BACKGROUNDER
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# Technical Report Project 5 – Impacts of salmon farms on Fraser River sockeye salmon

**Project description:** The researchers will evaluate the linkage between salmon farm operations and Fraser sockeye spawning returns, if any. The researchers will consider the impact on Fraser sockeye of sea lice exposure, farm wastes that affect benthic (collection of organisms living on or in sea or lake bottoms) and pelagic (inhabiting the upper layers of the open sea) habitat quality, Atlantic salmon escapees, and disease.

**Researchers:**

- **Dr. Josh Korman (Project 5A)** is a fisheries ecologist with Ecometric Research Inc. who holds both a PhD in Zoology and a Master's of Science in Biological Oceanography from the University of British Columbia. His research focuses on evaluating effects of flow regulation on salmonid populations in rivers downstream of hydro-electric dams, and in the statistical analysis of fisheries data and fisheries stock assessment.
- **Dr. Brendan Connors (Project 5B)** is currently a Postdoctoral fellow in the School of Resource & Environmental Management at Simon Fraser University. His research focuses on understanding how natural and human mediated processes interact to shape ecological dynamics. His recent work includes studying disease-mediated interactions between wild and farmed salmon.
- **Dr. Donald James Noakes (Project 5C)** is a Professor in the Department of Mathematics and Statistics and currently Associate Vice-President, Research and Graduate Studies at Thompson Rivers University. Dr. Noakes has almost 20 years experience working in biological sciences with the Department of Fisheries and Oceans. He has also served on and provided leadership to a number of fisheries science organizations including the North Pacific Anadromous Fish Commission, the Science Council of British Columbia's Fisheries Renewal BC Science Review Panel, and the Aquaculture Collaborative Research and Development Committee. Dr. Noakes' current research interests include studying the effects of climate change on marine fish populations, early marine survival of Pacific salmon, and socio-economic aspects of natural resource management.
- **Dr. Lawrence Dill (Project 5D)** is a Professor Emeritus at Simon Fraser University with over 40 years experience in biological sciences. Dr. Dill's research is on behavioural ecology, specifically the effect of predation risk on foraging and habitat selection behaviours and the influence of adaptive decision making by individuals on population and community characteristics. He served on the BC Pacific Science Forum scientific advisory committee, and co-authored the WWF Salmon Aquaculture Dialogue report on sea lice. He is a Fellow of the Royal Society of Canada.

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*The issue of interactions between salmon farms and Fraser River sockeye salmon is highly polarized. In response to the unique context of this topic, the commission contracted two reports (5C and 5D) to evaluate the potential impacts of salmon farms. The two researchers were provided with two additional reports intended to provide a common foundation for their investigations. The first report (5A) undertook data synthesis, and the second (5B) performed statistical analysis of these data. The majority of information used in these reports originated from the BC Salmon Farmers Association (BCSFA) and the British Columbia Ministry of Agriculture and Lands (BCMAL).*

## *5A: Summary of Information for Evaluating Impacts of Salmon Farms on Survival of Fraser River Sockeye Salmon*

Approximately 70 percent of salmon farm production in BC originates from sites located between the mainland and the east coast of Vancouver Island along the main migratory corridor for Fraser River
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sockeye. Over the last five years, an average of 32 million fish per year were held in net pens in BC waters, and 91 percent of these fish were Atlantic salmon.

Across all farms between 2003 and 2010, an annual average of 30 fish health events that indicated the presence of active or suspected disease infections was reported by industry. There was a statistically significant declining trend in the number of high risk diseases reported by salmon farms between 2003 and 2010. In the vast majority of audit cases by BCMAL where dead fish from salmon farms were tested, bacterial and viral infections were not found and no sign of disease was observed.

An average of 30,000 farmed Atlantic salmon has been examined per year between 2004 and 2010 to quantify sea lice abundance. Averaged over all seasons and years, 1.7 motile salmon lice (L. salmonis) were found per fish examined. There has been a modest but significant decline in the number of lice found in spring (when juvenile sockeye potentially contact salmon farms) and throughout the year. An average of 30,000 Atlantic salmon have escaped from salmon farms or juvenile production facilities annually from 1991-2008. Only 33 Atlantic salmon escapes have been caught or sighted in the Fraser River drainage or lower Strait of Georgia, and there is no documented evidence of spawning in this system.

There are only three to five years of overlapping Fraser River sockeye survival and salmon farm data available for statistical evaluation, so inferences from statistical analyses that correlate trends in abundance or survival of Fraser River sockeye with trends in pathogens found in salmon farms are extremely limited.

### *5B: Examination of relationships between salmon aquaculture and sockeye salmon population dynamics*

This report undertook two analyses to examine the relationship between Fraser River sockeye salmon dynamics and salmon aquaculture. In the first set of analyses Connors related the detailed information on salmon aquaculture from project 5A, i.e., high-risk pathogens on farmed salmon, sea louse abundance on farmed salmon, the proportion of farmed fish that died of disease or unknown causes and the number of salmon being raised in salmon farms, to the information on sockeye populations dynamics compiled in the commission's Technical Report 10. Connors found no statistical support for a relationship between these aquaculture variables and sockeye survival.

However, these analyses were based on short time series of aquaculture variables, beginning no earlier than 2003. Therefore, in the second set of analyses, Connors considered the one dataset that does span the entire Fraser River sockeye time series – the production of farmed salmon by Fisheries and Oceans management area since the early 1980s.

Specifically, Connors related sockeye productivity (the ratio of adult returns to the number of spawners that produced them) to the complete time series of salmon farm production as well as two other variables that have been independently identified as possible contributors to the decline in Fraser sockeye: oceanographic conditions and competition with pink salmon in the North Pacific Ocean. This analysis found a negative association between sockeye productivity and farmed salmon production, sea surface temperature and pink salmon abundance. In addition, the results suggest the negative influence of aquaculture production on sockeye productivity is greater when sea surface temperatures are low and particularly when pink salmon abundance is high. Uncertainty around these estimated effects precluded drawing strong inference from these findings.

### *5C: Impacts of salmon farms on Fraser River sockeye salmon: results of the Noakes investigation*

**Farm Salmon Production and Fraser River Sockeye Productivity**
The researcher addressed the question of whether farmed salmon production along the main migration path of Fraser River sockeye salmon, the waters between Vancouver Island and the British

Columbia mainland has affected sockeye returns over time. Noakes concluded that there is no significant correlation between farmed salmon production and the returns of Fraser River sockeye.

**Waste**
Salmon farms produce biological and chemical waste in the form of excretions from salmon, unprocessed food, and chemicals associated with salmon farm activities. Noakes found that the scale of potential exposure is inconsistent with the observed declines in productivity and concluded that there is no obvious plausible link or evidence to support a link between the deposit of waste on the sea bed or into the water column and sockeye salmon survival. The impact of waste appears to be limited to the immediate vicinity of the farms (within 30m).

**Escapees**
Adult and juvenile Atlantic salmon are known to escape from salmon farms, which have the potential to interact with Pacific salmon. Noakes noted that no juvenile Atlantic salmon have ever been observed in the Fraser River and only two adult Atlantic salmon have been found in the Fraser area in the last decade. He concluded that there is no evidence to suggest that escaped Atlantic salmon have contributed to the Fraser sockeye decline in recent years or that escaped Atlantic salmon pose any threat to these stocks.

**Sea Lice**
Atlantic salmon in farms are primarily infected by two species of sea lice – C. caliigus and L. salmonis – which can act as parasites and potentially interact with sockeye salmon. Noakes has concerns about the interpretation of data from studies examining the relationship between sea lice and Pacific salmon in the Discovery Islands. While recognizing that sockeye are exposed to sea lice, he notes that L. salmonis are not common on juvenile sockeye, and that sockeye are likely able to mount an effective defence against sea lice infections. At these levels of prevalence and abundance, he concludes that it is unlikely that sea lice have a significant lethal or sub-lethal effect on sockeye salmon at the population level. He also found no correlation between sea lice levels (C. caligus or L. salmonis) on farm salmon and the productivity of Fraser River sockeye salmon. Noakes notes that the transfer of disease via a sea lice vector is unlikely to be of significance at a salmon population level.

**Disease**
Salmon farms can be a source of infections and endemic diseases that infect sockeye salmon. There is a concern that known pathogens found on salmon farms could be directly or indirectly transferred to cause death and/or impair physiological function of Fraser sockeye. Noakes notes that fish health within the industry is closely monitored, and industry and government health reports over the last decade show few cases of high-risk diseases, particularly when viewed at the farm level. All of the diseases found on salmon farms are common in BC and there is no evidence that any exotic pathogens or diseases have been introduced by the salmon farming industry. Examining fish disease data at the individual farm level and on an aggregate scale, Noakes found no correlation between salmon farm production and observed declines in productivity of sockeye salmon.Noakes also has significant concerns about the long-term analyses presented in Project 5B.

### *5D: Impacts of salmon farms on Fraser River sockeye salmon: results of the Dill investigation*

**Farm Salmon Production and Fraser River Sockeye Productivity**
Dill concluded that the relationship between Fraser sockeye survival and salmon farm production suggests that the farms are having a negative impact on wild salmon productivity, most likely in concert with other factors in the marine environment. However the quantity and quality of the individual farm data available for detailed analysis makes it unfeasible to specify the mechanism(s) responsible, although the most likely candidate is disease transfer.

**Waste**
The researcher found that the effects of waste from salmon farms will likely be small and localized (i.e. within metres) in part due to high flushing and mixing of waters from the Discovery Islands. Dill concluded that it seems highly unlikely that such local effects could impact Fraser sockeye survival to

any great extent. The only possible exception to this might be if invertebrate species that are intermediate hosts of parasites flourish below the farms.

**Escapees**
Dill concluded that escaped Atlantic salmon are unlikely to pose a significant concern to sockeye through predation or competition. He notes that few Atlantic salmon have been found in the Fraser River basin, their spatial distribution has been limited, and colonization of freshwater areas has been lacking. There is, however, a slight potential for disease transfer to wild sockeye via escaped Atlantic salmon.

**Sea Lice**
Dill concluded that the science strongly supports a finding that pink salmon in the Broughton Archipelago, and perhaps other salmon species there as well, have been negatively impacted by lice from fish farms. He states that there is evidence that sockeye in areas adjacent to salmon farms in the Discovery Islands are infected with sea lice, which appear to be at higher levels than areas along the North Coast without salmon farms. However, there is no evidence of a direct harmful effect on Fraser sockeye. He notes, though, that lice may still play a role as disease vectors, even if only attached for a short time period before being shed.

**Disease**
Dill presents evidence that diseases documented on salmon farms can be transferred to sockeye salmon, based on studies that document the abilities of diseases to transfer through the water column or susceptibility of sockeye to infection from other fish. Dill also hypothesises that sockeye can be exposed to pathogens from salmon farms that are transferred through waste from processing plants or the benthic environment, or carried by escapees or sea lice. He concludes that disease transfer from salmon farms is the most likely mechanism of concern that could explain the negative correlation between salmon farm production and sockeye productivity.

## Recommendations:

All four reports make recommendations to better understand the relationship between salmon farms and sockeye salmon, including:

- Undertake research on pathogen transmission from farmed to wild salmon, along with evaluations of the fraction of wild fish infected and the additional mortality associated with infection, to determine if cause-and-effect relationships exist between Fraser sockeye returns and pathogens on fish farms.

- Develop a stronger test of the relationship between sockeye dynamics and aquaculture variables to include independent measures of salmon farm variables for each sockeye population.

- Repeat annually the sort of analysis undertaken by the commission (5B) to see if a pattern begins to emerge when more wild sockeye year classes can be included. To this end, create and maintain a single consolidated database of farm production, lice, disease and mortality on a farm-by-farm basis.

- Develop long-term disease monitoring programs for wild fish to provide data to the same level of quality and detail as available from the aquaculture industry. Monitoring should include the abundance and prevalence of sea lice and pathogens of concern for salmon.

- Establish regular and routine monitoring and reporting of water quality and oceanographic data and ensure public access to these data.