Appendix 9: Council Member View on Risk – Perspective 1

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Appendix 9 – Council Member View on Risk – Perspective 1

The Case for Caution – Executive Summary

Based on the level of risk of harm to the environment, First Nations' concerns and the potential for significant economic loss, we believe this is an important opportunity for the Minister of Agriculture to be the first in a very long time to stand up for wild Pacific salmon and to align B.C. with the established and emerging trends in both environmental and Indigenous law.

Giving consideration to the Council's mandate and the Case for Caution set out in this Appendix, we recommend that the Council's advice to the Minister encourage her to:

1. Acknowledge that British Columbians have a very low tolerance for putting wild salmon at risk, and accept that the science on impacts such as sea lice and pathogen transmission, combined with statistical data which strongly suggests that salmon which pass by open net-pen farms fare substantially worse than those which do not, confirms that open net-pen farms pose more than a minimal risk of serious harm to wild salmon and to the environment.

2. Urge Premier Horgan and his Cabinet to announce that the Province will not renew existing tenures and will not issue new tenures for marine finfish salmon farms using open net-pens on the basis that they are not socially and ecologically sustainable.

3. Call on the Federal Government to increase oversight and public transparency in compliance with conditions of licences and the management of existing farms in the interim, including a prohibition on the transfer of PRV-infected smolts to open net-pens.

4. Commit to the development and implementation of a plan to transition (and sustainably grow) British Columbia's aquaculture industry to closed containment by a set date (i.e. 2025).

5. Recognize the future risks from climate change and other environmental factors outside of our immediate control, and commit to investing in habitat restoration to further protect B.C.'s wild Pacific salmon and support sustainable, healthy, genetically diverse wild salmon populations that are more resilient to these risks.

These recommendations are based on the evidence and analysis supporting the conclusion that the risk of serious harm posed to wild Pacific salmon from open net-pen salmon farms is well beyond a minimal risk, and that the level of risk is far higher than what is required to conform to the precautionary principle, as required by law.

In our analysis, we find that Fisheries and Oceans Canada (DFO) has effectively abandoned its constitutional mandate to protect fisheries and oceans by, among other things, failing to adopt a precautionary approach in its regulation of open net-pen aquaculture, in order to promote and develop the salmon farming industry. Examples of this are:

- without explanation, departing from the International Standard for diagnosing Heart and Skeletal Muscle Inflammation (HSMI) in farmed Atlantic salmon, in favour of its own diagnostic approach – an approach that allows DFO to deny that HSMI has been present in B.C. salmon farms since at least 2011;
- failing in its 2016 management approach to the piscine orthoreovirus (PRV) to test Atlantic salmon smolts for PRV prior to transfer into open net-pens, contrary to the 2015 court decision in *Morton v. Canada (Fisheries and Oceans)* and its duty under the *Fisheries Act*; and
- failing to comply with s. 56 of the *Fishery (General) Regulations* by setting a risk threshold that only triggers harm reduction at a threat of species-level extinction.

In light of DFO's actions contrary to the prevailing science and the law with respect to its duty to protect wild salmon, it falls to the B.C. Government to do what is best for British Columbia. This accords with the broad authority under s. 11 of British Columbia's *Land Act* to dispose of Crown land only if the Minister considers it advisable in the public interest. It also accords with the emerging case law that requires the Minister to consider whether granting tenures for finfish aquaculture is consistent with the precautionary principle's requirement to anticipate and prevent potential environmental degradation or irreversible damage.

Further, Canada's Constitution requires the B.C. Government to respect First Nations' rights. The First Nations Fisheries Council of B.C.'s resolution not to support open net-pen salmon farms, and the occupation of salmon farm facilities in 'Na̱mgi̱s and Musgamagw territories, demonstrates that there is a significant level of First Nation opposition to open net-pen aquaculture. Allowing farms in First Nation territories without the consent of those Nations also violates the United Nations Declaration on the Rights of Indigenous Peoples. First Nations who rely on wild salmon that migrate near open net-pens are also impacted and must have their constitutional rights respected.

Our assessment of the level of risk is based on considering the cost of harm and the probability of harm occurring. In evaluating the potential cost of harm, we find that the full ecological, cultural and economic cost of a catastrophic loss of wild salmon is incalculable. In such circumstances, it follows that the risks to wild salmon of using open net-pens to raise farmed salmon must be extremely low to be acceptable.

Even if the decision is based solely on economics, the wild salmon economy is a greater driver of economic prosperity in B.C. than is the aquaculture industry. It provides British Columbians with 42% more jobs than aquaculture and contributes 26%, or $145.8 million, more to British Columbia's GDP annually. Importantly, it is the open net-pen aquaculture industry that poses a threat to the viability of the wild salmon economy, not the other way around. The risk of further damaging the wild salmon economy is not worth taking. Certainly not until the lack of harm to wild Pacific salmon is proven by the aquaculture industry.

Evidence presented to the Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (Cohen Commission), and the published science since that time, provides compelling evidence that the probability of significant harm is more than minimal, including:

- Dr. Rosenau's analysis in his presentation to Council, and that of other researchers, shows very good evidence that salmon passing close to open net-pens have substantially worse survival rates than those which do not;
- Dr. Dill's presentation to Council that risks to wild salmon from sea lice amplified by open net-pens are "unambiguous and substantial"; and
- research by Dr. Miller and others that shows while we do not yet have a complete picture of the impacts on wild Pacific salmon from high levels of exposure to PRV, the available evidence strongly supports a conclusion that the level of risk is high, warranting both caution and urgent further investigation.

Dr. Miller reported to Council that PRV-associated disease symptoms of HSMI and jaundice syndrome are present on B.C. Atlantic salmon and Chinook salmon farms, respectively. There is also published research finding that a PRV-like virus associated with HSMI-like symptoms has been confirmed in farmed Coho in Chile. The Strategic Salmon Health Initiative (SSHI) recently published a finding of correlational evidence that PRV is the one virus in common for the Chinook salmon farm (Creative Salmon) in B.C. and the Coho farm in Chile, and in a similar disease outbreak in Rainbow Trout in Norway. Japanese researchers have also found a cause and effect relationship between PRV-2 and a disease they call erythrocytic inclusion body syndrome (EIBS), which is highly similar to the jaundice/anemia and HSMI diseases described in B.C. Chinook salmon, Chilean Coho and Norwegian Rainbow Trout.

This evidence supports the conclusion that the risk associated with PRV is more than sufficient to trigger the legal requirement to apply the precautionary principle. This is especially so in light of the Committee on the Status of Endangered Wildlife in Canada's recent recommendation to the Federal Minister of the Environment that eight of the 24 Fraser River sockeye populations be declared endangered, and a further seven declared threatened or of special concern.

Further, Council was told that SSHI has identified several novel viruses yet to be thoroughly studied, and that the cause of the "mortality related genomic signature" discussed in the Cohen Commission proceedings which appears to have seriously disrupted Fraser River sockeye runs has still not been identified. Whether or not offending viruses originate naturally or in fish farms is immaterial. High rearing densities in fish farms act as bio-amplifiers, which present these contagious viruses (and sea lice) in breathtakingly large numbers to passing smolts heading out to sea and to adult fish returning to spawn.

The root of the problem is the inability of open net-pen farms to capture and control waste combined with the free flow of parasites and pathogens between the farms and the marine environment. As Dr. Dill said in his presentation to Council:

> *Unlike Las Vegas, what happens in the pens doesn't stay in the pens.*

Attempting to respond to risk by addressing simple, short-term objectives in a "harm reduction" approach suggests that the problem the aquaculture industry is facing is one of public perception and that perception can be managed by easy, short-term solutions that avoid significant regulatory reform. This approach mistakes cause for effect. Lack of public trust is not the cause of the aquaculture industry's problems. Lack of public trust is what we get when the regulator fails to adequately manage risk. Where it advocates for short-term objectives to sway public perception, the Council's Report is protecting the failing status quo at the expense of wild salmon.

Given the level of risk, we believe the only way to build trust is through reform of the regulation of the industry. That reform begins with the regulator following the science and the law and by ceasing to issue licences that introduce and transfer PRV-infected smolts into open net-pens until it can be shown that wild Pacific salmon are not impacted. This puts the burden of proof squarely where it should be – on the regulator and the industry. That reform continues by acknowledging that the risks presented by open net-pens, which require regular flushing to operate, cannot ever be adequately mitigated and continues further by embracing a transition to closed containment.

We do not accept any assertion that because there are other stressors impacting wild salmon that are much more difficult to control (such as climate change) that we should give up on controlling the stressors within our control, particularly given the Council on the Status of Endangered Wildlife's recognition of the fragility of wild salmon.

While reducing the risk of harm to wild salmon does not require that an alternative be available before harmful practices are halted, we do not believe it needs to be an either/or scenario – healthy populations of wild Pacific salmon or a successful aquaculture industry. Emergent closed containment aquaculture removes the risk of open net-pen aquaculture to wild salmon. Council heard that the open net-pen industry has evolved over the past 30 years. Published reports show that advancements in land-based closed containment technology are coming on stream faster than anticipated, with optimization, standardization and scale improving the economic feasibility, making closed containment technology the logical continuation of that evolution. While acknowledging that innovation typically occurs over several iterations, the risk of harm dictates that the transition in B.C. must begin now as closed containment technology provides B.C. with the best chance of protecting wild Pacific salmon and of taking advantage of the economic opportunity for sustainable aquaculture.

Last but not least, we must learn from the devastating demise of Canada's northern cod stock. With the benefit of hindsight, the demise has been shown to have resulted largely from regulatory mismanagement. DFO failed to acknowledge risk. DFO was willing to ignore uncertainty and interpret data optimistically. It squashed other viewpoints. By doing all this, DFO was able to hold that decisions were based on science when they were not. At the time, DFO blamed environmental factors outside of their control, though it became increasingly clear these factors played only a minor role in the destruction of the stock – all in the name of protecting jobs and the economic interests invested in the status quo, all of which were ultimately lost and may never be recovered.

The only good that can come from the loss of northern cod is to learn from it and make sure that it never happens again. Thus, in response, in 1996 Canadians entrenched the precautionary principle in Canada's *Oceans Act*. British Columbians expect the Minister and DFO to follow it and will accept no less for wild Pacific salmon.

It is on this basis that we make the recommendations set out in this Case for Caution.

The Case for Caution – Introduction

> ***There is a risk that DFO will not proactively examine potential threats to migrating sockeye salmon from salmon farms, leaving it up to other concerned parties to establish that there is a threat. – Mr. Justice Bruce Cohen*** [1]

When Mr. Justice Cohen wrote those words, it seems likely that he was mindful of the events leading up to the closure of the northern cod fishery in Atlantic Canada in 1992, the greatest crisis ever precipitated by DFO, a turn of events that resulted in the virtual closure of that fishery for the past 25 years. The history of decisions leading up to the crisis makes interesting reading. As a result of mismanagement of northern cod, in Newfoundland alone over 35,000 fishers and plant workers from over 400 coastal communities became unemployed.[2]

We are struck by the similarity of the attitudes of senior DFO personnel prior to the cod crisis with those attitudes seemingly prevalent in DFO today regarding aquaculture management in B.C. It reminds us of Yogi Berra's observation that it looks like "déjà vu all over again," as we watch DFO risk precipitating a second crisis, this time along the coast and watersheds of B.C. at a time when many wild Pacific salmon species are at dangerously low population levels.

Our strong desire and responsibility to protect wild Pacific salmon emanates not just because of the cultural and economic benefits they provide, but also because they are a keystone species, transporting nutrients that support aquatic and terrestrial ecosystems at each stage of their lives.[3] This calls for taking extreme care because the demise of wild Pacific salmon would devastate the cultures, economies and species that rely on them.

In this Case for Caution, we set out the evidence that supports finding that the risk of harm posed to wild Pacific salmon from open net-pen salmon farms goes well beyond a minimal risk of serious harm. Furthermore, the cost of that risk in ecological, cultural and economic terms is so high that we believe the Council's advice to the Minister of Agriculture must state that this level of risk is unacceptable to British Columbians.

We thank former Minister Letnick for appointing us to this Council and Minister Popham for allowing our work to continue and for taking this issue and the accompanying heavy responsibility so seriously.

Participating in the deliberations of the Council has been a valuable experience –one that has forced us all to confront some strongly held views different from our own. Based on these deliberations and some independent fact-gathering, we set out below our analysis and conclusions. Some readers may disagree with what we have written. None of us has a complete body of knowledge about wild and farmed salmon. We welcome comments from any reader, particularly if buttressed by facts.

The Starting Point – What Is the Level of Risk in Open Net-Pen Aquaculture?

Council members expressed a shared vision of "sustaining wild salmon within a healthy ecosystem while recognizing the interdependence and importance of salmon to communities in B.C." and expressed a desire to provide advice that conforms with this broader aim.

From our perspective, achieving this vision must start with an assessment of the level of risk, which is a factor of the cost of the potential harm that open net-pen aquaculture may cause and the probability that harm will occur. Only then can we discuss whether the level of risk is acceptable to British Columbians.

As we undertake our analysis, we share parallels to a time when comparable ecological and economic costs were realized: the devastating demise of Canada's northern cod stocks. We do this with the goal of helping to ensure a better outcome for wild Pacific salmon.

In 1988, only a few years before Canada admitted that the northern cod fishery was in collapse, the official word was that all was well:

> The Department of Fisheries and Oceans prides itself on world-class scientific capability. The unprecedented rebuilding of the Northern Cod resource since 1977 is ample testimony to sound management practices based on good scientific advice. Having nurtured the resource to a good stage of health overall, the department is now setting out to enhance that all-important achievement by addressing more intensively and more comprehensively other problems in the fishery.[4]

By 1989, reality mocked DFO's optimism. By 1992, there were virtually no northern cod left and Canada announced a moratorium on commercial cod fishing. By 1996, Canada had vowed never to let this happen again, passing the *Oceans Act*, which requires the Minister of Fisheries and Oceans to apply the precautionary principle to all matters within the Minister's jurisdiction.

The Cost of Harm

The enormous ecological and economic costs endured by the collapse of the cod fishery were caused, in part, by mismanagement. Repeatedly, Canada misidentified both the risks and the costs associated with those risks. Our government attempted to prevent short-term economic loss by protecting the economic interests vested in the status quo instead of embracing the fundamental change that was necessary:

> … the government established a pattern that it would follow until the cod stocks disappeared. Scientists would warn of serious stock declines and advise dramatic catch reductions; the government, afraid of throwing fishermen and processors out of work, would merely inch the TAC [total allowable catch] downwards. Its refusal to act quickly destroyed the cod

stocks, and, with them, the jobs the government wanted so desperately to protect.[5]

As a result of this mismanagement, over 35,000 fishers and plant workers from over 400 coastal communities became unemployed in Newfoundland alone.[6] History shows that ignoring the warning signs, and blindly protecting the status quo, can ultimately result in the demise of the resource the status quo depended upon. We keep this example in mind as we consider a more responsible approach to the protection and preservation of the economic and ecological value of wild salmon.

The Value of Wild Salmon

Wild salmon are a keystone species of fundamental ecological importance. How does one put a price on the extinction of the keystone species on the Pacific coast of Canada?

Keeping in mind the fundamental ecological importance of wild Pacific salmon and the fact that British Columbians revere wild Pacific salmon because of their social and cultural benefits, the economic value of the wild salmon economy in B.C. currently exceeds that of the B.C.'s open net-pen salmon farming industry. Further, the restoration of habitat and rejuvenation of wild salmon populations represents an important opportunity (and constitutional responsibility) for reconciliation with First Nations and further economic growth.

Attachment 2 to this Appendix provides charts of the Economic Impacts of Pacific Salmon Fisheries prepared for the Pacific Salmon Commission (the "PSC Report"). Over the period 2012 to 2015, the annual contribution of both the commercial and the recreational sectors to B.C. alone averaged:

- $703.6 million in Gross Domestic Product (converted from US$641 million in Attachment 2, based on page 61 of the PSC Report, which provides the annual impacts in Canadian dollars), and
- 9,450 full-time equivalent (FTE) jobs.

In comparison, Appendix 3 of the Council's Report relies on data from a recently released independent economic analysis of the salmon aquaculture industry in British Columbia that was conducted over three years. The Council's Report provides the following numbers for the best of those three years, 2016, a year that had record prices for salmon:

- the GDP generated by the B.C. farm-raised salmon industry (including processing) increased 36 percent to $557.8 million in Gross Domestic Product, and
- employment increased 33% to 6,610 FTE jobs.

Appendix 3 states that the increase for the salmon aquaculture industry over the past three years turned on record-high prices, which presumably also positively impacted the value of the commercial wild salmon fishery.

Without considering the monetary value of wild Pacific salmon to other industries such as tourism (0ver and above the recreational fishery included above), and the more important non-monetary values, it is evident that, from a purely economic perspective, the wild salmon economy holds significantly more value and more jobs for British Columbians than does open net-pen salmon farming.

Even when the economic contribution of wild salmon is averaged over four years (which did not include years with record-high salmon prices) and that averaged contribution is compared with the economic contribution of farmed Atlantic salmon in 2016 – a year with record prices for salmon – the economic contribution of wild salmon is significantly greater. Assuming that the PSC Report, and the report that the Council's Report relies on, both accurately and credibly represent the economic contributions of wild Pacific salmon and farmed Atlantic salmon, then the wild salmon economy provides British Columbians with 42% more jobs than aquaculture and contributes 26%, or $145.8 million, more to British Columbia's GDP annually. Wild salmon is a greater driver of economic prosperity in B.C. than the existing aquaculture industry. Most importantly, open net-pen aquaculture threatens the viability of the wild salmon economy, not the other way around.

<u>Reducing the risk of harm to wild salmon does not require that there be an alternative to open net-pen aquaculture available before harmful practices are halted</u>. However, the Council has acknowledged that the open-net-pen industry has evolved over the past 30 years, and we view closed containment technology as the likely continuation of that evolution.

There is evidence that the production challenges and biological issues with open net-pen aquaculture, combined with the associated increase in production costs and regulatory constraints restricting growth of the industry using old technology, are accelerating the development of land-based salmon aquaculture technology. In 2015, the Norway Research Council and its industry partners invested US$25 million into the CtrlAqua research program, with the main goal being to develop technological and biological innovations that will make closed systems a more reliable and economically viable technology.[7] Council also heard from Norwegian researcher Ann-Magnhild Solås that Norway is using development licences as incentives for capital-intensive innovative projects that reduce environmental footprint.[8]

The DNB Markets Report, prepared by a division of Norway's largest bank, is clear that recirculating aquaculture systems (RAS) technology has advanced faster than anticipated.[9] Optimization, standardization and scale are starting to positively impact the economics, investor interest and commercial-scale adoption.[10] While recognizing that new technologies typically must go through several iterations of innovation, land-based, closed containment aquaculture is already technologically viable and, if not already, will very soon be economically viable at a large scale.

British Columbia has plentiful land with access to both fresh and salt water, existing infrastructure to support aquaculture, low-cost hydro power and access to the US I-5 corridor and Pacific Rim markets, which positions B.C. to take advantage of a trend toward land-based closed containment aquaculture and the growing demand in Canada, the U.S. and Asia for sustainably produced seafood. The DNB Markets Report and industry media show that European land-based salmon farming companies are beginning to move into the U.S. with plans for large commercial-scale farms,[11] thus B.C. may need to respond quickly to the opportunity before it is lost to the U.S.

Hidden Costs Borne by the British Columbia Taxpayer

With open net-pens, there is no mechanism to control wastes and potentially hazardous substances that are flushed from open net-pens directly into the marine environment. Thus, British Columbians incur the ecological and biological costs, and wild salmon are put at risk. Land-based, closed containment aquaculture carries greater upfront capital costs, but the investment in new clean technology ensures that inherent risks caused by free-flowing waste from open net-pen aquaculture are avoided. RAS technology captures and controls waste, sea lice are avoided, and pathogens and pollutants from farmed fish do not interact with the marine environment.

B.C. currently grants ocean tenures, a public resource, at a very low cost to industry. The total annual rent collected by B.C. on <u>all finfish aquaculture tenures</u> for fiscal 2016/2017 was $1,953,295.[12] Assuming approximately 119 tenures (113 marine finfish tenures per Appendix 3 of Council's Report), we estimate that the annual lease payments for a tenure in B.C. at $16,414, with a present value of lease payments in perpetuity calculated to be in the $700,000 range.[13]

In comparison, in 2014, Norway last auctioned off a new, freehold open net-pen site for over Cdn$10 million, while adopting a policy that licenses sites for land-based, closed containment systems for free to incent research and development of alternatives. The policy used by Norway aims at ensuring that industry does not externalize the cost of its pollution, pathogens and parasites and that such costs are not borne by the taxpayer.

Industry's unwillingness to evolve to a more sustainable technology here in B.C., which would protect our marine environment (including wild salmon), appears more grounded in financial self-interest, than in the economic or ecological interests of British Columbians. We should not expect industry to change its practices here until there is a cost associated with failing to do so.

Ecological Costs

Most importantly, the ecological cost of endangering wild salmon is incalculable. As a keystone species, wild salmon transport nutrients that support aquatic and terrestrial ecosystems at each stage of their lives.[14] Thus, the full cost of a catastrophic loss of wild Pacific salmon simply cannot be calculated.

Dr. Brian Riddell best summed this up in his presentation to Council:

> ... of all the salmon aquaculture-producing countries of the world, it should be expected that British Columbia would have the greatest concern for potential impacts on wild salmon given the diversity and wide spread

geographic distribution of our salmon, and their high ecological and human importance (culturally and economically).[15]

The Probability of Harm

Aquaculture poses inherent risks to wild salmon, with sea lice and pathogen transmission being two of the most dangerous risks. Adequate risk assessment and management practice require an accurate assessment of the danger of inherent risks, followed by effective mitigations and controls to either eliminate the probability of those risks materializing or reduce that probability to an acceptable level. Such risk assessment and management cannot be undertaken without first accurately assessing the gravity of the inherent risks.

Unfortunately, DFO has a long history of ignoring the gravity of the risks:

> DFO routinely suppressed politically inconvenient research into the causes of the cod decline. An internal government report, based on meetings with almost every member of DFO's Science Branch in 1992, charged that "Scientific information surrounding the northern cod moratorium, specifically the role of the environment, was gruesomely mangled and corrupted to meet political ends." It noted that the department routinely gagged its scientists, leaving communication with the public to ill-informed spokespersons. "Management is fostering an attitude of scientific deception, misinformation and obfuscation in presenting and defending the science that the department undertakes and the results it achieves," the report said. "It appears that science is too much integrated into the politics of the department ... <u>It has become far too convenient for resource managers and others to publicly state that their decisions were based on scientific advice when this is clearly not the case</u>"[16] [emphasis added].

Every indication is that DFO continues to avoid and suppress science that is contrary to the status quo. As recently as November 30, 2016, Dr. Miller, a leading scientist with DFO, said the following before the Standing Committee on Fisheries and Oceans:

> It is also important that as regulators, we are not afraid to ask questions and conduct research that may unearth findings that are not immediately convenient to industry and may require us to rework policies to ensure minimal risk.
>
> When I started down this path of research in 2012, I was told by an upper manager, who's no longer with the department, that it was irresponsible to ask research questions that could potentially result in negative economic ramifications on an industry if we did not already know the answer. At the time, my lab was developing very powerful technology that could simultaneously quantitate 47 different pathogens – viruses, bacteria, and fungal parasites – in 96 fish at once ... The manager was concerned that by employing this technology, we would make our salmon in B.C. look dirty, and impact their economic value in the market, and that if we uncovered

> agents that were not known to be endemic, ENGOs and the public would immediately point to the aquaculture industry as the culprit. As such, the attitude was don't look closely, especially for things that we didn't know already were there.
>
> ...
>
> At a working level, I remain concerned that there is continued reluctance by scientists, veterinarians, most of whom have strong ties to the industry, and managers to ask questions and undertake research that might not turn out favourably for the industry.[17]

The probability of harm cannot be sufficiently reduced if the regulator "whistles past the graveyard," steadfastly avoiding acknowledging or investigating the risks and the harm posed. In the cod era, we were wrong and arrogant and reckless until after it was too late, and so, as discussed below, we took action to make sure it never happened again by entrenching the precautionary principle in the *Oceans Act*.

Evidence of Salmon Farming Reducing Survival of Wild Salmon

Despite the difficulties associated with collecting evidence on the effect of fish farms on wild fish, strong scientific evidence demonstrates that salmon passing close to open net-pens have substantially lower survival rates than do those that do not pass close to the farms.

In a 2008 paper entitled "A global assessment of salmon aquaculture impacts on wild salmonids,"[18] the authors found a significant reduction in marine survival of salmonids in areas with salmon farming compared to areas without farms in Scotland, Ireland and Atlantic and Pacific Canada:

> ... we show a reduction in survival or abundance of Atlantic salmon; sea trout; and pink, chum, and coho salmon in association with increased production of farmed salmon. In many cases, these reductions in survival or abundance are greater than 50% [per generation].[19] Meta-analytic estimates of the mean effect are significant and negative, suggesting that salmon farming has reduced survival of wild salmon and trout in many populations and countries.

The authors go on to state that:

> Populations in which juvenile salmonids pass by salmon farms during their migration were considered to be exposed to impacts of salmon farming. Exposed populations were carefully paired with control populations in the same region whose migrations did not lead past farms, but which otherwise experienced similar climate and anthropogenic disturbances. Use of such paired comparisons allowed us to control for confounding factors such as climate to detect population level impacts.

The authors add that:

> ... the comparisons in British Columbia include large numbers of rivers (> 80 rivers in each case), so differences in anthropogenic effects would have to hold over many watersheds to explain the effects we estimate.

In B.C., we have not acted on such findings, even in a precautionary way. Instead, Dr. Gary Marty, Senior Fish Pathologist for the Government of B.C.'s Animal Health Centre, has favoured contrary findings as reported by Torrissen et al., who compared changes in wild salmon catches for countries with and without open net-pen farms and found little difference.[20] However, this paper by Torrissen et al. invites the criticism that in the countries included in the study, permitted salmon catches are under government control and do not necessarily correlate well with actual salmon returns. Perhaps more importantly, the study did not pair and compare samples that had similar conditions for variables such as climate and water temperature. The reliance on the paper by Torrissen et al. is typical of DFO's pattern of favouring science that supports its aims at the expense of science that is contrary to its regulatory approach.

Given this practice by DFO, we believe it is important to bring forward some of the science that DFO is not acting on. In two papers published in 2012 and 2015, Ruggerone and Connors, and their collaborators, reported a negative correlation between sockeye salmon survival and the number of farmed salmon that wild Fraser sockeye migrate past early in life.[21]

Lastly, in March 2017, Dr. Marvin Rosenau, of the Fish Wildlife and Recreation Program at BCIT, appeared before the Council. Dr. Rosenau analyzed a wealth of B.C. salmon abundance data from the past 30 years and presented the results in 74 overheads, two of which are reproduced below.

Figure 1 (Slide 2 of Dr. Rosenau's presentation to the Council) graphs the number of returns per spawner for Fraser River sockeye. The precipitous drop in abundance after 1992 is clearly visible. This marked drop in salmon abundance coincides with the introduction of open net-pens in British Columbia. Unlike other historical drops in productivity of Fraser River salmon, the decline that began after 1992 has not been followed by any significant sustained increase in productivity.

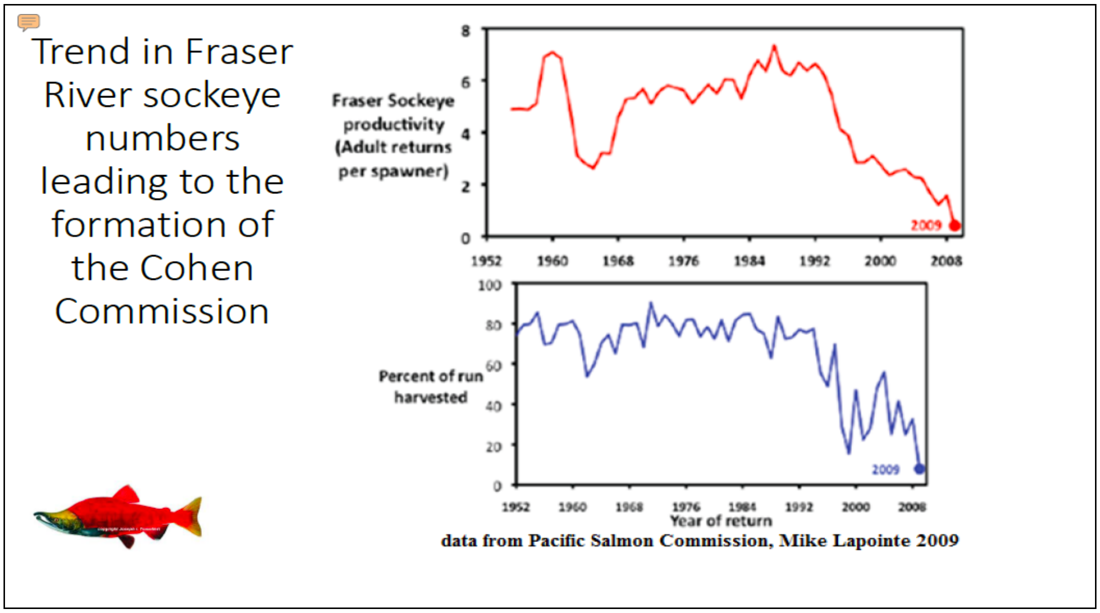

Figure 1 – Trend in Fraser River sockeye returns to spawn 1952-2009

The second graph on the overhead shows the percentage of the run that was harvested. Not surprisingly, that graph too shows a steep decline after 1992.

Figure 2 (a reproduction of Slide 72 from Dr. Rosenau's Briefing to the Council) shows an averaged rate of decline of several different runs of wild salmon as well as the ramp up of fish farm production.

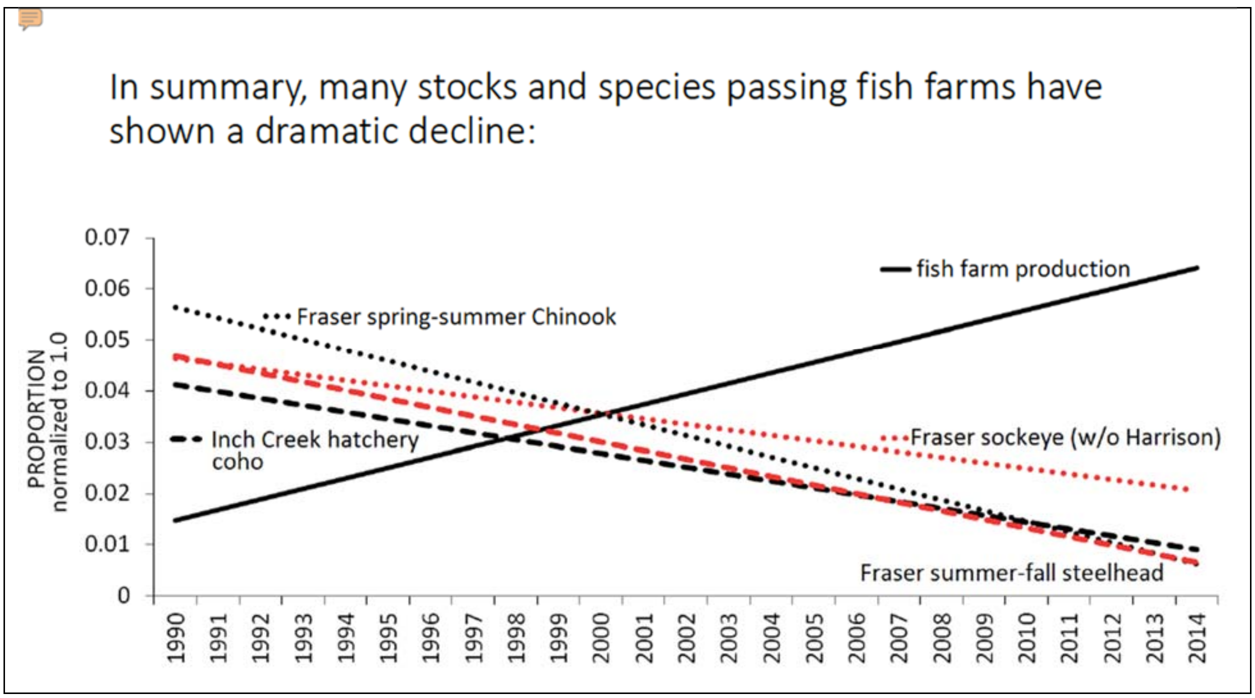

Figure 2 – Chart showing the decline of Fraser River salmon stocks 1990-2014

Dr. Rosenau's two major conclusions (reproduced from Slide 73 of his briefing to the Council) were as follows:

1. Multiple lines of evidence strongly support the conclusion that where juvenile salmonids migrate through areas of concentrated fish farms in south-western British Columbia, there have been large-scale collapses over many different species and populations, including the Gulf of Georgia, Fraser River and some west coast Vancouver Island watersheds.

2. This decline in salmon abundance has been the most catastrophic aquatic ecosystem collapse in the history of British Columbia, and the evidence points to the proliferation of fish farms, in timing and location, in south-western British Columbia.

The refereed papers cited here, combined with the Rosenau presentation, constitute an impressive body of evidence that points to open net-pen aquaculture being a likely contributor to the drastic decline in salmon abundance in south-western B.C. In the face of this precipitous 25-year decline in productivity, which Fraser River salmon have still not reversed, a harm reduction approach is hardly a sufficient response.

The next two sections consider research into two inherent risks from open net-pens – sea lice and pathogen transmission – that are implicated in causing this decline.

Sea Lice

Science has now confirmed that open net-pen salmon farms can cause unacceptable levels of sea lice transmission to wild salmon smolts.

Dr. Dill addressed the sea lice problem in his presentation to Council and in a report prepared to update the scientific literature published in refereed journals since the Cohen Commission (the Dill Report, provided as Attachment 1 to this Appendix).[22] His findings were supported by refereed journals and concluded that the sea lice problem alone is enough reason for B.C. to discontinue use of open net-pen farming:

> The risk to wild salmon from sea lice produced in Open Net Pens (ONPs) is unambiguous and substantial. Lice have been shown to reduce productivity of both wild pink and coho salmon populations in the Broughton Archipelago, and there is no reason to think they are not having similar effects elsewhere on the BC coast. The mechanisms by which lice impact individual survival are well understood, and these individual and population level effects have been found consistently throughout the world and are supported by large-scale experiments.[23]

The evidence on the risk of sea lice associated with open net-pen farming presented to the Council, especially when viewed in the context of the sea lice problems in other jurisdictions, notably including Norway, is very strong. In her presentation, Norwegian researcher Ann-Magnhild Solås told Council that the Norwegian Scientific Advisory Committee for Atlantic Salmon estimated the annual loss of wild salmon to Norwegian rivers due to salmon lice at 50,000 adult salmon for the years 2010-2014, corresponding to an annual loss of 10% of the total pre-fishery abundance of wild salmon due to salmon lice. In a January 2018 report released by the Norwegian Institute for Nature Research, the authors reported that:

> ... lice-induced mortality in farm-intensive areas can lead to an average of 12-29% fewer adult salmon ... Mortality of sea trout [similar to steelhead in B.C.] is likely to be higher than in Atlantic salmon, because unlike the ocean-migrating Atlantic salmon, they usually remain in coastal waters, where fish farms are situated.[24]

These losses occur despite Norway's much stronger regulation of sea lice in their open net-pen farms.

Figure 3 (which is Slide 1o of Ann-Magnhild Solås's presentation to the Council) cites Forseth et al. (2017) as <u>finding that in Norway salmon farming (through escapes, sea lice and infections) was the largest threat to wild salmon among those human impacts that we can do something about</u>:

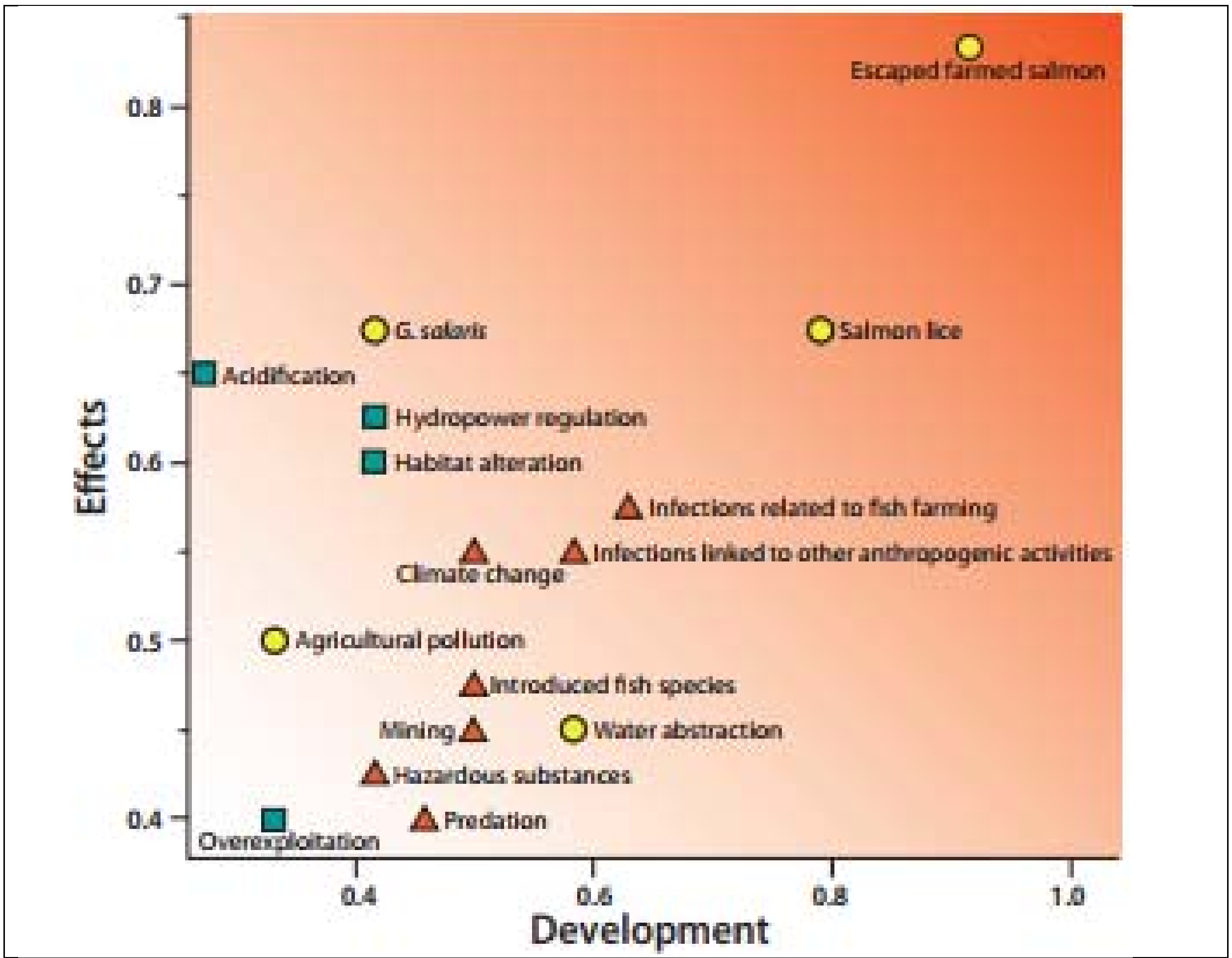

Figure 3 – Chart showing the threats to wild salmon in Norway

Not surprisingly, the biological challenges posed by sea lice are driving Norway to restrict growth and seek alternatives. Meanwhile, in our view Council let DFO and the industry "off the hook" with a theoretical presentation of regulation and farm management, without evaluating the actual practice. If it had, the Council would have found that the theory does not always match the reality.

With regard to sea lice, Council was told:

> In terms of sea lice management, the regulatory threshold set by DFO is three sea lice (*L. salmonis*) per salmon. If this number is exceeded on a farm between March 1 and June 30, the farm is currently required to initiate a management response that can include harvesting fish (to reduce the total number of sea lice) or therapeutic treatment of salmon. The number of wild, out-migrating juvenile salmon carrying a sea louse varies considerably year by year and by geographic location. Returning salmon, carrying sea lice from their ocean migration, have been known to become a source of sea lice in the autumn months, and annual trends in the rise and fall of sea lice numbers on net-pen farm salmon are predictable.[25]

There is debate about whether the regulatory threshold set by DFO is sufficient to safeguard wild salmon and debate over how that threshold is enforced.

In the well-researched Broughton Archipelago, the salmon farming industry engaged in lice treatments prior to the juvenile wild salmon out-migration, and for a period of time this appeared to successfully lower the number of sea lice per wild salmon. However, beginning in 2015 sea lice levels on wild salmon increased once again.[26] The salmon farms in the area of this research were recently approved for a near tripling of the number of fish per farm. Sea lice limits per fish were not lowered to suppress the overall sea louse population in each farm.

In B.C., farms currently operate with little mandated real-time transparency in farm management data, in stark contrast to Norway where the industry is required to publicly post information about sea lice infestations every week. When data is reported, we see significant non-compliance and disregard for out-migrating salmon smolts. For example, from DFO-published data two farms in the Nuchalitz Inlet (near Zeballos), Steamer and Esperanza, reported excessive sea lice levels that persisted during sensitive periods for out-migration of juvenile salmonids.[27] Steamer first reported excessive levels (14.5 per fish) in September 2016 and continued to note "alternative management action" planned or underway, while its lice levels rose from 25 in January 2017 to over 33 at the beginning of the sensitive period in March. By May, its harvest had not been completed and had only reduced lice levels to 15 per fish – five times the management trigger. No count was provided for June. Esperanza first reported excessive lice in July 2016 and then stopped reporting counts "due to environmental conditions" until November, when it reported levels of 10; "alternative management action" was "planned" but not undertaken, while levels soared to over 48 per fish by February 2017. That farm entered the sensitive period with levels at 39.82, and still only "planning" management action. The farm began to harvest in April but was unable to bring lice levels below the management target until harvest was completed in August. Taking six or more months, including at least three months of the sensitive out-migration period, to remedy these high levels of sea lice is unacceptable.

There is also a significant gap in DFO's monitoring program, as it does not monitor sea lice levels on out-migrating juvenile salmon passing through areas with open net-pen farms. Monitoring of wild salmon for sea lice loads is of critical importance because some species of juvenile wild salmon, such as pink and chum, passing the farms may weigh less than a gram in the early spring and thus are much more susceptible to impact.[28] Data was not provided to Council on the number of out-migrating juvenile salmon carrying a sea louse – just as stated above that it "varies considerably year by year and by geographic location." This level of ambiguity is, at best, unhelpful. Given the significant risk that sea lice from open net-pen farms pose to wild salmon, the relevant regulation lacks both the transparency and the efficiency required to address the harm posed.

Pathogen Transmission

This section considers the impacts of pathogen transmission from open net-pen farms to wild salmon, and the failure of the current management approach to pathogen transmission to reduce the risk. In this section we set out the evidence that:

- Industry and the regulator have ignored the trajectory of the science on pathogens such as PRV.
- The regulator adopted its own science, sometimes co-authored and funded by industry, when it served preserving the status quo. The regulator's approach to the diagnosis of HSMI is the most telling example.
- The regulator is openly defying the law requiring it to apply the precautionary principle to minimize harm.
- The regulator is erroneously setting risk thresholds that can only be triggered when there is the threat of extirpation of entire wild salmon populations or the sterilization of the ecosystems on which they depend.

The Science on Pathogen Transmission

Through the work of the Council, we have found that the emerging science regarding the transmission of disease from farmed to wild salmon is sufficient to call for extreme caution.

The Cohen Report, published in October 2012, provides the following paragraphs concerning the state of knowledge about salmon pathogens at that time, including a finding of at least some risk (and not accepting a quantification of low risk) posed from disease on salmon farms:

> The potential risk of disease spreading from farmed to wild salmon and how to describe that risk is the main difference between Dr. Dill and Dr. Noakes, and one on which other witnesses also commented. Of all the expert witnesses I heard from, no one told me there is no risk to sockeye;

> indeed, some said the risk could never be "zero," and others told me that salmon farms do increase the risk when compared with no salmon farms. Those (like Dr. Noakes) who ventured to quantify the risk told me it was "low" as a result of proactive policies and practices. Others (like Dr. Dill) did not believe the state of information was such that the risk could be quantified and said that disease on salmon farms could not be ruled out as posing a significant threat to Fraser River sockeye.
>
> I accept the undisputed evidence that there is some risk posed to wild Fraser River sockeye salmon from diseases on salmon farms. I also accept that management practices are intended to reduce that risk as much as possible and aim to keep both farmed and wild fish healthy. I agree with Dr. Noakes that the current regulatory data collected for the salmon-farming industry need to be maintained and that future work should focus on understanding diseases in wild fish. However, I am unable to agree with him that salmon farms pose a low risk to wild sockeye: I cannot make that determination on the evidence before me. I accept the evidence of Dr. Josh Korman, author of Technical Report 5A, Salmon Farms and Sockeye Information, and Dr. Dill that scientists need at least another 10 years of regulatory data before they can find relationships (if they exist) in the data.[29]

The Council's Report is being issued just over five years after the report of the Cohen Commission. We acknowledge that gaining an understanding of the factors affecting wild salmon abundance is difficult, but through the hard work of good scientists our knowledge has progressed. To illustrate this point, Attachment 3 to this Appendix provides a timeline for the research conducted to understand the fish health impairment potential of PRV.

Valuable new tools have also been added to the research arsenal, including rapid and low-cost techniques for the analysis of DNA and RNA, which can be focused on fish pathogens as well as on the fish themselves. With one small tissue sample clipped from a fish gill it is possible to determine not only the species of fish, but also where it was hatched and, most importantly, to identify the various pathogens the fish is carrying and their likely provenance. [30] Once the mutation rate of the DNA or RNA is known, it is possible to estimate how long ago a virus broke away from predecessor strains still reproducing elsewhere. Scientists are thus able to determine, for example, whether and when a particular strain of a virus diverged from another strain encountered elsewhere.

These tools also provide a means by which we can ascertain whether a fish is just carrying a virus without experiencing harmful effects or whether the fish is actually suffering from a disease the virus has caused. This discovery makes it much easier to study the physiological effects of a disease on a salmon, such as its ability to tolerate warm water, evade predators and traverse rapids en route to spawning sites.

Two scientists, Dr. Dill and Dr. Miller, spoke to the Council about the risks this emerging science has identified.

Dr. Dill informed the Council that the risks of PRV and HSMI could be substantial:

- PRV is on the farms where it can and does cause HSMI;
- PRV can be transferred to wild fish;
- PRV is implicated in the heavy pre-spawning mortality of Fraser sockeye, and there are logical and biological reasons why this might be so; and
- other pathogens, including viruses, are known to be present in ONP [open net-pens] and the risk they present to wild Pacific salmon is currently unknown, but could be substantial.[31]

Although Dr. Dill explained that the science about disease transfer from fish farms to wild salmon is less certain than the science concerning sea lice transmission, the risks are very real. DFO scientist Dr. Kristi Miller's presentation clarified the science on disease transmission and highlighted some of the dangers to wild salmon.

Dr. Miller reported that the PRV-associated disease symptoms of HSMI and jaundice are present on B.C. salmon farms.[32] A recent published paper by the SSHI has identified jaundice syndrome as a disease impacting a Chinook salmon farm near Tofino, and the disease is suspected to be viral-induced.[33] A PRV-like virus associated with HSMI-like symptoms has also been confirmed in farmed Coho in Chile.[34] There is correlational evidence that PRV is the one virus common to the farms in Tofino and in Chile, and to a finding of a similar disease outbreak in the farmed Rainbow Trout in Norway.[35]

Japanese researchers have also found a cause and effect relationship between PRV-2 and a disease they call erythrocytic inclusion body syndrome (EIBS), which is highly similar to the jaundice/anemia and HSMI diseases described in B.C. Chinook salmon, Chilean Coho and Norwegian Rainbow Trout.[36] This disease contains all of the hallmarks of these other diseases described in association with various strains of PRV in Pacific salmon around the world. It is important to note that there is only a single strain, and genogroup, of PRV in B.C., PRV-1a.[37] In B.C., we observe these same disease linkages with jaundice/anemia,[38] suggesting that the same strain of the virus that causes HSMI (and PRV-1a has been shown in Norway to be the cause of HSMI[39]) is associated with disease in Pacific salmon.

While there has not yet been research to determine the nature of the relationship between PRV and these outbreaks, certainly precaution is warranted in B.C. where we have wild Chinook salmon sharing the same water. This situation merits urgent attention given current concerns about declining Chinook abundance.

From Dr. Miller's presentation, Council learned that PRV is highly prevalent in farmed fish (~70% of farm audit samples), while PRV was detected, but not common, in migratory smolts.[40] Dr. Miller's presentation described a number of challenges associated with understanding disease impacts on wild populations and she explained that sub-lethal effects of infection in cultured fish may be more detrimental in wild fish. The spread of a lethal disease is limited by the death of the victim. Sub-lethal diseases have more opportunity to spread. Further, if a sub-lethal disease renders a wild fish more liable to predation, the result is still a premature death.

Finally, consistent with Dr. Dill's last point, we know from Dr. Miller's presentation that the SSHI has identified three novel viruses to date.[41] As this work is not yet finished, this number may well increase, and all merit more study.

Of further concern are recent scientific publications that demonstrate that PRV commonly proliferates in the red blood cells in the early stages of an infection. Red blood cells transport oxygen, and a fish whose swimming muscles are deprived of oxygen could be more likely to die from predation or fail to make it upriver to spawn. While we understand there are research projects underway to shed more light on this issue, the authors of the first publication identifying this phenomenon stated:

> PRV infection of erythrocytes [red blood cells] could have broader implications for fish health, irrespective of the presence of heart lesions.[42]

We understand that there is still more to learn about the effects of exposure to high levels of PRV on wild salmon. As Dr. Miller described in her presentation, there are a number of challenges in understanding disease impacts on wild populations, not the least of these is that we rarely see wild fish die.[43]

PRV is now very common in fish farms in many countries including Norway and Canada. As Dr. Miller presented, in B.C. farms, about 70% of farmed salmon are known to carry the virus. Industry has also acknowledged that a high number of Atlantic salmon smolts from hatcheries are infected with PRV.[44] DFO's current policy not to test for PRV means that fish farms must be transferring PRV-infected smolts into fish farms without any protective measures.

A very recent paper by Morton et al. indicates that PRV infection in wild smolts can be as high as 45% in areas where there are many salmon farms, but drops to about 5% where no salmon farms are on the migration route.[45] While the authors are very cautious to point out that the data quoted is indicative but not conclusive (due in part to the small sample size), the very high infection rate of wild salmon close to open net-pens surely highlights a need for further investigation.

Evidence suggests that the similarity of the RNA signatures of the Norwegian and B.C. forms of the PRV virus make it very likely that PRV carried by both farmed and wild salmon originated in a Norwegian salmon farm.[46]

We believe from the evidence presented to Council, and well supported by other research cited here, that we know enough about the level of risk to conclude that it is clearly sufficient to call for extreme caution.[47]

The Regulator's Response to the Science on Pathogen Transmission

Despite the science increasingly pointing to the risk posed by PRV, DFO as the regulator has chosen to refuse to take harm reduction measures that would be consistent with the body of science showing that PRV is a risk to wild salmon. As recently as January 30, 2017, DFO confirmed that it views PRV and HSMI as "not of serious concern in BC" and confirms that it is maintaining the status quo of not testing for PRV before transferring Atlantic salmon smolts into the marine environment.[48]

The conclusion that PRV and HSMI are not of serious concern in B.C. was flawed in both its reasoning and the data that reasoning relied on. DFO concluded that because DFO's Fish Health and Surveillance Program did not show elevated mortalities on fish farms, not testing for PRV did not create a risk to the protection and conservation of fish. The paper published by SSHI in February 2017 raised specific concerns about the Fish Health and Surveillance Program's methods and methodology.[49] But even if DFO's Fish Health and Surveillance Program were a paragon of regulatory efficacy, <u>the use of farmed salmon as a proxy for assessing the risk to wild salmon is logically flawed</u>: it assumes that conditions are the same for both wild and farmed salmon and fails to consider how sea lice and disease may affect those populations differently. Of critical importance, some species of juvenile wild salmon, such as pink and chum, passing the farms may weigh less than a gram in the early spring and thus are much more susceptible to impact.[50]

Despite our concern on this issue, DFO provided limited detailed information to Council on its management approach to PRV, and industry practices continue as though there is no cause for concern. Late last year, video shown by popular media raised concerns that bloodwater from plants processing farmed salmon may also be introducing PRV into the marine environment through processing activities.[51] This has now been confirmed: "*Ministry compliance staff conducted site visits to both the Browns Bay Packing (Campbell River) and Lions Gate Fisheries (Tofino) facilities the week of December 4, 2017. The facilities were inspected and samples collected, and lab results showed the presence of PRV.*"[52]

The Regulator's Deviation from the Science on HSMI

Industry and the regulator have long held that there were no instances of HSMI in B.C. farms. Following a year-long monitoring of four B.C. fish farms under the SSHI program managed by the Pacific Salmon Foundation, it was announced that HSMI had been diagnosed in one of the four farm sites monitored.

At a subsequent meeting of the MAACFA, Dr. Gary Marty told Council that he had diagnosed HSMI as early as 2011, only "we called it something different." As Council members now know, subsequent investigation has revealed that the "B.C. definition" of HSMI differs from the "International definition" in that in addition to pathological damage in the heart and skeletal muscles of the infected fish, the B.C. definition requires that the fish display "clinical signs" or behavioural anomalies (presumably while still alive!).

We do not understand why and how the Province of B.C.'s Ministry of Agriculture and DFO, during their respective time as the responsible regulator, and the Animal Health Centre, came upon a different definition of HSMI for B.C. and why this difference was not made public from the outset. This deviation from international standards, with a complete lack of transparency, is another example of the regulator (now DFO) avoiding mainstream science to ignore potential risks and maintain the status quo.

Between July 2014 and January 2016, representatives from DFO, the Ministry of Agriculture and Marine Harvest Canada Inc. published three papers that all downplay the then growing scientific consensus that PRV causes HSMI.[53] Those papers find, among other things, that the presence of PRV in British Columbia predates the salmon farming industry, PRV may not cause HSMI, HSMI has not been detected in British Columbia and the British Columbia strain of PRV does not cause HSMI. None of those three papers discloses which case definition they rely on for their findings – the case definition most often relied on in scientific literature, or the case definition developed by B.C.'s Animal Health Centre. We find it troubling that the regulator is co-publishing papers with industry that are contrary to the prevailing science on PRV and HSMI. More recent scientific developments place those papers co-published by industry and regulatory authorities further outside the mainstream science on this issue. In 2017, a paper co-published by 11 experts, five of whom were DFO scientists, confirmed that fish samples they obtained in 2013 from a B.C. fish farm had been diagnosed with HSMI.[54] Another 2017 paper confirmed that PRV causes HSMI.[55]

The Regulator's Failure to Follow the Law in Regulating Pathogen Transmission

Despite DFO's acknowledgement that PRV is widely considered the leading cause of HSMI,[56] DFO's management approach does not require testing of smolts for PRV, effectively allowing for the transfer of PRV-infected smolts into open net-pens without any preventive measures to reduce the risk to wild salmon.

As discussed in more detail in the precautionary approach section below, this regulatory inaction is in direct contradiction of the 2015 Federal Court decision in *Morton v. Canada (Fisheries and Oceans)*, in which Mr. Justice Rennie found that "the weight of the expert evidence before this Court supports the view that PRV is the viral precursor to HSMI."[57] Recall that Mr. Justice Rennie's job is to listen impartially and carefully to the expert witnesses before him, and to make a decision based on the evidence.[58]

More importantly, Mr. Justice Rennie found that not testing for PRV would be contrary to the Minister's duty under s. 56 of the *Fishery (General) Regulations* "to anticipate and prevent harm even in the absence of scientific certainty that such harm will in fact occur."[59] Contrary to this statement of the law, DFO has continued to maintain its policy of not testing for PRV.

Morton v. Canada (Fisheries and Oceans), and DFO's response to it, are important indications of DFO's approach to harm reduction. *Morton v. Canada (Fisheries and Oceans)* does not require DFO to agree with the prevailing science on pathogen transmission. However, even in the face of such scientific disagreement, *Morton v. Canada (Fisheries and Oceans)* clarifies that the law requires DFO to implement precautionary measures when the science indicates that pathogen transmission may pose a risk to wild salmon. DFO has refused to uphold this legal duty.

Despite the regulator's unwillingness to uphold its legal duties with respect to the prevention of harm and harm reduction, the Council's Report recommends a harm reduction strategy. Given the regulator's history of ignoring the science and the law, we cannot embrace or recommend such a strategy.

The Regulator's View of Acceptable Risk Thresholds

As discussed in more detail in the section on the precautionary approach below, contrary to the science and the law, DFO has adopted its own risk threshold for precautionary measures with respect to the introductions and transfers of fish. According to DFO, transfers of fish with disease should only be prohibited when there is the risk of extirpating an entire conservation unit:

> … the genetic diversity, species, or ecosystem of a stock or conservation unit may be harmed such that they cannot sustain the biodiversity and continuance of evolutionary and natural production processes.[60]

With this threshold for prohibiting transfers, DFO has indicated that in its view, the risk threshold that triggers harm reduction is set at a threat of species-level extinction. Such an approach leaves no margin for error.

Rather than interpreting the "protection and conversation of fish" as a mandate that animates all of the Minister's responsibilities, the Minister is instead interpreting it as a limit on the harm that can be caused by fish farms. In addition, the Minister's interpretation of s. 56 of the *Fishery (General) Regulations* is contrary to *Morton v. Canada (Fisheries and Oceans)*, where the Federal Court found that threshold for precautionary measures was triggered at a much lower level. The precautionary principle requires that regulators "anticipate, prevent and attack the causes of environmental degradation."[61] The threshold the Minister has set is inconsistent with the proactive nature of the precautionary principle. Instead, the threshold for precautionary measures must be triggered at levels that are aimed at preventing harm to the health of wild fish, not just shy of their extirpation.

Again, we cannot recommend a harm reduction approach going forward when the regulator tasked with implementing and overseeing that approach is willing to act contrary to the prevailing science and the applicable law with respect to its duty to protect wild salmon.

Assessment of the Risk

Based on the cost and probability of harm discussed above, we do not accept Dr. Marty's conclusion to Council that: "*Salmon farm diseases pose no more than minimal risk of serious harm to migrating wild salmon populations*."[62] Justice Cohen refused to accept this position in 2012, and the research implicating the risk of disease from open net-pens to wild salmon has increased substantially since that time.

We know from evidence concerning the northern cod crisis that DFO's assessment of risk can be based on a well-established pattern of relying on partial data that have been interpreted in the most favourable light:

> The tendency to ignore uncertainty and to interpret ambiguous data optimistically affected the political bureaucracy even more severely than the scientific bureaucracy. One DFO employee explained that although decision makers did not falsify documents, "they optimized what they had. The politicians and the senior bureaucrats would run away, pick the very best numbers and come out and present them in the very best light. They would hide any negative notions, numbers, information, anything at all that took the gloss off what they had presented. Any attempt by anyone on the inside to present a different view was absolutely squashed". John Crosbie admitted to sharing this tendency towards optimism: "we have opted for the upper end of the scientific advice always striving to get the last pound of fish."[63]

We cannot accept in these circumstances that because there are scientific uncertainties or personal differences in risk assessment and tolerance for risk that it is sufficient to drift to the timid conclusion that a reasonable compromise is "harm reduction."

This is particularly so when it leads to the recommendation for more flexibility in siting of open net-pen farms due to climate change, rather than calling for the removal of farms from wild salmon migratory routes. In the Dill Report it is noted that salmon infected with PRV have a reduced tolerance for high temperatures,[64] which would increase the impact of climate change on wild salmon, thus increasing the risk associated with PRV.

Attempting to respond to risk by addressing simple, short-term objectives in a "harm reduction" approach suggests that the problem the aquaculture industry is facing is one of public perception and that perception can be managed by easy, short-term solutions that avoid significant regulatory reform. This approach mistakes cause for effect. Lack of public trust is not the cause of the aquaculture industry's problems. Lack of public trust is what we get when the regulator fails to adequately manage risk. By advocating for short-term objectives to sway public perception, the Council's Report is protecting the failing status quo at the expense of wild salmon.

Given the level of risk, we believe the only way to build trust is through reform of the regulation of the industry. That reform begins with the regulator following the science and the law and by ceasing to issue licences to introduce and transfer PRV-infected smolts into open net-pens until it can be shown that wild Pacific salmon are not impacted. This puts the burden of proof squarely where it should be – on the regulator and the industry. That reform continues by acknowledging that the inherent risks imposed by fish farms cannot be adequately mitigated with open net-pens and follows that acknowledgement through to its logical conclusion by embracing a transition to land-based closed containment.

We do not accept any assertion that because there are other stressors impacting wild salmon that are much more difficult to control (such as climate change) we should give up on controlling the stressors that are within our control. This is particularly true given that the Council on the Status of Endangered Wildlife recently recommended that species of Fraser River sockeye salmon be listed under the federal *Species at Risk Act*, thus underscoring the fragile state of some populations of wild salmon.[65]

Rather, we accept:

- the research, including Dr. Rosenau's analysis, showing there is very good evidence that salmon passing close to open net-pens have substantially worse survival rates than those that do not;
- Dr. Dill's conclusion that risks to wild salmon from sea lice produced in open net-pens are "unambiguous and substantial"; and
- that while we do not yet have a complete picture of the effects of high levels of exposure to PRV on wild salmon, the available evidence presented by researchers such as Dr. Kristi Miller strongly supports a conclusion that the level of risk is high.

Overall, we conclude from the work of the Council, that the risk of harm is sufficiently high to call for extreme caution, and to require reform of the industry to be sustainable in B.C.

The Precautionary Approach

In hindsight, there is no question that failing to exercise sufficient caution in managing the northern cod stocks contributed to the collapse of the cod fishery. If we heed the lessons that were learned on the east coast, we will proceed with caution, rather than express regret for not having done so:

> By July [1992], CAFSAC [Canadian Atlantic Fisheries Scientific Advisory Council] estimated that the northern cod stock had fallen to between 48,000 and 108,000 tonnes. Only then did Crosbie impose a moratorium on fishing for northern cod. Was he too late? Crosbie has considered that question: "I wish I could say that we weren't too late in closing the fishery. I wish I could say the northern cod and other species are recovering and that the seas off Newfoundland will once again teem with fish as they did for the first five hundred years of our history. I wish I could say it, but I can't. Not yet. Probably never."[66]

The only good that can come of our failures is to learn from them. Our goal is to make sure we are not too late; that we don't have to say "probably never" when the generations that follow ask us about the recovery of wild Pacific salmon runs like Fraser River sockeye. Rather, our goal must be to be better, and to make the admittedly harder choice between short-term economic gain and longer-term ecological protection. We must listen to what science is telling us, making the choice to do all that we can to remove threats to wild Pacific salmon, including those posed by open net-pen fish farming. This is particularly so as climate change and future environments are expected to compound these risks and further complicate the management of open net-pens.

Science should be the ultimate arbiter of suppositions regarding actual and potential interactions between wild and farmed salmon; and where there is a risk of serious environmental damage, the law is clear: decision makers are obligated to take a precautionary approach to protect wild salmon, and they cannot use scientific uncertainty to excuse regulatory inaction. We need to stand firm on this. The precautionary principle is not optional; it is the law of our land.[67]

In 2012, Mr. Justice Cohen wrote:

> ... DFO suffers from conflicting institutional mandates – on the one hand to regulate salmon farms for the conservation of wild salmon, and on the other hand to promote salmon farm development and products. The testimony of the deputy minister to the effect that the minister of fisheries and oceans is not well placed to enforce section 36 of the Fisheries Act against salmon farms because of a conflict is telling and, in my view, is equally apparent in relation to section 35 ... DFO faces conflicting roles in having to tell the world that Canada's farmed salmon products do not threaten the sustainability of wild salmon, yet at the same time credibly examining the possibility that such products are not safe. DFO's regulatory work – to site farms, to set conditions restricting farm growth, and to monitor farms and take enforcement actions against them – all suffer from this institutional conflict.[68]

He went on to conclude:

> As long as DFO has a mandate to promote salmon farming, there is a risk that DFO will act in a manner that favours the interests of the salmon-farming industry over the health of wild fish stocks.[69]

He identified the following risks of DFO's conflicting mandates to conserve wild stocks and to promote the salmon farming industry:

- There is a risk that DFO will not proactively examine potential threats to migrating sockeye salmon from salmon farms, leaving it up to other concerned parties to establish that there is a threat.
- There is a risk that DFO will impose less onerous fish health standards on salmon farms than it would if its only interest were the protection of wild fish. Farmed salmon may tolerate certain diseases or pathogens differently from wild salmon, such that the farmed fish would not necessarily require treatment except for their potential to spread disease or pathogens to wild fish ...
- There is a risk that DFO will be less rigorous in enforcing the Fisheries Act against the operators of salmon farms.[70]

We see these risks playing out, manifestly in DFO's capture by industry and abandonment of the precautionary principle.

As discussed above, without explanation as to why, DFO's Fish Health and Surveillance Program has departed from the International Standard for diagnosing HSMI in farmed Atlantic salmon. By adding the requirement for "clinical signs" for a diagnosis of HSMI, DFO has adopted a diagnostic model that, by definition, will result in fewer diagnoses of HSMI. To the best of our knowledge, DFO's Fish Health and Surveillance Program has never diagnosed HSMI. This adoption of a model that under-diagnoses HSMI does not adhere to the precautionary principle. Moreover, while DFO's Fish Health and Surveillance Program has for many years said that the heart lesions it has observed were not HSMI, and instead recorded those lesions as cardiomyopathy of an unknown cause, it does not appear that DFO has investigated what may be causing the lesions it observed.

In *Morton v. Canada (Fisheries and Oceans)*, the court found that s. 56 of the *Fishery (General) Regulations* requires DFO to apply the precautionary principle with respect to HSMI and PRV, and that fish farm licence conditions were incompatible with governing legislation and regulations that embodied the precautionary principle, saying:

> ... [t]he respondents' [Marine Harvest and DFO's] arguments with respect to the precautionary principle are inconsistent, contradictory and, in any event, fail in light of the evidence.[71]

Justice Rennie also found that DFO's position on the relationship between PRV and HSMI were not aligned with the weight of scientific evidence.[72] Effectively, DFO was advancing positions favouring industry when those positions are contrary to what is accepted by the scientific community.

In October 2017, Council was provided with a detailed analysis of the legal and scientific failings of DFO's *Management Approach to PRV and HSMI for Fish Transfers in British Columbia*, approved in January 2017.[73] Despite DFO's acknowledgement that "PRV is widely considered the leading cause of HSMI,"[74] DFO's approved management approach is to allow for the transfer of smolts to open net-pens without even testing for PRV, relying on an interpretation of s. 56 that is expressly contrary to the court's decision in *Morton v. Canada (Fisheries and Oceans)*.

Simply put, DFO's response in the face of a decision by a Federal Court judge requiring it to apply the precautionary principle is to ignore the science and abandon the rule of law. With respect to the regulation of aquaculture in B.C., it appears that DFO has abandoned its constitutional mandate to protect fisheries and oceans and the fundamental principles of the Canadian legal tradition in order to serve industry's interests.

The precautionary principle requires government to anticipate and attack threats of environmental degradation and irreversible damage. The Council on the Status of Endangered Wildlife's recent recommendation that species of Fraser River sockeye salmon be listed under the federal *Species at Risk Act* underscores the fragility of wild salmon, and makes it almost impossible for any government official to argue that populations of wild salmon do not face the imminent risk of irreversible damage.[75]

A court reviewing a government official's decision with respect to the implementation of precautionary measures to protect wild salmon is likely to consider if the precautionary measures implemented are reasonably proportionate to the nature of the environmental damage they were aimed at preventing. Given the mounting evidence of the imminent threat to the long-term viability of wild salmon populations, it is increasingly likely that a court looking for a proportionate response to a threat of irreversible damage could find that significant, and perhaps drastic, precautionary measures are required.

The Minister of Fisheries and Oceans has interpreted s. 56 of the *Fishery (General) Regulations* as prohibiting introductions or transfers of fish that could threaten the viability of conservation units of wild salmon. While we do not agree with the Minister of Fisheries and Ocean's interpretation that s. 56 requires population-level effects, even if DFO's interpretation is correct, then the Council on the Status of Endangered Wildlife's recommendation to list species of Fraser River sockeye salmon must surely trigger protective measures and require the prohibition of introductions or transfers that could be harmful to those populations the Council on the Status of Endangered Wildlife has recommended be listed.

A Provincial Minister's Duty to Apply the Precautionary Principle

In the absence of DFO's willingness to apply the precautionary principle, we must look to the Province. Under s. 11 of British Columbia's *Land Act*, the Minister can only dispose of Crown land if the Minister considers it advisable in the public interest.

The precautionary principle has evolved into a norm of international law and is quickly becoming a norm within Canada's common law. The courts are increasingly interpreting statutes as embodying the precautionary principle even if those statutes do not expressly invoke the precautionary principle by name or adopt the language normally associated with its expression. The Supreme Court of Canada did this both in *114957 Canada Ltée (Spraytech, Société d'arrosage) v. Hudson (Town),* 2001 SCC 40, and in *Castonguay Blasting Ltd. v. Ontario (Environment),* 2013 SCC 52. In *Spraytech*, the Supreme Court found that municipal bylaws embodied the precautionary principle; in *Castonguay Blasting,* it held that provisions of Ontario's *Environmental Protection Act* embodied the precautionary principle. The Federal Court reached a similar result in *Morton v. Canada (Fisheries and Oceans),* 2015 FC 575, with respect to regulations under the *Fisheries Act.*

Based on this growing trend in the case law, it is increasingly likely that, where environmental issues may be involved, and a Minister is required to act in the public interest, a court could find that statutory provisions governing that minister's conduct engage or embody the precautionary principle.

Under s. 11 of British Columbia's *Land Act,* the Minister can only dispose of Crown land if the Minister considers it advisable in the public interest. Given the very significant environmental issues that must be considered when granting licences of occupation for finfish aquaculture, a court could very well find that the precautionary principle is engaged and the Minister must consider if granting tenures for finfish aquaculture is consistent with the precautionary principle's requirement to anticipate and attack potential environmental degradation or irreversible damage.

Thus, in our opinion, a timid recommendation for harm reduction does not go far enough to meet the legal duty to apply the precautionary principle which prohibits regulatory inaction when there is a threat of environmental degradation.

The Constitutional Obligation to First Nations

Simply stated, Canada's Constitution requires both the federal and the provincial governments to respect the rights of First Nations. A significant number of First Nations with open net-pen farms operating in their traditional territories, as well as First Nations that rely on wild salmon that must migrate near open net-pens, oppose open net-pen fish farms.[76] The occupation of salmon farm facilities in 'Na̲mg̲is and Musgamagw territories speaks to their level of concern. Going ahead without the consent and in the face of direct opposition from impacted First Nations, regardless of the consent of other First Nations, would violate the United Nations Declaration on the Rights of Indigenous Peoples and Canada's Constitution:

> While some First Nations have entered into agreements with salmon farming corporations, wild salmon originating from distant regions are passing through these salmon farm clusters and so impact is borne by First Nations who have not been consulted. As well, salmon farms exist in territories where they were never given permission to operate, were served with eviction notices, and drew strong opposition by First Nations and others to site expansions. There are First Nations who are suffering substantive losses as a result of recent sea louse outbreaks, with no compensation or relief in sight.[77]

Accordingly, we fully support the Council's recommendation to:

> Acknowledge and incorporate First Nations' rights, title and stewardship responsibilities in all aspects of fish farm governance, including tenuring, licensing, management and monitoring in a manner consistent with the United Nations Declaration of Rights of Indigenous Peoples (UNDRIP).

Further, both governments must act in accordance with constitutionally protected Aboriginal rights under section 35 of the Constitution.

In *Tsilhqot'in Nation v. British Columbia*, 2014 SCC 44, the Supreme Court of Canada found that the authorization for activities undertaken without the consent of First Nations who later establish Aboriginal title could be cancelled after Aboriginal title is proven and that the Crown must take steps to preserve Aboriginal interests pending proof of Aboriginal title.[78] Many First Nations have made it clear that they do not consent to fish farms in their territories. Few, if any, of those First Nations have ceded, released or surrendered their claim to Aboriginal title and may in the future prove Aboriginal title.

Additionally, a Minister when exercising discretion must consider how his or her decision will advance or impair reconciliation. Much like the precautionary principle limits the range of decisions a Minister can make to those that reasonably exercise precaution in the face of environmental risk, s. 35 of the *Constitution Act, 1982* limits Ministers to decisions that reasonably advance reconciliation.[79] Given the vociferous objections to fish farms by some First Nations, it is difficult to see how renewing licences in the territories of those First Nations could advance reconciliation.

We believe this is an important opportunity for the Minister, based on environmental and Indigenous concerns, to be the first in a very long time to align B.C. with the established and emerging trends in both environmental and Indigenous law.

Where We Should Be

> Canada's fisheries managers tried desperately to blame the groundfish collapse on forces beyond their control. Colder water temperatures, they suggested, had driven the cod away, while increasing seal populations had eaten both cod and capelin, cod's favourite food. It has become increasingly clear, however, that such environmental factors played only minor roles in the destruction of the stocks. The real problem, scientists now widely agree, was that the politicians and bureaucrats running Canada's Atlantic fisheries permitted nay, encouraged overfishing.[80]

<u>We must not allow regulators to take the disastrous path of blaming environmental factors for their failure to manage the risks associated with open net-pen aquaculture</u>. For all of the reasons outline above – the ecological and cultural importance of wild salmon, the economic value of the wild salmon economy, the risks posed by sea lice and pathogens, the legal duty to apply the precautionary principle, and the legal and moral obligation to First Nations – we believe that an approach that emphasizes "harm reduction" is simply not sufficient.

Mr. Justice Cohen was certain (and so are we) that most British Columbians, if allowed the opportunity to wade into the discussion on acceptable level of risk, would support nothing greater than minimal risk to wild salmon. We are convinced the weight of the science tells us we are well beyond "minimal risk." Justice Cohen did not define minimal risk. We contend this is because he understood that British Columbians should be the ones to make that decision. We should embrace public input and discussion, not supplant it with the industry's view of acceptable risk.

We all agree that given the importance of wild salmon to First Nations, to whom we owe a special duty, and to all British Columbians, this debate cannot boil down to simple economics. Even if we did base our decision on pure economics, the risk of damaging the wild salmon economy is not worth taking.

The responsible course of action, in our opinion, is to support the evolution of the industry and the development of alternative salmon farming technologies. As discussed above, optimization, standardization and scale are starting to impact the economics, investor interest and commercial-scale adoption of closed containment salmon farms.

B.C. has an important choice to make – do we want to be a leader in the new technology which is destined to replace open net-pen salmon farming, or do we want to cede the ground to Norway (again) and others more venturesome than ourselves, while putting our wild salmon and the economy that goes with it at risk?

If a program to transition open net-pens to closed containment systems comes into being, it would be highly desirable to have the salmon farm companies work with government to help effect a smooth transition. Norway is a highly respected country in the view of most Canadians. It is likely that the Norwegian companies that control the majority of the open net-pen salmon farms in B.C. will want to continue to build a stable business relationship based on sustainable production methods with the governments and people of British Columbia. However, it may also happen, that some, or perhaps all, of the existing salmon farm companies elect to close their operations in B.C. and move production elsewhere. If this happens, it would be disappointing, but this prospect should in no way slow the transition out of open net-pen farms to closed containment facilities, nor discourage Canadian operators from participating in this emerging opportunity. Our wild B.C. salmon are too important culturally, ecologically and financially to risk their further decline.

To help preserve jobs to the greatest extent possible, planning for the transition should start immediately. More work may be needed to determine the best types of closed containment facility to use, to determine how quickly to effect a transition and to determine interim measures for a transition out of open net-pens. All actions must proceed in a manner that minimizes the risk of serious additional harm to wild salmon; we have the opportunity to choose a better path now and we should not squander it.

Where to Now? – The Recommendations

> *"Cheshire Puss…Would you tell me, please, which way I ought to walk from here?"*
> *"That depends a good deal on where you want to get to," said the Cat.*
> *"I don't much care where–" said Alice.*
> *"Then it doesn't matter which way you walk," said the Cat.*
> *"–so long as I get SOMEWHERE," Alice added as an explanation.*
> *"Oh, you're sure to do that," said the Cat, "if you only walk long enough."*
>
> *Alice's Adventures in Wonderland (Chapter VI)*

Unlike Alice, we believe that most British Columbians know where we want to go:

1. Protect and restore wild Pacific salmon.

2. Grow B.C.'s salmon farming industry and help it evolve into a clean, green, sustainable closed containment industry we can be proud of.

3. Reconcile with First Nations.

To get there we need to chart our path. We can get to where we want to go if we do the following:

1. Acknowledge that British Columbians have a very low tolerance for putting wild salmon at risk, and accept that the science on impacts such as sea lice and pathogen transmission, combined with statistical data which strongly suggests that salmon which pass by open net-pen farms fare substantially worse than those which do not, confirms that open net-pen farms pose more than a minimal risk of serious harm to wild salmon and to the environment.

2. Urge Premier Horgan and his Cabinet to announce that the Province will not renew existing tenures and will not issue new tenures for marine finfish salmon farms using open net-pens on the basis that they are not socially and ecologically sustainable.

3. Call on the Federal Government to increase oversight and public transparency in compliance with conditions of licences and the management of existing farms in the interim, including a prohibition on the transfer of PRV-infected smolts to open net-pens.

4. Commit to the development and implementation of a plan to transition (and sustainably grow) British Columbia's aquaculture industry to closed containment by a set date (i.e. 2025).

5. Recognize the future risks from climate change and other environmental factors outside of our immediate control, and commit to investing in habitat restoration

to further protect B.C.'s wild Pacific salmon and support sustainable, healthy, genetically diverse wild salmon populations that are more resilient to these risks.

All of which is respectfully submitted by Council member Tony Allard.

Attachments to Appendix 9:

1. *The Risks of Open Net Pen Salmon Farms to Wild Pacific Salmon: Summary of Scientific Findings*, a report prepared for Wild Salmon Forever by Lawrence M. Dill, PhD FRSC, Professor Emeritus, Simon Fraser University, November 8, 2017.

2. Excerpt from Pacific Salmon Commission Report: Economic Impacts of Pacific Salmon Fisheries, July 2017.

3. Timeline for PRV Fish Health Impairment Potential, prepared by Dr. R.D. Routledge, Professor Emeritus, Simon Fraser University.

Endnotes

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[1] *The Uncertain Future of Fraser River Sockeye – Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River* (hereinafter "Cohen Commission"), Vol. 3 at p. 12.
[2] Lan Gien, "Land and Sea Connection: The East Coast Fishery Closure, Unemployment and Health," *Canadian Journal of Public Health* 91, no. 2 (2000): 121.
[3] See C.J. Cederholm, M.D. Kunze, T. Murota, and A. Sibatani, "Pacific Salmon Carcasses: Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems," *Fisheries* 24, no. 10 (1999).
[4] Department of Fisheries and Oceans Newfoundland Region, "The Science of Cod, Considerations in the Scientific Study and Assessment of Cod Stocks in the Newfoundland Region," *Fo'c'sle* 8, no. 2 (February 1988): p. 29 final para.
[5] Elizabeth Brubaker, *Unnatural Disaster: How Politics Destroyed Canada's Atlantic Groundfisheries* (hereinafter "Unnatural Disaster") at p. 18, https://environment.probeinternational.org/2000/01/18/unnatural-disaster-how-politics-destroyed-canadas-atlantic-groundfisheries/, accessed January 23, 2018.
[6] Lan Gien, "Land and Sea Connection: The East Coast Fishery Closure, Unemployment and Health," *Canadian Journal of Public Health* 91, no. 2 (2000): 121.
[7] See https://nofima.no/en/prosjekt/ctrlaqua/, accessed November 14, 2017.
[8] See Slide 16 of Ann-Magnhild Solås's presentation to Council for a description of Norway's development licences.
[9] See Appendix 8, Attachment 1 of the Council's Report for the Executive Summary of the DNB Markets Report *Deep Dive into Land-Based Farming* (February 1, 2017). The full report is at http://www.kuterra.com/files/1314/9669/9783/DNB_-_Deep_dive_into_land-based_farming.pdf, accessed November 17, 2017.
[10] See Appendix 8, Attachment 2 of the Council's Report for a list of planned and operating RAS Atlantic salmon production, as at 2017 per the Conservation Fund's Freshwater Institute.
[11] See the DNB Markets Report, supra., for an overview of the phases of Denmark's Atlantic Sapphire project under development in Miami, Florida. See also Neil Ramsden, "Nordic RAS Specialist Establishes US Subsidiary," *Undercurrent News* (January 9, 2018), https://www.undercurrentnews.com/2018/01/09/nordic-ras-specialist-establishes-us-subsidiary/, accessed January 21, 2018.
[12] In an email dated Friday, May 26, 2017, James Mack advised: "FLNRO [B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development] has provided that the total annual rent collected on finfish aquaculture tenures for fiscal 2016/2017 was $1,953,294.80. This is for all finfish, and therefore includes tenures culturing species other than Atlantic salmon, including the few lake aquaculture sites that are active." In contrast, the cost of a tenure in Norway is much more expensive; DNB Markets Report at p. 25 states that the last new licence made available for a new open net-pen site in Norway was in 2014, and it sold for approximately NOK66m, or approximately Cdn$10m.
[13] To compare the tenure cost of finfish farms in B.C. (rental) and in Norway (purchase of the site), it is helpful to calculate the present value of future annual rental costs. From the available data on tenure revenue in B.C. set out in the endnote above, and assuming 119 farm sites, the present value of the cost of an open net-pen aquaculture tenure in Canada, in perpetuity is estimated in Canadian dollars as follows:

Monthly payment: $1,368 Annual payment: $16,414

Present value:

Use as Discount Rate the 30-year Canadian bond rate (2.385% at January 11, 2018) is $688,218 or the 10-year bond rate (2.20 % at January 11, 2018) is $746,091.

Each farming company will have its own cost of capital and this will very likely be higher than the "risk free" government bond rate so the appropriate discount rate will be higher than the one used here (actual cost of capital) and therefore the resulting present value of the tenures in B.C. will be lower.

Assuming tenure rentals in B.C. at perpetuity, the cost is less than 10% of the cost of a new open net-pen site in Norway. Thus, it is understandable why the industry would not want to pursue closed containment in Canada. To encourage the adoption of closed containment technologies, Canada should at least level the playing field for the economics of closed containment aquaculture by charging tenure fees that more closely represent the cost of the use and inevitable degradation of the public resource.

[14] See C.J. Cederholm, M.D. Kunze, T. Murota, and A. Sibatani, "Pacific Salmon Carcasses: Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems," *Fisheries* 24, no. 10 (1999).

[15] See the summary of Dr. Brian Riddell's presentation to the Council in Appendix 5 of the Council's Report.

[16] Unnatural Disaster, supra. at p. 5.

[17] Standing Committee on Fisheries and Oceans, Number 038, 1st Session, 42nd Parliament, Wednesday, November 30, 2016.

[18] This paper by Jennifer S. Ford and Ransom A. Myers appeared in *PLOS Biology* 6, no. 2 (February 2008).

[19] The losses tended to be greater where both the farmed and the wild salmon were Atlantics. The losses for wild Pacific salmon were generally in the range of 10-50% per generation.

[20] O. Torrissen, S. Jones, A. Guttormsen, F. Asche, T.E. Horsberg, O. Skilbrei, D. Jackson, F. Nilsen, and P.A. Jansen, "Sea Lice – Impacts on Wild Salmonids and Salmon Aquaculture," *Journal of Fish Diseases* 36 (2013): 171.

[21] G.T. Ruggerone and B.M. Connors, "Productivity and Life History of Sockeye Salmon in Relation to Competition with Pink and Sockeye Salmon in the North Pacific Ocean," *Canadian Journal of Fisheries and Aquatic Sciences* (2015), doi:10.1139/cjfas-2014-0134; and B.M. Connors, D.C. Braun, R.M.M. Peterman, A.B. Cooper, J.D. Reynolds, L.M. Dill, G.T. Ruggerone, and M. Krkosek, "Migration Links Ocean-Scale Competition and Local Ocean Conditions with Exposure to Farmed Salmon to Shape Wild Salmon Dynamics," *Conservation Letters* (2012): 1.
The two references and the description of the negative correlation are contained in the critique of a document prepared by Dr. Gary Marty providing "Information Regarding Concerns about Farmed Salmon-Wild Salmon Interactions." The critique is co-authored by eight researchers affiliated with four Canadian universities: L.M. Dill, M. Krkosek, B.M. Connors, S.J. Peacock, A.W. Bateman, R. Routledge, M.A. Lewis and J. Reynolds. Neither paper was formally published. Both are available on request in electronic form from Wild Salmon Forever.

[22] Included here as Attachment 1: *The Risks of Open Net Pen Salmon Farms to Wild Pacific Salmon: Summary of Scientific Findings* (hereinafter "Dill Report"), a report prepared for Wild Salmon Forever by Lawrence M. Dill, PhD FRSC, Professor Emeritus, Simon Fraser University, November 8, 2017.

[23] Dill Report, supra. at p. 1.

[24] Eva B. Thorstad and Bengt Finstad, "Impacts of Salmon Lice Emanating from Salmon Farms on Wild Atlantic Salmon and Sea Trout, 2018" NINA [Norwegian Institute for Nature Research] Report 1449: 1, https://brage.bibsys.no/xmlui/handle/11250/2475746.

[25] See Appendix 3 of the Council's Report.

[26] See Andrew W. Bateman, Stephanie J. Peacock, Brendan Connors, Zephyr Polk, Dana Berg, Martin Krkošek, and Alexandra Morton, "Recent Failure to Control Sea Louse Outbreaks on Salmon in the Broughton Archipelago, British Columbia," *Canadian Journal of Fisheries and Aquatic Sciences* 73 (2016): 1164, doi:10.1139/cjfas-2016-0122 .

[27] The 2016 and 2017 sea lice counts for both farms are available at http://open.canada.ca/data/en/dataset/3cafbe89-c98b-4b44-88f1-594e8d28838d, accessed January 4, 2018.

[28] As discussed previously, Mr. Justice Cohen recognized this risk. See Cohen Commission, supra., Vol. 3 at p. 12.

[29] Cohen Commission, supra., Vol. 2 at p. 113.

[30] K.M. Miller et al., "Molecular Indices of Viral Disease Development in Wild Migrating Salmon," *Conservation Physiology* 5, no. 1 (2017), doi:10.1093/conphys/cox036.

[31] Excerpt from Dr. Dill's Slide 27 in his presentation to MAACFA, with more details provided on this issue in Slides 20 through 22. In assessing Dr. Dill's credibility on the matter of assessing disease risk, it may interest the Council to know that in the face of conflicting scientific expert evidence on risks to Fraser River Sockeye from salmon farms, Justice Cohen accepted the evidence of Dr. Dill. See Cohen Commission, supra., Vol. 2 at p. 113.

[32] See the summary of Dr. K. Miller's presentation to Council in Appendix 5 of the Council's Report.

[33] See Kristina M. Miller, Oliver P. Günther, Shaorong Li, Karia H. Kaukinen, and Tobi J. Ming, "Molecular Indices of Viral Disease Development in Wild Migrating Salmon," *Conservation Physiology* 5 (2017), doi:10.1093/conphys/cox03. Especially pp. 18-20 and 29.
[34] M.G. Godoy, M.J.T. Kibenge, Y. Wang, R. Suarez, C. Leiva, F. Vallejos, and F.S.B. Kibenge, "First Description of Clinical Presentation of Piscine Orthoreovirus (PRV) Infections in Salmonid Aquaculture in Chile and Identification of a Second Genotype (Genotype II) of PRV," *Virology Journal* 13 (2016): 98.
[35] See Kristina M. Miller, Oliver P. Günther, Shaorong Li, Karia H. Kaukinen, and Tobi J. Ming, "Molecular Indices of Viral Disease Development in Wild Migrating Salmon," *Conservation Physiology* 5 (2017), doi:10.1093/conphys/cox03, especially pp. 18-20 and 29.
[36] Tomokazu et al., "Full-Genome Sequencing and Confirmation of the Causative Agent of Erythrocytic Inclusion Body Syndrome in Coho Salmon Identifies a New Type of Piscine Orthoreovirus," *PLOS ONE* 11, no. 10 (2016): e0165424.
[37] M.J.T. Kibenge et al., "Whole-Genome Analysis of Piscine Reovirus (PRV) Shows PRV Represents a New Genus in Family Reoviridae and Its Genome Segment S1 Sequences Group It into Two Separate Sub-Genotypes, *Virology Journal* 10 (2013): 230.
[38] See Kristina M. Miller, Oliver P. Günther, Shaorong Li, Karia H. Kaukinen, and Tobi J. Ming, "Molecular Indices of Viral Disease Development in Wild Migrating Salmon," *Conservation Physiology* 5 (2017), doi:10.1093/conphys/cox03.
[39] Ø. Wessel et al., "Infection with Purified Piscine Orthoreovirus Demonstrates a Causal Relationship with Heart and Skeletal Muscle Inflammation in Atlantic Salmon," *PLOS ONE* 12, no. 8 (2017): e0183781.
[40] See the summary of Dr. K. Miller's presentation to Council in Appendix 5 of the Council's Report.
[41] See the summary of Dr. K. Miller's presentation to Council in Appendix 5 of the Council's Report.
[42] Ø.W. Finstad, M.K. Dahle, T.H. Lindholm, I.B. Nyman, M. Løvoll, C. Wallace, C.M. Olsen, A.K. Storset, and E. Rimstad, "Piscine Orthoreovirus (PRV) Infects Atlantic Salmon Erythrocytes," *Veterinary Research* 45 (2014): 35, doi:10.1186/1297-9716-45-35. PubMed PMID: 24694042; PubMed Central PMCID: PMC4234517.
[43] For more on this topic, see Van T. La and Steven J. Cooke, "Advancing the Science and Practice of Fish Kill Investigations," *Reviews in Fisheries Science* 19 (2011): 21.
[44] Marine Harvest stated in an application to the court that five out of six of its hatcheries are infected with PRV. See *Morton v. MFO, Marine Harvest Inc and Cermaq Canada*, S. 18.1 Application for Judicial Review (2016) FC T-1710-16 ("Written Representations of the Party Applicant," January 17, 2017, paras. 4, 8, 9).
[45] A. Morton, R. Routledge, S. Hrushowy, M. Kibenge, and F. Kibenge, "The Effect of Exposure to Farmed Salmon on Piscine Orthoreovirus Infection and Fitness in Wild Pacific Salmon in British Columbia, Canada," *PLOS ONE* 12, no. 12 (2017): e0188793, https://doi.org/10.1371/journal.pone.0188793.
[46] See p. 5 of the Dill Report. See also M.J.T. Kibenge, Y. Wang, A. Morton, R. Routledge, and F.S.B. Kibenge, "Formal Comment on: Piscine Reovirus: Genomic and Molecular Phylogenetic Analysis from Farmed and Wild Salmonids Collected on the Canada/US Pacific Coast," *PLOS ONE* 12, no. 11 (2017): e188690, https://doi.org/10.1371/journal.pone.0188690.
[47] See for example the following that support the conclusion that the link between PRV and HSMI has been proven:

1. Palacios G. et al. "Heart and Skeletal Muscle Inflammation of Farmed Salmon Is Associated with Infection with a Novel Reovirus." *PLOS One* 5, no. 7 (2010): e11487, which concludes "as our data indicate that a causal relationship is plausible, measures must be taken to control PRV not only because it threatens domestic salmon production but also due to the potential for transmission to wild salmon populations."
2. Finstad, Ø.W. et al. "Immunohistochemical Detection of Piscine Reovirus (PRV) in Hearts of Atlantic Salmon Coincide with the Course of Heart and Skeletal Muscle Inflammation (HSMI)." *Veterinary Research* 43 (2012): 27, which concludes "Our results confirm the association between PRV and HSMI, and strengthen the hypothesis of PRV being the causative agent of HSMI."
3. Wessel, Ø. et al. "Infection with Purified Piscine Orthoreovirus Demonstrates a Causal Relationship with Heart and Skeletal Muscle Inflammation in Atlantic Salmon." *PLOS ONE* 12, no. 8 (2017): e0183781, which concludes "Purified PRV particles were inoculated into naïve Atlantic salmon. The purified virus replicated in inoculated fish, spread to naïve cohabitants, and induced histopathological changes consistent with HSMI. PRV specific staining was

demonstrated in the pathological lesions. A dose-dependent response was observed; a high dose of virus gave earlier peak of the viral load and development of histopathological changes compared to a lower dose, but no difference in the severity of the disease. The experiment demonstrated that PRV can be purified from blood cells, and that PRV is the etiological agent of HSMI in Atlantic salmon."

We are not aware of any recent refereed journal articles that challenge these conclusions, but we would be very interested to learn of them.

48 *Management Approach to PRV and HSMI for Fish Transfers in British Columbia* (2016-502-00286), as approved by Rebecca Reid, Regional Director General Pacific Region, January 30, 2017 (hereinafter "DFO Management Approach to PRV and HSMI") at p. 2.

49 E. Di Cicco et al., "Heart and Skeletal Muscle Inflammation (HSMI) Disease Diagnosed on a British Columbia Salmon Farm through a Longitudinal Farm Study," *PLOS ONE* 12, no. 2 (2017): e0171471, doi:10.1371/journal.

50 As discussed previously, Mr. Justice Cohen recognized this risk: Cohen Commission, Vol. 3 at p. 12.

51 See, for example: https://www.ctvnews.ca/canada/b-c-fish-processors-spewing-potentially-dangerous-bloodwater-into-key-salmon-migration-corridor-1.3696793, accessed December 22, 2017. It is interesting to note that Dr. Dill predicted this problem in his testimony to the Cohen Commission (see Cohen Commission, Vol. 2 at p. 67, with footnote to Exhibit 1540, pp. 27-29).

52 Email from Eveline Xia, Ministerial Assistant to the Honourable George Heyman, Minister of Environment and Climate Change Strategy, to [Private Citizen], Wednesday, January 24, 2018, at 8:55 a.m., Re 313165_Blood Water testing.

53 G.D. Marty et al., "Piscine Reovirus in Wild and Farmed Salmonids in British Columbia, Canada," *Journal of Fish Diseases* 38 (2014). Siah et al., "Piscine Reovirus: Genomic and Molecular Phylogenetic Analysis from Farmed and Wild Salmonids Collected on the Canada/US Pacific Coast," *PLOS ONE* 11, no. 10 (2016): e0164926, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0141475. K. Garver et al., "Piscine Orthoreovirus from Western North America Is Transmissible to Atlantic Salmon and Sockeye Salmon but Fails to Cause Heart and Skeletal Muscle Inflammation," http://journals.plos.org/plosone/article/authors?id=10.1371/journal.pone.0146229.

54 E. Di Cicco et al., "Heart and Skeletal Muscle Inflammation (HSMI) Disease Diagnosed on a British Columbia Salmon Farm through a Longitudinal Farm Study," *PLOS ONE* 12, no. 2 (2017): e0171471, doi:10.1371/journal.

55 Ø. Wessel et al., "Infection with Purified Piscine Orthoreovirus Demonstrates a Causal Relationship with Heart and Skeletal Muscle Inflammation in Atlantic Salmon," *PLOS ONE* 12, no. 8 (2017): e0183781.

56 DFO's Management Approach to PRV and HSMI, supra. at p. 4.

57 2015 FC 575 ("*Morton v. Canada (Fisheries and Oceans)*") at para. 35.

58 For a more fulsome discussion, see the memo: *Precautionary Measures against the Spread of PRV*, submitted to Council, October 20, 2017, providing a detailed analysis of the legal and scientific failings of DFO's *Management Approach to PRV and HSMI for Fish Transfers in British Columbia* (2016-502-00286), as approved by Rebecca Reid, Regional Director General Pacific Region, January 30, 2017.

59 2015 FC 575 at para. 99.

60 DFO's Management Approach to PRV and HSMI, supra. at Tab 3, The Minister of Fisheries and Oceans' (Minister) Interpretation of Section 56 of the *Fishery (General) Regulations* (FGRs), para. 10.

61 *Morton v. Canada (Fisheries and Oceans)* at para. 41.

62 See the summary of Dr. Marty's presentation to Council in Appendix 5 of the Council's Report.

63 Unnatural Disaster, supra. at p. 15.

64 Dill Report, supra. at p. 5.

65 See, for example, the article by Ivan Semeniuk in the *Globe and Mail* (B.C. Edition), December 5, 2017, p. A5. In the article he reported that during a marathon session in Ottawa, scientists voted that eight of the 24 populations of Fraser River sockeye should be listed as endangered – representing the highest level of risk that the population could someday be lost. The Council determined that two other populations should be listed as threatened and five more designated "of special concern." The Council also voted that the remaining nine populations of sockeye still occur in large enough numbers on the Fraser that they do not warrant listing. See

https://www.theglobeandmail.com/news/national/what-these-species-say-about-the-worrisome-state-of-canadas-wildlife/article37193496/.

[66] Unnatural Disaster, supra. at p. 20.

[67] See Appendix 9 of the Council's Report for a full discussion on the legal obligation for the Federal Minister to take a precautionary approach. See also *Morton v. Canada (Fisheries and Oceans)* at paras. 96-99 where Mr. Justice Rennie found that DFO was not applying the precautionary principle as required by law and had unlawfully sub-delegated discretionary decisions to industry with respect to precautionary measures. Canada's Policy for the Conservation of Wild Pacific Salmon provides a useful framework for determining acceptable risks.

[68] Cohen Commission, supra., Vol. 1, *The Sockeye Fishery*, at p. 418.

[69] Cohen Commission, supra. at p.12.

[70] Cohen Commission, supra. at p. 12.

[71] *Morton v. Canada (Fisheries and Oceans)* at para. 35.

[72] *Morton v. Canada (Fisheries and Oceans)* at para. 44.

[73] DFO's Management Approach to PRV and HSMI, supra.

[74] DFO's Management Approach to PRV and HSMI, supra. at p. 4.

[75] See, for example, the article by Ivan Semeniuk in the *Globe and Mail* (B.C. Edition), December 5, 2017, p. A5.

[76] On September 12, 2017, the First Nations Fisheries Council of British Columbia issued a press release stating opposition to open net-pen fish farms:

> The First Nations Fisheries Council of British Columbia (FNFC) passed a resolution at their last Executive meeting expressing that the production of Atlantic salmon in open net pens along the Pacific coast poses too great a risk to wild salmon populations. While the FNFC recognizes that a small number of First Nation communities rely on agreements with fish farm operators for economic opportunity, the FNFC has heard from the vast majority of nations that fish farms cannot be supported.

The full press release is available at http://www.fnfisheriescouncil.ca/wp-content/uploads/2015/09/FNFC-Press-release-non-support-open-net-pens-sep-2017.pdf, accessed January 12, 2018.

[77] First Nations Wild Salmon Alliance, *Wild Salmon Strategy Session: The Future of Wild Salmon – Removing Barriers to Informed Decision-Making*, Report on Proceedings and Recommendations, April 18-19, 2016, at p. 20. Available at http://fnwildsalmon.com/wp-content/uploads/2016/05/WSA_Final_Report_v4-05.19-WEB.pdf, as of January 3, 2018.

[78] *Tsilhqot'in Nation v. British Columbia*, 2014 SCC 44, at paras. 91 and 92.

[79] *Kainaiwa/Blood Tribe v. Alberta (Energy)*, 2017 ABQB 107, at paras. 129 and 130.

[80] Unnatural Disaster, supra. at p. 4.

Attachment 1:

The Risks of Open Net Pens to Wild Pacific Salmon

The Risks of Open Net Pen Salmon Farms to Wild Pacific Salmon: Summary of Scientific Findings

A report prepared for Wild Salmon Forever by Lawrence M. Dill, PhD FRSC, Professor Emeritus, Simon Fraser University

November 8, 2017

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About the Author

Lawrence Dill obtained his PhD from UBC in 1972, returning to university after having spent 2 years as a DFO salmon biologist. He joined the Department of Biological Sciences at SFU in 1974 and rose through the ranks to become a University Research Professor. He was elected as a Fellow of The Royal Society of Canada in 1997 and was awarded the 2004 IgNoble Prize in Zoology for his landmark study of herring flatulence. Currently he is a Professor Emeritus at SFU and continues to supervise graduate students. During his career he has published nearly 170 scientific papers in refereed journals. In recent years much of his research and that of his students has been on the interactions between sea lice and wild salmon. He produced a research report for the Cohen Commission on the impacts of salmon farms on Fraser River sockeye salmon, and co-authored the WWF Salmon Aquaculture Dialogue report on sea lice. Never happy far from the water, he lives in a floating home in Victoria, BC with his wife Elizabeth and Digby, his Nova Scotia duck toller.

November 8, 2017

Executive Summary

Concern about the potentially harmful interactions between wild Pacific salmon and farmed salmon contained in open net pens has been a longstanding issue in British Columbia and elsewhere. Here I review recent scientific findings relevant to this debate.

My principal findings are as follows:

1. Because of the large numbers of farmed Atlantic salmon in close proximity in open net pens (ONPs), lice, viral and other pathogen populations can grow to very large sizes, shedding millions of infective stages (lice) or copies into the local environment outside the farm, where they can infect wild fish. In addition, conditions inside the farms are exactly those which evolutionary theory predicts will lead to selection for increased pathogen virulence, i.e., an increased negative effect on its host, and there is evidence that this has happened in aquaculture facilities. Therefore, what comes out of ONPs can be much more dangerous to wild salmon than the pathogens that the wild salmon may have passed to the farmed Atlantic salmon in the first place.
2. The risk to wild salmon from sea lice produced in Open Net Pens (ONPs) is unambiguous and substantial. Lice have been shown to reduce productivity of both wild pink and coho salmon populations in the Broughton Archipelago, and there is no reason to think they are not having similar effects elsewhere on the BC coast. The mechanisms by which lice impact individual survival are well understood, and these individual and population level effects have been found consistently throughout the world and are supported by large-scale experiments.
3. Piscine orthoreovirus (PRV) and the disease it causes (Heart and Skeletal Muscle Inflammation or HSMI) have recently been confirmed on a BC salmon farm. The virus has been implicated in the heavy pre-spawning mortality of Fraser River sockeye salmon. Additionally, it has been shown that productivity of these stocks depends in part on the number of Atlantic salmon in the ONPs that the smolts pass on their northward migration to the open ocean. While we do not know what it is about the farms that underlies this latter relationship, pathogen transmission remains the most likely explanation. It is tempting to speculate that PRV may be involved but we don't yet know the source of the PRV with certainty.
4. A number of other viruses and disease-causing organisms (bacteria, myxozoans and microsporideans) are known to be present in ONPs The risk they present to wild Pacific salmon is currently unknown, but could be substantial. There is evidence that some can be passed to wild salmon with harmful effect, but we cannot say with certainty that any wild salmon population has declined because of them.
5. Lice (and to an extent, viruses) have been shown to affect the vulnerability of wild salmon to other mortality agents, including starvation and predation. Even if these pathogens do not kill the fish directly, infected fish are likely to be rapidly removed from the population by a predator, making the business of proving that

a given agent causes widespread wild salmon mortality and population decline a very difficult task.

6. As a result of these indirect effects, the impact of parasites and viruses on wild salmon depends on environmental factors such as water temperature and competition with other species. The less benign the environment, the greater the impact to be expected.
7. Apparently healthy fish in the ONPs may still be fighting infection and releasing viral particles into the waters surrounding the farm, where they can infect wild fish. Therefore the fact that only a small percentage of farmed salmon die of a given disease greatly underestimates the risk they present to wild salmon.
8. Lice impacts on wild salmon can be mitigated by appropriate control strategies on the farms, particularly the timing of parasiticide treatment. Although there is concern that lice may evolve resistance to SLICE and other chemicals used to control them, a large wild fish population may help to maintain the efficacy of SLICE and delay the evolution of resistance, meaning that the preservation of healthy wild salmon populations is in the salmon farmers' self interest.
9. The evidence of risk to wild salmon is sufficient that the precautionary principle should be invoked, and Governments should mandate and support the aquaculture industry's move from ONPs to land-based closed containment production systems.

Introduction

Most farmed salmon in BC are grown to market size in open net pens. At any one time there are approximately 80 active farms in BC (out of 119 tenures), each consisting of a number of separate net pens, containing up to ¾ of a million fish in total. Roughly 95% percent of the fish raised in BC are non-native Atlantic salmon (*Salmo salar*); a small minority of farms, all in Clayoquot Sound, contain endemic chinook salmon. The farms are distributed widely along the coast, mostly south of Port Hardy in the Inside Passage as well as along the west coast of Vancouver Island. This places them along the migratory routes of wild juvenile salmon heading to the open ocean as well as of the adult fish returning to their natal streams to spawn.

Since the Cohen Commission of Enquiry (2011) and its associated scientific reports, there has been a considerable amount of new research published on the risks that open net pen salmon farms (hereafter ONPs) may pose to wild Pacific salmon, especially the juveniles. The present report is an attempt to update and summarize our scientific understanding of these risks. Because I believe that research findings do not become accepted knowledge until published in the peer reviewed scientific literature, I will base this report only on such sources, and not on grey literature, unpublished research, anecdotes or opinion. Although the focus will be on research conducted on the interactions between farmed Atlantic salmon and wild Pacific salmon (*Oncorhynchus* species) here in BC, research conducted in Europe will be referred to where appropriate. To avoid long lists of citations I will refer to synthesis or review articles wherever possible. I will also indicate some areas where more research is warranted.

The risk of ONP's comes entirely from the fact that they are "open" and form a single interacting system with the surrounding waters and their wild salmon inhabitants. As a result, anything infecting the salmon outside the pens can be transmitted to the fish inside, and vice versa. Both parts of this two way street are important, but we are concerned here with risks to wild salmon coming from inside the farms. Parasites and diseases, albeit sometimes introduced by wild fish, change in abundance and perhaps virulence in the ONP environment and can then be transferred back to the wild populations, sometimes at earlier and more vulnerable life stages. The likelihood of this occurring is likely to be increased by wild juveniles being attracted to the ONPs by excess food and
nighttime lighting. Unlike Las Vegas, what happens in net pens doesn't stay in net pens.

As implied above, parasites (lice) and diseases are the main potential threats to wild fish from salmon farms and will be the main focus of this report. I will deal with each separately before more briefly considering some other possible risks to wild salmon posed by ONPs.

Lice

There are two species of ectoparasitic lice commonly found in relatively large numbers on the Atlantic salmon in the farms: *Lepeophtheirus salmonis*, the salmon louse (hereafter Leps), and *Caligus clemensi*, the sea louse. Both are generally referred to as sea lice. A main difference between these two, apart from the fact that Leps is much larger, has to do with their host specificity: Leps is only able to complete its life cycle and produce eggs on salmonids, while *Caligus* is a host generalist and is commonly seen on herring (e.g. 60) and other species of fish. This has some important implications discussed below. Most of the research on lice has been conducted on Leps; little is known about the impacts of *Caligus* on their hosts. Despite the fact that *Caligus* is sometimes more abundant on farmed Atlantic salmon than is Leps, Government regulations mandating treatments at certain threshold louse infection levels deal only with the latter species.

Genetic analysis (85) has suggested that Leps from Europe and BC are not identical, but there is no indication that this is anything other than random variation, perhaps due to genetic drift, or that the two types are functionally distinct. In other words there is no reason to believe that the results from host-impact studies in Europe, where lice have been a huge problem for wild salmon and trout, are not just as applicable here in BC.

Despite earlier arguments in the scientific literature it is now undisputed that ONPs are the primary source of heavy Leps infestations on wild juvenile salmon, including on pink and chum salmon in the Broughton Archipelago where most of the BC field work has been conducted (45, 60, 33, 51) as well as on sea trout and salmon in Europe (76, 70). In addition, there is evidence that pink and chum salmon and Fraser River sockeye smolts pick up both Leps and *Caligus* as they pass ONPs on their way north through the Discovery Islands (68, 69). The only remaining contentious issue is what impact this has on wild salmon populations; the evidence, to be discussed below, suggests it may be considerable.

Viruses

Sea lice are relatively large and obvious, easily observed and counted, and can even be cultured in the laboratory. This is one reason that they have been extensively studied. Most other salmon pathogens are invisible to the naked eye, and so have largely flown under the radar. However, recently, and aided by new molecular methods, much more attention has been paid to understanding the potential risk that viruses and microparasites pose to wild fish in BC and elsewhere.

Piscine orthoreovirus: Among the viruses, much of the current concern has focused on Piscine orthoreovirus (PRV). It has long been suspected (e.g., 65, 17) to cause a disease known as Heart and Skeletal Muscle Inflammation (HSMI), and this has very recently been confirmed experimentally (83). One reason it has taken so long to identify PRV as the causative agent of HSMI is that the virus can be present without causing any obvious signs of disease (84, 23). Another has to do with disagreement over whether clinical behavioural indicators of disease must be present before HSMI can be diagnosed. The virus first appears in the fish's red blood cells where it replicates before spreading to other organs and causing the lesions associated with HSMI (18).

PRV is ubiquitous in farmed Atlantic salmon in Norway and has been shown to transfer to wild Atlantics there (22) and PRV or PRV-like viruses (there may be a diversity of "species") have been found in coho salmon in both Chile (24) and Japan (74) and in hatchery rainbow trout in Norway (64). PRV has also been isolated from wild cutthroat trout, and from steelhead, coho, chinook and chum salmon in BC (38, 71). It can be passed from fish to fish by cohabitation (41).

HSMI has been found on at least one open net salmon farm in BC (14; see also 38, 71). The presence of some sort of virus in ocean caught adult Fraser sockeye is a predictor of very low survival to spawning (they have a 13.5-fold greater chance of dying en route; 55), and PRV is one of the pathogens that seem to correlate with pre-spawn mortality (56). The latter study (56) was the first record of PRV in sockeye salmon, and it was subsequently reported in sockeye smolts (25). While it is tempting to suggest these fish picked up the virus when passing salmon farms, either as smolts or adults, there is no evidence to confirm or refute this hypothesis at this time. However, the PRV found in BC is genetically very similar to Norwegian strains, and may have diverged from it as recently as 2007 (38), suggestive of farm origin, at least initially.

There are good reasons why PRV may compromise a fish's ability to complete the arduous migration to the spawning grounds. The high proportion of red blood cells infected in the early stages of HSMI is likely to reduce their oxygen carrying capacity and result in anemia and poor swimming performance; the subsequent lesions in heart and muscle tissue undoubtedly also make the salmon less likely to complete their migration successfully. Finally, Atlantic salmon infected with PRV have reduced tolerance for high temperatures (48). Should this be true for Fraser sockeye salmon, it could also help to explain why PRV seems to be associated with low survival, given the unusually high temperatures in the river in recent years.

The findings that many (perhaps even a majority) of apparently healthy farmed fish may be infected with PRV and in a disease state, i.e., actively mounting a cellular defense to the virus (14), have exceedingly important implications. If this is generally true then these fish are most likely shedding millions of viral particles in their faeces, or through their gills and skin, into the ONPs and the water surrounding them, potentially putting wild fish at risk. Therefore the fact that only a small percentage of farmed salmon die of a given disease greatly underestimates the risk they present to wild salmon.

***Other viruses*:** Concerns have been raised that three other viruses may pose a risk to wild salmon: infectious salmon anemia virus (ISAV), infectious haematopoietic necrosis virus (IHNV), and salmon leukemia virus (SLV). A recent paper on risks of ONPs (58) summarizes the available information on each of these viruses and concludes that all of them (as well as PRV) pose " a greater than minimal risk of serious harm" to wild salmon in BC. SLV and IHN have certainly been responsible for disease outbreaks in BC farms, and (57) determined that a small percentage of wild migrating sockeye had IHNV, using a powerful new molecular technique able to detect an active viral disease state in fish that otherwise appear healthy. The evidence for ISA in BC is controversial but there is published evidence of a variant form of ISA being in both farmed Atlantic and wild Pacific salmon (39).

Another virus beginning to raise concern is ENV – erythrocytic necrosis virus, which is known to cause severe physiological disruption in chum salmon fry (49.). Herring is a major host for this virus (16, 28), which suggests the possibility that it could be introduced to ONPs by herring attracted there by feeding opportunities. Indeed, ENV has been found in farmed Atlantic salmon (57). The involvement of herring in the host-parasite dynamics, as is also the case with *Caligus* (see above), leads to the possibility of some deleterious food chain effects for wild salmon, i.e., reduced food availability.

Other Pathogens

In addition to sea lice and viruses, a number of other pathogens found in farmed fish may pose a risk to wild salmon.

Bacteria: Two bacterial diseases have the potential to impact wild salmon. The first, bacterial kidney disease (BKD) is caused by *Renibacterium salmoninarum*. It is relatively uncommon in Atlantic salmon in net pens (37) but very pathogenic to sockeye. The second, *Piscirickettsia salmonis* is a significant pathogen of fish in net pens, including Atlantics, chinook and coho, but has not been found in wild salmon to date (37).

Myxozoans: These tiny parasites, distantly related to jellyfish, have a two-host lifecycle involving an invertebrate. One species, *Parvicapsula minibicornis*, is found in both smolts and adults of sockeye salmon and heavy infection impedes the fish's ability to recover from exercise (81) and can cause mortality (37). It is considered to be of "high risk" to Fraser River sockeye (37).

Microsporideans: This is another group of microparasites, related to fungi. One species, *Loma salmonae*, a well-known aquaculture pathogen (37), reduces the probability of sockeye surviving to spawning (56).

While all of these other pathogens can on occasion be found in ONPs, and can pose a threat to wild salmon, there are no documented cases of disease transfer. It is unclear how one would demonstrate this, other than with large-scale manipulative experiments combined with genetic markers.

Interactions between Pathogens

Because they cause skin damage and impair the immune system, being infected with lice may increase the fish's susceptibility to other pathogens, including *Loma* (62) and ISAV (3). Infections by lice (or being in any disease state) may also be expected to increase susceptibility to adverse environmental conditions, such as the higher water temperatures associated with climate change. It is also noteworthy that co-infection (i.e., simultaneous infection by more than one pathogen) is one of the factors selecting for increased virulence (see the following section).

Finally there is some evidence that sea lice can act as a vector for bacteria (2) and viruses (30), transmitting these pathogens from fish to fish as the lice switch hosts, a not uncommon behaviour (10).

The Red Herring of Endemism

It is sometimes claimed that because a particular disease is already found in wild salmon (i.e., is endemic), its presence on farmed salmon is not a threat to the wild fish. This is not necessarily the case. Because of the large numbers of hosts in close proximity in ONPs, lice, viral and other pathogen populations can grow to very large sizes - a process called bioamplification - shedding millions of infective stages (lice) or copies into the local environment outside the farm, where they can infect wild fish. Additionally, conditions inside the farm are exactly those which evolutionary theory predicts will lead to selection for increased pathogen virulence, i.e., an increased negative effect on its host (36). Although evolutionary processes like this will take several generations, the generation time of these pathogens is short. In fact there is considerable evidence that evolutionary change has happened in aquaculture facilities: ISAV apparently mutated to a more virulent form in Norwegian net pens (53), as did the bacterium *Flavobacterium columnarae* (73). Of particular relevance here, Leps sampled from farms cause more skin damage to their hosts, and cause greater growth reduction, than do lice sampled from wild fish (78). Although evolutionary processes like this will take several generations, the generation time of these pathogens is short. The result is that what comes out of ONPs can be much more dangerous to wild salmon than the pathogens that the wild salmon passed to the farmed Atlantic salmon in the first place.

This is further exacerbated by the farms disrupting what has been called "migratory allopatry" (44), meaning that returning adult wild salmon that may be infected with sea lice or other pathogens do not interact directly with juveniles on their way to sea, because they are not in the same place at the same time. This prevents pathogens on the former from infecting the latter. However, placing ONPs on the migration route allows for the pathogens to find a readily available host population in the fall, and to retain and grow the pathogen population over the winter, providing a source of infection for juvenile fish passing by the farms in the spring. The fact that these fish are small, and in the case of very young pink and chum salmon, without scales, means they're less able to cope with infection, making the problem worse.

Consequences of Infection for Individuals

Sea lice and diseases may in some cases kill their salmon hosts directly, through stress and physiological dysfunction (12, 76, 6). For example, skin damage caused by lice may lead to osmoregulatory failure. However, it is widely believed that they more frequently make their hosts more susceptible to other mortality agents, particularly starvation and predation.

Recent research suggests that heavy infections with *Caligus* can reduce the ability of juvenile sockeye salmon to compete for food and thus reduce their growth (25, 26). This is important because salmon biologists have known for a long time that smaller fish in a cohort have a much lower probability of survival to adult return (e.g. 5), perhaps due in part to being more likely to be eaten by predators (77).

Predators may have an even more direct effect on salmon infected with sea lice because the lice *per se* may make them more susceptible to predators, as has been shown for pink and chum salmon fry (47). The mechanism for this is not entirely clear but may involve compromised swimming ability (50, 63), less attentiveness to predators while concentrating on feeding (47), and/or altered schooling behaviour (47) or surface activity (82).

Very little research of this sort has been done on fish infected with other disease agents but having BKD makes chinook salmon more vulnerable to predators (54), and Rhinoceros auklets (a seabird) have more sockeye infected with the myxozoan *Parvicapsula* in their diets than would be expected based on the proportion such fish make up of the population (56). Also, Chilko sockeye smolts showing signs of viral infection (including IHNv) have a much lower chance of surviving downstream migration to the mouth of the Fraser River than do their uninfected counterparts (31), perhaps due to in-stream predation. The source of these infections in not known with certainty, though ONPs are certainly one possibility.

The implications of these findings are extremely important. If generally true it means that juvenile fish heavily infected with lice, or fighting off viral infection, may be quickly removed from the population, ending up either in the guts of predators or sinking to the sea floor. As a result, it will be most unlikely that sampling of wild fish populations will find many of them to be infected, as only the survivors will still be present, thereby greatly underestimating the impact of ONPs. It also means that laboratory studies in benign environments devoid of predators (e.g., 35) will greatly overestimate the threshold level of infection likely to cause death. Thus (35) found that 7.5 lice per gram in small juvenile pink salmon were necessary to cause death in the lab, yet found few of such fish in the field, implying that lice were not a major cause of mortality (34). The fallacy of this argument should be apparent. It was clearly articulated 20 years ago (52):

"In contrast to cage or tank situations, sick fish in the natural environment that show any abnormal behaviour are likely to be rapidly removed from the area by predators and any random samples of fish taken will almost inevitably show only healthy animals, those with non-pathogenic infection levels or those with benign types of disease". (McVicar 1997)

Population Consequences

Worldwide Picture

A global assessment (20) suggests that local native salmonids are impacted negatively wherever there are fish farms (see also 13). A particularly well-documented case study of the effect of sea lice has recently been provided for sea trout in Europe, based on many years of research in Ireland, Scotland and Norway (76). As well, Atlantic salmon returns to the Erriff River in Ireland are 50% lower in years following high lice levels on farms (70).

It should be noted that since it is possible (and perhaps even highly likely) that fish infected by lice may be co-infected with other pathogens, some of the negative effects attributed to lice may be due to bacteria or viruses, which are harder to detect and may not have even been assayed. This caveat applies equally to the Broughton Archipelago lice studies to be described next.

BC

Broughton Archipelago pink salmon: An argument raged in the literature for several years over whether Broughton pink salmon populations were being severely impacted by sea lice. Early predictions (45) that lice would cause local pink salmon extinction if downward populations trends continued proved untrue, but this was likely due in part to changes in louse management practices (timing of anti-louse treatment prior to the wild salmon migration window; 66). In and of itself, this would suggest an impact of lice on wild fish. One study by the Provincial pathologist (51) was unable to find an effect of farmed salmon louse levels on pink salmon survival, but more thorough and powerful analyses (46, 43) revealed a significant effect on recruitment. Worryingly, lice levels on wild salmon in the Broughton have recently increased; this may be due to a combination of warmer water and less well-timed treatment on the farms (4).

Coho salmon: There is evidence that Broughton Archipelago coho salmon populations are also negatively impacted by salmon farms (9). Like the pinks, coho probably pick up lice directly from the farms, but they also pick up lice indirectly when consuming parasitized pink salmon (8).

Chum salmon: Curiously, although chum salmon fry are often just as heavily parasitized by lice as are pink fry, their survival does not seem to be negatively affected to the same extent (67). It is believed that this may be due to predators concentrating their attention on the more preferred, and now vulnerable, pinks, thereby reducing predation pressure on the chum.

Fraser sockeye: An analysis conducted for the Cohen Commission, and subsequently published (11), suggested that the number of fish in the ONPs passed by migrating sockeye smolts was a predictor of subsequent adult returns, i.e., more fish in the pens led to lower sockeye returns. But this was true only when competition with pink salmon in the open ocean was likely to be intense. Interestingly, this result is consistent with the above-mentioned finding that lice compromise sockeye competitive abilities (25).

Correlation, Causation and Experimentation

Studies such as that showing that heavily liced fish are less able competitors (25) can justly be criticized for assuming that the correlation implies causation. It may be that lower food intake compromises the fish's ability to avoid infection, or that inherently low quality fish are both competitively inferior and more vulnerable to lice. However, if a causal hypothesis based on a correlation leads to a prediction that can be confirmed by further observation, or if several correlations triangulate at the same cause from different angles, one can begin to have some confidence that the proposed causal mechanism is correct. This is especially true if the proposed cause aligns with known biological principles. Thus correlations provide important data in several fields, including epidemiology – and salmon epidemiology is essentially what we are dealing with here.

However, while it would be unwise to discount correlational evidence, a better way forward is through controlled experiments. This is not always possible, particularly at the individual level of analysis; it would require placing predetermined numbers of lice on randomly selected clean fish, and no one has devised a way to do this yet. But there are two kinds of experiments that have been conducted at the population level. The first is fallowing. Fallowing of farms during late winter and spring has been shown to reduce lice infection of sea trout in Ireland and increase their survival (21). A similar experiment was conducted in BC in 2003, when the ONPs along an entire migration corridor in the Broughton Archipelago were left fallow during the spring migration of wild fry. This resulted in an increase in adult returns the following year (59; see also 61) A problem with a study of this sort is the lack of replication, meaning that the improved survival in that year could have been due to some other factor favouring the fish, such as increased food availability in the ocean or reduced salinity lowering survival of the lice (33).

A far stronger experimental result has recently been reported. SLICE (emamectin benzoate) is used to rid farm salmon of sea lice. It has also been applied to batches of hatchery Atlantic salmon as a chemotherapeutic in the hope of reducing their likelihood of picking up lice when passing fish farms. A meta-analysis of 118 separate experimental releases of this sort leaves no doubt that it is effective in increasing survival (79; see also 72) and implicates ONP-origin lice as the cause of reduced survival in the absence of treatment. An interesting result of the analysis was that the impact of the anti-parasiticide, and by inference of lice, was stronger when the survival of the untreated control group was poorest. The treated salmon were 1.7 times more likely to survive as the untreated ones under such conditions. Like the analysis conducted on sockeye for the Cohen Commission (11) this suggests that the impact of ONPs may be greatest when other biotic and abiotic conditions are less favourable for wild salmon survival.

No similar experiments have been conducted with lice chemotherapeutics in BC and no such experiments have been conducted on bacteria and viruses. This would be a very worthwhile research project.

Experiments are difficult to conduct in large field systems with numerous uncontrollable variables, so researchers are sometimes forced to "experiment in silico" with mathematical models. Models describe the workings of a system to the extent it is currently understood, and allow manipulation of variables to see the consequences. They can focus attention on gaps in knowledge and the simulation results should be viewed as hypotheses for further testing; they can also suggest improved management practices. The extensive literature on salmon-sea louse epidemiological models has recently been reviewed (27). One of the outcomes was a greater realization of the importance of incorporating spatial structure, i.e., spacing and interactions between farms along a migration route.

Other Potentially Negative Impacts of ONPs

Escapes

The recent escape of something like 150,000 farmed Atlantic salmon from an aging ONP in Washington State, and their subsequent dispersal and capture far from the site, has cast the spotlight on another potential risk to wild salmon. It is known that farmed Atlantics can survive in the wild and may have established permanent populations in BC streams (80, 19). Because they are not closely related to Pacific salmon, there is very little likelihood of interbreeding and loss of genetic identity (with the possible exception of the Clayoquot Sound area where the farms raise chinook salmon, wild populations of which are found in local streams; 40). Rather, the risks come from their potential for competing with wild juvenile Pacific salmon and steelhead in streams, and possibly from disease transfer. Studies on the former suggest that while competition is possible it is unlikely to have severe consequences (summarized in 75). There has been no scientific study of disease transfer from escapees in BC, though it is known that some diseases can transfer from Atlantic to Pacific salmon sharing the same water, as could occur in streams (23, 41), and escaped Atlantic salmon are suspected of transmitting furunculosis (a bacterial disease) to wild salmon and trout in Norway (32).

ONPs have other negative consequences for the ecosystems that house them, including:

- attraction of wild forage fish (such as herring) and salmon and incidental harvesting of them ;
- pollution of the seafloor immediately below the pens with faeces and excess food;
- pollution from plastic debris (29), chemical agents (e.g. those used to clean nets; 7), diesel (spilled at a farm in the Broughton Archipelago in early 2017) and antibiotics;
- reduction of local crustacean populations as a result of SLICE spill-over;
- reduction of predator populations, including seals and sea lions, due to shooting.

Several of these are discussed in my report to the Cohen Commission (15), but are not treated in detail here because they are unlikely to have significant effects on wild salmon stocks comparable to the potential impacts of parasites and diseases.

Concluding Remarks

In my opinion the risk to wild salmon from sea lice produced in ONPs is unambiguous. Lice have been shown to reduce productivity of both wild pink and coho salmon populations in the Broughton Archipelago, and there is no reason to think they are not having similar effects elsewhere on the BC coast. The mechanisms by which lice impact individual survival are well understood, and these individual and population level effects have been found consistently throughout the world and are supported by large-scale experiments.

Experience in the Broughton Archipelago suggests that lice impacts on wild salmon can be mitigated by appropriate control strategies on the farms, particularly the timing of parasiticide treatment. However, there is concern that lice may evolve resistance to SLICE and other chemicals used to control them, as is happening elsewhere (1). Ironically, it seems that a large wild fish population may help to maintain the efficacy of SLICE and delay the evolution of resistance (42), meaning that the preservation of healthy wild salmon populations is in the salmon farmers' self interest!

PRV (and HSMI, the disease it causes) has been implicated in the heavy pre-spawning mortality of Fraser River sockeye salmon. Additionally, it has been shown that productivity of these stocks depends in part on the number of Atlantic salmon in the ONPs that the smolts pass on their northward migration to the open ocean. While we do not know what it is about the farms that underlies this latter relationship, pathogen transmission remains the most likely explanation. It is tempting to speculate that PRV may be involved but we don't yet know the source of the PRV with certainty.

The case is not so clear for other pathogens. While harmful pathogens – including viruses, bacteria, myxozoans and microsporideans - are certainly present in the ONPs, and there is evidence that some can be passed to wild salmon with harmful effect, we cannot say with certainty that any wild salmon population has declined because of them.

Research on these topics is badly needed, and indeed is ongoing, but in the meantime it seems that the evidence of risk to wild salmon is sufficient that the precautionary principle should be invoked, and Governments should mandate and support the aquaculture industry's move from ONPs to land-based closed containment production systems.

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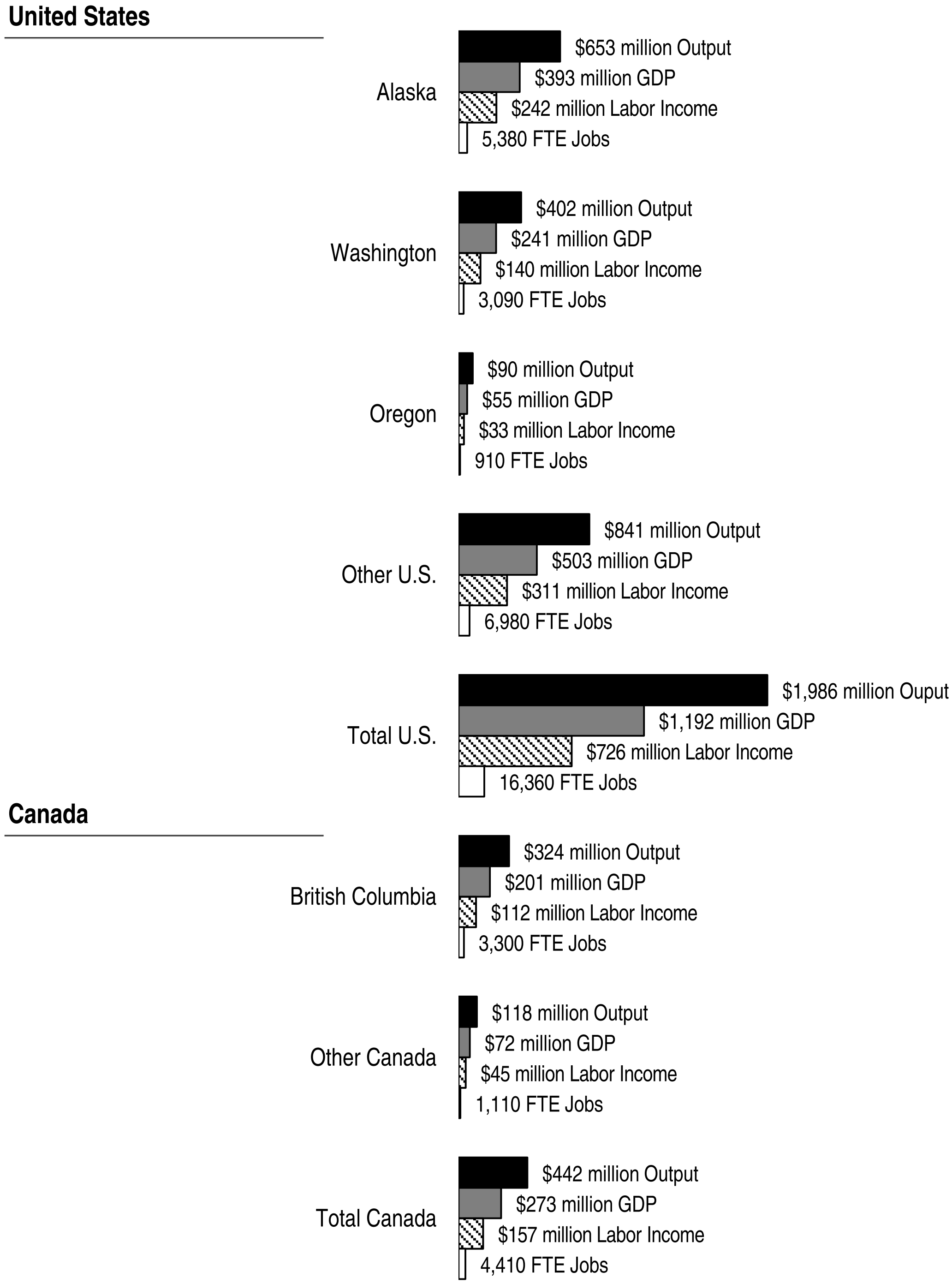
Attachment 2:

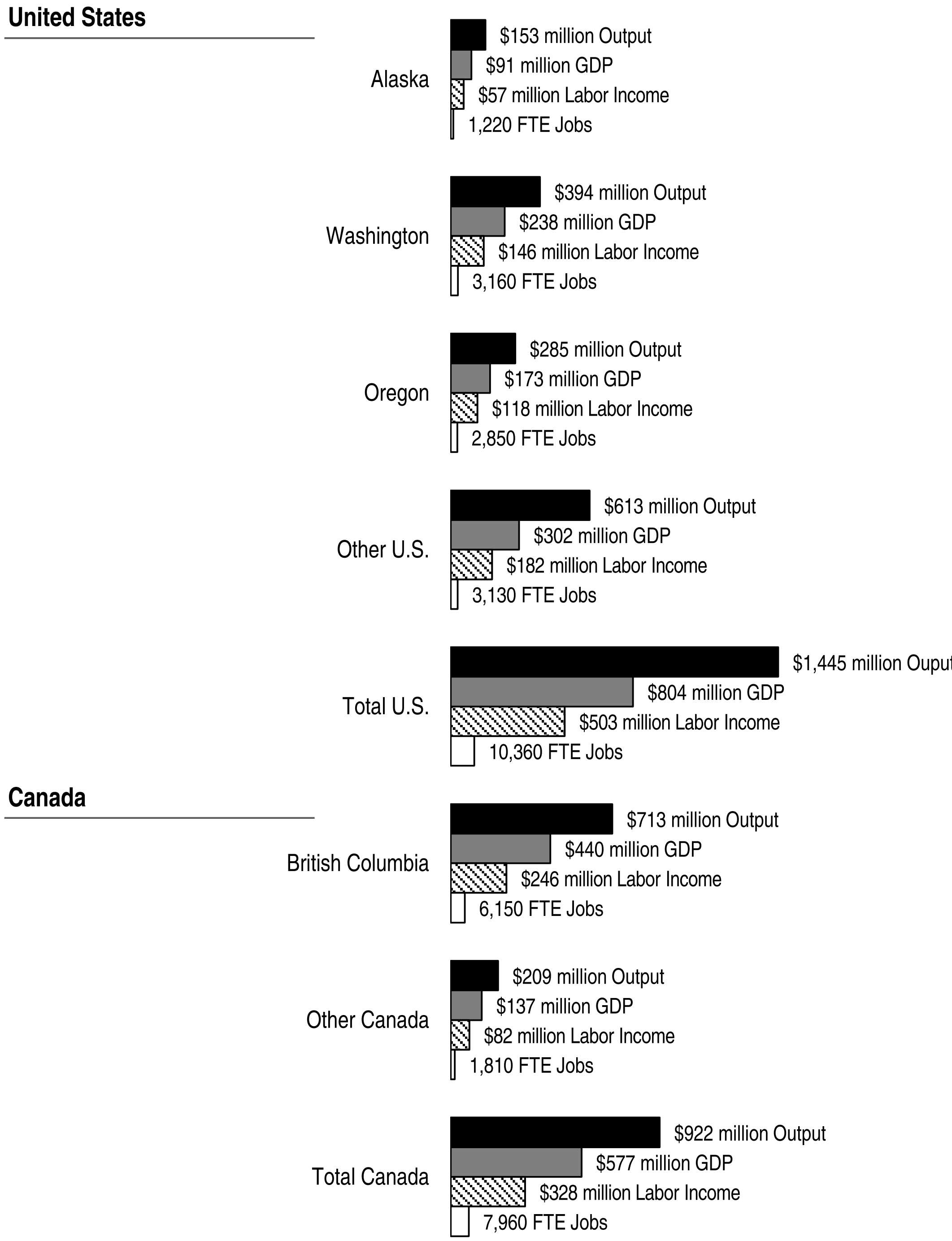
Economic Impacts of Pacific Salmon Fisheries

Exhibit A: Commercial Salmon Industry - Average 2012 to 2015 Economic Impacts*



* *Total impacts including direct industry, indirect supplier and induced consumer respending impacts for the regions in which the impacts occur (which may differ from where the fisheries occur). Values are expressed in USD.*

Exhibit B: Recreational Salmon Industry - Average 2012 to 2015 Economic Impacts



* *Total impacts including direct industry, indirect supplier and induced consumer respending impacts for the regions in which the impacts occur (which may differ from where the fisheries occur). Values are expressed in USD.*

Attachment 3:

Timeline for PRV Fish Health Impairment Potential

Timeline for PRV Fish Health Impairment Potential*

Prepared by R. Routledge, Professor Emeritus, Simon Fraser University

2004 Kongtorp *et al.* (a[1],b[2]): First case definition of HSMI and demonstration that it is infectious.

2006 Watanabe *et al.*[3]: Early evidence on potential viral cause of HSMI.

2009 Kongtorp and Taksdal[4]: Risks of spreading HSMI by transferring apparently healthy fish.

2010 Palacios *et al.*[5]: PRV discovered - reported as viral precursor of HSMI.

2012 Finstad *et al.*[6]: Further evidence that PRV causes HSMI.

Kristoffersen *et al*.[7]: Risk of long-distance dispersal of PRV over 50-100 km.

Garseth *et al*. (a, b, c): PRV widely dispersed (without HSMI) in wild Atlantic salmon, can spread from farm to wild salmon, sea-trout could play role in pathogen exchange with wild Atlantic salmon.

2014 Finstad *et al*.[8]: Discovery that PRV first proliferates in red blood cells with potential effects on fish health.

Miller *et al*.[9]: Shortened survival for PRV-infected sockeye salmon returning to Chilko Lake.

Marty *et al*.[10]: Heart lesions in BC not likely caused by PRV. PRV may not cause HSMI.

2015 Wessel *et al*.[11]: Technical progress on molecular-level functioning of PRV.

Wessel *et al*.[12]: More definitive evidence that PRV can replicate in red blood cells.

Olsen *et al*.[13]: HSMI-like disease and anemia along with PRV-like virus in rainbow trout.

Dahle *et al*.[14]: Found major phenotypic changes in PRV-infected red blood cells in Atlantic salmon. Functional consequences unexplored.

Bjørgen *et al*.[15]: Elevated PRV levels in damaged versus undamaged muscle cells. Further evidence that PRV causes HSMI.

DFO[16]: PRV in BC farmed and wild salmonids. No reports of HSMI in BC.

2016 Siah *et al*.[17,18]: HSMI not in BC. PRV widespread, long-present in BC.

Madhun *et al*.[19]: Low prevalence and intensity of PRV in wild sea trout.

Garver *et al*. (a[20], b[21]): BC strain of PRV can be transmitted to sockeye and chinook salmon, but does not cause HSMI or jaundice syndrome.

Haatveit *et al*.[22]: Molecular-level evidence related to PRV replication in red blood cells.

Godoy *et al*.[23]: HSMI in Chilean farmed Atlantic salmon. Heart lesions with PRV-like virus found in Chilean farmed coho salmon.

Takano *et al*.[24]: PRV-like virus causes blood disease, EIBS, in coho salmon.

Lund *et al*.[25]: PRV can help Atlantic salmon fight a SAV infection.

Polinski *et al*.[26]: Evidence of a limited early response to PRV infection in sockeye salmon, independent of co-infection with IHNV.

Wiik-Nielsen *et al*.[27]: Evidence that PRV is higher when HSMI symptoms observed in farmed Atlantic salmon. Evidence also of complex co-infection dynamics.

Morton and Routledge[28]: Review of aquaculture-related risk factors (including PRV) for wild Pacific salmon.

2017 Di Cicco *et al*.[29]: HSMI in BC. Strengthened connection between PRV and HSMI. Suggestion that DFO's Fish Health and Surveillance Program is not adequate to consistently diagnose HSMI.

Haatveit *et al*.[30]: Initial acute PRV infection in red blood cells lasts only 1-2 weeks before subsiding.

Wessel *et al*.[31]: Confirmation that PRV can cause HSMI on its own.

Miler *et al.*[32]: Correlational evidence that PRV may cause jaundice in farmed chinook salmon.

Purcell *et al.*[33]: Evidence of PRV prevalence in coho and chinook salmon in Washington and SE Alaska.

Kibenge *et al.*[34]: Critique of Siah *et al.* (2016).

Morton *et al.*[35]: Correlational evidence linking salmon aquaculture to PRV dynamics in wild Pacific salmon and PRV to weakened ability for Pacific salmon to return to higher-elevation spawning grounds.

**Descriptions selectively highlight major features of key papers related to the health impairment potential of PRV, and are not intended as full summaries.*

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