Pacific Fisheries Resource Conservation Council

Making Sense of the Salmon Aquaculture Debate—Executive Summary

Analysis of issues related to netcage salmon farming and wild salmon in British Columbia

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January 2003

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ISBN 1-897110-17-0

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EXECUTIVE SUMMARY

This is an Executive Summary of a 152 page report available at www.fish.bc.ca. The full report includes the references for the citations in the text below.

Introduction

Making Sense of the Salmon Aquaculture Debate provides a snapshot in time of what is currently known about farmed salmon-wild salmon interactions in British Columbia and other jurisdictions whose experience may be relevant. The topic is rife with uncertainties which will not be fully resolved soon, even if extensive new research is conducted. Despite, or because of, these uncertainties, the information presented in this report points to many reasons for a cautious approach to netcage salmon aquaculture.

The aim of this report was not to state definitive conclusions on risks posed to wild salmon by netcage salmon farming. Rather, the intention was to look behind the currently polarized and heated debate to examine the information and assumptions that support the arguments of opposing interests. It is hoped that the report will help observers of and participants in the debate to better judge the assertions of the various interests involved. Hopefully, the report will provide a basis for a more reasoned, collaborative approach to addressing some of the risks posed by salmon farming.

An honest broker for the salmon farming debate

Polarized debate has surrounded salmon aquaculture in British Columbia for years, if not decades. As government agencies, First Nations, industry representatives and environmentalists advance their positions, it has become difficult for the public to distinguish the rhetoric from reality. **The goal of this report is to expand and deepen the current public understanding about the potential impacts of salmon aquaculture on wild salmon by examining, evaluating and assessing the information and assumptions supporting the arguments of opposing interests**. The focus is on the interplay of salmon farming and wild salmon in three main areas: disease and fish health, escapes, and habitat impacts.

This report provides context and tools for understanding potential impacts of salmon farming on wild salmon, and it provides detailed analysis of the specific risks salmon farming poses to wild salmon. The report also describes ways to minimize both the risks and the gaps in our knowledge.

The research is based on an extensive review of print and electronic information sources, and on 38 separate interviews with key stakeholders and scientists. Given the need for an "honest broker," impartiality was critical to the research approach. Ways of ensuring impartiality included: careful consideration of, and reporting on, the relevant scientific information; attention to the advice of a range of key scientists from different backgrounds and accurate reporting of what they say; separation of perceptions from strong evidence; and full disclosure of information sources.

Understanding science and risk

The ideal solution to the polarization and conflict associated with the salmon aquaculture debate would be convergence of opinion around "the true facts." Unfortunately, our state of knowledge about the potential impacts of salmon farming on wild salmon allows few definitive declarations about where the truth really lies. Instead, we are faced with partial information, untested theories

and a great deal of uncertainty. What is more, science—even very good, definitive science—can only guide, not direct, difficult decisions in risk management, because these decisions are, for the most part, value-driven.

Risk assessment takes into account the probability or chance of an event occurring and the severity of its consequences. Important concepts in considering risk are: the precautionary principle; cumulative effects; scale effects; acceptable levels of risk; the burden of proof; effectiveness of mitigation; irreversibility; and values, costs and benefits.

This report provides estimates of risks related to issues in the salmon farming debate, based on analysis of available technical information. Those using these risk estimates will have to apply concepts like the precautionary principle to determine appropriate courses of action.

Risks posed by disease issues

Many factors influence the causes and impacts of disease. The development of a disease from an infection is determined by the interaction of the environment, the host, and the pathogen (agent of disease). The pathogens of concern here are viruses, bacteria, and parasites. Other important principles in understanding the potential risks posed by salmon farming connected to disease are:

- Different species are susceptible/resistant to different diseases.
- Susceptibility is affected by life stage.
- Susceptibility is affected by stress factors.
- Pathogens have a range of characteristics.
- Pathogens can be transmitted in a variety of ways.
- Fish must be exposed to the pathogen to acquire the associated disease.
- Fish can come into contact with pathogens without becoming infected, can be infected without becoming diseased, can be diseased without dying, or can die from infectious disease.

Overview of risks posed by specific pathogens

Sea lice: Causality in the spread of sea lice from farmed fish to wild fish in British Columbia has not yet been proven to the highest standard of scientific scrutiny. However, the combination of scientific results from Europe, preliminary studies of lice on juvenile salmon in B.C., and knowledge of sea lice-salmon dynamics presents a body of compelling evidence that sea lice from salmon farms do impact wild salmon. The main areas of uncertainty relate to how large or severe impacts will be, rather than to whether or not they will occur. A.H. McVicar, a leading European scientist, summarizing a 1996 International Council for the Exploration of the Sea workshop on sea lice, concluded that "lice from salmon farms will contribute to lice populations in wild salmonids, but the extent and consequences of this have not been quantified."

Improvements in fish health management at the farms will reduce but not eliminate the potential for transfer of lice to wild salmon. Despite the natural prevalence of sea lice, wild salmon, particularly smolts, are vulnerable to them. In heavy infections, death results from erosion of the skin of the fish. Other possible consequences include premature return to spawning and reduced seawater growth. Indirect effects associated with disease transfer via lice could be an emerging issue of concern.

Sea lice are the most serious, immediate risk out of the three fish health issues considered in this report (parasites, bacteria and viruses).

Bacteria: Wild Pacific salmon are generally well adapted to the bacteria found in B.C.'s coastal waters – they have a natural resistance to enzootic (naturally occurring) bacteria. Bacteria can, nevertheless, negatively affect their health. Concern expressed over the potential for transfer of furunculosis from farmed to wild salmon is warranted despite the lack of direct evidence. Furthermore, the effective use of vaccines substantially reduces the risk. Antibiotic resistance caused by the use of antibiotics on salmon farms does not appear to create significant risks to wild salmon (see discussion under "new" diseases below). Bacteria pose the lowest risk to wild salmon, among the three fish health issues considered.

Viruses: The potential for farm sources of viral pathogens to increase infection of wild fish is reduced by the natural resistance of Pacific salmon to enzootic viruses. As well, the literature does not provide evidence that the viruses which have caused problems at farms have spread from the farms and had negative effects on wild salmon. Nevertheless, migrating salmon could be exposed to viruses such as infectious hematopoietic necrosis (IHN) from farms at levels higher than those to which they are accustomed. In other parts of the world, infectious salmon anaemia (ISA) has been found to transfer from farms to wild fish.

The risk that the exposure will cause infection increases when farm sites act as reservoirs for the virus, especially if diseased fish are not culled. Good husbandry and lower stocking densities on the farms can make farm fish less vulnerable to infection and thus reduce the likelihood that salmon farms will act as reservoirs of viruses. However, efforts to control viral outbreaks are currently limited by a lack of effective treatments. The level of risk posed to wild salmon by viruses of farm origin is less than that from sea lice, and higher than that from bacteria.

Overview of risks posed by over-arching issues in the potential for disease transfer

Exotic diseases: The introduction of exotic diseases to B.C. through salmon farming could have severe – even irreversible – consequences for wild salmon stocks. Preventive measures related to fish and egg imports, and the industry practice of producing rather than importing eggs, have reduced the probability of importing exotic diseases. However, the risk will never be zero. Global experience shows that the introduction of exotic pathogens through fish culture is infrequent, but that when it happens it can have serious impacts. Of current international concern is the ISA virus. ISA has not been detected in B.C. although it has been found in New Brunswick and Maine. This virus appears to have spread from country to country through fish farming practices, though no significant impacts on wild salmon have been observed.

"New" diseases: The probability that new strains of disease will develop through salmon aquaculture (due to the use of antibiotics) and have negative impact on wild salmon appears to be low. When an antibiotic is used some bacteria that are resistant to that antibiotic survive and multiply. These "selected" bacteria are not newly created or mutated bacteria and they are not necessarily stronger or more virulent. However, the risk of a more virulent strain cannot be discounted. The impacts of this phenomenon, if it did occur, could be serious, although likely less catastrophic than the possible impacts of the introduction of an exotic pathogen. It is probable that previously undetected diseases that are native to this coast will be identified through outbreaks on salmon farms. The challenges will be to confirm that the pathogen does exist in wild stocks, and to ascertain the risks of biomagnification (increase) of the pathogen in the farm context.

Health conditions on farms: In principle, if farms had no higher levels of pathogens than the surrounding marine environment they would pose no added risk to wild salmon through disease transfer. However, farm conditions may well increase levels of pathogens at farm sites. High densities of fish in the net pens may increase susceptibility of farm fish to disease by increasing stress and will increase the probability of disease transfer among the fish in the net pen.

Much progress has been made in health management in salmon farming: from vaccines through to containment of outbreaks, improved farming techniques have reduced the loss of fish to disease in salmon farms. Nevertheless, it is likely that concentrations of pathogens (most importantly, sea lice and viruses) are higher in the net pen setting than in the natural marine environment. As well, the recent IHN epidemic in B.C. demonstrated that infection can spread from farm to farm during a disease outbreak.

Exposure of wild fish to enzootic (naturally occurring) pathogens: Fish in the wild do face disease risks, but evolutionary processes have led to a level of immunity in wild fish to the pathogens that surround them. The question is whether disease reservoirs in fish farms create a significantly higher likelihood of effective exposure of wild fish to infectious agents. In the case of sea lice, evidence is accumulating that it does. Chances of effective contact with pathogens are further increased by the siting of salmon farms on the migration routes of wild salmon. Another important variable in determining the risk of effective exposure is that of the survival time of pathogens that farmed fish may shed into the water column (which may then be carried by currents) or sediments below the net pens. In the case of lice and viruses such as ISA and IHN, survival time seems sufficient to pose a significant risk. In the case of bacteria such as furunculosis, the probability appears to be lower.

Evidence of disease transfer from farmed to wild fish: We know that farmed fish have diseases caused by exposure to pathogens from wild fish. Since pathogen transfer is a two-way phenomenon, it is also possible for wild fish to have diseases caused by exposure to pathogens from farm fish. While proof to the highest standards of scientific accuracy is lacking, circumstantial evidence, especially for sea lice transfer, continues to accumulate. Temporal and spatial associations between lice on farms and increases of sea lice on wild salmon are strong, and our increasing understanding of the role of lice in fish health suggests that causal connections are possible. Alternative explanations for increased lice on wild salmon in the vicinity of salmon farms do not appear to be as plausible as the explanation of lice transfer from farms.

Risks posed by escapes

Data limitations in the assessment of escapes

Beyond the theoretical level, a credible analysis of escape risks can only address Atlantic salmon. Without artificial markers, escaped Pacific salmon cannot be identified or distinguished from wild Pacific salmon. Therefore, information on Pacific salmon escapes in naturally spawning populations cannot be gathered. The inability to monitor escaped Pacific farmed salmon is one of the most significant limitations on our ability to assess the impacts of escapes on wild salmon. Other factors severely restrict our assessment of risk even for Atlantic salmon in B.C.'s river systems. These limitations include: only a small proportion of streams in B.C. are surveyed; budgets for surveys are limited; quantitative survey designs are lacking; survey designs differ between streams; and stream survey methodology leaves room for uncertainty (e.g., diver expertise, percentage of stream covered, visibility conditions and season, and survey effort per stream).

Of particular concern is the observation that more Atlantic salmon are observed in streams that are frequently surveyed than in streams with less survey effort. Annual surveys and properly designed sampling programs could demonstrate a higher incidence of Atlantic salmon in B.C. streams. Currently, the survey and data limitations allow some people to interpret the current observations to indicate a lack of Atlantic impacts. Others view these limitations as simply an inadequate assessment of a potentially extensive impact.

Overview of risks related to specific escapes issues

Intentional escapes: The question whether escapes are intentional as well as accidental remains unresolved at this time. Though industry escape prevention practices have improved in recent years, the true numbers of intentional releases are unknown and, at present levels of monitoring and reporting, they cannot be determined.

Implications for colonization of historic failure to successfully introduce Atlantics: Past experience and observations to date show that colonization by Atlantic salmon in B.C. waters is unlikely, though not impossible. However, sampling has been so limited that conclusions—for or against—cannot be reached with any certainty. If the industry expands and/or survival of escapes increases, then the chance of colonization will also likely increase.

Survival of Atlantic salmon in the wild: Generally, farmed Atlantic salmon survive poorly in the wild. However, the ability to assess survival is limited by the survey limitations noted above. In the future more escaped Atlantic salmon might be expected to survive as fish culture techniques improve their health and strength.

Spawning of Atlantic salmon in the wild: The presence of escaped Pacific salmon cannot currently be detected. Escaped Atlantic salmon have reached B.C. rivers and spawned there. Because survey efforts have been constrained, the reported numbers represent the minimum occurrence of escapes. Survey designs have not permitted extrapolation from samples to estimations of actual numbers of escaped fish.

Colonization by escaped Atlantic salmon: The small presence of juvenile feral (wild but descended from captive or domesticated) Atlantic salmon in B.C. streams does not prove that colonization is taking place. However, this data, combined with the observations of spawning Atlantic salmon, does suggest that colonization may occur. Moreover, these observations again represent the minimum occurrence, with actual numbers likely to be at an undetermined higher level.

Overview of risks posed by over-arching issues connected with escapes

Differing risks between Atlantics and Pacifics: There have been a few recent attempts to categorize and rank the different levels and types of risk that flow from different escape scenarios. Professor Mart R. Gross of the University of Toronto provided a ranking of concerns for wild salmon by category of impact and type of escapee – Atlantic or Pacific. He regarded the risks of genetic impacts on wild salmon as low for Atlantics and high for Pacifics. He ranked the risk of ecological impacts as medium in the case of Atlantics and high in the case of Pacifics. He ranked the risk of disease and parasite impacts as high for both. The attendees at the 2000 Speaking for the Salmon workshop in Vancouver concluded that, regarding possible interactions between Atlantic salmon (recently escaped or wild spawned) and Pacific salmon, the highest potential impacts on native stocks would be ecological in character (see ecological risks, below) and would involve juveniles. They agreed that if Atlantics were to successfully colonize and Pacifics decline in a given stream, risks would be greater. They also saw hybridization between Pacifics as having potentially high impact on wild salmon.

Genetic risks related to escapes: In theory, genetic impacts on wild salmon (via reduction of diversity and through interbreeding) could occur as a result of farmed salmon-wild salmon interaction. In B.C., the risk would be high from Pacific to Pacific interbreeding, and extremely low from Pacific to Atlantic interbreeding.

Overall, risk of genetic introgression (gene flow between distinct populations) between wild Pacific salmon stocks and domesticated farm fish of the same species is the most serious escape consequence.

Ecological risks related to escapes: Ecological risks to wild salmon from escaped salmon are theoretically possible. Atlantic and Pacific escapees are both capable of disrupting wild salmon habitat and spawning behaviour and competing with wild salmon for food and space. Among the ecological risks, the most obvious would be that of escapees sharing the same spawning grounds with wild salmon. The next most likely risk would be interactions amongst juveniles if spawning is successful. While establishment of feral Atlantic salmon populations in B.C. could occur with minimal ecological impacts on wild salmon, it remains to be determined what the actual extent of these impacts would be. Salmonids other than Pacific salmon (i.e., steelhead and trout) could be more seriously impacted.

Disease risks related to escapes: The risk of disease from escapes is difficult to assess with accuracy. Currently, the numbers of potentially diseased, escaped salmon are so low relative to the numbers of wild salmon that the potential for disease transmission is likely also low. Disease transfer from escaped salmon appears to be a lesser risk than impacts of disease from farm fish residing in net pens.

While the risks associated with the transfer of endemic (naturally present) disease via escaped farmed fish appear to be low, they cannot be ignored. The issue of transfer of non-endemic (exotic) diseases would be of greater concern. The risk of introduction of new pathogens appears to be low (see "Over-arching issues in the potential for disease transfer" above).

Summary of risks posed by escapes

The greatest risk of long term effects of escapes would be Pacific farmed salmon escapes affecting wild Pacific species, via genetic, ecological and disease impacts. However, our inability to monitor escaped Pacific salmon in the wild precludes any assessment of the associated risks. Information on escaped Pacific salmon (apart from reported escapes) is completely lacking.

The analysis of the specific risks of escaped farmed salmon concludes that escaped Atlantic salmon have survived in the wild and spawned in B.C. rivers, and that they have the potential to colonize in B.C. rivers. The extent of these phenomena and their potential to expand in the future is highly uncertain due to data limitations.

The risks that escaped, spawning and/or colonizing Atlantic salmon pose to wild salmon are in the form of genetic, ecological and disease impacts. At present, such risks exist in theory but there is little evidence of their occurrence. There are some occurrences of disease transfer, although infrequent, and given the ratio of escaped fish to wild fish, the risk in the long term is low. Ecological impacts of escaped Atlantic salmon on wild salmon may or may not be of concern, depending on environmental conditions and the status of the stocks. Long term genetic risks to wild Pacific salmon due to escaped Atlantic salmon are virtually zero.

Risks posed by habitat impacts

Overview of risks posed by seabed impacts

The literature on salmon farming frequently discusses possible negative impacts of salmon farm wastes on other fauna such as shellfish. The measurement of impacts on the seabed is controversial. There are concerns about the basis for the monitoring standard chosen by the provincial government and about the appropriateness of the use of performance-based standards in this application.

Despite recognition of environmental impacts of salmon farming on the seabed generally, there appears to be no evidence of impacts on wild salmon. In theory, however, indirect effects on wild salmon related to changes in the food chain as a result of seabed contamination are possible.

Overview of risks posed by water quality impacts

Wild salmon could be negatively impacted if disposal of diseased morts (farmed fish that have died before harvest) or blood water (an untreated mixture of blood and fish debris from harvested or slaughtered fish) coincides with their migration or spawning activity. However, at other times and places it is unlikely that diseases would be transmitted to wild fish from infected farmed morts or blood water.

Because wild salmon are migratory, they are unlikely to be exposed to antibiotic residues from salmon farms at levels that would be harmful. Similarly, the toxic effects of algal blooms are unlikely to affect wild salmon.

Summary of risks posed by habitat impacts

Habitat impacts—whether related to the seabed or to water quality—pose the lowest risks to wild salmon relative to escape-related or disease impacts. There are other potential risks beyond the scope of this research, such as those to biodiversity and human health, but the literature reviewed does not identify direct risks to wild salmon.

It is possible that there may be indirect risks to wild salmon via ecosystem effects or if the food chain becomes impacted as a result of the habitat impacts of salmon aquaculture. While this possibility is speculative at present, future impacts should not be discounted, and the employment of preventative measures does stand to benefit wild salmon.

Knowledge gaps

Our understanding of the risks posed to wild salmon by salmon farming – through disease, escapes and habitat impacts – is plagued by uncertainty. Our ability to assess risk is limited because we are dealing with a partial and, in some cases, a complete lack of data. We have results of research in other countries, accumulating knowledge of the ecological processes involved, and highly suggestive empirical data from B.C. Yet there is little we can say definitively about the impacts of salmon farming on wild salmonids.

Knowledge gaps in disease issues and fish health

Most studies related to disease and fish farming are about diseases affecting the health of farm fish in connection with productivity. Few studies have focused on assessing the transfer of disease to wild salmon populations.

Two knowledge gaps prevent definitive conclusions on a causal link in the transfer of infectious disease between farmed and wild salmon in B.C. First, we lack data on “normal” disease levels

(including sea lice infections) in wild salmon, so we have no way of knowing if those levels are rising near salmon farms. There is insufficient baseline data on the health of wild salmon, the stresses to which they are now subject, and the pathogens to which they are most susceptible. Second, because all of the diseases seen on salmon farms to date are also found in the wild it is very difficult to distinguish natural occurrence of disease in wild populations from disease originating from salmon farms.

Extensive research will be required to reliably determine the extent of the connection between disease in salmon farming and disease in wild salmon populations – or even to determine factors that affect the risk of transmission of diseases between farmed and wild populations. Following is a list of priority research needs:

- Monitor wild populations to investigate natural prevalence and range of diseases (including parasites) and to identify as yet unknown pathogens that exist in the wild.
- Establish the source of indigenous pathogens.
- Develop methods to detect changes in the level of disease in farmed and wild populations.
- Establish a structured disease surveillance program to determine relationships in the transmission of disease between farmed and wild salmon.
- Investigate the role of disease in early life cycle stages (fry and parr) and in the marine phase (especially regarding smolts).

Knowledge gaps related to escapes

Our present knowledge of escapes and their consequences is partial at best. The monitoring and reporting systems are limited in scope, opportunistic, and have, by their nature, a wide range of variability and accuracy. It is even more difficult to know how well the escapees survive, spawn, compete with wild salmon for spawning habitat, interbreed or transmit disease and parasites. A 2001 meeting of B.C. and international scientists, researchers and industry personnel concluded that the real impacts of Atlantic salmon escapes are not foreseeable or predictable based on the present level of knowledge.

Ongoing and more quantitative surveillance of both escaped fish and wild fish is required for the purpose of quantifying impacts and assessing how they affect population fitness. High priority research topics include methods for the identification of Pacific salmon escapes, habitat displacement in freshwater among juveniles, competition between juveniles for food and space in freshwater, nest superimposition, disruption of breeding behaviour and hybridization (i.e., relative reproductive success). Some observers have remarked upon the increasing importance of DNA research to further the understanding of genetic impacts.

Knowledge gaps related to habitat impacts

The authors of the most current and pertinent analysis of B.C. habitat impacts, Dr. Colin E. Levings et al. (2002) state that there is little peer reviewed literature from B.C. related to seabed impacts. These scientists caution against the extrapolation of data from other parts of the world to B.C. They suggest that there should be a multi-disciplinary scientific discussion to determine what parameters should be included in benthic (seabed) analyses that are appropriate for the B.C. environment.

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