Sea Lice Science: a World Apart

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Introduction

I am writing you, the participants of **Interactions between Aquaculture and Wild Stocks of Atlantic Salmon and Other Diadromous Fish Species: Science and Management, Challenges and Solutions,** Bergen, October 2006, because your conclusions (NINA Special Report 34) provide the world a template for true progress. I am writing you, the leaders in this field, out of profound concern that if western Canada further delays recognition of the problems around aquaculture and wild salmon survival that important wild Pacific salmon stocks will be lost. It is urgent and vital that scientists, salmon farmers and fishery managers accept the serious nature of the situation in British Columbia, in hopes that we too can move forward on this issue as you have.

No one is demanding salmon farming leave British Columbia and recently there has been significant improvement in collaboration between all parties. However, measurable biological progress continues to be thwarted by an inappropriate regime of denial by the regulatory agencies, industry and some scientists.

In this era of high-speed communication there should be no barriers to the sharing and implementation of scientific recommendations and management policies to preserve a world-class fish resources. But just such a barrier is in evidence between the Atlantic and the Pacific on the subject of impact of sea lice from salmon farms on wild salmon. This summary is in aid of bridging that gap

Background

In 2002, the unexpected 98% failure of the Pacific Area 12 Mainland pink salmon run, affecting seven adjacent rivers and the 3rd largest pink salmon population in BC, (Figure 1) triggered an assessment by the Pacific Fisheries Resource Conservation Council (PFRCC). In absence of political interference, sea lice from salmon farms were considered the most likely cause of this collapse because ocean survival was high coastwide and no calamity affecting all seven rivers was identified. There were 27 salmon farm sites in the nearshore and sea lice infestation reported on this pink salmon cohort when they were juveniles (Morton and Williams 2003). The PFRCC recommended fallowing the entire Broughton Archipelago for the 2003 juvenile wild pink salmon out-migration (www.fish.bc.ca).

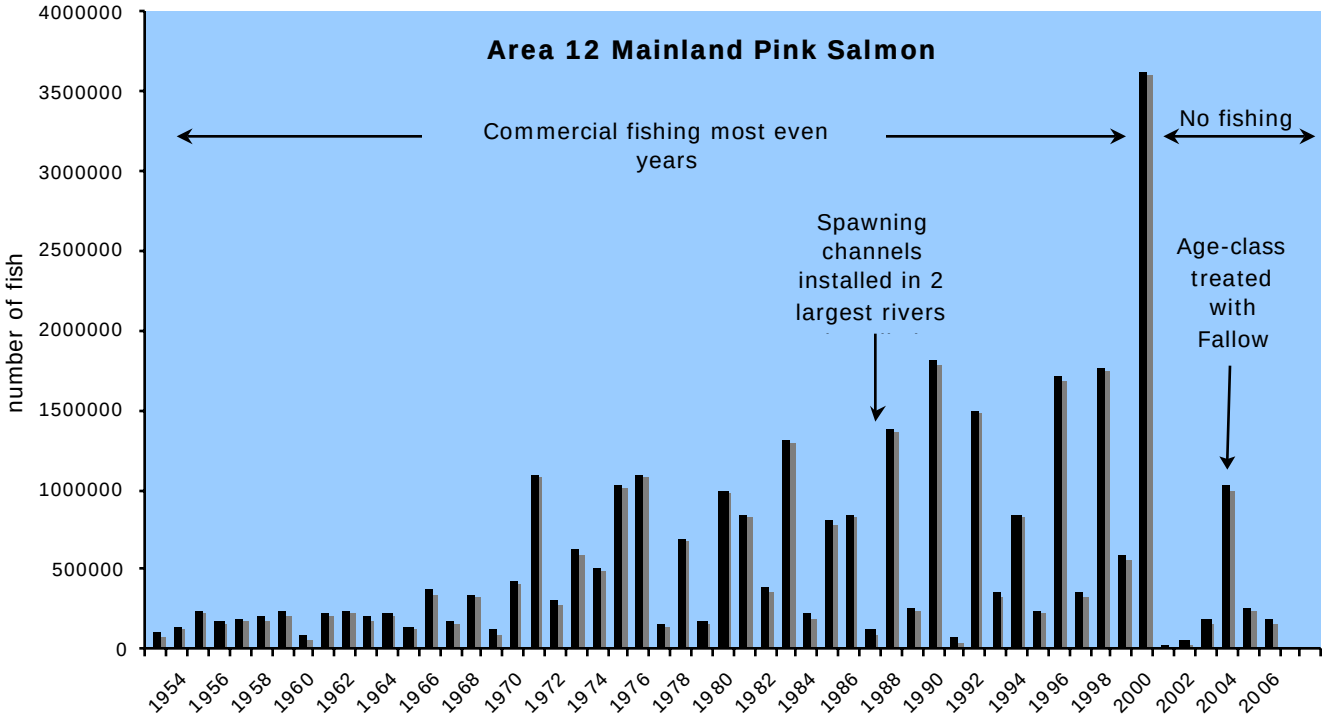


Figure 1 (DFO data)

A compromise was struck and in 2003 the proposed primary juvenile wild salmon out-migration corridor was fallowed (*Provincial Pink Salmon Action Plan*, Figure 2). Sea lice numbers fell significantly throughout the fallow route in 2003 (Morton et al. 2005) and survivorship for this pink salmon cohort exceeded all records for the species (Beamish et al. 2006).

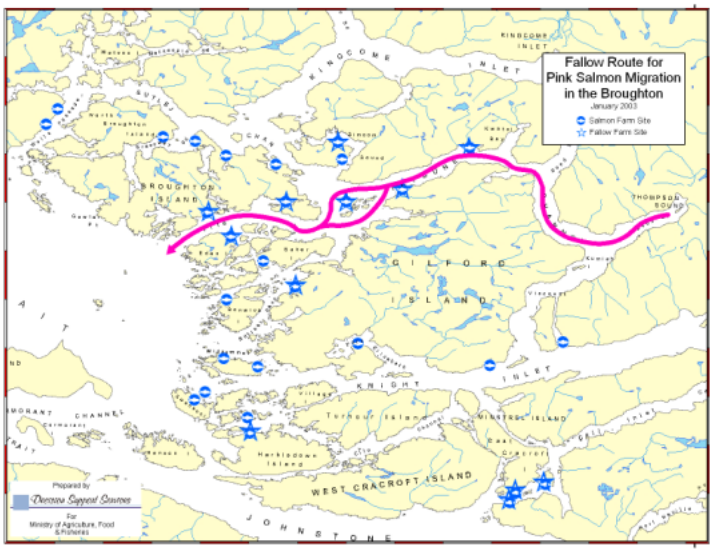


Figure 2 (Provincial government map)

Since 2003, the fallow route has been restocked and Slice (emamectin benzoate) administered to the farm salmon through emergency drug release. In 2004, sea lice prevalence and abundance on juvenile pink and chum salmon rose to pre-fallow levels (Morton et al. 2005). The pink salmon stock remains depressed despite complete closure of the commercial fishery and increased effort counting returning adults (Figure 1). The 3-year-old chum salmon that went to sea through the fallow also rebounded a year later (Figure 3).

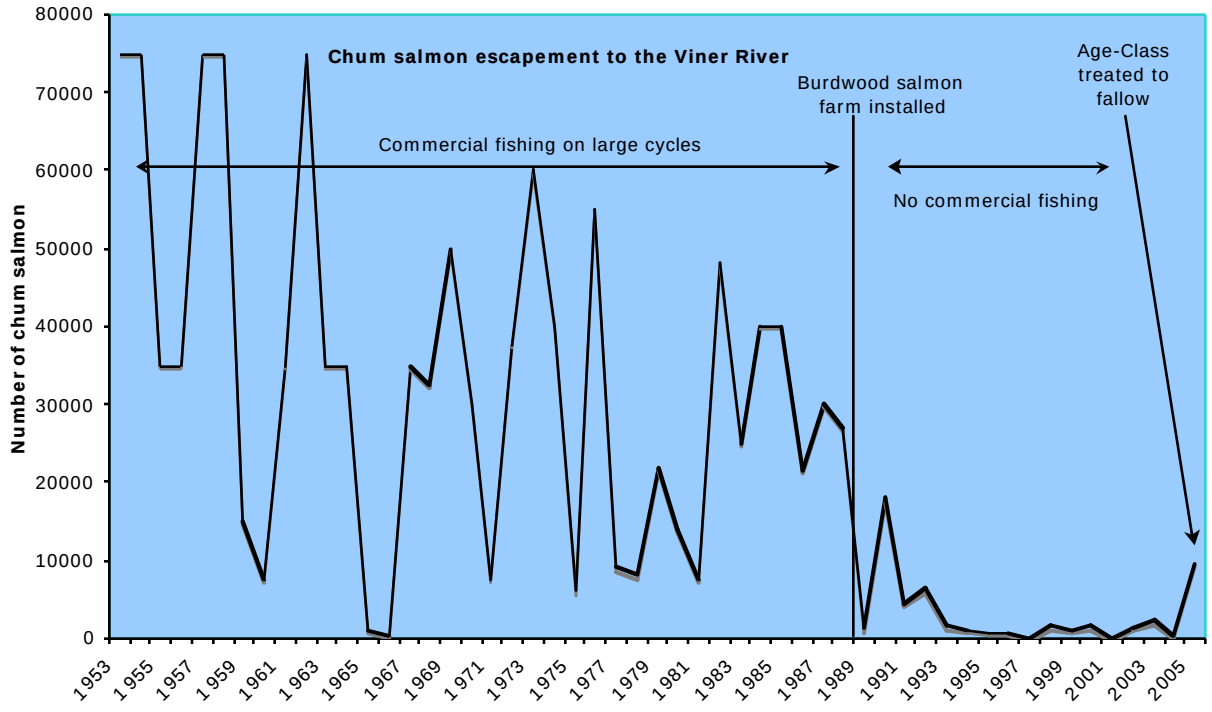


Figure 3 (DFO data)

When sea lice first became an issue in British Columbia, it was perhaps debatable whether salmon farms were the cause, as was already known in Europe. However, nine papers have now been published in primary scientific literature establishing a strong causal relationship between salmon farms and sea lice infestation of wild salmon in BC, similar to Europe, (Appendix1). These studies establish salmon farms as the source of lice infestations on juvenile wild salmon, and suggest that only 1 - 2 motile sea lice are killing juvenile pink and chum salmon, because these salmon weigh less than 0.5g at saltwater entry. The most recent study reports up to 91% of juvenile wild salmon passing salmon farms are dying of sea lice (Krkosek et al. 2006). Combined these papers provide ample weight of evidence to accept sea lice from salmon farms are killing wild salmon in BC, just as they are in Norway, Scotland and Ireland.

Juvenile pink salmon infected by *L. salmonis,* note the lack of scale development on this young fish and the "tracks" caused by gravid sea lice puncturing skin

Present

Interactions between Aquaculture and Wild Stocks of Atlantic Salmon and Other Diadromous Fish Species symposium, October 2006, Bergen, Norway, produced a seminal document (NINA Special Report 34) reporting:

- There was general agreement in the presentations in this session that compared to the symposium in Bath in 1977; understanding of the interactions between wild and cultured salmon has increased considerably.
- This information had **conclusively** identified a serious threat to wild salmon stocks from escapees, particularly where the wild stocks are depressed and **sea lice.**
- Furthermore, **the industry** now acknowledges that its activities can have **damaging impacts** on the wild stocks and we believe that this acceptance provides a basis for making real progress in finding cooperative solutions to the remaining challenges.
- The interactions between farmed and wild salmon can be damaging and need to be **eliminated,** not just reduced.

The "Debate"

While there is no substantive debate in the scientific literature, the pretense of scientific uncertainty is thwarting progress in BC. This impasse to effective management is political, based entirely on unpublished, unsubstantiated speculation. For example:

- **Sticklebacks** are still cited as over-wintering hosts for *L. salmonis* and a source of the observed infestation of juvenile wild salmon in complete absence of evidence.
  Fact – no gravid *L. salmonis* has been observed on sticklebacks. Jones et al. (2006), experimentally infected sticklebacks with *L. salmonis* and did not observe any develop to motile stages. Even if sea lice mature to motile stages on sticklebacks and then disperse in search of a salmonid host, as others have hypothesized, these lice would be without a host from early winter through late March when juvenile wild salmon enter seawater.

- **Over-wintering sea lice buried in estuarine sediments** are still cited as a source of the spring infestation of juvenile wild salmon.
  Fact – No *L. salmonis* have actually been reported in ocean sediments anywhere.

- **Large over-wintering wild salmon populations** are cited as the source of early spring sea lice infestation of juvenile wild salmon in complete lack of evidence.
  Fact – While Chinook salmon were traditionally, frequently caught during winter months in the Broughton Archipelago neither local fishermen, nor government test boats can find them anymore. If there are any over-wintering, adult, lice bearing wild salmon, their population is vastly smaller than the several million lice bearing farm salmon, now in the archipelago year round.

- **The pink salmon decline was due to over-spawn in 2000.**
  Fact – Over-spawn was not a factor in the biggest salmon producing river in the Broughton, the Glendale, because there is a managed spawning channel in that river. This channel was closed when it reached optimal capacity. If over-spawn was the cause of the collapse, the Glendale River should have been exempt from the collapse, but it was not.

- **The massive 2001 pink salmon fry out-migration exceeded capacity and starved.**
  Fact – First this does not address the heavy infestation of sea lice in spring 2001 highly correlated with adult stocked salmon farms (Morton and Williams 2002). Second, we know the weights of uninfected fry in 2001 were normal and do not suggest an inadequate food resource.

- **If salmon farms are the cause of sea lice infestation on wild juvenile salmon, sea lice would have appeared at the onset of salmon farming in 1987**.
  Fact – The first salmon farms in the area were stocked with 125,000 Chinook salmon per site. In the 1990's there was a shift to Atlantic salmon. In 1995, a moratorium capped influx of new sites, but BC farm salmon production continued to climb. The sites were simply stocked with more fish (up to 1.3 million/site).

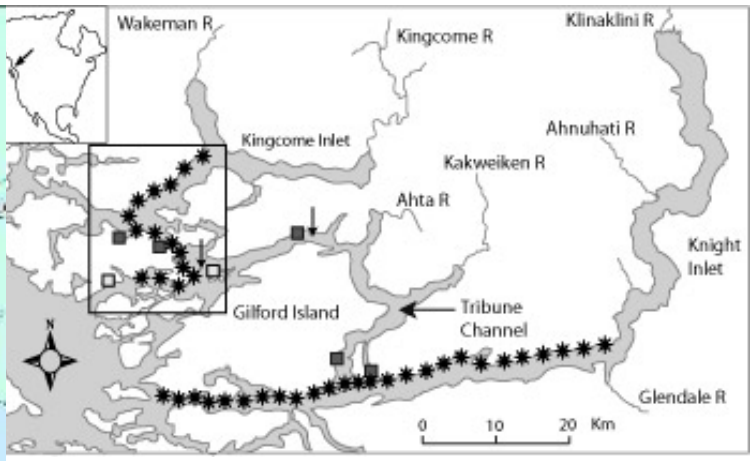
High stocking density precipitated sea lice infection of wild salmon. As in Norway, more hosts = more sea lice.

- **The Broughton Archipelago simply has more sea lice than elsewhere in BC.**
  Fact- We are finding high sea lice infestation rates wherever optimal salinity, salmon farms and wild salmon occur. In areas without salmon farms we do not find *L. salmonis* on juvenile wild salmon in the early spring. Of significant concern is an area where salmonids from BC's biggest salmon bearing river, the Fraser River, swim through narrow channels densely clustered with salmon farms. Young salmon of all species, steelhead and young-of-the-year herring are all infected near stocked salmon farms in this area (Morton et al. *in progress*).

- **DFO found pink and chum salmon are more resistant to sea lice than reported by Morton and Routledge.**
  Fact –DFO examined sea lice susceptibility in pink salmon averaging 10.6g and chum salmon averaging 12.4g. Morton and Routledge (2005b) observed mortality in lice-infected pink and chum salmon averaging 1.7g and pre-scale development. caught outside salmon farms. Because sea lice impact is host size dependant it is not surprising that Morton and Routledge (2005b) recorded much higher mortality than Jones et al. (2006). Morton and Routledge (2005b) used such small fish in their work because this is the age-class at issue.

- **DFO data do not show spatial relationship** between sea lice infestation of juvenile wild salmon and salmon farm sites.
  Fact- DFO (Fisheries and Oceans Canada) samples an extensive number of sites in the Broughton, but in analysis they clump up to 17 sites over approximately 20 km into a single value. Thus a diversity of exposure categories including estuaries, before farms, past farms, no farms are thrown together into one ambiguous number. In contrast, Krkosek et al (2006) examined infestation at point sources at precise intervals approaching and passing salmon farms. Thus, while DFO's data suggests sea lice infestation is more correlated with salinity than salmon farms, (perhaps because as a fish swims from low salinity to high salinity it also passes an increasing number of salmon farms), Krkoseks' data is much finer scale to reveal patterns specific to individual farms.

DFO grouped data from all sites between the lines



Krkosek reported infestation at each site individually, squares = farms

- **DFO has suggested sea lice infestation does not decrease condition factor in juvenile wild salmon.**

  Fact- When first infected with sea lice, pink and chum salmon fry feed voraciously and for a time remain robust. Then they stop feeding, lie still on the surface, non-responsive to movement from above and unable to school. Morton and Routledge (2005a) dubbed these "loners." Loners do have low condition factor values and die within days in the captive environment. In the wild, the behaviour of these fish would expose them to higher predation rates by birds and fish and thus selectively remove them from the population sampled by DFO. The black marks on these pink salmon are chalimus stage wounds. In healthy young pink salmon, the head is not the widest point on the body. Again these fish have not yet developed scales, exacerbating sea lice impact on condition of this age class of pink salmon.

The Denial

The denial within BC that sea lice from salmon farms are infecting and killing wild salmon will be familiar to most of you. The cost of delaying effective management of the problem is also likely familiar, in terms of loss of valuable wild salmon genetic diversity. The very recent statements below typify the depth of the current impasse in BC.

- **Federal government:** Fisheries and Ocean Canada "At this time our research does not support the close association between salmon farms, sea lice, and loss of wild salmon that has been reported"(DFO, Brian Riddell**,** section head, Salmon Stock Assessment and Enhancement Evaluation, Campbell River, Mirror Dec. 1, 2006)

- **Some scientists:** Sea Lice: The Science Behind the Hype (Nov 2006 www.FraserInstitute.ca) (Kevin G. Butterworth, K. Fiona Cubitt, Bengt Finstad, Felicity A. Huntingford and R. Scott McKinley), "more conclusive evidence is needed before a cause and effect relationship can be demonstrated between sea lice present on salmon farms, and infection levels among wild salmon…while higher sea lice infestations tend to occur in areas of BC with salmon farms, this correlation **cannot be used to conclude** that salmon farms are, in fact, the cause of the more intense infestations."

- **Provincial government:** Pat Bell, Minister, Agriculture and Lands (MAL) in charge of siting salmon farms in BC publicly dismissed the most recent science on sea lice to deny that 91% of some wild salmon stocks are being lost to salmon farms (Krkosek et al. 2006). "It was largely old data that had been collected using dipnet technology, as opposed to the hard science of doing a statistical regime around calculating the appropriate number of fish that have to be sampled in a long-term testing regime," (Dec. 20, 2006, North Island Gazette). Minister Pat Bell misidentified the gear type and the methods, both deemed appropriate for publication by The National Academy of Sciences of the USA

- **Industry**: "There is absolutely no scientific evidence demonstrating fish farms are causing sea lice infestations of wild fish," http://www.newswire.ca/en/releases/archive/October2006/03/c4671.html

Solution

There is no scientific uncertainty that farm-origin sea lice are a serious problem in B.C. as they are in Norway, Scotland and Ireland. The affect of sea lice on juvenile wild salmon in BC is exacerbated by two Pacific salmon species entering seawater in a substantially less mature phase than any Atlantic salmon or sea trout. A solution is known, British Columbia scientists, both government and non-government published on the efficacy of removing farm salmon from areas where wild juvenile salmon are both numerous and very immature. Delaying implementation of this solution will ultimately harm the salmon farming industry, as well as, the wild salmon resource. Obligations established by the **WTO** include "policies and practices that trade in fish should **not result in environmental degradation."**

However, not only is the solution being actively ignored, I feel we are going backwards. While pink and chum salmon are known to weigh less than 1.4g throughout the peak months of their out-migration in the Broughton juvenile migratory corridor (Morton et al. 2005), Norwegian-owned companies have applied to double the size of their farms in exactly this area. These companies must be familiar with impact of sea lice on small juvenile wild salmon. While using the drug Slice on farm salmon appears to have significantly reduced sea lice abundance on wild salmon in recent years, it has not reduced it enough to protect a pink or chum salmon weighing less than 1.4g. Unfortunately, it is irrelevant if a fish dies of one louse or 50 lice. In addition, we are warned that resistance is a likely outcome of continual use of any drug on very large farms.

Because Broughton salmon farms are sited on prime shrimp, prawn and other wild commercial and sport fishery grounds, drug contamination of wild stocks is also a looming concern. As well, even if the drugs suppress the number of sea lice per farm salmon, increasing the size of the farms places more hosts in the environment, negating any reduction of lice per fish. The tourism operators in British Columbia are now so worried they are calling for removal of the farms and some aboriginal nations in the Broughton Archipelago have adopted a zero-tolerance policy regarding salmon farms.

I have been contacted by enough scientists to recognize this state of affairs as analogous to what took place in Norway, Scotland and Ireland only recently. However, given your appraisal in Bergen: **interactions between farmed and wild salmon can be damaging and need to be eliminated, not just**

reduced it would not seem unreasonable to expect a close to the "debate," here in BC and immediate high efficacy management. The science is clear. We cannot line long, narrow, juvenile wild salmon migratory corridors with consecutively sited, large farm salmon populations and expect the wild salmon to survive. BC's scientific appraisal of 91% wild salmon loss under these conditions is nearly identical to what Holst et al. (2002) reported in comparable Norwegian hydrographics. If the farms increase in size they will place over 7 million farm salmon on the juvenile wild salmon migratory corridor of BC's 3rd largest pink salmon population.

Canadian fishery managers are already answerable to the demise of one of earth's greatest food resources, the North Atlantic cod stocks of the Grand Banks, This management error, duly forecast by the government's own scientist (Ransom A. Myers), and suppressed, resulted in irrevocable social and economic detriment to the economies of eastern Canada and the loss of a global food resource. At a time when the world recognizes fish stocks are finite and reaching extinction levels, DFO and MALs' denial of the impact of salmon farms on wild salmon became insupportable on publication of the Convener's Report (NINA Special Report 34).

Request

We experienced poor conditions in BC rivers last fall. A drought, followed by flood conditions made rivers inhospitable to spawning salmon. Sea lice infections have been reported on 6 Broughton pink salmon cycles (3 even year runs, 3 odd year runs). The even year cycle is the larger one and it was once again very depressed last fall. As a result of this collision of circumstances, survival of this stock may well depend on maximizing marine survival of the juveniles due to begin out-migration in March 2007. The only way we *know* how to do this is to fallow their migratory corridor. I am therefore calling on Cermaq, Marine Harvest and the Federal and Provincial regulatory agencies of Canada to apply the conclusion reached in Bergen, that sea lice from salmon farms are a serious impediment to wild salmon survival to the Broughton Archipelago salmon stocks.

This is not the only action required, but it would give us time to move forward. The *only* successful management action in BC with scientific verification is fallowing the migratory corridor that preceded the exceptional pink salmon marine survival reported by DFO scientists Beamish et al. (2006). In addition, in 2003, farms in the eastern portion of the migratory corridor either did not exist or were stocked with smolts and this likely helped reduce sea lice as well. These sites, scheduled to be fallowed this spring (2007) to protect out-migrating juvenile salmon, now intend to

remain stocked, due to poor growth rates. Unfortunately these fish are at the height of infective capability (adults, pre-harvest, thus reducing ability to delouse). These farms need to be towed seaward away from the rivers to give the migrating juvenile salmon time and space to increase in size before being infected.

I understand this proposal is extensive, but there is no point in repeating management actions that have not worked to date. Given the vulnerability of the wild stocks at this point the time to experiment with them is over. Chemical treatment is expensive and if the natural hydrographics and diminutive size of pink chum salmon negate the efficacy of this strategy it is a wasted effort.

By fallowing the area a second time we would also have the opportunity to substantiate or reject the hypothesis that moving farm salmon out of habitat used by wild salmon that have not yet developed scales and weigh less than a few grams caused wild salmon to rebound.

Given what has been so clearly summarized by you in Bergen, it is my opinion that the Canadian federal and provincial governments should either apprise First Nations, tourism operators, commercial and sport- fishermen and local residents that farm salmon have been given precedence at the expense of wild Broughton salmon runs, or they must mount an *effective* rescue before the 2007 juvenile wild salmon out-migration begins in March. Bergen gave us international consensus by industry, governments and scientists that siting large salmon farms, consecutively, in confined waterways, transited by juvenile wild salmon can be very harmful to wild salmon populations. To continue expanding and farming salmon under exactly these circumstances, with the understanding of how this will affect a world-class wild fish resource is a clear violation of the principles of the United Nations FAO **Code of Conduct for Responsible Fisheries** signed by Canada. It further violates **WTO** principles against environment degradation caused by practices that trade in fish.

Representatives of Fisheries and Oceans Canada are listed as participants in the *Conveners' Report* and I do not see any statement by them refuting the consensus that "the interactions between farmed and wild salmon can be damaging and need to be **eliminated,** not just reduced." It would be deceptive for DFO to agree on the world stage, and then tell British Columbians "**At this time our research does not support the close association between salmon farms, sea lice, and loss of wild salmon that has been reported**"(DFO, Dec. 1, 2006).

With this document, I have endeavored to contrast the "take-home messages" from Bergen (pg 64-69, Conveners' Report) with the stance by some of the same scientists, companies and agencies in BC. It is unacceptable that synchronized area management is still not in affect in the Broughton Archipelago. It is unacceptable that the regulatory agencies and industry are still denying relationship between salmon farms and sea lice. And it is unacceptable that despite a serious sea lice problem and evidence of resulting wild salmon decline, that the industry is pushing hard to increase both the number of farm salmon per site and the number of farms in the Broughton Archipelago.

I am hoping that you will help in the ways that you can to invite British Columbia to drop the strategy of denial and join the world community in moving towards solutions.

Thank you for giving us the opportunity to have both farmed and healthy wild salmon populations in British Columbia and thank you so much for reading through this.

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Coho salmon are also infected by sea lice in areas near salmon farms

Appendix 1

Morton, A.B**.,** and Williams R. 2003 Infestation of the sea louse *Lepeophtheirus salmonis* (Krøyer) on juvenile pink salmon *Oncorhynchus gorbuscha* (Walbaum) in British Columbia, *Canadian Field Naturalist* **117**:634-641.

Morton, A., Routledge, R., Peet, C., and Ladwig, A. 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. *Canadian Journal of Fisheries and Aquatic Sciences*, **61**:147-157.

Morton, A., Routledge, R., and Williams, R. 2005. Temporal patterns of sea lice infestation on wild Pacific salmon in relation to the fallowing of Atlantic salmon farms. *North American Journal of Fisheries Management*, **25**:811-821.

Morton, A., and Routledge, R. 2005. Fulton's Condition Factor: Is it a valid measure of sea lice impact on juvenile salmon? *North American Journal of Fisheries Management*, **26**: 56-62.

Morton, A. and Routledge, R. 2005. Mortality rates for juvenile pink and chum salmon (*Oncorhynchus gorbuscha* and *keta*) infested with sea lice (*Lepeophtheirus salmonis*) in the Broughton Archipelago. *Alaskan Fisheries Research Bulletin*, **11(2)**: 146-152.

Krkosek, M., Morton, A. and Volpe, J.P. 2005. Nonlethal Assessment of Juvenile Pink and Chum Salmon for Parasitic Sea Lice Infections and Fish Health. *Transactions of the American Fisheries Society*: **134(3)**: 711-716

Krkosek, M., Lewis, M.A. and Volpe, J.P. Transmission dynamics of parasitic sea lice from farm to wild salmon. *Proceedings of the Royal Society B*: **272**: 689-696.

Krkosek, M., Lewis, M.A., Volpe, J.P. and Morton, A. 2006. Fish farms and sea lice infestations of wild juvenile salmon in the Broughton Archipelago – A rebuttal to Brooks (2005). *Reviews in Fisheries Science* **14**:1-11

Krkosek, M., Lewis, M.A., Morton, A., Frazer, L.N., and Volpe, J.P. 2006. Epizootics of wild fish induced by farm fish. *Proceedings of the National Academy of Sciences***103**:15506-15510.