmon Louse (*Lepeophtheirus Salmonis*) on Wild Salmon Stocks in Europe and Recommendations for Effective Management of Sea Lice on Salmon Farms," pp. 37-46. Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. See also Scottish Executive Central Research Unit. 2002. "Review and Synthesis of the Environmental Impacts of Aquaculture." The Scottish Association for Marine Science and Napier University. http://www.scotland.gov.uk/cru/kd01/green/reia-01.asphttp://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf

[32] Gross, Mart R. 2002. "Net Risk: Assessing potential impacts of fish farming on BC's Wild Salmon", in: Ghost Runs: The Future of Wild Salmon on the North and Central Coasts of British Columbia.

In British Columbia, significant outbreaks of sea lice in the last few years have drawn local attention to the issue. The following is the abstract to a recent article in the *Canadian Journal of Fisheries and Aquatic Sciences* about research in the Broughton Archipelago:

> "This study compared sea lice (*Lepeophtheirus salmonis*) infestation rates on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon in five nearshore areas of the British Columbia coast selected on the basis of proximity to salmon farms. A 10-week study in the Broughton Archipelago found sea lice were 8.8 times more abundant on wild fish near farms holding adult salmon and 5.0 times more abundant on wild fish near farms holding smolts than in areas distant from salmon farms. We found that 90% of juvenile pink and chum salmon sampled near salmon farms in the Broughton Archipelago were infected with more than 1.6 lice·(g host mass)$^{-1}$, a proposed lethal limit when the lice reach mobile stages. Sea lice abundance was near zero in all areas without salmon farms. Salinity and temperature differences could not account for the higher infestation rates near the fish farms. The most immature life stages dominated the lice population throughout the study, suggesting the source of lice was a stationary, local salmonid population. No such wild population could be identified. The evidence from this control–impact study points to a relationship between salmon farms and sea lice on adjacent, wild, juvenile salmon. [33]

Scott McKinley, professor and senior Canada research chair of Animal Sciences at the University of British Columbia and executive scientific director of AquaNET, whose mandate is to foster a sustainable aquaculture sector in Canada, argues that there is no evidence to support the conclusion that farming results in declining wild fish populations:

> "'With any fish population, one or two years of surveys does not make a trend… There have been drastic declines in pink salmon before, and that was before there were farms here,' said McKinley. 'There is no study published showing a cause-and-effect relationship between sea lice on wild and farmed fish…All the work that's out there is based on correlations.'
>
> "McKinley suggests that other explanations for the population fluctuations in wild fish are also likely. For example, population crashes could result from limited resource availability or fishing pressure. Fluctuations in water temperature on a global scale, such as those caused by El Niño, could make the salmon sick and stressed. 'If you happen to be weak or stressed in terms of general health, you tend to be more susceptible to parasite infection.'" [34]

The difficulty in any of these discussions is: what constitutes conclusive evidence that fish farms make a significant contribution to, or are responsible for, an increased incidence of disease or parasites in wild salmon populations?[35]

---

http://www.raincoast.org/files/ghost_runs/chapter5.pdf

[33] Morton, Alexandra et al. 2004. "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", in *Canadian Journal of Fisheries and Aquatic Sciences*. 61(2): 147-157. http://pubs.nrc-cnrc.gc.ca/cgi-bin/rp/rp2_abst_e?cjfas_f04-016_61_ns_nf_cjfas2-04

[34] Canada. National Research Council of Canada press release, March 2, 2004. http://cisti-icist.nrc-cnrc.gc.ca/media/sea_lice_e.shtml

[35] See the following for a discussion on science and risk assessment. Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia," pp. 13-18. http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf

3.2 How many salmon escape the fish farms?

It is impossible, of course, to know how many salmon escape fish farms. Research has focused on the number and consequences of escaped Atlantic salmon. Under the Atlantic salmon watch program, 396,522 escaped Atlantic salmon were reported in BC between 1991 and 2001. Some suggest that the chance of survival of these salmon is low because of the domesticated existence and their docile behaviour.[36]

Determining the number of escaped Pacific salmon (coho or chinook) is even more complicated because they are difficult to distinguish from wild stock and because of the large number of hatchery-raised Pacific salmon released in BC. One in five escapes is believed to be Pacific salmon.[37]

As is often the case, numbers and statistics can be used in interesting ways to convey a particular point. The case of escaped farmed salmon is no exception, as pointed out by the Suzuki Foundation web site in interpreting BC government statistics, demonstrating that such information must be considered carefully:

> "'*In 1999, 0.3 per cent of farmed salmon were reported to have escaped, compared with 3.7 per cent in 1990. This decline can be attributed largely to the development of improved containment and harvesting technology and to better farm practices.*' What wasn't made clear in the press release is that the percentage quoted refers to the tonnes of salmon escaped compared to the total tonnage produced that year. It wasn't mentioned that between 1990 and 1999, farmed salmon production in B.C. tripled. So the percentage quoted for 1999 tells us very little about any change in the total number of individual salmon that escaped from farms between those two years. In terms of environmental impact, the more individual farmed salmon escape, the greater the impact…Any interpretation of trends, therefore, can only be reliable if looked at over a number of years. In 1990, 165,000 farmed salmon escaped compared to 35,730 in 1999, a five-fold reduction (not 12-fold as indicated in the government press release). But from 1993 to 2000 the number of escaped salmon almost doubled, from 22,113 to 40,617. Simply picking any two years and looking at the numbers is not very instructive."[38]

3.3 How large an impact do the interactions between escaped salmon and wild salmon have?

Farmed salmon and wild salmon have the opportunity to interact in the marine and freshwater environments. The potential for marine interactions is considered to be low. No evidence supports caged fish feeding on wild juvenile salmon nor is there evidence that farmed salmon and wild salmon compete for feed. There is the possibility, but no evidence, that wild salmon (especially juveniles) are attracted to or are displaced by the cage sites, thereby affecting migratory patterns.[39]

The major concern is the freshwater interaction of farmed and wild salmon. Escaped farmed salmon, whether they be Atlantic or Pacific, do compete with wild salmon for food, space and spawning habitat.[40] This is

---

[36] Nash, Colin E. June 2003. "Interactions of Atlantic salmon in the Pacific Northwest. VI. A synopsis of the risk and uncertainty" in *Fisheries Research*, Vol. 62, Issue 3, pp. 339-347.

[37] Gross, Mart R. 2002. "Net Risk: Assessing potential impacts of fish farming on BC's Wild Salmon", in: Ghost Runs: The Future of Wild Salmon on the North and Central Coasts of British Columbia. http://www.raincoast.org/files/ghost_runs/chapter5.pdf p. 141

[38] David Suzuki Foundation. http://www.davidsuzuki.org/Oceans/Fish_Farming/Salmon/Escapes.asp

[39] Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf p. 33.

[40] Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia," p. 81. http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf

particularly evident with Atlantic and Pacific salmon freshwater interaction: spatial and forage competition by juveniles in rearing habitat; superimposition of later-spawning Atlantic salmon on wild Pacific salmon and trout redds; and breeding disturbance.[41] Dr. Ian Fleming, a Norwegian researcher, makes a number of points about the breeding performance (mate and territory acquisition, egg deposition and fertilization) of farmed salmon in general:

- the performance of males in particular is significantly inferior to that of wild salmon;
- it appears to decline with life stage of escapees and with the number of generations of artificial rearing;
- the competitive and reproductive performance of farm salmon appears to decline with increased competition for breeding resources (e.g. mates and breeding sites), suggesting that a healthy and dense population of salmon in the wild is more likely to withstand the invasion of farmed salmon.
- nest destruction within native salmon rivers by escaped farmed females is a "near certainty".

Juvenile Atlantic salmon will compete for resources with Pacific salmon, but the outcome is uncertain. Some argue that domestication selection associated with salmon farming alters fitness-related traits (e.g. by increasing growth-hormone production and overall growth rate, modifying competitive ability and decreasing predator-response behaviour). The high growth rate may also influence the spawning time and subsequent emergence of juvenile salmon and, consequently, the prior-residence advantage during competition. Fleming concludes that all of these factors influenced the outcome of competition for resources in a large-scale experiment, which may result in the displacement of wild salmon and decrease wild salmon productivity.[42]

3.4 Do escaped salmon affect genetic diversity?

Research is ongoing to try to predict the success of progeny of escaped farmed salmon. The discovery of juvenile Atlantic salmon in the wild demonstrates that farmed salmon can escape and survive in salt water, migrate to fresh water and spawn successfully, and that their offspring can also survive in fresh water.[43]

Unlike farmed Atlantic salmon, farmed Pacific salmon can interbreed with wild Pacific salmon. Many people believe this threat to the genetic integrity of wild Pacific salmon stocks is far greater than the threats associated with escaped Atlantic salmon, particularly as interest in chinook salmon farming is increasing.[44] The experiences of interbreeding farmed and wild Atlantic salmon in eastern Canada and northern Europe support this argument. Some salmon populations in Norway are made up of 80 percent farmed fish. As John Volpe argues, the long-term viability of these populations is unknown but the risk of hybridization is extreme: the fish are increasingly homogenized as the natural variations among the wild populations are lost, and the hybrids are ill-adapted to local conditions.[45]

---

[41] Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf p. 36.

[42] Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf , p. 23, and Fleming, Ian A. et al. "Lifetime success and interactions of farm salmon invading a native population", The Royal Society, London, 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/fleming_proceedings.pdf

[43] Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf. While discussion at the workshop focused on Atlantic salmon interacting with Pacific salmon, the same model for discussion applied to escaped Pacific salmon. The participants identified research gaps about long-term effects of mixing of the salmon stocks. Page 35 of the paper has an interesting table showing ecological interactions between wild Pacific salmon and farmed Pacific salmon.

[44] Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia," p. 75. http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf

[45] Volpe, John. 2001. "Super Un-natural: Atlantic salmon in BC Waters," p. 27. http://www.davidsuzuki.org/files/Super_Un_Natural.pdf

Some researchers have argued that Pacific salmon hatchery programs pose a greater risk to genetic adaptation than fish farms due to the sheer numbers of cultured fish released into the wild and the transfer of hatchery fish throughout the Pacific Northwest over many years.[46] DFO researchers in 2000 explained: "The potential interaction between escaped farmed Pacific salmon and wild or hatchery Pacific salmon raises genetic and ecological concerns similar to those associated with hatchery-reared fish, especially transplanted hatchery stocks. The move away from farming Pacific salmon to farming Atlantic salmon, and the reduced number of escaped farmed Pacific salmon in recent years have reduced but not eliminated these risks." (Of course, since 2000, the aquaculture industry has begun to return to Pacific salmon.) In a similar tone to these comments, the following are the only points that AquaNet, a research network in aquaculture, makes about escaped Pacific salmon on its Web site:

- "Farmed Pacific salmon lost from BC salmon farms are capable of interbreeding with wild salmon, but their impact on the wild salmon gene pool is dwarfed by more than 500 million Pacific salmon released from fish hatcheries each year.
- "BC salmon farms have lost a total of 345,000 farm salmon over the past nine years. During the same time period, nearly five billion wild Pacific salmon have been released from salmon hatcheries, outnumbering farm escapes by a ratio of about 15,000 to 1."[47]

However, in their research paper on the aquaculture debate, Julia Gardner and David Peterson explain that, unlike hatchery fish, farmed fish undergo genetic selection: "Farmed fish are often developed from a limited number of source populations, and are selected for traits that improve performance in farm environments." They are expected to be different from localized wild fish and, over time, the genetic diversity of farmed fish decreases. For this reason, if the numbers of "leaked" farmed salmon reached a critical number, interbreeding of these "domesticated" fish with wild fish could have a devastating impact on the genetic makeup of "wild" Pacific salmon.[48]

3.5 Is there evidence that waste from fish farms impact the environment?

Waste from fish farms includes fecal material, urine, uneaten feed, chemical residues (from antibiotics, pesticides, net-cleaning agents) and marine organisms falling off the nets.[49] The decomposition of the waste causes chemical changes in the sediments under the pens and can result in oxygen reduction or depletion. These changes in the seabed may affect the marine organisms naturally occurring in the area.[50]

A series of articles in the journal *Fisheries Research* concludes that net-cage fish farming poses only two "most overall risks" to the environment. Both concern the sediments under the net cages: the accumulation of bio-deposits (feces and uneaten feed) and the accumulation of copper and zinc. In both of these cases, the researchers concluded that the impact of these accumulations is highly dependent on the management and location of the

[46] Noakes, Donald J., Beamish, Richard J., and Kent, Michael L. March 2000. "On the decline of Pacific salmon and the speculative links to salmon farming in British Columbia," in *Aquaculture*, Vol. 183, Issues 3-4, pp. 363-386.
[47] AquaNet. http://www.aquaculture.ca/English/InfoAboutAqua/CAIA_SalmonFacts.html
[48] Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia," p. 79. http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf
[49] For general descriptions of various pesticides, antibiotics, etc. used in fish farming, see David Suzuki Foundation. www.davidsuzuki.org/Oceans/Fish_Farming/Salmon/Pollution.asp and www.davidsuzuki.org/Oceans/Fish_Farming/Salmon/Drugs.asp.
[50] Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia," p. 96. http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf

sites (e.g. how well-flushed the farm sites are and the type of feed used) and, in the case of bio-deposit accumulations, conditions are said to naturally return to normal within a period of weeks to years of the site lying fallow.[51] One study shows that there are no impacts to the seabed between 30 and 225 metres from the site.[52]

It is not clear, however, whether or not the rapid increase in the number of farmed fish counteracts the fact that waste discharge per fish has dropped over the years (less use of antibiotics, more efficient feed causing a reduced volume of food per output of fish, etc.). According to the Salmon of the Americas web site, data from three Canadian provincial government studies reviewing the environmental impact of salmon farming waste in British Columbia show that: "The actual loss of wastes to the environment by today's industry is approximately one-third of what it was in the late 1980s. This, in spite of the fact that production levels at these sites have increased approximately three-fold."[53]

How salmon aquaculture affects water quality is another issue where there is no consensus. Water quality can be affected by algal blooms, antibiotic residues, blood water released during harvesting or processing, net-cleaning chemical agents, and so on. Julia Gardner and David Peterson provide a useful analysis of research in this area, concluding that: salmon farms do not appear to contribute much to algal blooms; wild migratory fish are exposed for an extremely short period of time to any antibiotic residue near fish farms; there is the risk that diseases in blood water may affect wild fish; copper, found in net-cleaning chemicals, can build up on the ocean floor or water column; and the waste water and debris created from net-cleaning can negatively impact oxygen levels in the marine environment.[54] Again, the words "may" and "can" illustrate a lack of clear evidence that the marine environment is negatively impacted in the long term.

[51] Nash, Colin E. June 2003. "Interactions of Atlantic salmon in the Pacific Northwest. VI. A synopsis of the risk and uncertainty" in *Fisheries Research*, Vol. 62, Issue 3 , pp. 339-347.

[52] Brooks, Kenneth M. September 2001. "An evaluation of the relationship between salmon farm biomass, organic inputs into sediments , physicochemical changes with those inputs and in the infaunal response." http://www.salmonfarmers.org/pdfs/FocusedStudyFinalReport1.pdf. The BC government introduced new regulations in 2002 to limit and localize the impact of a salmon farm on the seabed. For more details, see Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia," p. 96. http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf

[53] Salmon of the Americas. http://www.salmonoftheamericas.com/env_water.html

[54] Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia," p. 96. http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf

4 Literature consulted

4.1 Government and non-governmental organization Web sites

AquaNet – Canada's Research Network in Aquaculture. http://www.aquaculture.ca/EnglishWeb.html

British Columbia. Ministry of Agriculture, Food and Fisheries. Fisheries and Aquaculture. http://www.agf.gov.bc.ca/fisheries/index.htm

BC Salmon Farmers Association. http://www.salmonfarmers.org/index.htm

Coastal Alliance for Aquaculture Reform. http://www.farmedanddangerous.org/reports.htm

David Suzuki Foundation. http://www.davidsuzuki.org/Oceans/Fish_Farming/

Salmon of the Americas. http://www.salmonoftheamericas.com/index.html

Watershed Watch Salmon Society. http://www.watershed-watch.org/

4.2 General

Alaska Department of Fish and Game. March 2002. "Atlantic Salmon: a White Paper." http://www.adfg.state.ak.us/special/as/docs/as_white2002.pdf

Canada. [ca. 2001]. The Standing Senate Committee on Fisheries. Interim Report. "Aquaculture in Canada's Atlantic and Pacific Regions." http://www.parl.gc.ca/37/1/parlbus/commbus/senate/com-E/fish-e/rep-e/repintjun01part1-e.htm#E.%20Escaping%20Farmed%20Salmonids

Proceedings from *Speaking for the Salmon* workshop and think tank, March 2000. http://www.sfu.ca/cstudies/science/salmon/aquaculture/proceedings.pdf

Staniford, Don. 2002. "A Big Fish in a Small Pond: the global environmental and public health threat of sea cage fish farming." http://www.watershed-watch.org/ww/publications/sf/BigFishSmallPond(Chile).pdf

4.3 Economic issues

British Columbia. Ministry of Agriculture, Food and Fisheries. 2004. "SWOT (Strengths, Weaknesses, Opportunities and Threats): An Assessment of the BC Seafood Sector and Tidal Water Recreational Fishing – 2004". http://www.agf.gov.bc.ca/fisheries/reports/SWOT2004.htm

Harvey, David J. March 2002. "Aquaculture Outlook: Domestic Sea Food Consumption and Supply Move toward Imports." United States Department of Agriculture. http://usda.mannlib.cornell.edu/reports/erssor/livestock/ldp-aqs/2002/aqs15.pdf

Marshall, Dale. July 2003. "Fishy Business: The economics of salmon farming in BC," Canadian Centre for

Policy Alternatives, BC. http://www.policyalternatives.ca/bc/fish-farms.pdf

Nash, C.E. (Editor). 2001. "The Net-Pen Salmon Industry in the Pacific Northwest." U.S. Department of Commerce NOAA Tech. Memo NMFS-NWFSC-49.
http://www.nwfsc.noaa.gov/publications/techmemos/Tm49/TM49.pdf

PriceWaterhouseCoopers. May 2003. "A Competitiveness Survey of the British Columbia Salmon Farming Industry." Aquaculture Development Branch, Department of Agriculture, Food and Fisheries.
http://www.agf.gov.bc.ca/fisheries/reports/Competitiveness_Survey.pdf

Tuominen, Taija-Riitta and Esmark, Maren. February 2003. "Food For Thought: The Use of Marine Resources in Fish Feed." WWF-Norway. http://www.panda.org/downloads/marine/foodforthoug.pdf

4.4 Environmental issues

Brooks, Kenneth M. September 2001. "An evaluation of the relationship between salmon farm biomass, organic inputs into sediments , physicochemical changes with those inputs and in the infaunal response," prepared for the Technical Advisory Group, c/o BC Ministry of Environment.
http://www.salmonfarmers.org/pdfs/FocusedStudyFinalReport1.pdf

Brooks, Kenneth M. and Mahnken, Conrad V.W. June 2003. "Interactions of Atlantic salmon in the Pacific northwest environment. II. Organic wastes," in *Fisheries Research*, Vol. 62, Issue 3, pp. 255-293. [This article was purchased and is attached to the electronic version of this report.]

Canada. Health Canada. 2003. "Overview: Integrated Pest Management of Sea Lice in Salmon Aquaculture."
http://www.hc-sc.gc.ca/pmra-arla/english/pdf/spm/spm2003-e.pdf

Fleming, Ian A. et al. 2000. "Lifetime success and interactions of farm salmon invading a native population", The Royal Society, London. http://www.sfu.ca/cstudies/science/salmon/aquaculture/fleming_proceedings.pdf

Gardner, Julia and Peterson, David L. January 2003. "Making Sense of the Salmon Aquaculture Debate: analysis of issues related to net-cage salmon farming and wild salmon in British Columbia." Prepared for the Pacific Fisheries Resource Conservation Council. http://fish.bc.ca/reports/pfrcc_making_sense_report.pdf

Harvey, Brian and MacDuffee, Misty. 2002. "Ghost Runs: The Future of Wild Salmon on the North and Central Coasts of British Columbia." Raincoast Conservation Society.
http://www.raincoast.org/files/ghost_runs/execsumm_recomm.pdf

Milewski, Inka. [ca. 2001] "Impacts of Salmon Aquaculture on the Coastal Environment: A Review." Conservation Council of New Brunswick.
http://www.iatp.org/fish/library/uploadedFiles/Impacts_of_Salmon_Aquaculture_on_the_Coastal_E.pdf

Morton, Alexandra et al. 2004. "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", *in Canadian Journal of Fisheries and Aquatic Sciences*. 61(2): 147-157.
http://pubs.nrc-cnrc.gc.ca/cgi-bin/rp/rp2_abst_e?cjfas_f04-016_61_ns_nf_cjfas2-04

Nash, Colin E. June 2003. "Interactions of Atlantic salmon in the Pacific Northwest. VI. A synopsis of the risk

and uncertainty" in *Fisheries Research*, Vol. 62, Issue 3, pp. 339-347. [This article was purchased and is attached to the electronic version of this report.]

Noakes, Donald J., Beamish, Richard J., and Kent, Michael L. March 2000. "On the decline of Pacific salmon and the speculative links to salmon farming in British Columbia," in *Aquaculture*, Vol. 183, Issues 3-4, pp. 363-386. [This article was purchased and is attached to the electronic version of this report.]

Scottish Executive Central Research Unit. 2002. "Review and Synthesis of the Environmental Impacts of Aquaculture." The Scottish Association for Marine Science and Napier University. http://www.scotland.gov.uk/cru/kd01/green/reia-01.asp

Volpe, John. 2001. "Super Un-natural: Atlantic salmon in BC Waters." David Suzuki Foundation. http://www.davidsuzuki.org/files/Super_Un_Natural.pdf

Watershed Watch Salmon Society. December 2001. "Salmon Farms, Sea Lice and Wild Salmon: a Watershed Watch Report on Risk, Responsibility and the Public Interest." http://www.watershed-watch.org/ww/publications/SeaLice/WWSS_Sea_Lice_Report.pdf