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# Interaction Between Wild and Farmed Atlantic Salmon in the Maritime Provinces

**Proceedings of the Diadromous Subcommittee Regional Advisory Process**

**November 30 – December 4, 1998**
**Crystal Palace**
**Moncton, N.B.**

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**Department of Fisheries and Oceans**
**Science Branch, Maritime Region**
**Gulf Fisheries Centre**
**343 Archibald Street**
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**Abstract**

Since its beginning in the 1960s, commercial salmon farming has become a major industry in both Europe and North America. During the 1980s, scientists and managers became aware that substantial numbers of farmed salmon that had escaped from aquaculture facilities were intermingling with wild salmon. Since then, there has been mounting concern that interactions between wild and cultured salmon might prove harmful to the wild salmon stocks, leading to changes in their genetic composition, the introduction of diseases and parasites, and harmful ecological effects. This highly controversial issue has been debated internationally and locally both within the science community and between the aquaculture industry, conservation and traditional fishing (recreation, commercial and Native) groups. Here in the Maritimes, concerns have heightened as a result of growing evidence of escaped farmed salmon entering the marine ecosystem and ascending rivers. Evidence also exists of escaped farmed juvenile salmon entering rivers directly and migrating to sea. Although suspected locally, impacts had not been examined in Atlantic Canada.

In response to this situation, DFO held a special workshop under its Regional Assessment Process to evaluate the state of current knowledge of these interactions as they would apply to the situation in the Maritime Provinces and to recommend ways of minimizing any risks identified, options for improved management, and future research. The Workshop took place from November 30 to December 4, 1998 at the Crystal Palace Hotel in Dieppe, New Brunswick with over 70 participants from government agencies, the aquaculture industry, conservation organizations, local universities, and including experts from across Canada, the US and overseas.

Products from the workshop include nineteen research documents summarizing both the available information on the local salmon farming industry and the wild salmon stocks and the science pertaining to the potential interaction between wild and farmed salmon. In addition, a Habitat Status Report was produced highlighting future management and research recommendations for immediate and long-term action.

## Résumé

Depuis ses débuts, dans les années 1960, l'élevage commercial du saumon est devenu une grande industrie, tant en Europe qu'en Amérique du Nord. Dans les années 1980, les scientifiques et les gestionnaires ont pris conscience du fait qu'un nombre notable de saumons d'élevage évadés de pisciculture se mêlait aux saumons sauvages. Depuis, on s'inquiète de plus en plus de ce que les interactions entre le saumon sauvage et le saumon d'élevage puissent s'avérer néfastes pour les stocks sauvages, occasionnant des modifications de la composition génétique de ces derniers, l'introduction de maladies et de parasites ainsi que des effets écologiques nuisibles. Cette question très controversée a été débattue à l'échelle internationale et locale, tant parmi les scientifiques que parmi les aquaculteurs, les groupes oeuvrant dans la conservation et les pêcheurs traditionnels (sportifs, commerciaux et autochtones). Ici, dans les Maritimes, les inquiétudes ont été exacerbées par les preuves croissantes de la pénétration de saumons d'élevage évadés dans l'écosystème marin et dans les remontes des rivières. On a également des preuves que des saumons juvéniles évadés des élevages entrent directement dans les rivières et migrent vers l'océan. Bien qu'on soupçonnait localement que cette situation n'était pas sans avoir de répercussions, on n'avait jamais étudié ces dernières au Canada atlantique.

C'est pourquoi le MPO a tenu un atelier spécial, dans le cadre du Processus de consultation régional, pour évaluer les connaissances actuelles de ces interactions en ce qui concerne les provinces Maritimes et pour formuler des recommandations sur les moyens de réduire les risques qui y sont associés et d'améliorer la gestion des stocks, ainsi que sur les travaux de recherche à exécuter. Cet atelier a eu lieu du 30 novembre au 4 décembre 1998, à l'hôtel Palais de cristal de Dieppe, au Nouveau-Brunswick. Y participaient plus de 70 représentants d'organismes gouvernementaux, de l'industrie de l'aquaculture, d'organismes de conservation et d'universités locales ainsi que des experts de tout le Canada, des États-Unis et d'autres pays étrangers.

L'atelier a débouché sur dix-neuf documents de recherche résumant à la fois les renseignements disponibles sur l'industrie locale de l'élevage du saumon et sur les stocks de saumon sauvage, et les données scientifiques sur les interactions possibles entre le saumon sauvage et le saumon d'élevage. On a également produit un Rapport sur l'état de l'habitat contenant des recommandations pour la gestion future des stocks et pour la réalisation de travaux scientifiques axés sur des mesures immédiates et sur des mesures à long terme.

## Introduction

This report provides records of the peer review meeting for the evaluation of the state of current knowledge regarding the interactions (changes in genetic composition, introduction of diseases and parasites, and harmful ecological effects) between wild and farmed Atlantic salmon in the Maritime Provinces and to recommend options for improved management and future research (see Appendix 4 for remit of the meeting). The subcommittee convening the meeting consisted of the following 6 individuals from DFO Science: Gilles Lacroix, Renée Lavoie, Shane O'Neil, John Ritter, Kimberly Robichaud-LeBlanc and James Stewart. The meeting was co-chaired by James Stewart and Gilles Lacroix.

The Regional Assessment Workshop took place from November 30 to December 4, 1998 at the Crystal Place Hotel, Dieppe, New Brunswick. The review panel (authors, referees and other experts) consisted of 43 members from DFO Science (Maritimes, Newfoundland, Central and Arctic and Pacific regions and Headquarters), DFO Fisheries Management, Canadian National Research Council, the provincial governments of NB and Nova Scotia, the State of Maine, local universities (Universities of Dalhousie, New Brunswick and Toronto), Huntsman Marine Laboratory, government laboratories in Scotland and Norway, the private sector (consultant in aquaculture field), and the Atlantic Salmon Federation (their research scientist). See Appendix 1, (pages 65-74) for the list of participants and Appendix 2 for the review panel list (pages 98-101). Participants were selected to bring to the review a wide range of knowledge and expertise pertaining to this particular issue. In addition to panel members, invitations were also extended to interested groups to attend as observers. The workshop was also opened to the general public. An additional 33 observers from the aquaculture industry (New Brunswick, Newfoundland), the salmon angling interests, an Aboriginal group and other government departments (New Brunswick, Newfoundland and Maine) attended and participated in the review. The letters of invitation to panel members (pages 83-84) and observers (pages 86-86), as well as both mailing and observer attendance list (pages 87-94) are attached in Appendx 2.

Nineteen working papers on topics pertaining to the interaction between wild and farmed salmon in the Maritime Provinces were peer reviewed during the five-day session (see Agenda in Appendix 3). Nineteen referees contributed to the review of the nineteen working papers (letter of invitation with instructions attached in Appendix 2 (pages 95-97). Each paper was formally reviewed by one referee, but was also opened-up to questioning and comment from all participants in attendance.

The comments and concerns, with the author's responses, are summarized in the rapporteur reports prepared for each of the nineteen working papers presented and are detailed in Peer Review (pages 8-64) of this report. In addition to the general recommendations outlined in the resulting Habitat Status Report, these same reports present the detailed research and management recommendations for immediate and long-term action in each specific case (Appendix 6).

The remit for the meeting was:

- Are farmed Atlantic salmon interacting with wild Atlantic salmon in the Maritime Provinces?

- If so, what are the impacts of farmed salmon on the wild Atlantic salmon stocks in the Maritime Provinces?

- What should be done to eliminate or minimize these impacts?

## THE SALMON AQUACULTURE INDUSTRY IN THE MARITIME PROVINCES
**Res. Doc. 98/151**

**Working Paper(s):** DFO Working Paper 98/81

**Author:** Chang, Blythe. 1998

**Referees**: Cook, Bob

**Rapporteur:** Lavoie, René

### Summary/Abstract

The salmon farming industry of the Maritime Provinces began in the late 1970s when 6 t of Atlantic salmon were produced by a research project located near Deer Island, New Brunswick. By 1997, there were 30 freshwater hatcheries and over 90 marine growout sites for Atlantic salmon in the Maritimes. Production in 1997 was estimated at almost 20,000 t, worth over $140 million. Hatcheries producing Atlantic salmon smolts for aquaculture are located in all 3 Maritime Provinces. All hatcheries currently use salmon of mostly St. John River stock origin. Growout takes place in floating net cages located in protected, nearshore marine sites. The majority of the marine growout sites are in southwestern New Brunswick and there are 11 sites in Nova Scotia. The types of potential interactions between farmed and wild salmon can be divided into: spreading of diseases and parasites, behavioral-ecological interactions, and genetic modification. The potential for these interactions to occur increases with the number of salmon escaping from aquaculture operations. The number of adult salmon in sea cages in the Maritimes is estimated to be an order of magnitude greater than the estimated number of wild adult salmon returning to rivers in northeast North America. Various federal and provincial laws have relevance to aquaculture, most notably the federal Fisheries Act and provincial Aquaculture Acts of New Brunswick and Nova Scotia. Memoranda of Understanding on aquaculture development have been signed between Canada and New Brunswick and Nova Scotia. These give these provinces the right to issue and administer licenses and leases for aquaculture operations within their boundaries. The federal government continues its role in monitoring, diagnosis, prevention, and control of fish diseases in cultured and wild stocks.

### Issues/Concerns (including response)

1. The 20-40,000 escapees figures reported for the year 1994.
- There was considerable discussion about quoting these figures without having a secure source cited or a derivation methodology described.

2. Estimated number of wild salmon at 0.5 million.

- It was pointed out that the real numbers are "nowhere" near the 0.5 M mark. The issue was not resolved during the discussion of this paper.

**Consensus**

Research Recommendation

1. Quantification and qualification of escapees;

a) Data acquisition. The available data are preliminary and almost certainly incomplete.
b) Data on the causes of escapes are needed.
c) Research in cage design is needed with the objective of minimizing escape incidents.

- This should include research in cage design for open waters conditions. The results may be crucial for decision making on site licensing as pressures for expansion increases as a result of crowding or deterioration of sites in the nearshore.

2. Exposure coefficient

a) What is the real percentage of aquaculture standing stock which does escape.
b) What is the ratio between escapees and local salmon population as a means to measure the severity of the exposure risk.

- Theme b) came up again in the discussion of paper # 6, when it was pointed out that the escapees of concern should be those which survive the initial mortality occurring during the adaptation period after the escape. Factors affecting this mortality would include angling, predation by other fish, predation by birds (mergansers, loons, cormorans, ospreys etc), and predation by mammals (otters, seals).

3. Nature of the escapee threat

Information on the broodstock origin of escapees is weak and requires material for future research on the genetic impact of escapees on the so-called "wild" population.

4. Research is needed on:

a) the genetic impact of escapees breeding with wild fish;
b) impact possibly imposed through selection and evolution of a mixed population;
c) genetic drift resulting from a smaller number of wild fish in river systems.

5. Carrying capacity

Carrying capacity was mentioned as an area needing research although for fish culture, holding capacity" may be a more appropriate term. Cultured fish are not "carried" by the environment, since its food source is artificial as compared to molluscs which filter their food from the environment, and are therefore truly carried by it.

Management Consideration

1. Escapement reporting

- A mandatory reporting mechanism is required to help quantify and qualify escapements as to the timing of their occurrence, their cause, the number of fish involved, their size, age, origin and the broodstock from which they came.

2. Code of practice

A code of practice should be developed which should include :
- Site selection to minimize exposure to escapement caused by storms, ice, exposure to seal attacks, etc.
- Fish handling procedures.
- Procedures to monitor net integrity for early detection of potential causes of escape and correct them before an escape occurs.

**Other**

1. Freshwater smolts

- The province of New Brunswick is looking into the possibility of increasing the number of sites to produce freshwater smolts. The possible implications of escapees in the freshwater environment ought to be considered before large expansions are considered.

## HISTORY AND DESCRIPTION OF THE ATLANTIC SALMON AQUACULTURE INDUSTRY IN MAINE
**Res. Doc. 98/152**

**Working Paper(s):** DFO Working Paper 98/82

**Author:** Baum, Ed. 1998.

**Referees**: Saunders, Richard

**Rapporteur:** Goff, Trevor

**Summary/Abstract**

The successful rearing of Pacific salmon in Maine in the early 1970s, and Atlantic salmon in New Brunswick in the late 1970s, led to the culture of Atlantic salmon in Maine in the early 1980s. Large-scale operations began in Maine in 1986 utilizing the technology developed in Norway. Although numerous European salmon stocks were initially used in Maine, only three stocks are currently utilized. Two stocks originated from Bay of Fundy rivers (Penobscot River, Maine, and Saint John River, New Brunswick); the third stock (Landcatch) originated from

Norway, having been originally imported from Scotland in 1989. Hybridized Landcatch strains (with either of the other two local stocks) now account for approximately 30-50% of the production fish in Maine. The current Maine industry is composed of twelve companies that operate 33 sea-cage sites with 773 cages on about 800 acres of leased water, five freshwater smolt rearing hatcheries, and five fish processing plants. More than 4.0 million smolts are stocked into sea cages each year, and the annual production (harvest) exceeds 12,000 metric tons. Information pertaining to escapes, potential impacts to wild stocks, and current measures being taken in Maine to reduce potential negative impacts of escapes upon wild Atlantic salmon stocks are discussed.

**Issues/Concerns (including response)**

1. Author highlights the potential impacts on wild Atlantic salmon stocks include the following interactions: (1) genetic, (2) ecological, (3) disease (including parasites), and (4) habitat. Management interactions (awkwardness for managers to regulate the strains, farmed and wild, separately) are also an issue.

2. The author documents the first incidence of farmed salmon in Maine rivers in 1990 and documented escapees in a total of 8 Maine rivers to date from 1994 to 1998 (>50% of runs in some rivers). He emphasizes that the small native salmon populations in eastern Maine would be most vulnerable to genetic interactions by intrusions of large numbers of farm-origin salmon. It was pointed out that only a few sexually mature escapees have been observed - most farm-origin salmon in Maine rivers are immature.

3. Are there federal US initiatives to eliminate the use of European strains in the industry?

- The NMFS has asked the industry to remove those strains but the industry feels it is vital to their survival to maintain them. US federal regulations may not be strong enough to break the impasse.

4. Maine and U.S. federal laws prohibit only the importation of European fish or eggs. The author indicates that this has permitted the importation in 1997 of milt from Icelandic (Bolak strain) salmon. The reviewer pointed out the paper does not provide details of the numerous European stocks initially used in Maine, other than the Landcatch stock. What became of the other European stocks? The panel asked that additional information on those stocks be added to the document.

5. In light of the in-bred nature of the Landcatch strain, the industry believes that the incorporation of new genetic material would be beneficial for industry stock improvement.

6. The number of salmon which escape from Maine aquaculture sites is unknown and there is no legal requirement in Maine to report such occurrences. Industry representatives tend to keep such information confidential for business and insurance reasons (also fear of over-reaction by govt regulators.

7. What is status of endangered species legislation for Maine salmon stocks?

- Currently there is a 60-day notice of intent to sue by several environmental groups and individuals; will likely go to court soon.

8. Has there been a smolt stock imported into Nova Scotia from Maine?

- Author did not know.

9. Included in the paper is a description of a fee on the industry (one cent per pound of whole fish harvested) to support a monitoring program that assesses the impact of net-pen culture on the marine environment. Unlike waste from most conventional farming, wastes from salmon farming are released directly into the environment. Although there is no evidence of negative impacts to wild Atlantic salmon habitat in Maine from wastes or the use of drugs and chemicals, there is the potential to affect water quality, benthic organisms, etc. The levy program includes an annual site evaluation and a characterization of the benthic substrate and associated community (in alternate years) along with descriptions of the bottom conditions. The author indicated that this program is designed to maintain quality of the culture sites.

10. The feasibility of marking farm fish to facilitate identification of escapees?

- Various options were discussed and European and North American experiences were provided with general consensus that, due to cost, it is impractical to apply current proven techniques.

11. Effort should be directed at preventing escapes rather than marking fish for later identification.

- In spite of large gains in escape prevention, fish will always be able to escape. The majority of escapees seem to disappear.

12. One panel member suggested that eventually genetic markers could be used to identify progeny of farm-origin fish but also stipulated that it might be impractical (cost) to screen fish.

13. Given the antibiotics and parasite treatments that cultured fish undergo, would there be a public health risk if escapees were consumed?

- This problem has not yet been addressed.

**Consensus**

<u>Research Recommendation</u>

1. Development of a suitable mark for the identification of farm-fish escapees.

2. Development of a viable method of sterilization of salmon for farm use.

3. Research into seal behavior around sea cages, possibly leading to selective removal of some animals.

Management Consideration

1. Ninety percent of Maine farmed salmon production is within 50km of the New Brunswick industry. International cooperative management of the industry to implement joint wild Atlantic salmon population protection strategies is recommended.

2. Recommend adoption of a joint Canada-US marking program for the identification of farm-fish escapees.

3. Farmed salmon sterilization methods must be universally applied, cost-effective, acceptable to the industry and not affect marketability of the product.

4. Universal reporting of escapes (numbers, dates, sizes, species, stock origin, location, etc.) to a central North American clearinghouse.

5. Universal reporting of disease and parasite outbreaks in the salmon farming industry to a central North American clearinghouse.

**Other**

1. In Maine, the presence of farmed salmon in the wild, especially if numerous, potentially masks the status of wild stocks and complicates the regulation and management of fisheries. It has been recommended that managers of wild salmon stocks ensure that those stocks are in a strong condition so that they can withstand impacts from aquaculture, as well as other threats. To address this issue in Maine, a river specific stocking program, initiated in 1992, is in effect for most Maine rivers with existing salmon runs. In those rivers located close to aquaculture operations, the goal is to increase the number of native salmon to reduce the potential impacts of interbreeding with farmed salmon. Stocking is primarily based on fry releases as well as parr and smolts. Smolts are also being reared to sexual maturity in freshwater hatcheries and in sea cages to provide eggs for restocking programs or to supplement spawning escapement in the wild.

2. Weirs will be installed in several eastern Maine rivers to intercept and remove farm fish and to monitor wild returns.

## STATUS OF WILD ATLANTIC SALMON (SALMO SALAR) STOCKS IN THE MARITIME PROVINCES
**Res. Doc. 98/153**

**Working Paper(s):** DFO Working Paper 98/83

**Author:** Chaput, Gérald 1998.

**Referees:** Randall, Bob

**Rapporteur:** Dempson, Brian J.

**Summary/Abstract**

There are important geographic differences in the status of wild salmon populations in the Maritime Provinces. Wild adult salmon abundance in the inner Bay of Fundy is critically low with juvenile abundance in these rivers currently at their lowest observed levels. The wild salmon returns to Mactaquac Dam in the Saint John River in 1997 were the lowest of record for both 1SW and MSW age groups. Total egg depositions in the Saint John River have been below conservation requirements since 1986 and in recent years have been below 50% of requirement. Abundance of wild adult salmon has also declined in the Atlantic coast of Nova Scotia rivers many of which are acid-impacted. The abundance of juveniles in these rivers is declining or low. The southern Gulf of St. Lawrence rivers have fared better; relative abundance in these rivers is currently described as medium to high. Sea survivals of three hatchery stocks show a declining trend over time with the lowest survivals observed in recent years. Although sea survivals of the Saint John smolts are weakly negatively correlated with the level of aquaculture production in the Bay of Fundy, stronger associations with marine conditions and seal abundance indicate that other factors may be more important in the reduced abundance of Atlantic salmon in the Maritime rivers.

**Issues/Concerns (including response)**

1. Reviewer indicated that there could have been additional reference to the potential level of returns to salmon rivers in the Maritimes Region, similar to that shown in Figure 21 as it relates to the present level of abundance.

- The author replied that one means by which this could be addressed would be to use current conservation levels as a base with, perhaps, an additional contribution of 2- to 3 recruits per conservation level number of spawners to reflect overall potential stock production.

2. Reviewer would have liked to have seen more reference to stock status and trends in other regions (e.g. Quebec and Newfoundland).

3. The reviewer inquired as to whether there was any complementary information regarding the status of stocks in Europe in the context of common areas of aquaculture development.

4. More details should be added to components of the methods section that pertain to the various multivariate approaches used to categorize salmon return data.

5. With respect to information presented in the various correlation matrices (Figs. 16-19), the author should acknowledge that some of the relationships or associations referred to are not necessarily linear, and that in these cases the associations could possibly be explored further. Also, the author should indicate the respective sample sizes, range in data, and where appropriate some reference to median or mean values. The inclusion of these figures (16-19) in the paper was questioned by one individual, although the referee reiterated that these figures were clearly useful and should be maintained.

6. In some places, additional details should be added to the text to support the various figures and tables.

7. The conclusion section of the paper should be expanded to include: 1) reference to research that should be carried out in relation to status of stocks where there are aquaculture concerns; 2) management measures that should be introduced; and 3) identification of areas where there are data deficiencies to address questions related to aquaculture issues. One example related to (1) above was to monitor wild smolts and subsequent adult returns to determine marine survival to complement information available on hatchery stocks.

- The author indicated that there are now two years of marine survival data from the La Have River, while one additional wild stock was now being monitored.

8. More specific reference should be made concerning stock losses as a result of recreational fisheries, along with identifying what, if any, are the impacts of Aboriginal fisheries on salmon stock status.

9. DFO appears to use the term 'conservation' in a manner that differs from how others use this term. As such, the author was asked to clarify how conservation is determined and quantified in the context of the current paper.

- The author referred to the 1991 Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) Advisory Document that defined conservation for Atlantic salmon, both in a formal sense, as well as the practical application of the definition. As it currently stands, DFO uses conservation levels as a threshold, or the level below which there is no good reason to allow stocks to fall below.

10. There appeared to be a contradiction or inconsistency between a statement written in the paper's Abstract referring to the possible implication of seals affecting the status of stocks and marine survival, with that which is made in the conclusion section of the paper where only reference to potential implications resulting to aquaculture escapees is identified as the "greatest threat to the wild salmon populations". This potential inconsistency should be rectified.

- The author replied that there was no contradiction but that reference to both aspects should be made in the same paragraph. Also, it was noted that potential impacts from farmed salmon affects rivers whereas impacts associated with seals relate to the ocean phase of the salmon's life cycle.

11. It was noted that ecological interactions could be much greater than genetic impacts resulting from aquaculture escapees affecting wild stocks.

12. The referee, as well as several other individuals, indicated that this paper was well done and very informative. The primary referee also stated that wild salmon stocks are extremely valuable and they should be preserved and conserved.

**Consensus**

Research Recommendation

1. Wild smolt populations should be monitored in some stocks to obtain information on marine survival to complement similar information available on hatchery stocks.

**Other**

1. The author posed the question that for the subsequent report prepared from this workshop, a clear definition of what constitutes a '**wild salmon**' should be included. In addition, the author asked for clarification as to the definition of a '**stock**' and a '**population**'.

## ATLANTIC SALMON AQUACULTURE ESCAPEES AND OCCURRENCE IN RIVERS OF THE MARITIME PROVINCES. Res. Doc. 98/154

**Working Paper(s):** DFO Working Paper 98/84

**Author:** O'Neil, Shane. 1998.

**Referees:** Sephton, Tom

**Rapporteur:** Marshall, Larry

**Summary/Abstract**

Much of the evidence regarding Atlantic salmon aquaculture escapees is based on northern European experience where Atlantic salmon culture for commercial use has been active since the 1970s. The information available on Atlantic salmon escapees from aquaculture is briefly summarized for several northern European countries, western Canada, Newfoundland, and Maine. Little data are available on the number of Atlantic salmon which escape from sea-cages or hatcheries which supply the industry in the Maritime Provinces, Canada. The occurrence of aquaculture escapees is usually reported only as occasional sightings; few confirmed cases of successfully reproducing cultured Atlantic salmon have been described. Evidence of farm-origin fish in rivers of the Maritime Provinces is provided as is reference to confirmed spawning of cultured salmon.

Atlantic salmon that have escaped from sea-cages occur principally in rivers located in close proximity to the industry. Documentation of various factors which influence movement of cultured fish into rivers is reviewed. Research data confirm that aquaculture and wild fish interbreed.

Recommendations include: (1) Mandatory reporting of escapes by the industry; (2) reporting of escapee sightings data to be encouraged from traps or other sources; (3) the establishment of an objective agency to monitor such data such as the Atlantic Salmon Watch program in Western Canada; (4) possible penalties to reduce the incidence of escapes.

**Issues/Concerns (including response)**

1. The document will be regarded as the "source" for documented occurrence of escapees entering rivers of the Maritime Provinces and in that regard should (i) provide original substantiated details of (e.g.,) escapees, (ii) exclude unsubstantiated statements, (iii) exclude from the "conclusions/recommendations" reference to potential impacts (e.g., disease) that were not treated in previous sections, (iv) exclude, at least as a section, discussion of genetic strains used in the region (covered in another document), (v) consider the use of qualitative statements, e.g., presence/absence in place of the quantitative numbers or estimated escapes in some rivers, (vi) standardize escapement to "fish" from eggs (Stewiacke), and (vii) provide source references and original details of occurrence of escapees outside the Maritimes Region. The author voiced no objection.

2. It was asked if the author was certain that there are no self-sustaining sea-run populations of Atlantic salmon established outside its historical range, e.g., Australia, and that evidence of successful spawning on the west coast be omitted until substantiated.

- The author indicated that the former point would be further checked and that the later point would be substantiated or refuted within the coming weeks.

3. The large number of escapees cited in Norway happened about a decade ago and new cage construction and detainment technologies in the intervening years had probably contributed to a lessening of the magnitude of the problem in recent years. Therefore it was perhaps fair to acknowledge a possible reduction in escapes?

- In defense, the author offered that an escape rate of only 0.5% would suggest the potential for equally large numbers of escapes today. Another reviewer reinforced the author by noting that only large escapes are likely reported in Norway, while a second reviewer reminded the panel that over 30% of salmon captured in Norway are of farmed origin.

4. The escape from hatcheries and occurrence of juvenile aquaculture fish in the Waweig, Digedguash and Magaguadavic rivers (ref. Papers by Lacroix, Whoriskey etc.,) should be brought forward in this document. It was noted that these escapes are easily technologically preventable. Reference to the presence of juvenile escapees from the hatcheries on those rivers is included in the summary table in the document and will be included in the summary in the text.

5. There is an unwritten implication that all escapes found in rivers will contribute to spawning. The data from Magaguadavic indicate otherwise and support an argument for cautious interpretation of the presence of unhandled escapes among populations of wild salmon just prior to spawning.

6. Concern was expressed that the later run-timing of aquaculture fish to rivers (documented in Europe and in Magaguadavic by Whoriskey et. al., might mean that seasonal efforts to count wild salmon in rivers may have been terminated prior to the entry of all cage fish, i.e., counts and estimates may be a minima. Thus, were there plans to extend fall monitoring activities to ensure completeness of data?
- The author responded that there was no comprehensive sampling program in place but that if one was initiated, coverage of the entire time period that escapees may enter the river would be an obvious guiding tenant.

7. It was noted that there were already regulations for mandatory reporting of escapes (and sales) by the industry (Recommendation number 1) in both New Brunswick and Nova Scotia and that there had not been compliance. A representative of the NBDFA suggested that the information "could be collected"; several panel members expressed the need for this type of information and current status/ reductions over time of escapees.

8. One observer suggested that some inner Fundy rivers had natural or man-made barriers which prevented the entry of escapees. In response it was noted that most of the 33 inner Fundy rivers were accessible to escapees.

9. The inclusion within "conclusions" of the cited concern that NBDFA was in a position of conflict with the industry re: promotion of development to better realize economic gain and would have difficulty steering a slow growth, is unwarranted in the context of evidence provided.

10. There was a concern that some of the older broodstock collections in Salmon River, Yarmouth Co., may have yielded additional information re: presence/absence of escapees.
- The author indicated that there was no scale material with which to make conclusions about origin. Further there was a suggestion that there may be a cage loss in St. Margarets Bay that may still be documentable.

11. One observer wondered that the scope for the paper might also have warranted a comparison overview of the occurrence of "enhanced" fish in the rivers of the Region.

12. Other observers thought there was a need to (I) state a preferred method of differentiating wild and cage-reared fish and (ii) indicate that handling of Atlantic salmon in search of aquaculture fish at fishway and counting fences was non-obtrusive and unlikely to adversely affect wild stocks.

**Consensus**

Research Recommendation

1. Investigate run-timing differences of mature and immature escapees (with particular reference to Whoriskey's Magaguadavic data)

Management Consideration

1. Mandatory reporting of escapes by the industry (note Issues/Concerns).
2. Reporting of escapee sightings data to be encouraged from traps or other sources.
3. Establishment of an objective agency to monitor possibly modeled after the Atlantic Salmon Watch program in Western Canada.
4. Possible penalties to reduce the incidence of escapes.
5. Avoid placement of cages in locations frequented by wild stocks.

## A REVIEW AND UPDATE OF AQUACULTURE IMPACT STUDIES CARRIED OUT ON THE MAGAGUADAVIC RIVER, SOUTHERN BAY OF FUNDY, NEW BRUNSWICK

**Res. Doc. 98/155**

**Working Paper(s):** DFO Working Paper 98/85

**Author(s):** Whoriskey, Fred; Lacroix, Gilles; Carr, Jonathan; Stokesbury, Michael

**Referees**: Cronin, Peter

**Rapporteur:** Bradford, Rod

**Summary/Abstract**

The Magaguadavic River is located near the heart of the New Brunswick salmon aquaculture industry, and has been monitored since 1992 to document the potential interactions between wild Atlantic salmon and escaped fish from aquaculture facilities.

Escaped aquaculture fish may enter the river from the sea as salmon or grilse. They may also infiltrate as juveniles from the three smolt rearing facilities located within the watershed, or as large and sometimes precocious parr from a brackish water cage site located in the Magaguadavic estuary. Since 1997, no escaped adult salmon or estuarine parr have been knowingly permitted into the river.

Wild adult fish returns to the river have steadily declined since 1992, and in every year, wild fish have been significantly outnumbered by adult escaped aquaculture fish.

Hatcheries within the watershed are also leaking juvenile salmon and possibly smolts. Electrofishing surveys showed that the number of parr caught per 100 seconds of fishing time were highest near the hatcheries, and body sizes, fin condition and scale characteristics indicate most of these fish were escapees. Smolt samples collected in 1996 found that 51-67% of the fish sampled were escapees. In 1998, about 75% of the smolts sampled were of cultured origin, resulting from a combination of small- scale planned hatchery releases and escapees. Exact percentages for these two groups are not yet determined.

In 1997 and 1998, tagged adult escapees were moved back to the ocean at distances of up to 50 km away from the river to see if they would return. In 1997, 77 fish were moved, and only one returned. Since this fish had been released in the Magaguadavic estuary, it is not conclusive evidence for homing. By contrast, in 1998, a significant fraction (> 30%) returned to the river from distant release points.

Spawning between aquaculture escapees and wild fish has been confirmed in the river, and there is some evidence that wild salmon gene frequencies have shifted since the escapees began to arrive. The ecological consequences of the "hybridization" and gene shifts have not been evaluated.

No pathogenic bacterial or viral organisms were found in incidental testing of wild or cultured salmon from 1992 to 1996. More comprehensive sampling of escapees has been carried out in 1997 and 1998. In 1997, five of 34 fish were suspect for HKS (now termed ISA) based on a visual postmortem. Unfortunately, viral cultures were not done. In 1998, so far no fish have tested positive for ISA, and one case of BKD has been detected. Sampling is ongoing. Sea lice infestations have been monitored on both wild and aquaculture adult returnees, and prevalences and intensities will be presented.

**Issues/Concerns (including response)**

1. The appearance of escaped farmed Atlantic salmon from seacages and escapement of parr and smolts from hatcheries within the watershed of the Magaguadavic River has occurred at a time when the river has not been meeting conservation requirements for wild production. The wild population is in an extremely fragile state.

2. Escapees from marine cages outnumber returns of wild fish.

3. Smolts artificially-reared within the watershed for aquaculture outnumber wild smolts.

4. Condition factors of escaped farmed salmon appearing at the St. George fishway and how they compare to returns of wild fish were not reported.

5. It needs to be noted that the Magaguadavic is a wild fish river, there have been no planned stocking except for one instance.

6. It needs to be noted that rainbow trout appearing in the St. George fishway were/are aquaculture escapees.

7. The issue was raised of whether or not the eggs of cultured fish deposited in redds were/are viable?

8. There was some question as to whether or not wild and hatchery-reared fish sampled at the fishway could still be mis-identified, are further improvements to identification protocols possible?

9. It should be noted that some client groups have expressed an interest in developing a (in-river) recreational angling fishery targeting aquaculture escapees, a practice that runs contrary to the current policy of preventing escapees from ascending the river beyond the fishway. Health risks associated with the human consumption of escaped farmed Atlantic salmon cannot be appraised since the past medical history of the fish while held in the seacages vis a vis vaccinations, consumption of medines added to food etc, cannot be known.

10. The issue was raised of whether freshwater residency time and either the occurrence or presence or absence of sea lice could now be better determined based on the translocation work on escapees in 1998. Residency time is defined as the time from salt water to the fish collection facilty at St. George.

11. It was noted that the quantity and quality of the aquatic rearing habitat in the watershed needs to be better determined/described.

**Consensus**

Farmed Atlantic salmon have impacted the wild Magaguadavic River population at the genetic level. Ecological interactions/impacts are probable but not fully understood at this time.

Research Recommendation

1. Acquire through research genetic maps of wild fish in the Fundy region rivers and of the escapees in order to evaluate the level of introgression and fitness.

2. Higher level of stable funding is required to adequately address the full suite of wild resource conservation issues associated with escapements of farmed Atlantic salmon.

3. Are progeny from farmed and wild fish that successfully close the life-cycle to be considered 'wild' fish or should they be removed from the reproductive pool?

4. What do salmon do after escapement from pens; what are the potential avenues for interaction of wild and farmed fish in the marine habitat?

Management Consideration

1. Prevent escapees from entering river systems either as adults or smolts (the referee indicated that "management options" could be added to the title.

2. Are changes required to the current regulations governing expansion of the industry? There is a need to recognize advances in knowledge regarding the fact of and nature of interactions so that problem of interactions does not extend beyond current area of impact.

3. Two estimates of rearing habitat were reported. Which one should be used?

**Other**

1. The studies on the Magaguadavic River are important by virtue of the fact that they represent the sole time series of information on the interaction between wild and farmed salmon in the Maritimes Region.

## GENETIC IMPACTS ON WILD ATLANTIC SALMON *(SALMO SALAR* L) STOCKS FROM ESCAPED FARM CONSPECIFICS: AN ASSESSMENT OF RISK. Res. Doc. 98/156

**Working Paper(s):** DFO Working Paper 98/87

**Author:** Verspoor, Eric. 1998.

**Referees**: Fleming, Ian

**Rapporteur:** Kenchington, Ellen

**Summary/Abstract**

The potential exists for stocks of wild Atlantic salmon (*Salmo salar* L.) to be genetically altered when escaped farm conspecifics enter rivers. Changes can occur indirectly, through ecological interactions, or directly, by interbreeding. Wild salmon stocks are composed of locally adapted populations whose gene pools are moulded by selection to increase survival and reproductive success i.e. Darwinian fitness, and adaptive differences can be assumed to exist between farmed and wild salmon. As a result, genetic changes have the potential to alter Darwinian fitness and are unlikely to be positive. Limitations in our knowledge, and in our ability to detect and monitor both changes and fitness, make it difficult to predict the extent of fitness depression which might occur. Variation in the genetic nature of farm and wild stocks, and the environmental circumstances associated with interactions, ensure each outcome will be more or less unique, and impacts could be short or long term. Where relative numbers of farm salmon or genetic differences with wild stocks are small, interbreeding is sporadic, and wild stocks are healthy, natural selection can be expected to reverse any genetic change. If relative numbers of farm

salmon or genetic differences are large, interbreeding persistent, and stocks declining, stock viability can be expected to be further reduced. Long term, or even permanent, changes to stock character may result and contribute to the demise of wild stocks or their constituent populations. In the absence of any predictive capacity, current management must proceed using a precautionary approach. Where feasible, escapes of reproductively competent farm fish should be eliminated. Otherwise escapes should be reduced to a small proportion of wild stocks and the sustainable abundance of wild stocks maximized. Research effort should focus increasing empirical knowledge by assessing specific interaction scenarios, and enhancing understanding of the nature and extent of local adaptation in the Atlantic salmon.

**Issues/Concerns (including response)**

1. There is a need to understand the interaction between genes and the environment. It is likely that these will be highly varied if not unique to each stock/site combination. Presently, most predictions need to be based on theoretical models using qualitative genetic data (allele frequencies, genotypes). Data on quantitative trait loci (QTL) are only just becoming available to link traits to genes. Data on quantitative traits are available through breeding programs in Canada and Norway. However, lack of empirical data conducted in the field (as opposed to the lab) has limited the predictive outcome of gene-trait-site interactions. In general, the outcome of an interaction between wild and farmed salmon is unlikely to be positive.

2. Genetic changes to wild populations associated with interbreeding will occur at a number of levels (allele, genotype, phenotype, ecotype) and the potential impacts on the wild population will be similarly diverse. One generalization was made: changes to allele frequencies are expected to have a greater impact than the loss of rare alleles and these changes may occur very quickly depending upon the genetic characteristics of the interbreeding stocks and relative proportion of hybrids.

3. There is compelling evidence that Atlantic salmon populations are adapted to their local environments. An example of the resistance of salmon stocks to *G. salaris* only within the endemic range of that species was cited.

4. What is a wild fish? a) A wild fish is a fish that has completed its life cycle in the wild. With this definition these fish exclude hatchery reared smolt and farmed fish. b) Wild fish could also be defined as fish whose genealogy has been completely wild, in which case this may exclude some existing self-sustaining populations.

5. What are the differences between "hatchery" and "farmed" fish in terms of impact on the genetic integrity of wild stocks upon interbreeding? The artificial selection on hatchery produced fish as currently practiced is "soft". The genetic composition of hatchery fish is probably similar, and possibly the same, as that of the wild stock. Release of fish at different stages mitigates the reduced selection associated with nurturing through to the smolt stage. Conversely, farmed fish are the progeny of a broodstock selection program which is designed to produce fish with desirable economic traits (e.g., increased growth rate, size) often at the expense of ecologically desirable traits (homing behaviour, predator avoidance, prey

recognition). The genotypes represented in the cultured farm population may consequently differ dramatically from those present in the wild stocks both as a result of a relaxation and altered direction of selection. Inbreeding depression may also occur in these farmed stocks. The impact on wild stocks will be potentially much greater with production of hybrids between wild and farmed fish than with those between wild and hatchery produced fish.

6. What is a population? We have two concepts. The management stock and the genetic population. The later are very difficult to identify unless physical boundaries between populations occur. Most river systems have more than one genetic population if they have tributaries but we need more information as to where to draw the line. Timing of breeding may also separate genetic populations in the same physical space. For practical reasons we need to look at rivers as the management unit. In the context of farmed salmon, the unit is a group of salmon sharing a common genetic background.

7. What is the normal straying rate in the wild and what is their genetic impact on local populations relative to those of an aquaculture operation? Straying occurs at a very low frequency. However, the fact that fish stray is not the issue as they may not be reproductively successful. Generalizations cannot therefore be made without evidence of genetic transfer.

**Consensus**

The potential exists for negative impacts on the genetic structure of wild Atlantic salmon populations where they interact with escaped farm conspecifics. Wild salmon populations are genetically adapted to local environmental conditions and most genetic changes brought about by hybridization with farmed stock are expected to reduce mean survival and reproductive success. All of these effects will be greater in wild stocks which are declining or at low levels. Safe levels of farm escapes cannot be specified and the precautionary approach must be used to guide management.

Research Recommendation

1. Genetic characterization of wild and farmed stocks under natural conditions is required in order to evaluate the potential magnitude and direction of interactions.

2. Research into the indirect genetic effects of interaction in natural situations is required. Examples include behaviourial and competitive interactions which will alter selection in the breeding population.

3. Research into biological containment measures (e.g., triploidy) should be encouraged.

4. The capacity to accurately identify and quantify risk, and remedy impact, can be increased by empirical and theoretical research which takes advantage of developments in molecular biology which allow the specific genetic characterization of individual salmon populations. Future research should use these developments to monitor the inputs and outcomes of existing interactions and to develop a deeper understanding of the nature and extent of local

adaptation in Atlantic salmon populations. Where historical sources of data are available, valuable information on the historical genetic nature of populations, and effects of bottlenecks and mixing should be researched.

Management Consideration

1. Elimination of the risk of farm escapes. Where elimination is not possible, the number and frequency of escapes should be reduced to the minimum feasible level. In addition to reducing escapes, selective trapping or angling of escaped fish entering rivers should be implemented.

2. Minimization of adaptive genetic differences between farm and wild stocks by cultivating farm stocks established solely from local river stocks is preferred where interactions can not be more or less eliminated.

3. Technologies which provide biological containment of the genome (sterilization techniques such as triploidy) should be considered to avoid the risk of direct genetic impacts (indirect effects will not be eliminated by this technique).

**Minority Report**

1. No strong oppositional views were left standing. Explanations on the relative impacts of hatchery produced versus farmed fish appeared to be accepted.

## EAST COAST SALMON AQUACULTURE BREEDING PROGRAM: HISTORY AND FUTURE.
**Res. Doc. 98/157**

**Working Paper(s):** DFO Working Paper 98/88

**Author:** Glebe, Brian. 1998.

**Referees**: Benfey, Tillmann

**Rapporteur:** Robichaud-LeBlanc, Kim

**Summary/Abstract**

This paper provides an overview of ongoing breeding programs for performance improvement of Atlantic salmon (*Salmo salar*) strains used in aquaculture. While the emphasis is on the New Brunswick Salmon Broodstock Development Program (ASBDP), comparisons will be made with local corporate programs and those programs in Maine. Maine is important due to its aquaculture business connections to New Brunswick and due to the relatively free movement of genetic material across this political boundary. The new direction of salmon breeding in New Brunswick and possible collaboration with other similar international programs is elaborated. The role of

directed breeding programs in minimizing the impact of aquaculture escapes on world populations is discussed with reference to genetic diversity and out-breeding depression.

**Issues/Concerns (including response)**

*Referee comments: Tillmann Benfey*

- Within context of existing knowledge, some reference to other breeding programs (e.g. Norway) would be useful. In light of this point, the first sentence in the last paragraph of the introduction should end with the words "in New Brunswick and Maine".

- Need for better explanation to how diallel crosses work.

- Some indication of the economic traits to be evaluated by the ASBDP should be included (are these the same as were used for the Salmon Genetics Research Program (SGRP)).

- In "Management Considerations" section: problem with first paragraph under "Genetic diversity and outbreeding depression". There seems to be an assumption that so long as there is a similar amount of genetic diversity between stocks, then interbreeding is not a problem. If this is not what is meant, then please reword. If it is what is meant, then I disagree - genetic diversity with a different combination of alleles is a problem.

- Use of vague terminology ("may be", "suggestive", etc.). Need more precise terms (and references).

- In terms of recovering cryopreserved stocks, androgenesis can be used to avoid mixing the cryopreserved genome with some other genome. See papers by Gary Thorgaard.

- The "Summary" is really a mix of summary and conclusions; there are no research recommendations.

- No mention is made of using sex-reversed broodstock which are still available in New Brunswick for generating monosex populations – is this not worth considering within the breeding program?

- Needs some outline of how new strains will be tested (or select local strains, for that matter) - What will be the benchmarks for comparison?

- Little mention is made of molecular methods that are available (other than DNA fingerprinting), such as marker-assisted selection.

1. Dick Saunders: Jerry Friars once said "St. John stock has all the diversity needed" so why do we want to strain other stocks?

2. John Bailey: Progress (change in growth rate) has been made.

3. Ellen Kenchington: Are you looking at genetic environmental interactions.

4. Brian Glebe: Performance both in fresh and sea water cages.

5. Peter Cronin: River specific stock program. Example where it would work, why and yardstick used to measure success?

6. Brian Glebe: small program in place. Cooperation with DFO and Natural Resources. Conners Brothers has Hammond River and Mag. River.

7. Iola Price / Dave Meerburg / Jim Stewart: "nutritional deficiency that would make fish unviable outside of pen" (i.e. dependence on wild food so fish would die if they didn't get it).

8. David Cairns: "Salmon can survive several months without feeding. If aquaculture fish do escape and interbreed before succumbing to starvation we could be worse off than before."

**Consensus**

Management Consideration

1. Genetic diversity and outbreeding depression.

2. Evaluation of non-local stocks for aquaculture.

3. DNA profiling and genetic management of farmed salmon stocks.

4. River specific stocking.

5. Cryopreservation of salmon sperm

## GENETIC INTROGRESSION OF THE DOMESTIC ATLANTIC SALMON GENOME INTO WILD POPULATIONS: A SIMULATION OF REQUIREMENTS FOR CONSERVATION.
**Res. Doc. 98/158**

**Working Paper(s):** DFO Working Paper 98/89

**Author(s):** Lacoix, Gilles; Korman, Josh; and Heath, Daniel

**Referees:** Verspoor, Eric

**Rapporteur:** Amiro, Peter

**Summary/Abstract**

A model was developed to assess the effects that escaped, farmed Atlantic salmon interbreeding with wild Atlantic salmon had on the genome and recruitment in a known population where the level of introduction of farmed fish, the extent of interbreeding, and the survival of offspring could be varied. After interbreeding and with offspring survival, spawners with the pure wild genome were rapidly replaced by a population of backcrosses whose survival was a function of mean genetic introgression of the domestic genome from farmed fish into the population. Model predictions were sensitive to variability in the probability of mating between farmed and other spawner groups, the relative survival of offspring with farmed genome, and the magnitude of farmed spawner introductions. Under some scenarios, a "hard selection" on offsping with farmed genome (as for a distant strain) was found to be more beneficial to population persistence than a "soft selection" (for closely related stocks). The impact of farmed spawner introductions was minimized by early action to eliminate escapees or prevent interbreeding. The model identified a need to dramatically decrease response time for applying conservation measures to preserve a population with a mean genetic introgression low enough to prevent extinction after farmed spawner introductions were stopped. Quick management action was especially important at levels of farmed spawner introductions that have recently been observed in some rivers. Failure to act to stop introductions resulted in a high mean genetic introgression in backcrosses and extinction of a self-sustaining population. The escape of juvenile salmon from commercial hatcheries and their return as farmed spawners was predicted to greatly accelerate the increase in genetic introgression and population extinction, and to complicate the successful application of conservation measures.

**Issues/Concerns (including response)**

1. The reviewer indicated that the introduction of the paper needs to state more clearly the purpose the model is intended to serve in the current management context. Was its intention to increase general understanding or to informing on the Maguagadavic situation specifically.

2. The reviewer pointed out that paper states in the introduction that "...potential genetic impact is carefully considered..." when referring to stocking and enhancement work. This is not

supported and in the reviewers opinion was not the case. They suggested that while the intent is usually a positive outcome, a detailed consideration of genetic issues is seldom carried out in reality.

3. The reviewer indicated that the genetic component of the model needs to be explained in more detail. In particular the assumptions made and its simplification of the true genetic nature of salmon population mixing needs to be discussed. They indicated that it needed to be made clear what was meant in the paper by the term introgression as it was not being used in a traditional sense and referring to the introduction of novel genetic variants from one distinct species into another. It was also pointed out that it needed to be made clear that this is a "geneological" mode and that geneology by itself will not determine fitness and is being used a proxy in the model. The point was made that the genetic basis of heritable differences between farm and wild salmon needs to be better understood.
- The author's response was to agree to clarify these issues.

4. The reviewer stated that it was not clear if and how the precautionary approach follows from the results of the model, particularly taking point 3 above into account.

5. The reviewer indicated that the reference to the microsattelite data in the paper is meaningless in the context of the model and should be left out as there is no evidence that the observed differences are due to interbreeding with farm escapes. The author agreed.

6. The reviewer pointed out that the reference to maladaptive genes should refer to maladaptive genotypes as there is no evidence that farm and wild fish contain uniquely different allelic variation; differences will be predominantly with regard to allele frequencies and changes in the expected genotypes (i.e. allelic combinations).

**Consensus**

The general concensus was that the model provided a more detailed appreciation of what might happen under different scenarios of numbers of escaped farm salmon and their degree of maladaptation. While the specific details of the outcome might be questionable, the model makes clear the wide range of scenarios under which a serious negative impact might be expected. However, while the model tells us what might happen, given the assumptions and simplifications made, it can not tell us what has happened or will happen. The model does, however, highlight the utility of using a modeling approach to identify key variables in the breeding interaction between farm and wild fish and identify aspects of the interaction which may be of particular concern or where research might be most profitably directed. The model in so far as it goes reinforces that concern for potentially negative impacts is merited.

Research Recommendation

1. Additional modelling could be a useful method for understanding potential impacts of interbreeding if the genetic component is more realistically defined and for evaluating different management scenarios.

2. Field research needs to focus on the relative survivability of farm strains and their hybrid offspring as this will be a major determinant of the outcome.

3. The nature and extent of "introgression" needs to be better understood to identify management needs.

Management Consideration

1. The modeling indicated the need for immediate action in stopping introductions of farm fish to preserve wild self-sustaining populations of Atlantic salmon in affected rivers.

## A REVIEW OF POTENTIAL IMPACTS ON WILD SALMON STOCKS FROM DISEASES ATTRIBUTED TO FARMED SALMON OPERATIONS
**Res. Doc. 98/159**

**Working Paper(s):** DFO Working Paper 98/90

**Author:** Olivier, Gilles. 1998.

**Referees:** Campbell, Malcolm

**Rapporteur:** O'Neil, Shane

**Summary/Abstract**

The prevalence, incidence and pathogenicity of diseases affecting wild Atlantic salmon is limited compared with fish health data originating from fish farms where Atlantic salmon are raised. There has been limited research efforts in studying diseases of wild fish including Atlantic salmon, largely due to the expensive nature of such research and logistics problems associated with sampling. The association of wild salmon disease with the negative environmental effects of fish farming has in recent years been targeted as a high priority field of research, but data generated to date do not confirm this hypothesis. No significant disease problems of wild Atlantic salmon have been linked to the presence of fish farming. The highest risk of disease impact on wild salmonids would be the introduction of an exotic disease for which the wild population has no innate resistance. International and national regulations are in place to restrict the occurrence of such events. Nonetheless, in some instances there are confirmed reports of negative impacts of farmed fish diseases affecting wild salmon populations namely; epizootics of furunculosis in Norwegian fish farms have been associated with mortalities of wild Atlantic salmon in several feral populations in Norwegian rivers. The devastating effect of whirling disease on wild salmonids (trout) in several US states is another example as is the impact of the parasite *Gyrodactilus salaris* in wild Norwegian stocks of Atlantic salmon. In contrast to the limited information available on the transfer of fish diseases from cultured fish to wild fish, there are numerous confirmed reports of fish diseases of wild fish affecting farmed salmonids. This paper will try to summarize the available information regarding the potential impact of cultured Atlantic salmon diseases on wild Atlantic salmon in the Maritimes Region.

**Issues/Concerns (including response)**

1. Presentation was more in keeping with direction provided by the workshop objectives than the paper. Would recommend that you would reorganize the paper to reflect your presentation and add the necessary material such as the venn diagram. Consensus was that the authors "blend" the presentation with the paper which was tabled.

2. Would prefer to see more on the disease situation in the Maritimes.
- Paper by Ann Margaret MacKinnon will cover that in much more detail. Perhaps a bit more detail in this paper would assist the reader in understanding the breadth of the diseases in the area.

3. Wild fish do not get the same scrutiny as cultured fish and thus knowledge of the fish disease situation in the wild is poorly understood. Would prefer that you elaborate on the lack of knowledge of the disease situation in the wild fish and provide more details through examples.

4. Atlantic salmon from inner Bay of Fundy rivers do not leave the bay so would those stocks be more susceptible to infection and not available for observation because they die rather than return to the rivers.
- We do not know whether the fish have come in contact with the virus or if they were susceptible to the disease.

5. Concerned that you haven't convinced the panel that this transfer of disease has not occurred.
- Author replied that no statement of fact was made that the disease has not been transferred.

6. Page 9. Are furunculosis and ISA considered exotics and are they capable of mutating rapidly? Is it possible that the fish are more susceptible today due to new stressors?
- Yes these pathogens are exotics for most fish stocks and yes some mutation appears to have occurred in some pathogens such as VHS. Not aware of any data which confirms that fish are under additional stressors as a general statement.

7. Understanding of risk of transfer of disease such as ISA should involve examination of existing data on the transfer such as the Scottish example. Perhaps you could include that example in your paper.

8. Has anyone looked at fish pathogens in ballast water to explore the possibility of cross Atlantic contamination?
- I do not believe the working group which is looking at ballast water for other reasons has "fish pathogens" on its list of agents to look for. That might be an interesting addition to their investigations.

**Consensus**

Research Recommendation

1. Disease surveillance of wild salmon and possible other marine species to document existence of reservoirs of pathogens.

2. Governments and industry should collaborate to institute a comprehensive fish health program.

Management Consideration

1. Continue with work of technical committee reviewing disease status of cultured fish as is currently being done with ISA.

2. Emphasis should be placed on keeping fish healthy rather than finding out why fish are sick and management approaches should use that principle as a guide.

## OVERVIEW OF FISH DISEASE AGENTS IN CULTIVATED AND WILD SALMONID POPULATIONS IN THE MARITIMES
**Res. Doc. 98/160**

**Working Paper(s):** DFO Working Paper 98/91

**Author(s):** MacKinnon, Anne-Margaret; and Campbell, Malcolm

**Referees**: St. Hilaire, Sophie

**Rapporteur:** McClelland, Gary

**Summary/Abstract**

The majority of fish health diagnostic testing in the Maritimes is performed on cultivated salmonid populations due to extensive salmonid aquaculture; economic consequences of a disease outbreak; and live trade of cultivated fish stocks. There are a number of laboratories available for diagnostic testing and as a result of the lack of mandatory reporting of infectious disease agents of concern, the Department of Fisheries and Oceans (DFO) is not always privy to pertinent fish health information. The demand for diagnostic inspections under the Fish Health Protection Regulations (FHPR) has dramatically increased since their promulgation in 1977. The Government of Canada assumes the cost of performing FHPR inspections within Canada and the provision of these diagnostics examinations exhausts the majority of resources available for DFO's Maritime Region Fish Health Unit. Limited testing of wild finfish populations has been performed through collection and submission of samples by other agencies and groups within DFO, the necessity for regulatory diagnostics on wild broodfish populations and

investigations of fish kills in the wild. This paper will provide a review of available fish health information collected for wild and cultivated salmonid populations, in recent years.

**Issues/Concerns (including response)**

1. Nature of fish screened: primarily non-clinical cultivated salmonids; very few moribund fish examined.

2. Wild fish surveillance: due to the demands of regulatory (FHPR & RFHP) diagnostics, the resources available for wild fish surveys are limited.

3. Mandatory reporting: without reports of diagnoses performed by provincial and private laboratories, DFO records may not accurately reflect the distribution of disease agents in the aquaculture industry.

4. Investigation of long term trends in occurrence of diseases: possible, but early records not on current database.

**Consensus**

Research Recommendation

1. Establish surveys of diseases in wild fish populations to provide information on disease interactions between wild and cultivated fish.

2. Conduct follow-up research on specific diseases, when required.

Management Consideration

1. Major revisions to the FHPR including: creation of a list of disease agents of concern for each province; mandatory reporting of disease agents; inclusion of non-salmonid finfish species; designation of zones as positive or negative for disease agents in cultivated and wild fish stocks; and inclusion of a quality assurance program.

2. Increased funding and resources to enable monitoring of diseases in wild finfish populations, enhanced screening of cultivated fish and follow-up research.

**Other**

1. According to provincial representatives, mandatory reporting already exists in Nova Scotia and New Brunswick.

2. In response to concern over the confidentiality of veterinarian reports, it was pointed out that, in New Brunswick, aquaculturists are given 24 hours to notify neighboring farms in the event of a reportable disease agent being identified in their stock; in Scotland restrictions on sites are published after 30 days.

3. Also noted was the fact that, unlike their counterparts in the agriculture industry, fish farmers are not compensated for stock eradicated after diagnoses of reportable diseases.

4. It was suggested that comparison of disease profiles of Atlantic salmon cultivated on the east and west coast might provide insight into the rate at which farmed fish acquire diseases from wild fish.

5. Concern was expressed over the fact that the FHA had not been screening inner Bay Salmon.

## A REVIEW OF THE POTENTIAL EFFECTS OF SALMON LICE AMONG AQUACULTURE SALMON ON WILD SALMON. Res. Doc. 98/161

**Working Paper(s):** DFO Working Paper 98/92

**Author:** McVicar, Alasdair

**Referees**: McClelland, Gary

**Rapporteur:** Johnson, Stewart

**Summary/Abstract**

The prevention of lice infection on farmed salmon is likely to be an unachievable objective, at least in the foreseeable future. Although conclusive evidence is lacking, it is realistic to assume that lice from farmed salmon will contribute to lice in wild fish populations. The extent of this contribution and the consequences are the areas of current intense controversy. Much of this controversy can be attributed to an inadequate data-base. There is a concerning tendency for researchers to be selective in the interpretation of available data and to take highly polarised stances where any proper consideration of an alternative interpretation is avoided as being a sign of weakness of their position. It is essential that realistic dialogue between different groups involved in this topic area is fostered at every opportunity.

The general absence of historical (pre-fish farming) data on lice levels in wild salmon populations, and of an adequate more recent time-series on fish farms, prevents evaluation of temporal changes in lice levels and the factors (including farms) which may be contributing to these. Similar difficulties are found with spatial variations in lice levels. The pathogenicity of lice to salmon is well established in experimental and farm situations, but such information is difficult to obtain for wild populations. A focus of effort on achieving a reduction in farm lice levels and on understanding the biology of transmission of infection to new hosts could maximize output from resources allocated to this field.

**Issues/Concerns (including response)**

1. A major criticism of this working paper was that it did not stand alone without the ICES document on sea lice interactions between wild and farmed fish. It was suggested that a new synthesis of the ICES document is required.

2. This paper lacked information on areas where progress has been made since the ICES document was tabled.

3. It was felt that a description of the pathology of sea lice disease on wild and farmed salmonids is required.

4. There was concern that little mention was made of species of *Caligus* which infect and can cause disease in salmon. The author responded that he excluded these species because of their lower pathogenicity and the fact that their biology (especially host range) was vastly different than that of the salmon louse *Lepeophtheirus salmonis*. These differences in their biology mean that many of the techniques used to control *L. salmonis* are not as effective in controlling *Caligus* infections.

5. There was no mention of documented epizootics of sea lice in wild salmon stocks that have occurred in the absence of fish farming (Moser River, 1930s; Alberni Inlet, 1990s).

6. It was felt that figures should be used to illustrate the geographical distribution of sea lice epizootics and the pattern of distribution of the infectious stage in the vicinity of farm sites.

7. The section on treatment and husbandry techniques used to control sea lice gives no indication of how these practices affect sea lice levels on farmed salmon.

8. It was asked if the work on identification of sea lice from farmed salmonids using molecular techniques was successful.

- Data still not yet published, review of progress by Stirling indicates that there is no identifiable difference in sea lice between wild and farmed salmonids

The working paper will be changed to reflect these concerns and references will be cited in the text.

**Consensus**

<u>Research Recommendation</u>

1. There is a lack of data on historical levels of lice on wild salmonids in the absence of fish farming. Therefore it is not possible to determine if there have been subsequent changes in theses levels due to farming. Natural background levels of sea lice need to be monitored.

2. The most important requirement for further work in this area is the development of a stable funding base for sea lice research.

3. Due to the complexity of this problem research needs to focus on one variable at a time and to ask clearly defined questions.

4. It is important that we develop an understanding of the behaviors of the infectious copepodid stage of sea lice.

5. There is evidence that sea trout held in cages in the vicinity of an infected farm site will become infected with sea lice. However, there is no scientific evidence that the infections seen on wild sea trout were of a farmed origin.

6. There is a need to understand if and for how long wild salmon remain in the vicinity of sea cages. This behavior is likely to be highly site specific.

7. Differences in susceptibility of different species to sea lice infection also need to be taken into consideration when discussing possible impacts.

8. Any addition to the number of lice in inshore or offshore areas may result in changing the balance of sea lice away from natural levels of infection.

Management Consideration

1. Reduced lice loads on farmed fish will improve their health and reduce the possibility that wild fish in the vicinity of farms would become infected with sea lice.

2. Reduction of lice loads on farms is best achieved using treatments timed to reduce lice loads prior to the onset of sea lice disease.

3. Management practices such as site selection, net cleaning and fallowing can reduce the necessity for chemical treatments of farmed fish.

4. Cooperation between farms in the timing of their sea lice treatments, fallowing etc. can also help reduce sea lice abundance on farms.

**Other (comments from the floor)**

1. It was pointed out the New Brunswick monitors sea lice levels and has a set level of infection at which time treatment is initiated.

2. There was also concerns about sea lice acting as a vector for ISAV. The author acknowledge that ISA virus has been found on sea lice from infected fish and that these sea lice can transfer the disease if placed on naïve hosts. However the rate transfer of the mobile pre-adult and adult stages between fish is thought to be extremely low making this unlikely route for transmission.

3. It was mentioned that the pest management regulatory agency would be producing an integrated pest management strategy for sea lice in Canada. This document will be available in the New Year.

## ECOLOGICAL AND BEHAVIOURAL INTERACTIONS BETWEEN FARMED AND WILD ATLANTIC SALMON: CONSEQUENCES FOR WILD SALMON.
**Res. Doc. 98/162**

**Working Paper(s):** DFO Working Paper 98/93

**Author(s):** Lacroix, Gilles, and Fleming, Ian

**Referees**: Hutchings, Jeff

**Rapporteur:** Cairns, David

**Summary/Abstract**

The distribution of hatcheries and sea cages for Atlantic salmon farming in the Maritimes Region presents a unique situation for intensive ecological effects on wild Atlantic salmon in the Fundy Isles area. Farmed salmon escape into fresh water (fry to smolt) and in coastal marine areas (smolt to spawner), and they can move from one habitat to the other and interact directly or indirectly with wild salmon. In fresh water, escaped farmed spawners can influence natural migration and spawning. Behavioural interactions can affect mating selectivity and interbreeding that control genetic interactions and population performance. Between the fry and smolt stages, competition for food and space can increase with the introduction of large numbers of conspecific organisms with a distinct developmental and size advantage. In addition, predator–prey relationships can be altered by flooding streams with farmed juveniles and smolts. These interactions would lead to changes in productivity of native salmon populations through processes affecting growth and survival. In the marine environment, post-smolts and adults must migrate through a gauntlet of closely-spaced cage sites, with high densities of farmed fish in captivity and at large and often unhealthy conditions, on their migrations to and from marine feeding grounds. This may alter their normal migratory behaviour but, more importantly, these conditions are ideal for the transfer of diseases and have attracted predators and altered the natural predator–prey balance. These interactions would increase the marine mortality rate of wild salmon from local and distant stocks that migrated through the area during their marine phase. The possible homing behaviour of escapees from sea cages to their native hatchery waters would make some rivers magnets for farmed fish and intensify the ecological impacts on local salmon stocks.

**Issues/Concerns (including response)**

Jeff Hutchings' comments:

- Nice paper, comprehensive document.

- What are competitive abilities of precocious male parr that have escaped from culture?

- Need caveats to the point that breeding tends to be between wild males and cultured females, - shouldn't assume that the competitive inferiority of cultured males will persist in hybrid offspring.

- Differences in egg size: In other species faster growth in individuals when fed well will produce more eggs but smaller. Do cultured fish produce smaller eggs? If so implications should be mentioned.

- In some cases it's not clear whether work is specific to a particular area, or if it's based on a broad geographic area and therefore generalizeable. Geographic differences are important and should be given full attention in the paper.

- Interspecific interactions: Other fish could be affected. Predation could increases due to predator attraction. Escaped parr could eat eggs of smelt, gaspereau, etc.

- The paper says there are increased seal densities near cages. Evidence for this should be given in paper.

- How accurate is identification of farmed salmon vs. wild salmon? This should be discussed in the paper.

- Regarding the recommendation that hatcheries be sited on non-salmon rivers - This could harm other species of fish due to community interactions noted above.

- Research recommendations should be put in form of hypotheses.

- It was noted that wild precocious parr may assure fertilization when cultured males breed with wild females. Will populations with low incidence of male parr maturity be more at risk from farm escapees?

- Gilles Lacroix: precocious parr are actually precocious subadults that escape from brackish sites.

- Tom Sephton - suggests that authors and referees should have a dialogue instead of each giving speeches.

- Tom Sephton: other species interactions should be brought out in other papers.

- Tom Sephton: a point for John Ritter: we need a working definition of precautionary approach.

- Ian Fleming: in hindsight we should have had a paper on community effects.

- Rod Bradford: I'm trying to get an impression of what densities are in river currently. What are combined densities relative to production potential in system?

- Gilles Lacroix: Wild juveniles are presently far below carrying capacity, except in some tribs near hatcheries where they are above carrying capacity. Escapees from these hatcheries lead to new size classes in the stream, with growth advantages.

- Rod Bradford: to what extent are wild and escapees co-distributed on the Magaguadavic?

- Gilles Lacroix: densities of wild juveniles are very low. Only a few pockets where interactions could occur, including upper part of river where best spawning areas are.

- Ellen Kenchington: The paper assumes that breeding for higher growth rate in farmed fish is an advantage when fish escape. But this could also be disadvantage in wild, due to poorer environmental conditions in the wild, which cannot support the more rapid growth.

- Ian Fleming: I agree that higher growth rate would bring on increased mortality. However those escapees who survive will be bigger.

- Ellen Kenchington: The migration of salmon in SW NB is different than elsewhere. Would pattern of migration affect interpretation of results?

- Gilles Lacroix: I leave this to next speaker (only inner Fundy, not including Saint John, have the unique migration pattern).

- Trevor Goff: Re: supposition that large farmed parr outcompete wild parr - this seems unlikely due to inferior swimming, and other maladaptions to life in wild. Is there research that demonstrates the putative advantage of faster growth?

- Ian Fleming: There is research on other salmonids that analyse size advantages. Size does help. Many escapees do so as fry and have time to develop good swimming ability etc.

- Jeff Hutchings: Competitive ability of wild vs. farmed is still an open book.

- Iola Price: The paper's title should be narrower, mentioning the comparison between the Magaguadavic River and Norway, rather than mentioning the Maritimes. There is very little information on NS & PEI. Maritimes is a poor choice of words in title.

- Ian Fleming: The paper reflects where information and industry exists.

- Iola Price: The title should reflect data in paper.

- Iola Price: Differences between Norway and Canada are great.

- Giles Lacroix: There are both similarities and differences.

- Ian Fleming: Scotland and Ireland are also sources of information, not just Norway. There are also references to Pacific salmon.

- Iola Price: Changes in marine survival of salmon have been tracked for the Maritime Provinces. Is it possible to subtract impact of changes in marine survival to parse out changes due to aquaculture?

- Gilles Lacroix: Marine survival is like the present issue of this workshop. Supporting research is not available. Aquaculture, predators, habitat, and climate are all factors.

- Iola Price: We need to tease out what is going on among variety of factors. The workshop's summary should reflect consideration of a range of issues.

- Iola Price: Have there been experiments to show whether hybrids of farmed fish vs. wild fish are intermediate in their response predators, on the scale of risk adversity or risk proneness.

- Ian Fleming: Experiments have been done. Result is intermediate. In hybrids, growth is intermediate or superior.

- Russel Henry: Management considerations - Brackish sites that were previously approved have been discontinued. Movement of fish from the Kennebecasis has been restricted (ISA consideration). Gov't is wrestling with what to do with Kennebecasis fish. Review is looking at what do to with sites close to river mouths.

- Peter Cronin: Smallmouth bass have been mentioned. They have been in the system for 50-70 years. I suggest that if there's a change in smallmouth numbers in the Magaguadavic it may be responding to declining juvenile salmon populations because they do not prefer similar habitats. Hence increase in smallmouth populations is likely a response rather than a cause. The stupidity of cultured fish causes communication problems with wild fish. The consequence is that smaller cultured fish may displace larger wild fish.

- Ian Fleming: Communication is often impaired with cultured-wild interactions.

- Steve Moyse, Nfld. Salmon Growers Association: The Industry he represents should be recognized for day to day things they are doing. In Bay d'Espoir, number of initiatives to deal with escapee issues. These include a code of practice, ice booms, sonic tracking, and recapture program. Would like to see recognition of efforts of industry towards precautionary approach.

- Stuart Johnson: The statement that farmed fish have overwhelmed wild populations in the Magaguadavic needs to be put into perspective. Concurrent with the decline in the Magaguadavic is a drastic decline in number of wild fish. Things should be taken in context. We need a statement that decline of Magaguadavic run could be partially due or linked to generalized decrease in wild stocks.

- Brian Glebe: Gilles made a comment about dumping of fry. Is dumping an escapement? This seems to be an educational issue. Hatchery managers may not realize they shouldn't do this.

- Gilles Lacroix: Education is needed and should be done. Obvious from the pattern of fish that turn up in electrofishing that there must be intentional dumping.

- Brian Glebe: There is a tradeoff. You can only force so much effort towards containment.

- Gerald Chaput: You recommend not siting hatcheries on rivers with salmon. What is the evidence that escapees return to rivers where they were hatched?

- Gilles Lacroix: There is some supporting information but this needs to be pursued.

- Gerald Chaput: The strength of recommendations is too strong for evidence behind it.

- Gilles Lacroix: Recommendations are put up for discussion, to see which ones stand.

- Fred Whoriskey: This year (or last year) there was a failure of a cage on Deer Island. Within 4 days post-smolts turned up on Magaguadavic. This is the first evidence of homing. In other situations the hatchery origin of escaped fish was not know.

**Consensus**

Research Recommendation

*Those taken during presentation:*

1. Determinants of gene flow between farmed and native fish.

2. Maturation and reproductive interactions, wild escapees, farmed $F_1$ and b cross.

3. Competitive displacement of native fish by farmed salmon escapees, farmed $F_1$ and hybrids.

4. Natural selection relative survival.

5. Effect of freshwater and marine culture sites on migration and disease transfer.

6. Behaviour and migration of escapees from sea cages.

7. Behaviour of predators around cages, monitor impact on wild salmon.

8. Migration routes and destinations of native salmon in Bay of Fundy.

9. Modelling to understand mechanisms, and evaluate action.

*Complete list from MS:*

1. Studies on the potential for competitive displacement of native salmon by farmed salmon, escaped from hatcheries and offspring of farmed spawners (also hybrid offspring).

2. Survival and natural selection during $F_1$ generation (interactions during the $F_1$ generation remain at a very basic level).

3. More comprehensive studies on determinants of gene flow between farmed and native populations (reproductive interactions).

4. Potential for reproductive interactions at the $F_1$ generation and continued genetic introgression.

5. Need to monitor changes in population dynamics and genetic structure, but also understand mechanisms leading to these changes and their implications. By understanding the mechanisms and causes, generalities can be identified and solutions found; without doing so, we are working in the dark.

6. Studies on the effects of farmed fish and rearing/grow out facilities on migratory behaviour of, and disease transmission to native fish in freshwater and marine habitat. Need to monitor the survival of wild salmon after migrating through corridors or to areas with diseased farmed fish.

7. Need to identify the migratory routes and destination at sea of wild salmon stocks in the Bay of Fundy to better understand the potential cause/effect of interactions, and to effectively manage cage site location.

8. Studies to understand the behaviour of farmed fish after they escape from sea cages. Needed to determine their role in disease transmission, changes in predator–prey balance, and to find solutions to eliminate reproductive interactions.

9. Studies to understand the behaviour of predators (e.g. seals) around aquaculture areas, and need to monitor their impact on wild salmon migrating through or to these areas.

10. Modelling studies and associated tests are needed to understand mechanisms and identify appropriate/effective management actions.

<u>Management Consideration</u>

1. Review and revise containment codes and practices for sea cages and for hatcheries using a precautionary approach. Escapes/releases of domesticated farmed salmon into the environment must be reduced/eliminated.

2. Enforce existing policy to prevent/eliminate the release of juvenile farmed salmon into rivers (conservation measure).

3. Review and revise policy for the siting of salmon hatcheries that rear domesticated stock. Hatcheries should be located on rivers and bodies of waters that do not have a run of wild salmon to prevent interactions with wild stocks (precautionary approach).

4. Prevent escaped farmed salmon access to fresh water and to known spawning grounds for wild salmon, and remove escaped farmed salmon where possible (conservation measure).

5. Review and revise policy for siting of aquaculture cages using a precautionary approach. The use of freshwater sites for grow out should be eliminated/prevented in rivers with wild salmon stocks. The use of brackish water sites in estuaries with wild salmon stocks should be reviewed. The use of narrow passages around the Fundy Isles for cage sites should be reviewed, and suitable migratory corridors for wild salmon stocks should be maintained to reduce possibilities of predation and disease transfer.

6. The allowed density of cage sites in any area used by wild salmon as a destination should be reviewed to reduce the potential for predation and disease transfer.

7. Existing methods of predator control (e.g. seals) in aquaculture areas should be reviewed, and an appropriate management plan devised.

## AN ASSESSMENT OF THE POSSIBLE IMPACT OF SALMON AQUACULTURE ON INNER BAY OF FUNDY ATLANTIC SALMON STOCKS. Res. Doc. 98/163

**Working Paper(s):** DFO Working Paper 98/94

**Author:** Amiro, Peter. 1998.

**Referees**: Whoriskey, Fred

**Rapporteur:** Randall, Bob

**Summary/Abstract**

The uniqueness and status of inner Bay of Fundy Atlantic salmon (*Salmo salar*) is reviewed. Possible explanations for historic and recent low recruitment are postulated. Concurrent with the most recent and perhaps severe decline is the developing salmon farming industry in the southern Bay of Fundy. Past tag recovery data place marine distribution of inner Bay of Fundy stocks coincident with the salmon cages for extended periods of time. Mechanisms for the possible negative impact of salmon aquaculture occurring in the historic migration area of this stock are examined and logistically assessed. Two possible mechanisms could be rejected: 1) disease and 2) predator attraction induced by salmon escapes from aquaculture preying on both wild and escapes.

**Issues/Concerns (including response)**

1. Does marine survival of inner Bay of Fundy stocks track the outer stocks, or is it totally independent?
- Trends of inner Bay of Fundy stocks are asynchronus with outer Bay of Fundy stocks.

2. Regarding the historical 'boom or bust' trend - are data available, and is a cyclical trend obvious?
- Historical data were initially analysed by Huntsman and others, but no predictable trend was identified (although low and high peaks in catches were evident). Currently, the abundance levels in the inner Bay of Fundy (e.g., Big Salmon River) are the lowest on record.

3. Is there evidence that 'superchill' affected the abundance of Atlantic salmon in the past?
- It is difficult to test this hypothesis. However, it may be possible to look at meterological data, but this has not been done.

4. Is there data on the historical abundance of seals or other predators in the Bay of Fundy?
- Trends in the abundance of predators in the inner Bay of Fundy are probably different from the outer Bay of Fundy, but the author is not aware of any data. It is possible that a Type III predator-prey relationship may be involved. There must be conditioning by the predator, involving a predation advantage (salmon as prey), such as high caloric/energy content (lipids). Encounters are important for conditioning. The hypothesis of a Type III predator-prey relationship has not been investigated.

5. What is the aquaculture experience with seals - do seals stay in the area? Would you expect seals to profit from 'opening' a net?
- It was noted that the only recorded tag recapture (from Stewiacke River) was from the stomach of a harbour seal sampled at Grand Manan.

6. Is it possible that an extinction event will occur, and if so, what would be your recommendations?
- There are three possibilities – 1) do nothing; 2) select a stock that avoids the predation zone (or use another species, sea-run brown trout?); buy time by maintaining/supporting the current stock by some means (e.g., parr secured in hatchery). A research priority is to track wild smolts to try to confirm the hypothesis of residency in the inner Bay of Fundy.

7. Emphasized that there is a significant conservation issue in the inner Bay of Fundy.
- Unqualified agreement.

8. Chaput: Were past cycles of salmon abundance in the inner Bay of Fundy driven by exploitation (note the data were catches, not abundance)?
- This was unlikely.

9. Chaput: Suggested that there may have been changes (chaos, destabilization; used the Petitcodiac causeway as an example) to the ecosystem in the inner Bay of Fundy, but there

are no data to support this theory. It is too soon to discount the hypothesis of ecosystem change. There is a need to monitor smolt out-migrations.

- Destabilization in inner tidal areas may be an issue. For example, why hasn't another species invaded the prime habitat (e.g., brown trout). Agreed with the idea of monitoring smolts, as suggested earlier by the referee.

10. Cusak: Noted the distinction between inner Bay of Fundy stocks and the outer stocks. Did the 'superchill' events of 92/93 affect the outer stocks?

- It is not appropriate to compare the response of caged fish to these events with the response of freely swimming salmon.

11. Glebe: Crooked Creek is the only inner Bay of Fundy hatchery - are there any data that can be used? Also, is there information from Big Salmon River?

- There is a barrage on Crooked Creek, and there are no data. In Big Salmon, there were a few fish this year (25), but the origin is unknown. Commented on the risk of loss of diversity because of the small broodstock size.

12. Hutchings: Commented on Type III predator/prey relationships and the need for information on the local density of escaped salmon around sea-pens. For predation to be a factor, it is not necessary to have very many seals to have an impact.

- There is a need to have data on the numbers of escapees around sea pens.

13. Goff: Are post-smolts recaptured in the Georges Bank area? Do you have information on the density of other predators like dogfish or bluefish?

- There have been no inner Bay of Fundy tags recaptured at Georges Bank. Regarding the second question, it is suggested that the potential effect of all predators could be lumped into one category (Type III hypothesis). It is difficult to get data on this topic; there is no diet evidence of predation by dogfish.

14. Johnson: Is there evidence of other changes in the Bay of Fundy, like changes in prey densities or by-catch in weir data? Agreed that small numbers of predators can be important, and gave examples from the west coast (L. Washington).

- Gray seals have been observed recently; groundfish are scarce, and herring are the dominant prey species in the Bay of Fundy.

15. Baum: Requested information on the status of other pelagic species (gaspereau, shad, eel, and striped bass) in the Bay of Fundy.

- Herring and gaspereau stocks are stable, eels have independent recruitment (therefore are not relevant), and there is no information on lampreys. The need for stock recruitment data was emphasized.

16. Cook: Why is the Saint John River not considered, when looking for interactions with cultured fish? Asked if it would be possible to look at several rivers that are declining, e.g., Big Salmon River and Magaguadavic, to try to determine cause and effect.

- There is little exposure of the Saint John stock, or other outer Bay of Fundy stocks, to the industry. The Magaguadavic River stock is also different from the inner Bay of Fundy. [There was other discussion between Cook, Amiro and Whoriskey].

17. St-Hilaire: Emphasized that she felt that the habitat issues/concerns were not being addressed. What about changes in human population density, or the effects of farming and forestry.
- Habitat quality in the inner Bay of Fundy rivers is not the issue. The habitat quality, using qualitative measures, is good. Quantitative data on habitat could be obtained, but the qualitative information is adequate.

18. Forsythe: Indicated that in the 1970s post-smolts of Saint John River origin had been captured in a herring weir on the Nova Scotia side.
- This was the normal migration path for out-moving Saint John smolts. There are few high head weirs left.

19. Kenchington: There is a need for a comparative model: has the genetic structure of inner Bay of Fundy stocks changed?
- Agrees, and indicates that the study could be done by contract.

**Consensus**

Research Recommendation

(Note from Rapporteur - I am assuming that the following items might be considered to be research recommendations):

1. (F. Whoriskey and others). Use the inner Bay of Fundy as a test location for the conservation of critically low populations? Minimum population size.

2. (F. Whoriskey): Tagging studies of wild smolts to test hypothesis that inner Bay of Fundy stocks utilize the western regions of the Bay of Fundy as an adult staging area?

3. (Chaput, St. Hilaire): Information is needed on long-term environmental changes in the inner Bay of Fundy.

4. (Hutchinson): Information is needed on the density of escapees around sea pens (Type III predator-prey hypothesis).

5. (Several): Information is needed on changes in abundance of predator and prey species in the Bay of Fundy.

**Minority Report:**

1. Note: At least two participants (Chaput and St.-Hilaire) felt that the habitat/environmental issue (possible changes to the environment in the inner Bay of Fundy) have not yet been investigated.

## A REVIEW OF EXISTING CONVENTIONS, REGULATIONS, AND POLICIES PERTAINING TO THE CONTROL AND MINIMIZATION OF NEGATIVE IMPACTS FROM AQUACULTURE ON WILD SALMONID STOCKS
**Res. Doc. 98/164**

**Working Paper(s):** DFO Working Paper 98/95

**Author:** Porter, Rex. 1998

**Referees**: Meerburg, Dave

**Rapporteur:** Rose, Carol Ann

**Summary/Abstract**

There are many international conventions and agreements, as well as, national and provincial regulations and policies that potentially influence DFO's regulation of salmonid aquaculture activities relative to Atlantic salmon conservation in the Maritime Provinces. These conventions, agreements and regulations generally fall into two categories: those that were developed with the primary intent of conservation and sustainable use of the aquatic resources, such as the Convention on Biological Diversity, and; those that were developed for trade, such as, the North American Free Trade Agreement. Some of the conventions and agreements require a commitment from Canada to implement agreed-on procedures, while others provide guidelines, or good operating practices. International conventions and agreements tend to provide a "level operating field" and standards for conducting business among contracting parties. Although many of the agreements were developed to conserve and protect wild stocks, they also assist the industry, particularly in the area of fish health and quality of the environment. This review will consider international agreements, such as, those within NASCO (North American Commission Protocols for the Introduction and Transfer of Salmonid, the Oslo Resolution, and the Precautionary Approach) and ICES, Convention on Biological Diversity, and trade agreements. Federal and provincial regulations and policies, including among others, the Wildlife Policy for Canada, and the policy specific to rainbow trout in New Brunswick, Nova Scotia, and Prince Edward Island will also be discussed.

**Issues/Concerns (including response)**

1. Convention regarding Stradling stocks not yet ratified even though Canada initiated it.
- Process it ongoing and it should be ratified in near future.

2. DFO I&T Committees should be on page 10 – better fit.
- Yes.

3. Endangered species does not apply to salmo salor but to some stocks/populations. No response.

4. Terminology of some protocols inconsistent with Fisheries Act and regulations thus making it difficult to apply them in conditions of licences ie. for introductions and transfers.
- Acknowledged.

5. Section 56 Fishery (General) Regulations applies nationally even in provinces with provincial Aquaculture Acts.
- Acknowledged.

6. Fish and fish habitat defined in the Fisheries Act. Aquatic resources not a legal term.
- Acknowledged.

7. In the US, endangered species applies to an evolutionary unit. A definition was read – too fast for me. Ed Baum has definition. No response.

8. Aquaculture Site Evaluation Committee in NB is joint Federal/Provincial and reports to the Provincial Minister of Fisheries and Aquaculture. No response.

9. In NB, Rainbow Trout Policy not being enforced.
- Policy extended one more year as agreed between DFA & DNRE.

10. Endangered Species Act if passed (Jan) plans for application to salmon
- Being monitored.

11. DFO has the authority to regulate coastal and inland waters. There are cases where Provinces and Territories according to the BN Act have authority under the constitution.
- Not clear on application.

12. Rainbow Trout Policy - Province allowed for a 5-year phase in period from diploid to triploid. Grandfather clause for those already in. One more year allowed for phase in. Expires in April May 1999. No response

13. Title of article (paper presented) totally inappropriate. Conventions not drawn up to control negative impacts.
- Requested recommended changes.

14. Like to see in paper how other countries apply protocols.
- Author cannot account for all the other countries but can give general context.

15. Industry guidelines agreed to at a conference in 1994 (ethical responsibilities). This fact should be included in paper. Meeting held in OSLO but no one from Canada involved.

- Author will follow up.

16. ISA Containment Policy and Sea Lice Treatment Policy developed for NB. Work being done by Industry with Government.

17. Crown Lands & Forest Act covers leasing of Aquaculture sites in NB.

**Consensus**

Research Recommendation

1. "DFO must consider its mandated responsibilities for conservation and protection of the aquatic resources as required under federal legislation when establishing controls on the aquaculture industry."

2. "DFO must also consider provincial legislation and policies and international commitments."

Management Consideration

1. Protocols & Conventions serve as guidelines for management decisions.

## A REVIEW AND ASSESSMENT OF MITIGATIVE MEASURES TO ELIMINATE OR MINIMIZE POTENTIAL IMPACTS OF FARMED SALMON OPERATIONS ON WILD ATLANTIC SALMON (*SALMO SALAR*) STOCKS
**Res. Doc. 98/169**

**Working Paper(s):** DFO Working Paper 98/96

**Author:** Ritter, John A. 1998.

**Referees**: Porter, Rex

**Rapporteur:** Meerburg, Dave

**Summary/Abstract**

An overview is provided of mitigative measures for Atlantic salmon (*Salmo* salar) freshwater hatcheries and marine farms to minimize genetic, fish disease and ecological effects on wild salmon in the Maritime Provinces. Measures to prevent or reduce interactions with wild salmon stocks include maintaining healthy wild stocks, improved containment of cultured salmon in both hatcheries and marine farms, selected siting of hatcheries and farms to minimize interactions between farmed and wild salmon, use of local stocks to minimize genetic effects, sterilization of farmed fish to prevent genetic introgression, and application of good husbandry and disease prevention measures to produce healthy farmed salmon. Other measures, such as recapturing escapees, enhanced training and education of aquaculture workers, reporting farmed

escapees, more rigorous enforcement of existing regulations, domestication of the farmed strains, blocking passage of farmed escapees into salmon rivers, and gene banking, are identified. Mitigative measures are assessed in terms of their effectiveness as a conservation measure for wild salmon, their technical and economic feasibility, and their acceptability to industry. Effective implementation of mitigative measures is dependent upon the support and involvement of the aquaculture producers.

**Issues/Concerns (including response)**

Reviewer's Comments:

1. Reviewer felt paper was a useful contribution and that paper could have benefited from commentary on how such measures were being used (successes and failures) in other countries and other parts of Canada.

2. Further comments would also be useful on recapture programs and codes of containment.

3. Whether it is necessary to upgrade this working paper to a research document was questioned as much of the information was also available in individual preceding papers, however, comment was made that this was a useful consolidation.

4. The reviewer asked what useful lessons have been learned with respect to the maintenance of healthy wild stocks in the Bay of Fundy.

5. Reviewer questioned statement that recapture of escapees can be effective because studies in this line were not referenced.

6. Concerning rigorous enforcement, the reviewer questioned the commitment of governments to this if there are regulations that are not currently being enforced and also noted that there is presently inconsistency within Eastern Canada in the enforcement of regulations. Examples were mentioned concerning lack of permitting in the case of some interprovincial/international and within province transfers.

7. The reviewer felt that the federal and provincial governments must work closely together as well as with all the stakeholders involved and that this has to involve New England also.

8. Additional research recommendations noted by the reviewer would include the development and maintenance of genetic profiles of wild stocks as well as further studies to investigate interactions between wild and farmed salmon.

Other comments:

1. Baum: the statement in the paper that large number of farmed salmon are escaping and interacting with wild stocks are not substantiated. There are certainly salmon escaping cages, however, the numbers, which subsequently show up in rivers, are low and often immature.

- The author agreed that the escaping numbers are unknown and that the numbers of rivers escapees are entering are not large, however in some cases the numbers are of significantly high proportions in relation to the wild stocks in the rivers.

2. Cronin: questioned which mitigative measures could be undertaken now and which would be of the most benefit to industry.

3. Verspoor: pointed out that it is in the interest of the aquaculture industry to conserve wild genetic stocks for their own possible future use. He also felt that it might be appropriate for governments within Canada to increase their support for selective breeding for domestication of stocks as it is expected that fish farmers want to access improved growth performance.

4. Cook: suggested that there are many possible reasons for the demise of wild stocks and that aquaculture should not be singled out. Even if aquaculture ceased to exist, he was of the opinion that wild stocks would continue to decline. He indicated that definitions are needed for the terms healthy and wild when talking about the needs of wild populations. He felt that part of the solution may be enhanced releases and questioned the government's intentions as they appear to be withdrawing from this activity.
- The author responded that enhancement is still ongoing, although under different mechanisms, and that the Federal government has moved towards more partnerships in the management of the wild resource.

5. Bailey: pointed out that conserving of genes via cryopreservation may be different from conserving of phenotypes.

6. Price: it would be helpful to add to the table in the report to identify which agencies have prime and secondary responsibility for implementing various mitigative measures.
- This was agreed by the author.

7. Tingley: felt that governments are mainly concerned with economic issues and not environmental concerns. He said that enforcement actions often lack accountability and rigour. He agreed that all salmon farmers must cooperate with respect to disease concerns and that they must utilize practices, which prevent wild stocks from being contaminated by such diseases.

8. Chaput: emphasized that there was nothing presented at this meeting which would allow anyone to conclude that we are blaming aquaculture for the recent demise of Bay of Fundy stocks.

9. Benfey: pointed out that the feasibility is high for producing sterility in commercial quantities however the acceptance of such by the industry is acknowledged to be low.

10. Cusack: expressed concerns on many fronts, including the past impact of enhancement, the need to use local stocks and its effect on N.S., the suggestion that infected stocks should be destroyed (his view was that this only should apply to exotic diseases) and that all Canadian wild salmon stocks are in poor health.

- The author responded that many wild stocks, particularly in the Gulf of St. Lawrence, are being maintained above their conservation requirements and hence could be considered healthy even though current levels of production are lower than historically.

11. Amiro: suggested that the mitigative measures noted in Table 1 should be dealt with in a risk analysis framework along with decision theory models to assist governments in decisions on where to spend money.

12. Hutching: pointed out that the author had focused on genetic issues in the research recommendations and felt more consideration should be given to ecological issues.
- The author agreed that this had been an oversight.

13. Rose: pointed out that transfers within Provinces have far-reaching implications for discrete stock management and that rigorous attention needs to be paid to the permitting system.

14. Loch: pointed out that pending Canadian legislation on endangered species may have implications for the Inner Bay of Fundy stocks and possible recovery plans for these.

15. Johnston: agreed with Mr. Cook's view's that there are many possible factors affecting wild stocks and that in his view we do not know why stocks are declining.

16. Henry: felt that further research on seal predation on both wild and farmed salmon is warranted and also that the Province of NB is revising their site allocation policy and that it would be timely if others wish to input to their process.

17. Gross: felt it was important to link specific recommendations with the table on mitigative measures and develop a hierarchy of possible approaches. He also suggested that it might be possible to come to a consensus on the effectiveness, feasibility and acceptability of mitigative measures by a voting procedure among the panel members.

**Consensus**

The consensus was that the paper was useful and should be included as a research document with additional work on the table by including an indication of responsibility for action and a linking to specific recommendations.

Research Recommendation

1. Priority should be given to researching the tripoidization procedure as the most promising method of rendering farmed fish, and thereby potential escapees, reproductively sterile. Without sterilization the risks to the genetic integrity of the wild salmon stocks are significant from farmed escapees, even when the escapees are the offspring of strains derived from local stocks. As well, industry wishes to test and utilize strains of non-local origin, and ongoing research on transgenics is progressing towards their use in open cages on a production scale.

2. Genetic profiles of the existing strains of Atlantic salmon grown in Maine and eastern Canada should be created and testing procedures established to enable enforcement of introductions and transfers regulations.

Management Consideration

1. Aquaculturists, salmon conservationists and governments should collaborate in the formulation and implementation of plans to reduce interaction between farmed and wild salmon, and on how to conserve any stocks adversely impacted. Plans should be aimed at a broad spectrum of measures including ways to improve containment, to ensure the production of healthy farmed salmon, and to restore and/or conserve impacted stocks. For wild stocks threatened with extirpation, consideration should be given to creating live gene banks and cryopreserving milt from the threaten populations.

2. The NASCO Protocols for the Introduction and Transfer of Salmonids should continue to be followed in regulating such activities considering the evidence that salmon continue to escape from hatcheries and farms and significant numbers are entering rivers and interacting with wild salmon. Consistent with these protocols, the culture of salmon derived from strains of European stock should continue to be prohibited unless the salmon are sterilized or their complete containment can be assured.

3. Conditions of licenses pertaining to both facilities and fish movements should be more rigorously enforced to ensure compliance. Examples of particular concern are fish "leaking" from hatcheries and the inadequacy of technology and procedures to effectively regulate fish transfers relative to genetic concerns.

4. Contingency plans to recapture farmed salmon escapees should be established for each marine farm to maximize the success of recapture operations.

5. Effort should be made to enhance awareness among aquaculture workers of the potential for farmed salmon escapees to adversely effect the wild salmon stocks.

6. A system for reporting escapees should be developed and made mandatory for both hatcheries and marine farms. The system should require immediate reporting of unusual and significant numbers of escapees (i.e., an event) and a year-end reporting of all known escapees.

7. Procedures should be established for identification, removal and disposal of all aquaculture escapees recovered in monitoring traps and as might be feasible and practical elsewhere.

## OPTIONS FOR CONTAINMENT OF FARMED ATLANTIC SALMON
**Res. Doc. 98/165**

**Working Paper(s):** DFO Working Paper 98/97

**Author:** Bailey, John. 1998.

**Referees:** Henry, Russell

**Rapporteur:** Chaput, Gérald

### Summary/Abstract

Protocols for containment are the solution to the problem of escapes. There is a need for two protocols: one for land-based facilities, the other for floating cages. Possible places to control include: the naive release of "culled" fish, equipment failure and operator failure. There exists in some operations a resistance to destroying culled fish (undersized fish, etc.) with the result that fish are released to the environment instead. This could be rectified by education, clear management positions and possibly consequences for non-compliance. Equipment failure including net failures (most frequent), mooring failure and cage failure are insurable losses. Protocols for reducing these include: education, certification/standards for equipment, and regular inspections. Operator error is probably the most unreported. This includes losing fish during transfers, collisions and carelessness. Operator error could be reduced by education and certification of facility managers/employees. Uncontrolled losses occur through acts of vandalism which frequently occur at night. Predators (seals) cause significant losses of fish. There are installation options for reducing predator damage but none are 100% effective. Collisions with boats, debris or ice flows can also cause damage. Boat collisions can be reduced by appropriate marking and site identification. Debris impacts can be reduced with booms, siting of the farm and increased vigilance during periods of inclement weather. Overall risk reduction would be greatest by recognizing the importance of continued upgrading of equipment and knowledge of workers (certification).

### Issues/Concerns (including response)

1. Introduction was vague. Identify number of fish in New Brunswick to define magnitude. Some wording is confusing and short of detail ( example improvements).

2. No references in working paper.

3. Title should reflect that the paper deals mostly with marine cage farming, not salmon aquaculture operations. There was a lack of information on the freshwater containment issues. There are existing situations and protocols for freshwater operations.

4. Find a more appropriate phrase for "Bambi" effect, i.e. preference to release undesired fish rather than culling them. The extent of this problem should be qualified, is it small or big?

5. Insurers in New Brunswick could have provided summary data on type and extent of damage claims.
- Author responded that he inquired and they provided data from European newsletter.

6. Seal damage remains a probelm but dogfish can also be a problem.

7. Referee indicated that in many cases, economics to grower is the key point for failing to take immediate corrective measures with equipment.

8. Referee indicated that industry is probably reluctant to quantify escape levels because of potential negative reactions from the science and environmental communities.

*Other panel members and observers:*

1. Introduction should say that there has been a reduction in chemicals and medicine going in as a result of oil-based vaccines.
- Author indicated that this was probably true on a per fish basis but with increased production, total amount of chemicals used may have leveled off.

2. There a need to monitor regular escapes and one would think such records would be part of a regular business operation. Otherwise, there is no way of determining improvements. Referee indicated that such records are required for insurance claims. Questioned whether such information would be readily available from insurance companies.

3. Bob Cook suggested that the concept of contingency plans should be detailed and the procedures established for the Wycocomaugh loss could serve as a good template. Bob Cook indicated he would provide these to the author.

4. Ed Baum (Maine) indicated that on October 8, 1998, a Code of Practice was signed in Maine defining equipment standards for nets, inspections, cage design, siting, equipment, freshwater hatchery containment issues, transferring procedures, harvesting, etc. Most of the author's recommendations have been addressed in Maine. Document was to be copied and made available to interested people.

**Consensus**

Research Recommendation

1. Develop certification procedures for all aspects of cage facilities including regular inspections to ensure construction and maintenance standards are respected.

2. Develop certification and licensing procedures for workers and on-site managers.

3. Development of contigency measures.

## USE OF TRIPLOID ATLANTIC SALMON (*SALMO SALAR*) FOR AQUACULTURE
**Res. Doc. 98/166**

**Working Paper(s):** DFO Working Paper 98/98

**Author:** Benfey, Tillmann. 1998.

**Referees**: Hutchings, Jeffery

**Rapporteur:** Pepper, Vern

**Summary/Abstract**

Induced triploidy is the only effective method presently available in Canada for the mass production of reproductively sterile salmonids for aquaculture. Pilot-scale culture of triploid Atlantic salmon in New Brunswick has revealed that these fish perform reasonably well during freshwater smolt production, but less well during marine sea-cage grow-out to market size. Repeated studies at the Atlantic Salmon Federation's hatchery showed only minor differences between triploids and diploids in survival to S1 smolt age (15 mo), percentage of the population which became S1 smolts, and mean S1 smolt size. However, a similar study at a commercial hatchery was terminated due to exceptionally high mortality of triploids prior to the start of feeding. Marine grow-out trials in sea-cages showed that triploids grew well in seawater, but had reduced survival rates and high rates of jaw abnormalities compared to diploids. Similar results have been reported with triploid Atlantic salmon in Newfoundland, British Columbia, Washington State, Scotland and Tasmania. Although induced triploidy can be used effectively as a management tool to ensure lack of reproduction in Atlantic salmon, it would at present be difficult (and unreasonable) to have the aquaculture industry switch to their large-scale use. In light of fundamental biological differences between triploids and diploids, it is perhaps somewhat naive to expect triploids to perform as well as diploids using standard salmon culture methods. Triploids should be considered as a new species for aquaculture development, beginning with research to determine their optimum rearing requirements.

**Issues/Concerns (including response)**

1. Triploid salmon address the concern about genomic containment. However, like any other salmon placed in a cage environment, this is no guarantee triploid salmon will remain in the cage. There is little understanding of the potential ecological consequences of triploid salmon that escape from aquaculture cages. How long will triploid aquacultured salmon survive relative to aquacultured diploid salmon? How long relative to wild salmon? As there is some evidence that triploid (i.e., reproductively incapacitated) salmon will live longer than their diploid counterparts, triploids may achieve much greater size. There are reports that the somewhat greater longevity of triploid salmon can result in individuals of 30 to 40 kg. What are the energy requirements for such fish and how will this impact on aquatic community structure? This needs to be addressed.

2. There is evidence of triploid oysters reverting to their diploid state. As much as present treatments for producing triploid Atlantic salmon appear to be 100% effective, is there a possibility these triploid inventories of salmon also can revert. While flow cytometry confirms 100% triploidy on the basis of blood samples, are all other cells also triploid. There is the phenomenon of mosiacs in which different tissues can have different ploidy status. This is something that should be examined.

3. The present paper makes reference to maturing salmon being more susceptible to disease. This point could be significant in the context of potential for transmission of disease between wild and aquaculture salmon. References should be provided to document times of increased disease susceptibility during the Atlantic salmon life cycle.

4. Triploid male salmon, though incapable of successful reproduction, still develop a substantial gonad. Triploid males produce spermatozoa that are capable of activating egg development but not sustaining egg development. All such activated eggs will die. The paper makes reference to mature male parr being graded out of the triploid population. It needs to be clarified that these parr are culled from the hatchery population before they are placed in marine cages. Otherwise such males could pose a threat to wild salmon reproduction. This is an important distinction in how the technology is applied. It should be pointed out that the process of sex-reversal, once an all-female population has been achieved (i.e., in the second generation following initial gender manipulation to eliminate genetic males), will not be hampered by the presence of any genetic males in the sex-reversed group.

5. Mean harvest weights as depicted in Table 2 appear similar between the diploid and triploid salmon. It may be informative to compare overall harvest biomass for the two groups by adding two more columns to the table.

6. Pressure treatment or temperature shock are the only practical means currently available with which to produce commercial quantities of triploids. However, there are other approaches that might eventually be applied such as immune system manipulation to result in sterility through autoimmunity. Such processes should not be overlooked as they may result in reproductively incapacitated salmon that have better performance characteristics than triploids.

**Consensus**

Research Recommendation

1. What are the optimum culture requirements for triploid Atlantic salmon? Research is required to:
   a. Determine environmental tolerances and optima regarding;
      - temperature
      - oxygen
      - salinity
      - nutritional requirements
      - disease resistance

b. Remedy the problem of jaw deformities.
c. Determine ecological consequences of interactions of triploid salmon with wild salmon regarding;
   - migratory behaviour, especially in relation to freshwater homing
   - interactions with other species
   - potential life span of triploids and likely changes in ecological impacts with increasing size.

Management Consideration

1. All-female, triploid Atlantic salmon will effectively eliminate concerns about genetic impacts on wild salmon populations; however.

2. Performance of all-female Atlantic salmon has proven too variable for use by the aquaculture industry. Such variability in performance is a liability to aquaculture industry viability. Husbandry practices would have to be worked out to the extent of ensuring predictability of performance of triploid Atlantic salmon in order for this approach to be adopted by and financially justifiable to industry.

**Other**

1. Resource managers need to be aware that technologies imposed on the industry have serious economic implications to industry development and stability. Care should be taken when considering resource management options that the strategies being considered are in fact workable. Dictates that drive the industry to collapse do no one any good.

## OPTIONS FOR CONTROLLING DISEASE AND IMPROVING HEALTH IN FARMED SALMON, AS A MEANS OF REDUCING RISKS POSED BY ESCAPES
**Res. Doc. 98/167**

**Working Paper(s):** DFO Working Paper 98/99

**Author:** McVicar, Alasdair. 1998.

**Referees**: Olivier, Gilles

**Rapporteur:** Gross, Mart

**Summary/Abstract**

Wherever possible, the prevention of infection is preferable to treating established disease in fish farms. As regional variations exist in the natural occurrence of fish disease, the prevention of the spread of new diseases to new areas should form a cornerstone of sensible disease control. At the international, national and local levels, there has been considerable success in controlling the spread of important diseases both by regulation and by voluntary codes of practice. Failures have

occurred, leading to the appearance of previously exotic diseases and an evaluation of such cases has led to the continued evolution of preventative measures.

Most farmed fish are continually exposed to the range of naturally occurring infections present in the local environment and these are the main cause of disease in fish farms. Of potential importance to wild salmon is the risk of an abnormally high focus of infections being established in an area. However, not all of these infections can cause significant pathogenicity. The development of a disease condition from an infection and its severity is a consequence of the complex interaction between environment, host and pathogen. Options for control of disease can lie in any one of these areas. Management of stress in farmed fish populations is a recurring theme in disease control in fish farms, although it is inevitable that the level which can be achieved has to be tempered by commercial reality. Similarly the interruption of disease cycles on individual farm sites or in larger areas, through management policies such as fallowing, has both financial implications and consequences on the number of sites required. Many significant infections have responded well to treatment with chemicals. In general, such an approach to disease control should be considered to be a temporary way of achieving respite and that longer term solutions should lie in achieving enhanced resistance in the farmed fish or in management approaches.

**Issues/Concerns (including response)**

Referee comments (Olivier):

1. Wild fish can catch disease by passing near infected cages, and this is a major concern, but it wasn't addressed in this paper.
- McVicar responds that this is only because the title of the paper given to the author doesn't include this. McVicar strongly agrees that wild fish can catch diseases by going past infected cages – there are clear examples in Scotland with IPN.

2. Epizootic in Norway is the only clear demonstration of major disease from farmed fish going into the wild and infecting wild populations (in spite of large number of escapees there).
- McVicar agrees.
- McVicar adds that there are major strain differences in resistance. Therefore, there is potential within the gene pool to fulfill many needs of controlling disease in farms.

3. There is a massive reduction in chemotherapy use in Norway, Scotland, and in the Maritimes. This should be included into the paper. This reflects an overall improvement in fish farm disease development.

4. John Bailey – is there an increase in multiple resistance to chemical treatments? He is concerned especially about use of chemicals as a prophylactic.
- McVicar: Yes, there are many examples. For instance, this happened very rapidly to the drugs used in treating furunculosis. Within two years a new drug for furunculosis resulted in increased resistance. There is discouragement in the use of chemicals as a prophylactic, but it is still done (e.g., peroxide for sea lice).

5. Iola Price – She is not sure if it is possible within Canada to have mandatory disinfection of recreational fishing equipment. DFO may want to consider this. Theraputants – Canada does not condone prophylactic use of chemicals. There is a difference in the amount of active ingredient in a drug and the total amount of drug used – for instance each 'pill' contains large amounts of binders, and other unactive ingredients. The data in the press often misunderstand this.

- McVicar: Iceland has a strong disinfection program, including at the airport, for the entry of recreational equipment. They considered this in the UK but felt that there were too many entry points, and so they have turned to education instead. When people wish to purchase fishing permits, they are asked to read a paper that asks whether they have been abroad, etc. and may have infected equipment.

6. Ian Fleming – what are the effects of increasing production in net pens, and the incidence of disease?

- McVicar: in Scotland, they are trying to consider the 'carrying capacity' for the entire water body, while the farm industry worries about within a farm. The official limits to density are much lower than in Norway.

7. Rene Lavoie: what percentage of escapees get into a position of having an impact of any kind on wild fish?

- McVicar: in Scotland they have no record of the number of escapees. They try to use weight data – number into net and pounds out at the end, the difference is presumed to be loss (e.g., escapees). In one case, IPN was picked up in all wild fish near a particular farm area and this can be attributed to the farms. The disease was so severe in the farms that it destroyed their stock. However, within a few years after the farms left, the wild fish had shed the IPN and were infection free.

8. Tillman Benfey – he agrees that fish should be raised to minimize stress, but another approach in Norway is to select fish with low stress response. Tillman disagrees with this as he feels that a stress response is important. Stress is an 'adaptive' response by fish, so to remove it can be a concern.

- McVicar; domestication is willingly or unwillingly selecting for reduced stress reduction. There is no quantification of the relationship between stress reduction and disease rates.

9. Roland Cusack – In Canada, vets prescribe both prescription and nonprescription antibiotics. This relates to conclusion on page 9.

- McVicar – for this line on page 9 he was thinking specifically of the incidence of furunculosis in Norway. But there is also ISA in France , and other countries in Europe. It took about 40 years for the wild populations in the UK to respond to furunculosis and 'recover' after major outbreaks that occurred naturally, long before aquaculture came on the scene.

10. Rex Porter – were there any brown trout or sea trout in the area of the farm(s) that succumbed to IPN? And if so, how did they respond to IPN?

- McVicar: there were very few brown trout in the area and they don't really know what happened to them. There were also some sea trout. All fish within two kilometers (?) of the

farm(s) were infected, but the infection only existed while the farm(s) was there. Once the farm(s) left, the fish became infection free. The salmon were certainly picking up IPN from the fish farms by passing through the area. This is a loch system.

11. Brian Glebe – charr populations are also often landlocked (like the trout). What are the risks with them?
- McVica: same risk as when culturing trout, but no different in risk from salmon.

12. Rusell Henry – What is done when infected fish are found in both marine and freshwater sites.
- McVicar – disease in UK is required to be reported. On confirmation, there will be public notice and restriction on moving these fish. With ISA, there is no power to demand slaughter until the fish show clinical signs of the disease. In Scotland, 10 farms have been taken out due to ISA, another 11 are suspected.

13. Olivier – there are standard techniques for this in the Maritimes.

14. Are 'diseased' fish escaping, do they survive and potentially transmit disease to wild fish?
- Yes, they are escaping, some do survive, and there are examples of transmitting disease to wild fish (e.g., Norway).

15. Is disease from farms affecting/causing disease problems in wild fish?
- There are examples, but the overall pattern is not yet well understood.

16. How can one prevent the introduction of new diseases?
- Two means are by not allowing new introductions of live fish, and by disinfecting equipment (e.g., recreational, farm) moved among sites.

17. How can one reduce the risk from farms contributing to local diseases?
- There are several possible routes, discussed further below.

There will never be zero risk. What needs to be determined is the acceptable level of risk. There are many questions: What is the level of escapes? Fate of escaped fish? Fate of disease in escaped fish?

- There are about 80 different infections in Scotland waters, all a potential source of disease. The most common diseases are least likely to be of concern – the rare diseases are the most dangerous.
- Natural mortality rates in the wild due to predation cannot be used – a diseased fish has a different mortality rate than a wild fish from predation. In the latter case it is probably much larger.
- Outside controls – legislation, QA schemes
- Internal controls – incentives (good husbandry practice, knowledge, commercial pressures).

Farm diseases originated from two sources - from new introductions of disease, and from local epidemics.

- "New disease": all exotic diseases usually come from two sources - live fish importation, or farm equipment.
- "Endemic diseases": are picked up from the local environment.

In a fish farm all diseases are stress related (virtually all). Steps to reduce stress will therefore reduce disease (e.g., lower densities).

- Disease reduction – influenced by stress levels on stocks and susceptibility of stock (genetic, immunity).

**Consensus**

Research Recommendation

1. We need to discover new and improved indicators of "stress" in farmed fish.

2. We need to determine the optimal and effective fallowing periods in farms in order to break disease cycles.

3. We need to determine stocking densities that are "ideal' for stress reduction.

4. We need to improve our diagnostic screening methods for diseases.

Management Consideration

1. Improve upon disease prevention with methods that replace chemotherapy, e.g., further improvements in husbandry; increased fallowing and area management agreements.

2. Development of codes of good practice linked to QA schemes (verification of compliance).

**Conclusions**

1. The movement of live fish, fish carcasses and equipment between areas carries the greatest risks of introducing new infectious agents and disease to an area. Several serious disease incidents in wild salmon populations have been directly associated with these.

2. Fish farms often carry elevated levels of locally endemic disease in their stocks, which are likely to transfer to the wild with any escaped fish. No serious disease incidents have been shown to be associated with the escape of such fish.

## FACTORS AFFECTING THE HEALTH OF FARMED AND WILD FISH POPULATIONS: A PERSPECTIVE FROM BRITISH COLUMBIA
**Res. Doc. 98/168**

**Working Paper(s):** DFO Working Paper 98/100

**Author(s):** St. Hilaire, Sophie; Kent, Micheal; and Iwama, George

**Referees**: Cusack, Roland

**Rapporteur:** Price, Iola

**Summary/Abstract**

With the increase of mariculture, particularly netpen rearing of salmonids, has come the need to address whether these operations have a significant impact on coastal marine environments. Models have been made to assess this impact, but these models have not considered the potential risk of increased disease in wild fishes that mariculture may impose. At this time, much of the information needed to create models to assess the impact of farmed fish diseases on wild fish populations is not available. The transmission and development of disease is a complex process that involves numerous factors that affect the pathogen, host, and environment. The following paper describes some of these factors and compares their occurrence in wild and farmed salmonids. We also describe some of the management strategies currently used by the British Columbia salmon aquaculture industry and regulatory agencies to mitigate the possible effects of these factors.

**Issues/Concerns (including response)**

1. This paper was a general review and dealt with issues about and from a British Columbia perspective. The issue of fish health is complex and there is a large literature on the subject (although not as vast as for the livestock and poultry industry).
- The paper notes that many other species carry the diseases of concern to salmonids; the weight of evidence in Canada is for transmission from wild to cultured fish.

2. The paper could expand upon other potential sources of pathogens such as ballast water discharge and frozen, in-the-round foreign fish brought in from other countries (they are gutted here and in some locations, wastes are discharged directly to the marine environment). Many pathogens reside in the viscera, leading countries to restrict and tightly control the movement of salmonids unless they are eviscerated.

3. Stressors on wild (and cultured) fish were not adequately dealt with in the paper. Catch and release, routine handling for marking, broodstock collection activities, the act of spawning in the wild, variable water temperature, predation, competition for food and habitat, interaction with other fish and possibly the presence of fish farms are all stressors that are known or suspected.

**Consensus**

Research Recommendation

1. Although not mentioned per se, there seems to be a need for more information on the impact of chronic and acute stress and the duration and impact of various stressor events.

Management Consideration

1. There is a need for information on levels of disease organisms (pathogen identity, prevalence and location [geographic and by species]) in the Maritimes Region. Properly designed surveillance programs should be instituted, possibly based on that of the Pacific Region's large database on pathogen and parasites in pacific salmon (and the smaller database on other marine species).

Management considerations listed in MS

1. *Regulations:*
- regulations to help reduce the likelihood of importing exotic pathogens to the area.
- site regulations that require a 3 km distance between salt water sites, and that sites not be within a certain 1 to 3 km of salmon bearing rivers.

2. *Husbandry:* Reducing stress in fish farms can be achieved by good predator control/ evasion strategies, reduced handling of the fish, and when handling is necessary, using extreme care.

3. *Vaccines, etc:* increase fish's resistance to pathogens through the use of vaccines and good nutrition (acquired resistance).

4. *Screening:* screening smolts before seawater entry or screening broodstock is a common practice used by fish farmers to reduce the prevalence of certain important pathogens.

5. *Water Control:* Hatcheries with well water have in general fewer pathogens than those using surface water, and some facilities have the ability to ozonate their surface water supply which reduces the pathogen contamination in incoming water.

6. *Removing Infected Fish*

7. *Year-class Separation:* Stocking fish as single year-classes at individual sites is very beneficial for reducing transmission of diseases at netpen farms.

8. *Fallowing*

9. *Densities.* Another method of reducing exposure to pathogens is reducing the stocking density in pens or tanks in an aquaculture facility.

**Appendix 1.** List of Participants

| Participant | Affiliation/Address | Telephone | Fax | E-Mail |
|---|---|---|---|---|
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**Appendix 2.** Invitation Letters

**Letter to Authors**

Fisheries and Oceans / Pêches et Océans
Science Branch
Maritimes Region
343 Archibald Street
Moncton, N.B.
E1C 9B6

August 5, 1998

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»,
«Address2»
«City», «State»,«PostalCode»

Dear «Title» «LastName»:

This letter is to confirm my invitation to you to present a paper at a Special Workshop on the "Interaction Between Wild and Farmed Atlantic Salmon in the Maritime Provinces". This Workshop is being carried out as part of our Regional Assessment Process. Our task is to carry out a scientific review of the subject with the objectives being to provide management advice and recommendations for future research.

The Workshop will be held November 30 – December 4, 1998 in the Scoudouc Room of the Best Western Crystal Palace Hotel, Paul Street, Dieppe, N. B., Moncton, N.B. It will commence at 1:00 pm on Monday, the 30th.

The paper that we are asking you to present is "xxxxxxxx". For your information and guidance, we are pleased to provide a copy of the most recent draft Terms of Reference for the Workshop. We would ask you to pay particular attention to the "Schedule" which is detailed last in the Terms of Reference document. We will be forwarding to you in the near future an agenda, a list of the invited participants, special instructions to authors, and information on accommodations.

We will reimburse you for all travel expenses. If you are travelling by air, we hope that you would agree to stay over one Saturday night in order to save on the air costs.

Should you have questions, please feel free to contact me by telephone (506-851-2945), fax (506-851-2147), or e-mail (ritterja@mar.dfo-mpo.gc.ca).

Thank you for agreeing to participate in this important scientific review exercise.

Sincerely,

Original signed by:

John A. Ritter, Manager
Diadromous Fish Division

Attachment

Canada

**Instruction to Authors**

Fisheries and Oceans / Pêches et Océans
Science Branch
Maritimes Region
343 Archibald Street
Moncton, N.-B.
E1C 9B6

August 25, 1998

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»,
«Address2»
«City», «State»,«PostalCode»

**RAP Workshop:** ***Interaction Between Wild and Farmed Atlantic Salmon in the Maritime Provinces***

Dear «Title» «LastName»:

This letter is to confirm arrangements for the Workshop. The preparations are going well and we expect a productive and well-attended meeting.

With regard to the time allotted to each speaker, we would ask you to speak for no longer than 15 minutes, following which an appointed referee will have 15 minutes to direct questions. Invited participants will then have 15 minutes to voice their remarks. The floor will then be open to observers for an additional 15 minutes for a total of 1 hour allocated per paper.

All invited papers will be upgraded to Research Documents following the meeting. Attached you will find the details on the required format for your paper(s). I have also enclosed a copy of a recent Research Document to assist you in setting out your manuscript. Please take note that publication as a Research Document does not preclude publication elsewhere. As applicable, we request that you incorporate both future research and management recommendations in your paper.

We intend to provide each participant with a folder containing the final Terms of Reference for the Workshop which will include the final titles and a listing of the main points to be covered in each paper. We also will be including the abstracts in the folder. To assemble this package we require your final title(s), the main points to be covered in your paper(s) (preferably in bullet form), and your abstract(s) by no later than 1 October, 1998. We would appreciate receiving an

electronic version of these items in Word 6.0 format, if feasible. Please send these to RobichaudK@mar.dfo-mpo.gc.ca.

I look forward to receiving your manuscript in due course and to seeing you at what promises to be a productive workshop.

Sincerely yours,

John A. Ritter, Manager
Diadromous Fish Division
Attachment

Canada

Department of Fisheries and Oceans
Regional Assessment Process Workshop on
*"Interactions Between Wild and Farmed Atlantic Salmon in the Maritime Provinces'*

# Notes to Authors

## General:

1. Research documents should be type-written single spaced and on one side of good quality white bond paper size 8½ x 11 inches (220 x 280 mm).

2. Leave all margins 1 inch (25 mm) to 1½ inches (38 mm).

3. A cover page is required and is to be set up in accordance with the attached sample.

4. Number pages consecutively with Arabic numerals this includes page numbers on the tables and figures. The cover page will be considered the first page and will not be numbered.

5. Wherever practical, the text should be subheaded into Abstract, Résumé, Introduction, Materials and Methods, Results, Discussion, Management Considerations, Research Recommendations, Acknowledgements, References, Tables, Figures and Appendices. If the author wishes to include a summary of the conclusions it should follow the "Discussion" section.

6. All measurements, linear, weight, and time should be given in numerals (not words) in the metric system. The Celsius scale should be used as a standard. Notations used are left to individual preference. However, once a particular notation is adopted it is to be used consistently throughout the paper.

7. An electronic version of all abstracts are to be submitted in Word 6.0 format to RobichaudK@mar.dfo-mpo.gc.ca by October 1, 1998.

8. All documents are to be submitted in hard copy or on a disk in Word 6.0 format to the address at the head of this letter or via e-mail to RobichaudK@mar.dfo-mpo.gc.ca by October 23, 1998.

## Abstract/Résumé:

1. An abstract or résumé is to be included in the document. This section should not exceed 3% of the length of the text or 250 words whichever is smaller.

2. The translation of the abstract or résumé will be coordinated by the Canadian Stock Assessment Secretariat in Ottawa, however, an author may submit this section in both French and English.

**Bibliography:**

1. References to literature in the text should be by the author date system, for example:

   It was reported that (Collins 1960) the ...
   In examining the situation, Rossini (1959) felt ...

Where more than one paper by the same author(s) have appeared in one year, reference should be given as follows:

   Osborne and Mendel (1914a); Osborne and Mendel (1914b)
   or Osborne and Mendel (1914a and b)

2. While the names of two authors may be used in a citation as shown above, three or more authors should be cited as (Collins et al. 1960). Reference to papers submitted but not yet published should be indicated as being "in press" or "submitted for publication" depending on whether or not the paper has been accepted for publication.

Reference to material not submitted for publication should be written in the text...e.g. George (pers. comm.) or George (unpublished manuscript).

3. All references cited by the author-name system in the text should be listed in the bibliography alphabetically by the surname of the first author. year of publication follows the authorship. Then give the full title of the paper. This should be followed by the abbreviated name of the periodical with the volume and pages in Arabic numbers. Abbreviations of periodicals should, if possible, follow the "World List of Aquatic Sciences and Fisheries Serial Titles", published periodically by FAO. References to monographs should, in addition to the authors, year and title, contain the name of the publisher, place and number of pages in the volume.

4. References cited in the text must be given in the bibliography and conversely, items listed in the Bibliography must be cited in the text.

5. CSAS working papers and subcommittee reports have no status as documents and cannot be cited.

6. CSAS, DFO, NAFO, ICNAF, ICCAT and ICES research documents are unpublished material and should be referenced as manuscripts, e.g. (Collins MS 1960), in both text and bibliography.

**Tables**:

1. Tables can be set out on separate sheets following the bibliography or they can be incorporated into the text.

2. Tables should be numbered consecutively in Arabic numbers.

3. Tables must be referred to in the text.

4. Each table should provide a description heading which together with the column heading must make it intelligible without reference to the text. The caption is to be typed on the same page as the table to which it applies.

5. If two or more small tables can be placed on one page in an aesthetically pleasing manner, this should be done.

6. The calculations made in the tables should be checked for accuracy at the office of the author prior to the submission of the document.

**Figures**:

1. Figures can be placed following the tables and should commence on a separate sheet or they can be incorporated into the text.

2. All illustrations, whether black-and-white drawings, tone drawings, maps, graphs, or photographs are considered figures. If photographs are included, a black-and-white print must be submitted. All material will be reproduced by a photocopy unit, therefore the submission must be of sufficient line density that touch-up is not required.

3. Figures should be on 8½ x 11 inches (220 x 280 mm) white paper. The margins to be observed are 1 to 1½ inches (25 to 38 mm). Lettering should be of sufficient density and size to photocopy clearly.

4. Figures are to be numbered consecutively in Arabic numerals.

5. Each figure must be referred to in the text.

6. Each figure should provide a description heading and a legend and should be intelligible without reference to the text. The caption is to be typed on the same page directly underneath the figure to which it applies.

**Submission of Research Documents:**

1. The original of the research document is to be submitted to the Atlantic Stock Assessment Secretariat at the address noted below along with an electronic version of the abstract to Hamelj@dro-mpo.gc.ca:

   Canadian Stock Assessment Secretariat
   Department of Fisheries and Oceans
   200 rue Kent Street, 12032
   Ottawa, Ontario
   Canada

2. Research documents must be accompanied by a memorandum, letter or form signed by the line manager of the author approving the document for release. This applies to documents submitted by personnel from Fisheries and Oceans and other agencies. Please note authority for approval is restricted to line managers at the Division Chief level and equivalent or above.

3. Manuscripts requiring substantial revision to bring them into conformity with the above format will be returned to the author for correction.

**Letter to Panel Members**

Fisheries and Oceans / Pêches et Océans

Science Branch
Maritimes Region
P.O. Box 550
Halifax, NS
B3J 2S7

Nov. 13, 1998

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»,
«Address2»
«City», «State»,«PostalCode»

Dear «Title» «LastName»:

This letter is to invite you to serve on our scientific review panel for a Special Workshop on the "Interaction Between Wild and Farmed Atlantic Salmon in the Maritime Provinces". The Workshop is being carried out as part of our Regional Assessment Process (RAP). Our task is to carry out a scientific review of the subject with the objectives being to provide management advice and recommendations for future research. As a member of the review panel you would be expected to attend all sessions, to the extent possible.

The Workshop will be held from **November 30, 1998 to December 4, 1998**, in the Scoudouc Room of the Best Western Crystal Palace Hotel, Paul Street, Dieppe, N. B. It will commence at 11:00 a.m. on Monday, the 30th.

The format for the review centers around one hour being assigned to each of the nineteen formal papers. That hour will be divided into fifteen minute segments for presentation of the paper, comments from the assigned referee, comments from the scientific review panel, and comments and questions from the attendees at large.

Enclosed is a program for the Workshop. It includes a brief outline of each of the formal papers along with the proposed agenda and schedule for their presentation. Also for your information we have included a list of invited review panel members, and some background information on the subject including a copy of Dr. Stewart's report "Sharing the Waters" and summaries of the recent workshops in Bath and Norway that addressed this same issue. We will also be sending you copies of each of the papers being presented at the workshop as we receive them.

We will reimburse you for all travel expenses. Regarding accommodations, a blanket booking has been made at the Best Western Crystal Palace Hotel, for November 30, 1998 to December 4, 1998 (Monday through Friday). Please note that you would be responsible for any room charges. To take advantage of the blanket booking, it is essential that you **confirm your reservation by November 13, 1998**. The Crystal Palace reservation numbers are (506) 858-8584 or 1-800-561-7108.

We hope you agree to participate in this important scientific review exercise. As space is limited we **require an RSVP** which can be sent to Kimberly Robichaud-LeBlanc at the above address, or she can be contacted directly by telephone (902-426-5836), fax (902-426-6814), or e-mail (RobichaudK@mar.dfo-mpo.gc.ca).

Sincerely,

John A. Ritter, Manager
Diadromous Fish Division

Attachment

Canada

**Letter to Observers**

Fisheries and Oceans / Pêches et Océans
Science Branch
Maritimes Region
P.O. Box 550
Halifax, NS
B3J 2S7

Nov. 17, 1998

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»,
«Address2»
«City», «State»,«PostalCode»

Dear «Title» «LastName»:

This letter gives notice of a Special Workshop on the "Interaction Between Wild and Farmed Atlantic Salmon in the Maritime Provinces". This workshop is being carried out as part of our Regional Assessment Process (RAP). Our task is to carry out a scientific review of the subject with the objectives being to provide advice for management and recommendations for research.

The Workshop will be held from November 30, 1998 to December 4, 1998, in the Scoudouc Room of the Best Western Crystal Palace Hotel, Paul Street, Dieppe, N. B. It will commence at 11:00 a.m. on Monday, the 30th.

Space is limited, however you and/or representatives of your organization are welcome to come and participate in those sessions in which you have interest. The format for the review centers around one hour being assigned to each of the formal papers. That hour will be divided into fifteen minute segments for presentation of the paper, comments from the assigned referee, comments from the scientific review panel, and comments and questions from the attendees at large. A few minutes of the final fifteen minutes will be used for summing-up as well. This format will be clearly layed-out at the start of the workshop and will be adhered to by necessity in order to complete the lengthy agenda.

Enclosed is the program for the Workshop. It includes the proposed agenda and schedule for presentation of the various papers. Please note however that the schedule is subject to last minute changes due to the possibility of discussions of some papers running-on longer than the assigned one hour. To confirm timings of particular presentations, please contact Marie Daigle at (506) 851-6253.

We welcome your attendance and participation in this important workshop. We are unable however, to assist in any way with your travel expenses.

Sincerely,

John A. Ritter, Manager
Diadromous Fish Division
Attachment

Canada

## OBSERVERS

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| **Thompson**, Bill<br>General Manager | NB Salmon Growers<br>R.R. No. 4<br>Lime Kiln Road<br>St. George, New Brunswick<br>E0G 2Y0<br><br>(tel) 506-755-3526<br>(fax) 506-755-6237<br>nbsga@nbnet.nb.ca |
| **Tremblay**, Serge<br>Coordonnateur des grands migrateurs | Ministère de l'Environnement et de la Faune du Québec<br>Direction de la faune et des habitats<br>Service de la faune aquatique<br>150, boul. René-Lévesque est, 5ième étage, bte 92<br>Québec (Qc)<br>Canada, G1R 4Y1<br><br>(tel) 418-521-3940<br>(fax) 418-646-6863<br>serge.tremblay@inetsrv1.mef.gouv.qc.ca |
| **Tupplin**, Graham<br>President | Native Council of Prince Edward Island<br>33 Allen Street<br>Charlottetown, PEI, C1A 2V6 |

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**Letter to Referees**

Fisheries and Oceans / Pêches et Océans

Science Branch
Maritimes Region
P.O. Box 550
Halifax, NS
B3J 2S7

Oct. 20, 1998

«Title» «FirstName» «LastName»
«JobTitle»
«Company»
«Address1»,
«Address2»
«City», «State»,«PostalCode»

Dear «Title» «LastName»:

This letter is to confirm my invitation to you to serve as a referee at a Special Workshop on the "Interaction Between Wild and Farmed Atlantic Salmon in the Maritime Provinces". This workshop is being carried out as part of our Regional Assessment Process (RAP). Our task is to carry out a scientific review of the subject with the objectives being to provide management advice and recommendations for future research.

The Workshop will be held November 30, 1998 to December 4, 1998, in the Scoudouc Room of the Best Western Crystal Palace Hotel, Paul Street, Dieppe, N. B. It will commence at 11:00 a.m. on Monday, the 30th.

The paper(s) that we are asking you to review is (are) entitled "Salmon aquaculture breeding program: history and future" xxxxxxxx (paper xx of outline). For your information and guidance, we are pleased to provide a copy of the most recent draft "Terms of Reference" for the Workshop. We will be forwarding the paper(s) to you in the near future along with an agenda, a list of the invited participants, and some suggested "Considerations for Referees".

We are pleased to reinburse you for all travel expenses. If you are travelling by air, we hope that you would agree to stay over one Saturday night in order to save on the air costs. Regarding accommodations, a blanket booking has been made at the Best Western Crystal Palace Hotel, for November 30, 1998 to December 4, 1998 (Monday through Friday). It is essential that you **confirm your reservation by November 13, 1998**. The Crystal Palace reservation numbers are (506) 858-8584 or 1-800-561-7108.

Thank you for agreeing to participate in this important scientific review exercise.

Sincerely,

John A. Ritter, Manager
Diadromous Fish Division

Attachment

Canada

Department of Fisheries and Oceans
Regional Assessment Process Workshop on
*"Interactions Between Wild and Farmed Atlantic Salmon in the Maritime Provinces"*

**Notes of Guidance for Referees**

Please review the document and provide comments (at the peer review) on the methodology, interpretations and recommendations. You will be expected to provide an oral review of the paper assigned to you along with written comments and/or edits to the senior author. Also, we are hoping that you will agree to provide a final review of the same manuscript prior to its publication.

Referees may find it helpful, when reading the manuscript, to have in mind the key questions on which your advice is being sought, namely:

1. Is the purpose of the Working Paper clearly stated?

2. Does the paper make a worthwhile contribution to knowledge; e.g., by way of new data, techniques or ideas? If so, is it properly placed in the context of existing knowledge, giving due recognition to published work?

3. Is the evidence and argument presented clearly and concisely, or is the paper unduly long for the message it is conveying? If the latter, how might it be shortened without loss?

4. If appropriate, is the methodology (including sampling, experimental design and theory) sound?

5. Are the text, tables and figures mutually consistent, sufficient (but not excessive) and clear?

6. Are there specialised parts (e.g. mathematics/statistics) on which you would prefer someone else to comment? If so, could you suggest a name?

7. Are the conclusions valid and recommendations justified? Are there competing conclusions or recommendations that should be considered?

8. Taken overall, is the manuscript in your opinion appropriate for publication as a *DFO Research Document:*

a) As it stands or with minor revision?
b) Only if modified substantially along the lines proposed?
c) Not at all?

November 6, 1998

## REVIEW PANEL

| Name | Title | Affiliation | Status |
|---|---|---|---|
| **Amiro**, Peter | Assessment Biologist | DFO, Science, Diadromous Fish Division / Halifax, NS | senior author paper 13 |
| **Bailey**, John | Former Geneticist & Manager, Broodstock Development Program | Atlantic Salmon Federation | author paper 15 |
| **Baum**, Ed | Senior Fisheries Scientist | Maine Atlantic Salmon Authority / Bangor, Me | senior author paper 2 |
| **Benfey**, Tillmann | Professor and Director Graduate Studies | UNB, Biology Dept. / Fredericton, NB | senior author paper 16 |
| **Bradford**, Rod | Assessment Biologist | DFO, Science, Diadromous Fish Division / Halifax, NS | referee paper 7 |
| **Cairns**, David | Assessment Biologist | DFO, Science, Diadromous Fish Division / Charlottetown, PEI | |
| **Campbell**, Malcolm | Fish Health Biologist | DFO, Science, Fish Health Unit / Moncton, NB | referee paper 9 |
| **Chang**, Blythe | Program Biologist | DFO, Science / St. Andrews, NB | senior author paper 1 |
| **Chaput**, Gérald | Assessment Biologist | DFO, Science, Diadromous Fish Divison / Moncton, NB | senior author paper 3 |
| **Cook**, Bob | Former Head of Aquaculture Coordination Office Maritimes Region | DFO, Science / Halifax, NS | referee paper 1 |
| **Cronin**, Peter | Director of Fisheries | DNRE, Fish and Wildlife Branch / Fredericton, NB | referee paper 5 |
| **Cusack**, Roland | Chair Marine Finfish Technical Sub- | DoF NS / Halifax, NS | referee paper 18 |

## REVIEW PANEL

| Name | Title | Affiliation | Status |
|---|---|---|---|
| | Committee | | |
| **Dempson**, Brian | Research Scientist | DFO, Northwest Atlantic Fisheries Centre / St. John's, Nfld | |
| **Fleming**, Ian | Research Scientist | Norwegian Institute for Nature Research / Norway | referee paper 6 |
| **Glebe**, Brian | Program Manager, Atlantic Broodstock Program | Huntsman Marine Science Centre / St. Andrews, NB | senior author paper 7 |
| **Goff**, Trevor | Manager, Mactaquac Fish Hatchery | DFO, Science / Yorkes, NB | |
| **Gross**, Mart | Professor of Zoology | University of Toronto, Dept. of Zoology / Toronto, ON | |
| **Hutchings**, Jeffery | Assistant Professor | Dept. of Biology, Dalhousie University / Halifax, NS | referee papers 12 and 16 |
| **Johnson**, Stewart | Associate Research Officer | National Research Council of Canada, Institute for Marine Biosciences / Halifax, NS | |
| **Kenchington**, Ellen | Benthic Ecologist | DFO, Science, MESD / Dartmouth, NS | |
| **Kershaw**, John | Director of aquaculture | NB DFA / Fredericton, NB | referee paper 15 |
| **Lacroix**, Gilles | Research Scientist | DFO, Science / St. Andrews, NB | senior author papers 8 and 12 co-chair |
| **Lavoie**, René | Assistant Director of Science | DFO, Science / Halifax, NS | |
| **MacKinnon**, | Head, Fish Health | DFO, Science, Fish Health | senior author paper |

## REVIEW PANEL

| Name | Title | Affiliation | Status |
|---|---|---|---|
| Anne-Margaret | | Unit / Moncton, NB | 10 |
| **Marshall**, Larry | Assessment Biologist | DFO, Science, Diadromous Fish Division / Halifax, NS | |
| **McClelland**, Gary | Research Scientist / Parasitologist | DFO, Science / Moncton, NB | referee paper 11 |
| **McVicar**, Alasdair | Head Fish Health Inspectorate for Scotland | Fisheries Research Services, Marine Laboratory / Aberdeen, Scotland | senior author papers 11 and 17 |
| **Meerburg**, Dave | Senior Policy/Program Advisor, Anadromous Fish, Fisheries Research Branch | DFO, Science / Ottawa, ON | referee paper 14 |
| **Olivier**, Gilles | Research Scientist | DFO, Science / St. Andrews, NB | senior author paper 9<br>referee paper 17 |
| **O'Neil**, Shane | Assessment Biologist | DFO, Science, Diadromous Fish Division / Halifax, NS | senior author paper 4 |
| **Pepper**, Vern | Senior Biologist | DFO, Aquaculture Research, Northwest Atlantic Fisheries Centre / St. John's, Nfld | |
| **Porter**, Rex | Section Head, Pelagic Fish, Shellfish and Salmonids | DFO, Northwest Atlantic Fisheries Centre, St. John's, Nfld | senior author paper 14<br>referee paper 19 |
| **Price**, Iola | Director, Aquaculture and Ocean Science | DFO, Science / Ottawa, ON | |
| **Randall**, Bob | Fish Habitat Scientist | former DFO, Science / Moncton, NB | referee paper 3 |
| **Ritter**, John | Manager, Diadromous Fish Division | DFO, Science, Diadromous Fish Division / Halifax, NS | senior author paper 19 |

## REVIEW PANEL

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| **Ross**, Jim | Acting Head, Habitat Management Unit South | DFO, Habitat Management / Halifax, NS | |
| **Saunders**, Richard | Research Scientist | SABS / St. Andrews, NB | referee paper 2 |
| **Sephton**, Tom | Director St. Andrews Biological Station | DFO, Science / St. Andrews, NB | referee paper 4 |
| **Stewart**, James | Microbiologist | DFO, Science / Dartmouth, NS | co-chair |
| **St. Hilaire**, Sophie | Veterinarian | DFO, Science / Nanaimo, BC | senior author paper 18<br>referee paper 10 |
| **Verspoor**, Eric | Section Leader, Molecular Genetics, Fish Cultivation Team | Fisheries Research Services, Marine Laboratory / Aberdeen, Scotland | senior author paper 6<br>referee paper 8 |
| **Whoriskey**, Fred | V.P Research and Environment | Atlantic Salmon Federation / St. Andrews, NB | senior author paper 5<br>referee paper 13 |

**Appendix 3.** Meeting Schedule

## AGENDA

**Monday, November 30**

AM 11:00
- Introduction and Orientation (*Stewart*)
- Lunch

PM 1:00
- The salmon farming industry in the Maritimes provinces (*Chang*)
- The salmon aquaculture industry in Maine (*Baum*)
- Coffee Break
- Salmon aquaculture breeding program: history and future (*Glebe*)
- Status of the wild salmon stocks in the Maritimes (*Chaput* )
- Sum up

**Tuesday, December 1**

AM 8:30
- Housekeeping Remarks
- Distribution and magnitude of salmon aquaculture escapees in Maritime rivers (*O'Neil*)
- Review of aquaculture impact studies on the Magaguadavic River, Southern Bay of Fundy, NB (*Whoriskey*)
- Coffee
- Genetic impacts on wild salmon stocks of escaped farm conspecifics: an assessment of risk (*Verspoor*)
- Lunch

PM
- Genetic introgression of domestic salmon genome into wild salmon populations: a simulation of requirements for conservation (*Lacroix*)
- A review of potential impacts on wild salmon stocks from fish diseases attributed to farmed salmon operations (*Olivier*)
- Coffee
- Overview of salmonid fish diseases and parasites in both the salmonid aquaculture industry and in wild salmon populations (*MacKinnon*)
- Sum up

**Wednesday, December 2**

AM 8:30
- Housekeeping Remarks
- Effects of sea lice infestation among aquaculture salmon on wild salmon (*McVicar*)
- Ecological and behavioural interactions between farmed and wild salmon: consequences for wild salmon in the Maritimes region (*Lacroix and Fleming*)

- Coffee
- Impact of salmon aquaculture on Inner Bay of Fundy salmon stocks *Amiro*)
- Lunch

PM

- Existing conventions pertaining to the control and minimization of Aquaculture impacts on wild salmon stocks (*Porter*)
- Containment code of practice to prevent escapes from salmon farming and hatchery operations (*Bailey*)
- Coffee
- Use of triploid Atlantic salmon for aquaculture (*Benfey*)
- Sum up

**Thursday, December 3**

AM 8:30

- Housekeeping Remarks
- Options for controlling disease and improving the health in farmed salmon as a means of reducing risks posed by escapes (*McVicar*)
- Coffee
- Factors affecting the health of farmed and wild fish populations (*St. Hilaire*)
- Mitigative measures to eliminate or minimize potential impacts of farmed salmon operations on wild salmon (*Ritter*)
- Lunch

PM

- Future research to define the extent of the problem and ensure protection of wild stocks
- Management considerations to safeguard the wild salmon stocks
- Coffee
- Closing comments
- Report review

**Friday, December 4**

AM 8:30

- Report review con't

# OUTLINE

## Interaction Between Wild and Farmed Atlantic Salmon in the Maritime Provinces

**Workshop Terms of Reference**
**Sponsored by the Diadromous Subcommittee of the Regional Assessment Process (RAP)**

### REMIT / QUESTION

- **Are farmed Atlantic salmon interacting with wild Atlantic salmon in the Maritime Provinces?**

- **If so, what are the impacts of farmed salmon on the wild Atlantic salmon stocks in the Maritime Provinces?**

- **What should be done to eliminate or minimize these impacts?**

### OBJECTIVES

- To assess the impact (present and potential) of farmed Atlantic salmon operations (in both marine and fresh water) on the wild Atlantic salmon stocks in the Maritimes Region.

- To outline present and potential mitigative measures for managing or controlling possible harmful effects of the farmed salmon industry on the conservation of the wild salmon stocks.

- To recommend to DFO line management research activities required to understand the nature and scale of potential impacts and to address such impacts.

### ISSUES TO CONSIDER

- *Definition of the scope of the RAP:*
  - RAP will be confined to the Maritime Provinces;
  - farmed salmon include fish cultured for commercial aquaculture purposes;
  - wild salmon refer to self-sustaining populations of salmon;
  - stock enhancement activities will be excluded from the RAP.

- *Extent of salmon aquaculture in the Maritime Provinces including:*
  - freshwater and marine operations;
  - geographic mapping of the sites (including those in Maine);
  - duration of operations (when farming started by location and sector);
  - size of operations (numbers of fish in pens and in hatcheries by age class, what operations are licensed by Province to retain);
  - numbers and locations of escapes (to the extent known);
  - origin of stocks used (local or distant);
  - comparisons relative to industry scale and distribution in Norway, Scotland, etc.;

- benefits of aquaculture to salmon conservation;

- *Status of wild salmon stocks in the areas where aquaculture is concentrated (e.g., Bay of Fundy and Bras d'Or Lakes), in comparison to the rest of the Region:*
  - current levels relative to conservation requirements;
  - potential and/or recent production levels;
  - description of stocks in terms of numbers of stocks, genetic uniqueness, stocking history, etc.

- *Evidence for interaction*:
  - mapping of known distribution of farmed salmon as juveniles and adults;
  - distribution of farmed salmon in Maine rivers should be included.

- *Impact of interaction pertaining to*:
  - genetic effects (e.g., introgression);
  - fish disease (including parasites) effects;
  - ecological effects.

- *Existing conventions to which DFO Maritimes Region is bound or associated with:*
  - NASCO Protocols;
  - ICES Protocols;
  - Federal fisheries (DFO) and environmental (EC) policies;
  - Regional or Provincial policies and/guidelines.

- *Mitigative measures (what actions on farmed fish or aquaculture would be required for conservation of wild stocks of salmon)*:
  - measures that industry might implement for containment of farmed fish or to prevent interaction with wild stocks (include consequences of mitigative measures on aquaculture production performance, e.g., triploidy);
  - measures that might be implemented in the streams to protect the wild stocks from intereactions with farmed fish.

- *Outstanding research falls into the following categories (what needs to be done and at what cost):*
  - describing first and then monitoring the extent of the problem;
  - defining the nature of interactions and the level of impact;
  - developing cost-effective mitigative measures.

**Questions, Contributed Papers and Writing Assignments**

**1. What is the extent of the salmon aquaculture industry in the Maritime Provinces?**

Paper 1 (WP98-81): The salmon aquaculture industry in the Maritimes Provinces, by Blythe Chang, (refereed by Bob Cook).

Paper to include:
- legislative responsibilities and administrative roles;
- regulatory control measures and authorities;
- freshwater and marine operations;
- geographic mapping of hatcheries and marine growout sites;
- duration of operations;
- size of operations, i.e., total production;
- scale or numbers of escapes (locations and numbers by sector);
- origin of stocks used and proposed/considered for future use (local or distant);
- comparisons relative to industry scale and distribution in Norway, Scotland, etc.;
- the potential impacts of the aquaculture of other species on wild salmon;
- benefits of salmon aquaculture to conservation of wild salmon.

Paper 2 (WP98-82): History and description of the Atlantic Salmon aquaculture industry in Maine, by Ed Baum, (refereed by Dick Saunders).

Paper to include:
- legislative responsibilities and administrative roles;
- regulatory control measures and authorities;
- freshwater and marine operations;
- geographic mapping of the sites;
- duration of operations;
- size of operations, i.e., numbers of fish produced by age or size class;
- scale or numbers of escapes (locations and numbers by sector);
- origin of stocks used and proposed/considered for future use (local or distant);
- the potential impacts of the aquaculture of other species on wild salmon;
- measures being taken to reduce potential impacts of salmon aquaculture on wild salmon stocks.

**2. How does the status of the wild salmon stocks in the areas where aquaculture is concentrated compare with the stocks in other parts of the Maritimes Region?**

Paper 3 (WP98-83): Status of Wild Atlantic Salmon *(Salmo salar)* Stocks in the Maritime Provinces, by Gerald Chaput and Larry Marshall, (refereed by Bob Randall).

Paper to include:
- current levels relative to conservation requirements;
- potential and/or recent production levels;
- description of stocks in terms of numbers of stocks, genetic uniqueness, etc;
- comparison of stocks in areas of aquaculture concentration with stocks in other parts of the Region.

**3. What evidence exists in Maritime rivers that aquaculture fish are present and potentially interacting with wild salmon?**

Paper 4 (WP98-84): Atlantic salmon aquaculture escapees and occurrence in rivers of the Maritime Provinces, by Shane O'Neil, (refereed by Tom Sephton).

Paper to include:

- Identification of the location and size of salmon farms around the Maritime Provinces;
- Literature review, including DFO research documents, recent primary papers, workshop reports, etc. to locate confirmed reports of the presence of aquaculture escapees and any further evidence of successful spawning of those fish. The nature of the report of escapees will be categorized into regular presence with spawning confirmed, annual presence noted, sightings on a somewhat regular basis but less than annually, occasional sightings, and reported once;
- The source of the sightings will be incorporated in a table by category of presence, as will some indication of the abundance of the escapees;
- Review of the literature to estimate the potential for presence of fish in the various streams by establishing a rough measure of the abundance of escapees;
- Brief review of evidence that escapees are present in rivers and a potential problem elsewhere, such as in B.C. and northern Europe;
- Map of the rivers of the Maritime Provinces which indicates the known presence of escapees by shaded circles, as is done with the Atlantic salmon zonal report, indicating the category of presence on rivers with known sightings.

Papers 5 (WP98-85): A review and update of aquaculture impact studies carried out on the Magaguadavic river, Southern Bay of Fundy, New Brunswick, by Fred Whoriskey, Gilles Lacroix, Jonathan Carr, Michael Stokesbury, (refereed by Peter Cronin).

Paper to include:

- evidence of presence of aquaculture origin adults and juveniles and potential for interaction;
- sea lice infestation on aquaculture escapes and wild salmon returning to the Magaguadavic River.

**4. What are the potential impacts of the aquaculture industry on wild salmon stocks?**

Paper 6 (WP98-87): Genetic impacts on wild Atlantic salmon (Salmo salar L.) stocks from escaped farm conspecifics: an assessment of risk, by Eric Verspoor, (refereed by Ian Fleming).

Paper to include:

- problem definition;
- intraspecific genetic variation;
- concept of adaptation;
- geneflow vs introgression;
- genetic nature of Atlantic salmon stocks;

- genetic differences between farm and wild stocks;
- assessing genetic risk: qualitative and quantitative considerations;
- risk management.

Paper 7 (WP98-88): East coast salmon aquaculture breeding program: history and future, by Brian Glebe, (refereed by Tillmann Benfey).

Paper 8 (WP98-89): Genetic introgression of domestic Atlantic salmon genome into wild salmon populations: a simulation model, by Gilles Lacroix, Josh Korman, and Daniel Heath, (refereed by Eric Verspoor).

Paper 9 (WP98-90): A review of potential impacts on wild salmon stocks from diseases attributed to farmed salmon operations, by Gilles Olivier, (refereed by Malcolm Campbell).

Paper to include:

- define and explain the concept of disease which is a complex interaction between the pathogen, the host and the environment;
- overview of the infectious disease agents that have impacted on wild populations of non salmonid fish;
- review of infectious disease agents that have impacted specifically on wild Atlantic salmon populations;
- significance of the fish disease data collected in the Maritimes;
- define the various steps required before a disease can be establish in a wild population;
- summarize the measures available to the industry in order to minimize the potential impact of cultured salmon diseases on wild Atlantic salmon populations.

Paper 10 (WP98-91): Overview of fish disease agents in cultivated and wild salmonid populations in the Maritimes, by Anne-Margaret MacKinnon and Malcolm Campbell, (refereed by Sophie St. Hilaire).

Paper to include:

- review of infectious agents of concern for the Maritimes Region aquaculture industry;
- review of infectious agents of concern identified in wild fish populations in the Maritimes;
- overview of the recent effort and results (to date) of screening wild finfish populations for infectious disease agents, including infectious salmon anemia virus;
- necessity for mandatory reporting of disease agents isolated by private and provincial diagnostic laboratories to federal authorities;
- impact of the provision of regulatory finfish diagnostics on DFO's ability to investigate the impact of salmonid finfish diseases for wild salmonid populations.

Paper 11 (WP98-92): A review of the potential effects of salmon lice among aquaculture salmon on wild salmon, by Alasdair McVicar, (refereed by Gary McClelland).

Paper to include:

- contribution of lice from fish farms to lice populations on wild salmon (i.e. evidence, lice to fish contact);
- consequences of the lice contribution from farms (i.e. evidence with individual fish, implications to populations);
- -implications of farm lice control strategies;
- -targeted research.

Paper 12 (WP98-93): Ecological and behavioural interactions between farmed and wild Atlantic salmon: consequences for wild salmon, by Gilles Lacroix and Ian Fleming, (refereed by Jeff Hutchings).

Paper 13 (WP98-94): An assessment of the possible impact of salmon aquaculture on Inner Bay of Fundy salmon stocks, by Peter Amiro, (refereed by Fred Whoriskey).

Paper to include:

- Review of the status of the inner Bay of Fundy Atlantic salmon stock historically and relative to conservation;
- Review of the evidence of marine distribution of post-smolts of inner Bay of Fundy stock origin;
- Review of hypotheses concerning the recent decline of the inner Bay of Fundy salmon stock including interaction with salmon farming operations.

**5. What existing conventions exists that potentially influence or constrain DFO's ability to regulate salmon aquaculture activities relative to salmon conservation in the Maritime Provinces?**

Paper 14 (WP98-95): A review of existing conventions, regulations, and policies pertaining to the control and minimization of negative impacts from aquaculture on wild salmonid stocks, by Rex Porter. Paper would also address the precautionary approach to managing the Atlantic salmon relative to potential impacts of aquaculture. (refereed by Dave Meerburg).

Paper to include:

- Consideration of International Conventions and Agreements, such as: Those adopted through NASCO and the North American Commission including protocols for the Introduction and Transfer of Salmonids, the Oslo Resolution, and the Precautionary Approach; ICES Code of Practice;
- ICES Code of Practice
- L'office International des Epizooties (OIE);
- Convention on Biological Diversity
- Canadian Bio-diversity Strategy;
- World Trade Organization (WTO);
- Canada-USA Free Trade Agreement and the North American Free trade Agreement (NAFTA);
- Convention on International Trade in Endangered Species (CITES);
- FAO – Code of Conduct for Responsible Fisheries;

- Consideration of Federal Legislation including the Fisheries Act (FHPR, Fisheries General and Provincial Regulations), Food and Drug Act, Health and Animal Act and Regulations, and the Pest Control Products Act;
- Consideration of Provincial Laws and Regulations including Aquaculture Acts, Environmental Regulations, and Fish Acts and Regulations;
- Consideration of Federal and Provincial Policies and Agreements including: Wildlife Policy of Canada; Fish Habitat Management Policy; NB policy for BKD, furunculosis, and ISA; and the Maritime policies on Rainbow trout;
- Discussion as to the influence that the above referenced conventions, agreements, acts and regulations has on the aquaculture industry.

**6. What mitigative measures would be feasible, if required, to contain farmed salmon and stop or minimize the potential harmful effects of the salmon aquaculture industry on wild salmon stocks?**

Paper 15 (WP98-96): A review and assessment of mitigative measures to eliminate or minimize potential impacts of farmed salmon operations on wild Atlantic salmon *(Salmo salar)* stocks, by John Ritter, (refereed by Rex Porter).

Paper to include:

- consideration of potential impacts of both hatchery and grow-out operations;
- overview of measures to minimize potential genetic, fish disease and ecological risks;
- measures that industry might implement to prevent interactions with wild stocks;
- measures include containment in hatcheries and grow-out facilities, efficient recapture of escapees, use of local stocks to minimize genetic effects, sterilization of cultured fish to prevent genetic introgression, adherence to strict health management measures to minimize disease risks from escaped salmon, and zoning and siting of hatcheries and grow-out facilities to minimize interactions with wild salmon;
- measures in streams that might be implemented to protect the wild stocks from interaction with farmed salmon, such as blockage of passage of escapes into salmon rivers;
- requirement for documentation of the numbers, by stage, of escaped salmon;
- consequences of implementing mitigative measures on aquaculture industry;
- identification of where measures are being applied and the implications of their application;
- recommendations on which measures might be applied to local aquaculture operations;
- recognition that effective implementation of mitigative measures is dependent upon the endorsement of the aquaculture producers.

Paper 16 (WP98-97): Options for containment of farmed Atlantic salmon, by J. Bailey, (refereed by Russell Henry).

Paper 17 (WP98-98): Use of triploid Atlantic salmon (*Salmo salar*) for aquaculture, by Tillmann Benfey, (refereed by Jeff Hutchings).

Paper to include:
- explanation of what triploids are;
- outline of how to produce and identify triploids;
- overview of biological differences between triploids and diploids;
- summary of a 5-year collaborative study on pilot-scale aquaculture of triploid Atlantic salmon in New Brunswick (University of New Brunswick, Atlantic Salmon Federation, New Brunswick Salmon Growers' Association and Connors Bros. Ltd.);
- overview of experiences with triploid Atlantic salmon in other regions (Newfoundland. British Columbia, Scotland and Tasmania);
- implications of advocating the use of triploids for aquaculture.

Paper 18 (WP98-99): Options for controlling disease and improving health in farmed salmon, as a means of reducing risks posed by escapes, by Alasdair McVicar, (refereed by Gilles Olivier).

Paper to include:
- evidence for disease in farm escapes being a disease problem to wild salmon;
- difficulty in measuring effects;
- prevention of introduction of disease;
- reducing levels of disease occuring;
- management practices.

Paper 19 (WP98-100): Factors affecting the health of farmed and wild fish populations: a perspective from British Columbia, by Sophie St. Hilaire, Micheal Kent and George Iwama, (refereed by Roland Cusak).

**7. What research needs to be done to better define the extent of the problem and to ensure the protection of the wild salmon stocks against potential harmful effects of the salmon aquaculture industry? What are the costs?**

**8. What are management considerations required to safeguard the wild salmon stocks?**

## REVIEW PROCESS

The format for the review centers around one hour being assigned to each of the formal papers. That hour will be divided into fifteen minute segments for presentation of the paper, comments from the assigned referee, comments from the scientific review panel, and comments and questions from the attendees at large. A few minutes of the final fifteen minutes will be used for summing-up as well. This format will be adhered to by necessity in order to complete the lengthy agenda.

### Products

- Fisheries Status Report on this issue.
- Supporting Research Documents (upgrading of all Working Papers presented)
- Meeting Proceedings
- Clear Recommendations and Action Plan

## ARRANGEMENTS

### Location and Date

Crystal Palace Hotel, Dieppe, New Brunswick,
November 30 - December 4, 1998

### Convenors

- John Ritter (506-851-2945)
- Kim Robichaud-LeBlanc

### Chairperson

- James Stewart
- Gilles Lacroix as co-chair

### Media Spokespersons

- John Ritter (Lead Spokesperson)
- Gilles Lacroix
- James Stewart

### Review Panel

Limited to the authors and referees of the formal papers and other individuals essential to the peer review (i.e., rapporteurs and scientific experts).

### Observers

Meeting open to everyone, including media. Special invitations sent to the following:

*Provinces*
- NB DFA and NB DNRE
- NS DOF (both Aquaculture and Inland Fisheries Divisions)
- PEI Department of Fisheries and Environment (both Aquaculture and Fish and Wildlife Divisions)

*Industry*
- Recreational Fishing groups (Atlantic Salmon Federation, NB Salmon Council)
- First Nations and Native / Aboriginal Peoples Councils
- Aquaculture industry (NB Salmon Growers, NS Aquaculture Association)
- NB Conservation Council

**Appendix 4.** Meeting Remits

**REMITS:**

- Are farmed Atlantic salmon interacting with wild Atlantic salmon in the Maritime Provinces?
- If so, what are the impacts of farmed salmon on the wild Atlantic salmon stocks in the Maritime Provinces?
- What should be done to eliminate or minimize these impacts?

## Appendix 5. List of Documents Tabled

| Paper Numbers | Paper Titles | Authors | Rapporteurs | Referees |
|---|---|---|---|---|
| 98-81 | The salmon aquaculture industry in the **Maritime Provinces**. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/151** | Chang, Blythe D. 1998. | Lavoie, René | Cook, Bob |
| 98-82 | History and description of the Atlantic Salmon aquaculture industry in Maine. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/152** | Baum, Ed T. 1998 | Goff, Trevor | Saunders, Richard |
| 98-83 | Status of Wild Atlantic Salmon (*Salmo salar*) Stocks in the Maritime Provinces. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/153** | Chaput, Gérald. 1998 | Dempson, Brian J. | Randall, Bob |
| 98-84 | Atlantic salmon aquaculture escapees and occurrence in rivers of the Maritime Provinces. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/154** | O'Neil, Shane F. 1998 | Marshall, Larry | Sephton, Tom |
| 98-85 | A review and update of aquaculture impact studies carried out on the Magaguadavic river, Southern Bay of Fundy, New Brunswick. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/155** | Whoriskey, Fred G.; Lacroix, Gilles L., Carr, Jonathan; and Stokesbury, Michael J. 1998 | Bradford, Rod | Cronin, Peter |
| 98-87 | Genetic Impacts on wild Atlantic Salmon *(Salmo salar* L.) stocks from escaped farm conspecifics: an assessment of risk. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/156**. | Verspoor, Eric 1998 | Kenchington, Ellen | Fleming, Ian |
| 98-88 | East coast salmon aquaculture breeding program: history and future. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/157** | Glebe, Brian D. 1998 | Robichaud-LeBlanc, Kim | Benfey, Tillmann |
| 98-89 | Genetic introgression of the domestic Atlantic salmon genome into wild populations: a simulation of requirements for conservation. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/158** | Lacroix, Gilles L.; Korman, Josh; and Heath, Daniel D. 1998 | Amiro, Peter | Verspoor, Eric |
| 98-90 | A review of potential impacts on wild salmon stocks from diseases attributed to farmed salmon operations. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/159** | Olivier, Gilles and MacKinnon, Anne-Margaret. 1998 | O'Neil, Shane | Campbell, Malcolm |

| Paper Numbers | Paper Titles | Authors | Rapporteurs | Referees |
|---|---|---|---|---|
| 98-91 | Overview of fish disease agents in cultivated and wild salmonid populations in the Maritimes. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/160** | MacKinnon, Anne-Margaret; and Campbell, Malcolm and Olivier, Gilles. 1998 | McClelland, Gary | St. Hilaire, Sophie |
| 98-92 | A review of the potential effects of salmon lice among aquaculture salmon on wild salmon. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/161** | McVicar, Alasdair H. 1998 | Johnson, Stewart | McClelland, Gary |
| 98-93 | Ecological and behavioural interactions between farmed and wild Atlantic salmon: consequences for wild salmon. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/162** | Lacroix, Gilles L; and Fleming, Ian A., 1998 | Cairns, David | Hutchings, Jeff |
| 98-94 | An assessment of the possible impact of salmon aquaculture on Inner Bay of Fundy Atlantic salmon stocks. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/163** | Amiro, Peter G. 1998 | Randall, Bob | Whoriskey, Fred |
| 98-95 | A review of existing conventions, regulations, and policies pertaining to the control and minimization of negative impacts from aquaculture on wild salmonid stocks. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/164.** | Porter, Rex ; Carey, T.; Harris, D.; and Coombs, K. 1998 | Rose, Carol Ann | Meerburg, Dave |
| 98-96 | A review and assessment of mitigative measures to eliminate or minimize potential impacts of farmed salmon operations on wild Atlantic salmon (*Salmo salar*) stocks. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/169** | Ritter, John A. 1998 | Meerburg, Dave | Porter, Rex |
| 98-97 | Options for containment of farmed Atlantic salmon. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/165** | Bailey, J. 1998 | Chaput, Gérald | Henry, Russell |
| 98-98 | Use of triploid Atlantic salmon *(Salmo salar)* for aquaculture. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/166** | Benfey, Tillmann J. 1998. | Pepper, Vern | Hutchings, Jeffrey |
| 98-99 | Options for controlling disease and improving health in farmed salmon, as a means of reducing risks posed by escapes. | McVicar, Alasdair H. 1998 | Gross, Mart | Olivier, Gilles |

| Paper Numbers | Paper Titles | Authors | Rapporteurs | Referees |
|---|---|---|---|---|
| | Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/167** | | | |
| 98-100 | Factors affecting the health of farmed and wild fish populations : a perspective from British Columbia. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat **Res. Doc. 98/168** | St. Hilaire, Sophie; Kent, Michael L.; and Iwama, George K. 1998 | Price, Iola | Cusack, Roland |

**Appendix 6.** List of Recommendations

**THE SALMON AQUACULTURE INDUSTRY IN THE MARITIME PROVINCES**
**Res. Doc. 98/151**

**Working Paper(s):** DFO Working Paper 98/81

# Recommendations taken from Rapporteur Report

**Research Recommendation**

1. Quantification and qualification of escapees:

a) Data acquisition. The available data are preliminary and almost certainly incomplete
b) Data on the causes of escapes are needed.
c) Research in cage design is needed with the objective of minimizing escape incidents.

- This should include research in cage design for open waters conditions. The results may be crucial for decision making on site licensing as pressures for expansion increases as a result of crowding or deterioration of sites in the nearshore.

2. Exposure coefficient:

a) What is the real percentage of aquaculture standing stock which does escape.
b) What is the ratio between escapees and local salmon population as a means to measure the severity of the exposure risk.

- Theme b) came up again in the discussion of paper # 6, when it was pointed out that the escapees of concern should be those which survive the initial mortality occurring during the adaptation period after the escape. Factors affecting this mortality would include angling, predation by other fish, predation by birds (mergansers, loons, cormorans, ospreys etc), and predation by mammals (otters, seals).

3. Nature of the escapee threat:

Information on the broodstock origin of escapees is weak and required material for future research on the genetic impact of escapees on the so-called "wild" population.

4. Research is needed on :

a) the genetic impact of escapees breeding with wild fish;
b) impact possibly imposed through selection and evolution of a mixed population;
c) genetic drift resulting from a smaller number of wild fish in river systems.

5. Carrying capacity:

Carrying capacity was mentioned as an area needing research although for fish culture, holding capacity" may be a more appropiate term. Cultured fish is not "carried" by the environment, since its food source is artificial as compared to molluscs which filter their food from the environment, and are therefore truly carried by it.

**Management Consideration**

1. Escapement reporting.

- A mandatory reporting mechanism is required to help quantify and qualify escapements as to the timing of their occurrence, their cause, the number of fish involved, their size, age, origin and the broodstock from which they came.

2. Code of practice

A code of practice should be developed which should include :

- Site selection to minimize exposure to escapement caused by storms, ice, exposure to seal attacks, etc.
- Fish handling procedures.
- Procedures to monitor net integrity for early detection of potential causes of escape and correct them before an escape occurs.

**Other**

Freshwater smolts.

- The province of New Brunswick is looking into the possibility of increasing the number of sites to produce freshwater smolts. The possible implications of escapees in the freshwater environment ought to be considered before large expansions are considered.

## Recommendations taken from Paper:

**N/A**

**HISTORY AND DESCRIPTION OF THE ATLANTIC SALMON AQUACULTURE INDUSTRY IN MAINE**
**Res. Doc. 98/152**

**Working Paper(s):** DFO Working Paper 98-82

# Recommendations taken from Rapporteur Report

### Research Recommendation

1. Development of a suitable mark for the identification of farm-fish escapees

2. Development of a viable method of sterilization of salmon for farm use.

3. Research into seal behaviour around sea cages, possibly leading to selective removal of some animals.

### Management Consideration

1. Ninety percent of Maine farmed salmon production is within 50km of the New Brunswick industry. International cooperative management of the industry to implement joint wild Atlantic salmon population protection strategies is recommended.

2. Recommend adoption of a joint Canada-US marking program for the identification of farm-fish escapees.

3. Farmed salmon sterilization methods must be universally applied, cost-effective, acceptable to the industry and not affect marketability of the product.

4. Universal reporting of escapes (numbers, dates, sizes, species, stock origin, location, etc.) to a central North American clearinghouse.

5. Universal reporting of disease and parasite outbreaks in the salmon farming industry to a central North American clearinghouse.

### Other

1. In Maine, the presence of farmed salmon in the wild, especially if numerous, potentially masks the status of wild stocks and complicates the regulation and management of fisheries. It has been recommended that managers of wild salmon stocks ensure that those stocks are in a strong condition so that they can withstand impacts from aquaculture, as well as other threats. To address this issue in Maine, a river specific stocking program, initiated in 1992, is in effect for most Maine rivers with existing salmon runs. In those rivers located close to aquaculture operations, the goal is to increase the number of native salmon to reduce the potential impacts of interbreeding with farmed salmon. Stocking isprimarily based on fry releases as well as parr and smolts. Smolts are also being reared to sexual maturity in

freshwater hatcheries and in sea cages to provide eggs for restocking programs or to supplement spawning escapement in the wild.

2. Weirs will be installed in several eastern Maine rivers to intercept and remove farm fish and to monitor wild returns.

## Recommendations taken from Paper:

### Future Research and Management Recommendations

1. Adoption of an international agreement between Canada and the US to implement joint wild Atlantic salmon population protection strategies. The agreement must be universally applied to the salmon farming industry on both sides of the international border.

2. Adoption of a marking program that can be applied to all farmed Atlantic salmon, in order to be able to readily identify farmed salmon in the wild. Marking must be universally applied in Canada and the US, universally applied and not negatively impact marketability of farmed salmon product(s).

3. Development of viable methods of sterilization of farmed salmon. Method(s) must be universally applied, cost-effective, acceptable to the industry and not affect marketability of product(s).

4. Universal reporting of escapes (numbers, dates, sizes, species, stock origin, location, etc.) to a central North American clearinghouse. Requirements should be universally applied in Canada and the US; individual grower confidentiality must also be maintained, where appropriate.

5. Universal reporting of disease/parasite outbreaks in the salmon farming industry to a central North American clearinghouse. Reporting requirements and recommended remedial actions must be universally applied and acceptable to all parties.

**STATUS OF WILD ATLANTIC SALMON *(SALMO SALAR)* STOCKS IN THE MARITIME PROVINCES**
**Res. Doc. 98/153**

**Working Paper(s):** DFO Working Paper 98/83

## Recommendations taken from Rapporteur Report

### Research Recommendation

1. Wild smolt populations should be monitored in some stocks to obtain information on marine survival to complement similar information available on hatchery stocks.

### Other

1. The author posed the question that for the subsequent report prepared from this workshop, a clear definition of what constitutes a '**wild salmon**' should be included. In addition, the author asked for clarification as to the definition of a '**stock**' and a '**population**'.

## Recommendations taken from Paper:

### Conclusion

There is a clear geographic distinction in stock status of Atlantic salmon in the Maritime Provinces. Trends in returns, escapements relative to conservation requirements, juvenile abundance, and measured sea survivals of hatchery released smolts indicate that the stocks of the Bay of Fundy and Atlantic coast of Nova Scotia have declined to low levels with reduced recovery potential. Hatchery-origin fish have increased proportionally to wild salmon as the wild salmon abundance declines. Many of the stocks of the southern Gulf of St. Lawrence have also declined in recent years but juvenile abundances are at medium to high levels and most of the rivers are near or above conservation.

The intrusion of aquaculture escaped fish into local stocks is potentially the greatest threat to the wild salmon populations. The magnitude of the impacts is expected to be related to the relative proportions of farm fish mixing with wild salmon (Lacroix et al. 1998; Verspoor 1998). The abundance of Atlantic salmon by size group and SFA has been estimated for the period 1971 to 1997 (ACFM 1998). Between 1992 and 1997, the total stock size of wild and hatchery origin Atlantic salmon adults returning to rivers of the Maritimes was between 115,000 and 229,000 fish (Fig. 21). This contrasts with approximately 5.6 million market sized salmon harvested from cages in New Brunswick and Nova Scotia in 1997 (Chang 1998). The number of salmon escaping production facilities is generally unknown but in 1994, an estimated 20,000 to 40,000 salmon escaped from sites in southwestern New Brunswick (Chang 1998). This escape was about twice the total number of wild and hatchery origin salmon returning to rivers of the entire Bay of Fundy (11,000 to 22,000) and equivalent to the average annual total returns to the Bay of Fundy and Atlantic coast of Nova Scotia between 1992 and 1997 (19,000 to 43,000) (Fig. 21).

There are only three rivers in the Maritimes with total stock size in excess of 10,000 fish annually (Fig. 22). The many small rivers contain stocks whose annual returns by size group combined are generally less than 500 fish. It would not be surprising to find less than 100 adult salmon in individual rivers of the inner Bay of Fundy. The stock size in most of the Atlantic coast rivers where populations are threatened by acid-deposition have not been estimated but are also believed to be very low.

**ATLANTIC SALMON AQUACULTURE ESCAPEES AND OCCURRENCE IN RIVERS OF THE MARITIME PROVINCES, CANADA. Res. Doc. 98/154**

**Working Paper(s):** DFO Working Paper 98/84

# Recommendations taken from Rapporteur Report

### Research Recommendation

1. Investigate run-timing differences of mature and immature escapees (with particular reference to Whoriskey's Magaguadavic data)

### Management Consideration

1. Mandatory reporting of escapes by the industry (note Issues/Concerns).

2. Reporting of escapee sightings data to be encouraged from traps or other sources.

3. Establishment of an objective agency to monitor possibly modeled after the Atlantic Salmon Watch program in Western Canada.

4. Possible penalties to reduce the incidence of escapes.

5. Avoid placement of cages in locations frequented by wild stocks.

# Recommendations taken from Paper:

Recommendations include: (1) Mandatory reporting of escapes by the industry; (2) reporting of escapee sightings data to be encouraged from traps or other sources; (3) the establishment of an objective agency to monitor such data such as the Atlantic Salmon Watch program in Western Canada; (4) possible penalties to reduce the incidence of escapes.

Collectively the evidence on escapees from sea cages indicates the time and location of escape influences the homing ability and timing of river ascension for fish lost as post-smolts or mature adults: (1) Immature fish (smolts or post-smolts) will return (home) to the area of escape or to the river where they were reared, particularly if they escape during the spring, summer or autumn; (2) Conversely, adult or sexually-mature fish released in the winter months have little homing tendency and tend to wander and possibly ascend nearby rivers seemingly at random (cf. Jonsson 1997); (3) Mature fish lost during the winter months typically enter rivers later, during the summer or autumn, than wild fish, during spawning migrations (Gausen and Moen 1991; Thorstad *et al.* 1998; Carr *et al.* 1997b); and, (4) Non-sexually mature cultured fish may also ascend rivers but usually late relative to the natural spawning run (Carr *et al.* 1997a; Lacroix *et al.* 1997).

The occurrence or likelihood of occurrence of cage-culture escapees in a particular river is heavily influenced by the proximity to the industry, the relative discharge from the river, and the timing of the escape from the cages.

Improved containment practices would reduce the risk of cultured fish passing diseases to wild conspecifics or of interbreeding. The presence of wild fish in close proximity to salmon farms may still result in disease organisms being passed from one group to the other. Avoiding the placement of cage operations in locations where wild stocks are known to feed or migrate would reduce the risk of interaction and the possibility of transfer of disease. Existing research data indicates that escaped salmon from sea-cages have a variable probability of ascending a particular river and impacting on that river stock. Placement of cages in estuaries or partial-freshwater embayments greatly increases the probability that escapees would ascend the river where they were caged and thereby have a more significant impact.

Regulatory responsibility for the industry in New Brunswick underwent changes in the late 1980s which gave the province the ability to license sites for aquaculture (Milewski *et al.* 1997). The provincial agency responsible for regulating the industry, the New Brunswick Department of Fisheries and Aquaculture also promotes development to better realize economic prosperity for the province. In other words, industry proponents and those who encouraged slower growth believed the agency was in a position of conflict and could not act objectively (Milewski *et al.* 1997; Percy 1996).

The difficulty in obtaining reliable data on the number of fish which have escaped from hatcheries or grow-out sites highlights the need for mandatory reporting. Evidence of the occurrence of escapees in rivers is not readily available or collected or recorded in any systematic fashion except at some permanent trapping facilities. I recommend that a vehicle be put in place to record data on escapees (escapes and river occurrences) and suggest a review of the Atlantic Salmon Watch program on the Canadian west coast as a possible model.

At present, there are no regulatory measures in place requiring the industry to report losses. In order to measure or manage the risk associated with escapees, managers or regulators need to know the number and location of the losses. I recommend that reporting of losses become mandatory and that the data be reported to an agency not involved with active promotion of the industry. Containment has a cost so excessive losses must be challenged with penalties sufficient to make the containment cost worthwhile.

Industry use of Atlantic salmon stocks should be limited to local approved strains.

**A REVIEW AND UPDATE OF AQUACULTURE IMPACT STUDIES CARRIED OUT ON THE MAGAGUADAVIC RIVER, SOUTHERN BAY OF FUNDY, NEW BRUNSWICK**
**Res. Doc. 98/155**

**Working Paper(s):** DFO Working Paper 98/85

# Recommendations taken from Rapporteur Report

### Research Recommendation

1. Acquire through research genetic maps of wild fish in the Fundy region rivers and of the escapees in order to evaluate the level of introgression and fitness.

2. Higher level of stable funding is required to adequately address the full suite of wild resource conservation issues associated with escapements of farmed Atlantic salmon.

3. Are progeny from farmed and wild fish that successfully close the life-cycle to be considered 'wild' fish or should they be removed from the reproductive pool?

4. What do salmon do after escapement from pens; `what are the potential avenues for interaction of wild and farmed fish in the marine habitat?

### Management Consideration

1. Prevent escapees from entering river systems either as adults or smolts (the referee indicated that "management options" could be added to the title.

2. Are changes required to the current regulations governing expansion of the industry? There is a need to recognize advances in knowledge regarding the fact of and nature of interactions so that problem of interactions does not extend beyond current area of impact.

3. Two estimates of rearing habitat were reported. Which one should be used?

### Other

1. The studies on the Magaguadavic River are important by virtue of the fact that they represent the sole time series of information on the interaction between wild and farmed salmon in the Maritimes Region.

# Recommendations taken from Paper:

1. The Atlantic salmon population of the Magaguadavic River, similar to that of other rivers draining into the Bay of Fundy, is in an extremely fragile state. Returning adults are providing a small fraction of the required egg depositions, and wild juvenile numbers are

low. This makes these rivers particularly vulnerable to the impacts of influxes of non-native fish.

2. Aquaculture escapees now far outnumber wild fish in Magaguadavic fish ladder counts, although their annual numbers vary greatly and unpredictably. In the past, these fish have spawned in the river and have probably mixed their genes with wild fish. Meanwhile, wild juveniles are also being swamped by fish escaping from hatcheries in the system. In European work, genetic and ecological swamping have been implicated in negative fitness effects on wild salmon populations (Fleming and Einum 1997, McGinnity et al 1997). We have not had the resources to conduct similar work in the Bay of Fundy region.

3. In 1998, systematic disease screening suggested a low frequency of disease for the escapees. However, viral cultures are still being conducted. In 1997, five escapees had symptoms consistent with ISA, but no viral cultures were done on the fish and the conclusion is uncertain. In all years, the great majority of escapees examined did not test positive for diseases. This suggests that aquaculture fish may pose a limited risk of carrying diseases to freshwater. Sea lice counts were also low on returning fish. However, none of our work addresses the possibility that wild fish at sea might pick up and die from diseases which originate at cage sites. We are only screening the survivors.

4. In one of two years, transplanted aquaculture fish showed a degree of homing and returned to the Magaguadavic River. These fish may have been raised to the smolt stage in one of the hatcheries located in the system, and hence have imprinted to it. The fact that many of them were not maturing shows that homing ability is decoupled from the reproductive cycle.

Given the fragile state of the wild fish of this river, and of other rivers in the Fundy region, we recommend:

(A) Continued improvements need to be made to eliminate escapements.

(B) If this is not feasible, sterilization of the fish used in aquaculture is necessary.

(C) If sterilization is not possible, any escaped net pen and hatchery fish be stopped from spawning in these rivers by other means. Emergency response teams can be developed to set gill nets in the vicinity of catastrophic cage failures soon after escape events. This requires a comprehensive, real time reporting network which presently does not exist. At sites where counting facilities permit the collection of adults, aquaculture fish should be stopped from going upstream. Perhaps smolts in hatcheries could be artificially imprinted upon a chemical like morpholine, then lured into capture sites.

(D) A concerted effort be made to genetically map the fish of this and other Fundy region rivers, and of the escapees, to evaluate the level of introgression occurring and the fitness effects.

(E) A major infusion of sustained funding is necessary to do all of these things.

(F) Government should be proactive and take measures to avoid spreading the problems which occurred in the Fundy region to other areas as it considers expanding salmon aquaculture. Expanding the industry to other regions using the same old ways of growing fish will generate the same old problems in a new place.

(G) A consensus needs to be reached on what to do about "wild" fish which show varying degrees of introgression with aquaculture fish. If progeny of aquaculture parents survive as juveniles in the stream, and return as adult fish, should they be treated as wild or excluded from future breeding populations?

**GENETIC IMPACTS ON WILD ATLANTIC SALMON (*SALMO SALAR* L) STOCKS OF ESCAPED FARM CONSPECIFICS: AN ASSESSMENT OF RISK.**
**Res. Doc. 98/156**

**Working Paper(s):** DFO Working Paper 98/87

## Recommendations taken from Rapporteur Report

### Research Recommendation

1. Genetic characterization of wild and farmed stocks under natural conditions is required in order to evaluate the potential magnitude and direction of interactions.

2. Research into the indirect genetic effects of interaction in natural situations is required. Examples include behavioural and competitive interactions which will alter selection in the breeding population.

3. Research into biological containment measures (e.g., triploidy) should be encouraged.

4. The capacity to accurately identify and quantify risk, and remedy impact, can be increased by empirical and theoretical research which takes advantage of developments in molecular biology which allow the specific genetic characterization of individual salmon populations. Future research should use these developments to monitor the inputs and outcomes of existing interactions and to develop a deeper understanding of the nature and extent of local adaptation in Atlantic salmon populations. Where historical sources of data are available, valuable information on the historical genetic nature of populations, and effects of bottlenecks and mixing should be researched.

### Management Consideration

1. Elimination of the risk of farm escapes. Where elimination is not possible, the number and frequency of escapes should be reduced to the minimum feasible level. In addition to reducing escapes, selective trapping or angling of escaped fish entering rivers should be implemented.

2. Minimization of adaptive genetic differences between farm and wild stocks by cultivating farm stocks established solely from local river stocks is preferred where interactions can not be more or less eliminated.

3. Technologies which provide biological containment of the genome (sterilization techniques such as triploidy) should be considered to avoid the risk of direct genetic impacts (indirect effects will not be eliminated by this technique).

**EAST COAST SALMON AQUACULTURE BREEDING PROGRAMS: HISTORY AND FUTURE**
**Res. Doc. 98/157**

**Working Paper(s):** DFO Working Paper 98/88

## Recommendations taken from Rapporteur Report

### Research Recommendation

"None mentioned"

### Management Consideration

1. Genetic diversity and outbreeding depression.

2. Evaluation of non-local stocks for aquaculture.

3. DNA profiling and genetic management of farmed salmon stocks.

4. River specific stocking.

5. Cryopreservation of salmon sperm.

**GENETIC INTROGRESSION OF THE DOMESTIC ATLANTIC SALMON GENOME INTO WILD POPULATIONS: A SIMULATION OF REQUIREMENTS FOR CONSERVATION.**
**Res Doc. 98/158**

**Working Paper(s):** DFO Working Paper 98/89

## Recommendations taken from Rapporteur Report

### Research Recommendation

1. Additional modelling could be a useful method for understanding potential impacts of interbreeding if the genetic component is more realistically defined and for evaluating different management scenarios.

2. Field research needs to focus on the relative survivability of farm strains and their hybrid offspring as this will be a major determinant of the outcome.

3. The nature and extent of "introgression" needs to be better understood to identify management needs.

### Management Consideration

1. The modeling indicated the need for immediate action in stopping introductions of farm fish to preserve wild self-sustaining populations of Atlantic salmon in affected rivers.

**A REVIEW OF POTENTIAL IMPACTS ON WILD SALMON STOCKS FROM DISEASES ATTRIBUTED TO FARMED SALMON OPERATIONS**
**Res. Doc. 98/159**

**Working Paper(s):** DFO Working Paper 98/90

## Recommendations taken from Rapporteur Report

### Research Recommendation

1. Disease surveillance of wild salmon and possible other marine species to document existence of reservoirs of pathogens.

2. Governments and industry should collaborate to institute a comprehensive fish health program.

**Management Consideration**

1. Continue with work of technical committee reviewing disease status of cultured fish as is currently being done with ISA.

2. Emphasis should be placed on keeping fish healthy rather than finding out why fish are sick and management approaches should use that principle as a guide.

## Recommendations taken from Paper:

**Recommendation**

There is an urgent need for increased disease surveillance in wild fish. Disease surveillance should include marine non-salmonid species because recent data strongly suggest that marine non salmonid fish can be reservoirs of several fish pathogens. However, improved diagnostic methods are urgently needed in order to increase our detection of several fish pathogens.

Governments and industry should collaborate to institute a comprehensive fish health program aimed at limiting disease impacts on farms. Such a program will benefit all by reducing the incidence of diseases at the farm level (economically significant for the farmer) and reducing the risk of disease transfer from cultured to wild fish.

It is time to change our basic philosophy on diseases, we should investigate how to keep fish healthy and not necessarily focus so much on why the fish are sick!

**OVERVIEW OF FISH DISEASE AGENTS IN CULTIVATED AND WILD SALMONID POPULATIONS IN THE MARITIMES.**
**Res. Doc. 98/160**

**Working Paper(s):** DFO Working Paper 98/91

## Recommendations taken from Rapporteur Report

**Research Recommendation**

1. Establish surveys of diseases in wild fish populations to provide information on disease interactions between wild and cultivated fish.

2. Conduct follow-up research on specific diseases, when required.

**Management Consideration**

1. Major revisions to the FHPR including: creation of a list of disease agents of concern for each province; mandatory reporting of disease agents; inclusion of non-salmonid finfish

species; designation of zones as positive or negative for disease agents in cultivated and wild fish stocks; and inclusion of a quality assurance program.

2. Increased funding and resources to enable monitoring of diseases in wild finfish populations, enhanced screening of cultivated fish and follow-up research.

**Other**

1. According to provincial representatives, mandatory reporting already exists in Nova Scotia and New Brunswick.

2. In response to concern over the confidentiality of veterinarian reports, it was pointed out that, in New Brunswick, aquaculturists are given 24 hours to notify neighboring farms in the event of a reportable disease agent being identified in their stock; in Scotland restrictions on sites are published after 30 days.

3. Also noted was the fact that, unlike their counterparts in the agriculture industry, fish farmers are not compensated for stock eradicated after diagnoses of reportable diseases.

4. It was suggested that comparison of disease profiles of Atlantic salmon cultivated on the east and west coast might provide insight into the rate at which farmed fish acquire diseases from wild fish.

5. Concern was expressed over the fact that the FHA had not been screening inner Bay Salmon

## Recommendations taken from Paper:

**Conclusion**

The DFO Maritimes Region Fish Health Unit primarily screens salmonid populations from freshwater facilities for FHPR and RFHP microbial agents. Due to the resources required to provide these regulatory diagnostics there are limited resources available to perform wild finfish surveys and additional diagnostics on cultivated populations. The majority of these additional diagnostics are provided by private and provincial diagnostic laboratories. Without mandatory reporting of disease identifications by these agencies to DFO, our records may not accurately reflect the distribution of disease agents or the presence of disease agents within the aquaculture industry. This information is crucial for the formulation of fish health policies/regulations that adequately protect and conserve both wild and cultivated finfish populations without being unjustly restrictive for aquaculturists. The existing FHPR allows interprovincial transfer between facilities/drainage basins with like disease profiles. In the absence of knowledge of the identity and distribution of disease agents in both wild and cultivated finfish populations, importations that do not pose a significant risk to salmonid populations may be unnecessarily denied. These concerns are among many that are currently being addressed during the major revision of the FHPR. Planned revisions include: the creation of a list of disease agents of concern for each province; mandatory reporting of disease agents; inclusion of non-salmonid finfish species; the designation of zones as positive or negative for disease agents supported by a

disease surveillance program of both wild and cultivated finfish populations; and inclusion of a quality assurance program. These changes should result in enhanced knowledge of the health status of wild and cultivated finfish populations for relevant disease agents and confidence that the information available is accurate.

**A REVIEW OF THE POTENTIAL EFFECTS OF SEA LICE INFESTATION AMONG AQUACULTURE SALMON ON WILD SALMON**
**Res. Doc. 98/161**

**Working Paper(s):** DFO Working Paper 98/92

## Recommendations taken from Rapporteur Report

### Research Recommendation

1. There is a lack of data on historical levels of lice on wild salmonids in the absence of fish farming. Therefore it is not possible to determine if there have been subsequent changes in theses levels due to farming. Natural background levels of sea lice need to be monitored.

2. The most important requirement for further work in this area is the development of a stable funding base for sea lice research.

3. Due to the complexity of this problem research needs to focus on one variable at a time and to ask clearly defined questions.

4. It is important that we develop an understanding of the behaviors of the infectious copepodid stage of sea lice.

5. There is evidence that sea trout held in cages in the vicinity of an infected farm site will become infected with sea lice. However, there is no scientific evidence that the infections seen on wild sea trout were of a farmed origin.

6. There is a need to understand if and for how long wild salmon remain in the vicinity of sea cages. This behavior is likely to be highly site specific.

7. Differences in susceptibility of different species to sea lice infection also need to be taken into consideration when discussing possible impacts.

8. Any addition to the number of lice in inshore or offshore areas may result in changing the balance of sea lice away from natural levels of infection.

### Management Consideration

1. Reduced lice loads on farmed fish will improve their health and reduce the possibility that wild fish in the vicinity of farms would become infected with sea lice.

2. Reduction of lice loads on farms is best achieved using treatments timed to reduce lice loads prior to the onset of sea lice disease.

3. Management practices such as site selection, net cleaning and fallowing can reduce the necessity for chemical treatments of farmed fish.

4. Cooperation between farms in the timing of their sea lice treatments, fallowing etc. can also help reduce sea lice abundance on farms.

**Other (comments from the floor)**

1. It was pointed out the New Brunswick monitors sea lice levels and has a set level of infection at which time treatment is initiated.

2. There was also concerns about sea lice acting as a vector for ISAV. The author acknowledge that ISA virus has been found on sea lice from infected fish and that these sea lice can transfer the disease if placed on naïve hosts. However the rate transfer of the mobile preadult and adult stages between fish is thought to be extremely low making this unlikely route for transmission.

3. It was mentioned that the pest management regulatory agency would be producing an integrated pest management strategy for sea lice in Canada. This document will be available in the New Year.

## Recommendations taken from Paper:

**Conclusion**

Any addition to the numbers of lice in an inshore or offshore area has the potential of altering the balance away from natural levels of infection. Although there is some evidence for relatively stable population structures of lice occurring on wild salmon, in the absence of usable historic data on lice levels prior to the development of farming it is not possible to determine if there have been any subsequent changes occurring.

**Research Recommendations**

The ICES Workshop on the Interactions Between Salmon Lice and Salmonids (ICES CM 1997/M:4 Ref.:F) identified areas where there was inadequate data on interactions between sea lice and salmonids and suggested a comprehensive series of research topics which could fill these gaps. Many of these suggestions had the characteristics of a "wish list" and it is unlikely that adequate resources will be made available to meet their full requirements. Realistically, research topics should be identified which are firmly based on good scientific principles, are likely to provide good returns from budgets and where there is a high probability of a scientifically definitive result (either positive or negative) being realised on clearly defined questions.

**ECOLOGICAL AND BEHAVIOURAL INTERACTIONS BETWEEN FARMED AND WILD ATLANTIC SALMON: CONSEQUENCES FOR WILD SALMON**
**Res. Doc. 98/162**

**Working Paper(s):** DFO Working Paper 98/93

# Recommendations taken from Rapporteur Report

## Research Recommendation

*Those taken during presentation:*

1. Determinants of gene flow between farmed and native fish.
2. Maturation and reproductive interactions, wild escapees, farmed $F_1$ and b cross.
3. Competitive displacement of native fish by farmed salmon escapees, farmed $F_1$ & hybrids.
4. Natural selection relative survival.
5. Effect of freshwater and marine culture sites on migration and disease transfer.
6. Behaviour and migration of escapees from sea cages.
7. Behaviour of predators around cages, monitor impact on wild salmon.
8. Migration routes and destinations of native salmon in Bay of Fundy.
9. Modeling to understand mechanisms, and evaluate action.

*Complete list from MS:*

1. Studies on the potential for competitive displacement of native salmon by farmed salmon, escaped from hatcheries and offspring of farmed spawners (also hybrid offspring).
2. Survival and natural selection during $F_1$ generation (interactions during the $F_1$ generation remain at a very basic level).
3. More comprehensive studies on determinants of gene flow between farmed and native populations (reproductive interactions).
4. Potential for reproductive interactions at the $F_1$ generation and continued genetic introgression.

5. Need to monitor changes in population dynamics and genetic structure, but also understand mechanisms leading to these changes and their implications. By understanding the mechanisms and causes, generalities can be identified and solutions found; without doing so, we are working in the dark.

6. Studies on the effects of farmed fish and rearing/grow out facilities on migratory behaviour of, and disease transmission to native fish in freshwater and marine habitat. Need to monitor the survival of wild salmon after migrating through corridors or to areas with diseased farmed fish.

7. Need to identify the migratory routes and destination at sea of wild salmon stocks in the Bay of Fundy to better understand the potential cause/effect of interactions, and to effectively manage cage site location.

8. Studies to understand the behaviour of farmed fish after they escape from sea cages. Needed to determine their role in disease transmission, changes in predator–prey balance, and to find solutions to eliminate reproductive interactions.

9. Studies to understand the behaviour of predators (e.g. seals) around aquaculture areas, and need to monitor their impact on wild salmon migrating through or to these areas.

10. Modelling studies and associated tests are needed to understand mechanisms and identify appropriate/effective management actions.

**Management Consideration**

1. Review and revise containment codes and practices for sea cages and for hatcheries using a precautionary approach. Escapes/releases of domesticated farmed salmon into the environment must be reduced/eliminated.

2. Enforce existing policy to prevent/eliminate the release of juvenile farmed salmon into rivers (conservation measure).

3. Review and revise policy for the siting of salmon hatcheries that rear domesticated stock. Hatcheries should be located on rivers and bodies of waters that do not have a run of wild salmon to prevent interactions with wild stocks (precautionary approach).

4. Prevent escaped farmed salmon access to fresh water and to known spawning grounds for wild salmon, and remove escaped farmed salmon where possible (conservation measure).

5. Review and revise policy for siting of aquaculture cages using a precautionary approach. The use of freshwater sites for grow out should be eliminated/prevented in rivers with wild salmon stocks. The use of brackish water sites in estuaries with wild salmon stocks should be reviewed. The use of narrow passages around the Fundy Isles for cage sites should be reviewed, and suitable migratory corridors for wild salmon stocks should be maintained to reduce possibilities of predation and disease transfer.

6. The allowed density of cage sites in any area used by wild salmon as a destination should be reviewed to reduce the potential for predation and disease transfer.

7. Existing methods of predator control (e.g. seals) in aquaculture areas should be reviewed, and an appropriate management plan devised.

## Recommendations taken from Paper:

### Management Considerations

Conservation measures used in the model identified the need for immediate action in stopping introductions of farmed fish in the breeding population of any river where there is a will to preserve a wild, self-sustaining population of Atlantic salmon. The ways to prevent interbreeding are varied, and effectively stopping interbreeding will probably require the use of combinations of these precautionary measures. The model pointed out the need to eliminate all introductions in a population to preserve it; reductions in the number of escapees and introductions will not be effective in preserving the population, but will only alter the rate of extinction. The precautionary approach to management of the wild salmon stocks requires immediate action aimed at completely stopping introductions of farmed salmon or their ability to interbreed and survive in the wild. Wherever there is a counting fence or migratory passage facility on a river, all farmed salmon need to be removed. The extensive release or escape of juvenile salmon of domestic origin from hatcheries that occurs throughout the region must be stopped immediately; the model indicated that their returns as wild spawners would greatly accelerate the rate of genetic introgression and loss of the wild stock.

### Recommendation

With the incontrovertible evidence that farmed Atlantic salmon, escaped from aquaculture sites, interbreed with wild stocks of Atlantic salmon and have some reproductive success, the model has identified the potential impacts on a wild population. Large differences in the rate at which these impacts occur under different model scenarios revealed the importance of accurately defining the extent of interbreeding and the survival of the different offspring types that include some of the domestic genome. The behaviour of the model also pointed out the need to define the survivability in the wild of the strains of salmon in use or proposed for use in aquaculture because differences in fitness have the potential to greatly alter the outcome of interactions between farmed and wild fish. Research on the migratory and spawning behaviour of farmed spawners and on the factors that control maturation in escaped farmed salmon are of utmost importance in defining the rate of impact on the wild population and the extent of genetic introgression of the domestic salmon genome. Research on the survival of offspring with different levels of introgression of the domestic genome, in the first and subsequent generations, is needed to accurately predict the rate of impact on wild salmon stocks. Without some understanding of the extent of genetic introgression in the population and its impact on fitness, attempts at management of the wild stocks that have interacted with farmed fish are bound to fail, and the impacted stocks are headed for extinction. Research and monitoring on the effectiveness of applying conservation measures, such as completely stopping introductions, on

the survivability of a wild stock where some genetic introgression has already occurred should be carried out in a model system to determine the resiliency of the affected population and its ability to rebound because the attained level of introgression is irreversible.

**AN ASSESSMENT OF THE POSSIBLE IMPACT OF SALMON AQUACULTURE ON INNER BAY OF FUNDY SALMON STOCKS**
**Res. Doc. 98/163**

**Working Paper(s):** DFO Working Paper 98/94

## Recommendations taken from Rapporteur Report

### Research Recommendation

(Note from Rapporteur – I am assuming that the following items might be considered to be research recommendations):

1. (F. Whoriskey and others)Use the inner Bay of Fundy as a test location for the conservation of critically low populations? Minimum population size.

2. (F. Whoriskey): Tagging studies of wild smolts to test hypothesis that inner Bay of Fundy stocks utilize the western regions of the Bay of Fundy as an adult staging area?

3. (Chaput, St. Hilaire): Information is needed on long-term environmental changes in the inner Bay of Fundy.

4. (Hutchinson): Information is needed on the density of escapees around sea pens (Type III predator-prey hypothesis).

5. (Several): Information is needed on changes in abundance of predator and prey species in the Bay of Fundy.

## Recommendations taken from Paper:

### Conclusion

These observations suggest the conclusion that inner Bay of Fundy salmon do not migrate to the North Atlantic and have similar marine distribution.

As a cross-check to this conclusion one can look at recaptures of tagged smolts from outer Bay of Fundy and Atlantic coast salmon stocks for the same 1985 to 1990 time period. This comparison clearly shows that while other stocks were recaptured in Newfoundland and Greenland fisheries, inner Bay of Fundy salmon were not (Amiro and Jefferson MS 1996). The distribution of inner Bay of Fundy post-smolts in the southern Bay of Fundy in the fall of the year, together with a lack of tag returns from interceptory fisheries, supports the hypothesis that inner Bay of Fundy salmon do not utilise the North Atlantic for their winter habitat. While there

is no direct information on the over winter location of inner Bay of Fundy salmon, there is ample evidence that inner bay of Fundy post-smolts spend significant time in the Passamaquoddy - Grand Manan Island areas during the summer and fall.

### Summary

Historic declines of salmon to inner Bay of Fundy rivers complicates the conclusion that this stock is on the brink of extirpation (loss of a species to an area). Inner Bay of Fundy salmon have previously been at very low levels and have returned to substantial populations. The frequency of these low abundance periods seems to be in the one to two decade range. Based on juvenile salmon populations the amplitude of the last low population event was not as low as the current observation. The mechanism of this variation remains as much a mystery today as when Venning first wrote about the decline of inner Bay of Fundy salmon. In any event, the frequency of low abundance of inner Bay of Fundy salmon make them more susceptible to any new additional loss factor. Two mechanisms cannot be rejected as contributory to the recent low recruitment of inner Bay of Fundy salmon. These mechanisms are: 1) disease and 2) predator attraction. In either case, the Aquaculture industry may have exacerbated factors negatively effecting recruitment of inner Bay of Fundy salmon. The advent of a new possible player in the stability of the inner Bay of Fundy salmon stocks requires close attention.

**A REVIEW OF EXISTING CONVENTIONS PERTAINING TO THE CONTROL AND MINIMIZATION OF AQUACULTURE IMPACTS ON WILD SALMON STOCKS.**
**Res. Doc. 98/164**

**Working Paper(s):** DFO Working Paper 98/95

## Recommendations taken from Rapporteur Report

### Research Recommendation

1. "DFO must consider its mandated responsibilities for conservation and protection of the aquatic resources as required under federal legislation when establishing controls on the aquaculture industry."

2. "DFO must also consider provincial legislation and policies and international commitments."

### Management Consideration

1. Protocols & Conventions serve as guidelines for management decisions.

# Recommendations taken from Paper:

**Discussion**

There are a number of international conventions, agreements, and obligations as well as federal and provincial legislation, agreements, and policies that pertain to controlling and minimizing potential negative effects of aquaculture on wild salmon stocks. These negative effects could be in the form of changes in genetic fitness of populations, fish health, or ecological effects. The international agreements and codes tend to fall into one of two categories: those that were developed for the primary intent of promoting or ensuring conservation and sustainability of fisheries resources; and those that were developed to provide consistent international standards for fish health and quality of fish for international trade. International agreements also provides a mechanism for protecting a countries aquatic resources from adverse effects of activities which are occurring or proposed to occur in another country.

These international agreements also benefit the aquaculture industry by providing consistent standards for conducting business so that one country does not have a competitive advantage over the other in some aspects of the aquaculture operations, including trade barriers. Although many of the international agreements that are signed or adopted by Canada are not legally binding, Canada is obligated to uphold commitments made under these agreements. These commitments certainly influence the way DFO makes decisions about fisheries management and aquaculture. The NAC Protocols for the Introduction and Transfers of Salmonids forms the basis for DFO's policy on introductions and transfers in eastern Canada at the present time.

There are federal-provincial agreements on the development of aquaculture that define the responsibilities of the two levels of government. DFO has a mandate for conservation and protection of the wild salmon stocks as well as promoting aquaculture development. New Brunswick and Nova Scotia governments have the authority for leasing and licencing aquaculture, and place controls on husbandry practices including restrictions on movements of fish. The movement of live salmonids requires an import permit to traverse provincial boundaries and a transfer licence for all movements, which is issued by DFO. It is through a review of applications for movement of fishes that DFO can determine if the proposed introduction or transfer has a risk of adverse effects on wild fish populations or cultured fish. The review also provides the opportunity to determine if proposed fish movements would comply with existing regulations or policies. The permit/licence requirement is an important and essential mechanism for protecting wild salmonids and industry. However, there are instances in which some government agencies and industry do not comply with this requirement, which poses a risk of adverse impacts on wild stocks and farm fish vulnerable.

The Fish Health Protection Regulations are important for protecting both wild and aquaculture salmonids. New Brunswick has additional constraints on the movement of salmonids to reduce the risk of spreading specific fish diseases.

DFO must consider its mandated responsibilities for conservation and protection of the aquatic resources, as required under federal legislation, when establishing controls on the aquaculture industry. DFO is required to give the aquaculture the same consideration with respect to access

to aquatic resources as afforded other resources users. DFO must also consider provincial legislation and policies, and international commitments. Most of the international commitments contain good stewardship practices for conserving the natural resources. These agreements not only emphasize the federal government's commitment to protect the aquatic resources, but also establish a level and consistent operating regime and standards for industry, including trade.

The precautionary approach for managing fisheries is gaining acceptance, both nationally and internationally as governments recognize that past practices have not been sufficient to protect the aquatic resources. Implementation of the precautionary approach will put added constraints on industry if the impacts of certain activities are uncertain.

**A REVIEW AND ASSESSMENT OF MITIGATIVE MEASURES TO ELIMINATE OR MINIMIZE POTENTIAL IMPACTS OF FARMED SALMON OPERATIONS ON WILD ATLANTIC SALMON (*SALMO SALAR*) STOCKS**
**Res. Doc. 98/169**

**Working Paper(s):** DFO Working Paper 98/96

## Recommendations taken from Rapporteur Report

### Research Recommendation

1. Priority should be given to researching the tripoidization procedure as the most promising method of rendering farmed fish, and thereby potential escapees, reproductively sterile. Without sterilization the risks to the genetic integrity of the wild salmon stocks are significant from farmed escapees, even when the escapees are the offspring of strains derived from local stocks. As well, industry wishes to test and utilize strains of non-local origin, and ongoing research on transgenics is progressing towards their use in open cages on a production scale.

2. Genetic profiles of the existing strains of Atlantic salmon grown in Maine and eastern Canada should be created and testing procedures established to enable enforcement of introductions and transfers regulations.

### Management Consideration

1. Aquaculturists, salmon conservationists and governments should collaborate in the formulation and implementation of plans to reduce interaction between farmed and wild salmon, and on how to conserve any stocks adversely impacted. Plans should be aimed at a broad spectrum of measures including ways to improve containment, to ensure the production of healthy farmed salmon, and to restore and/or conserve impacted stocks. For wild stocks threatened with extirpation, consideration should be given to creating live gene banks and cryopreserving milt from the threaten populations.

2. The NASCO Protocols for the Introduction and Transfer of Salmonids should continue to be followed in regulating such activities considering the evidence that salmon continue to escape from hatcheries and farms and significant numbers are entering rivers and interacting with wild salmon. Consistent with these protocols, the culture of salmon derived from strains of European stock should continue to be prohibited unless the salmon are sterilized or their complete containment can be assured.

3. Conditions of licenses pertaining to both facilities and fish movements should be more rigorously enforced to ensure compliance. Examples of particular concern are fish "leaking" from hatcheries and the inadequacy of technology and procedures to effectively regulate fish transfers relative to genetic concerns.

4. Contingency plans to recapture farmed salmon escapees should be established for each marine farm to maximize the success of recapture operations.

5. Effort should be made to enhance awareness among aquaculture workers of the potential for farmed salmon escapees to adversely effect the wild salmon stocks.

6. A system for reporting escapees should be developed and made mandatory for both hatcheries and marine farms. The system should require immediate reporting of unusual and significant numbers of escapees (i.e., an event) and a year-end reporting of all known escapees.

7. Procedures should be established for identification, removal and disposal of all aquaculture escapees recovered in monitoring traps and as may be feasible and practical elsewhere.

## Recommendations taken from Paper:

### Conclusions

1. Large numbers of salmon are escaping from both freshwater hatcheries and marine farms and significant numbers of them are entering rivers and interacting with wild salmon (O'Neil 1998; Whoriskey et al. 1998).

2. Most wild salmon stocks in the areas where farm operations are located are well below their established conservation requirements and thereby vulnerable to harmful intrusion from farmed salmon escapees (Amiro 1998; Chaput and Marshall 1998).

3. Both need and opportunity exist to improve containment of farmed salmon and their health. Improvements in both these areas would benefit both conservation of the wild salmon stocks and the fish farming industry.

4. Development and implementation of contingency plans to recapture salmon escaping from marine farms would reduce the numbers of escapees and their interaction with wild salmon populations, and also benefit the industry. Plans should detail the procedures for reporting

the loss and the action to be taken, e.g., the method of capture, the area and time frame over which the recapture effort would take place.

5. Enforcement of existing regulations is inadequate. Examples include inadequate genetic testing procedures to support regulation of introductions and transfers and no investigation and follow-up enforcement of reported escapees from hatcheries.

6. Industry has a responsibility to conservation of the wild stocks as well as the success of its commercial enterprise. Because industry "buy-in" is essential to the successful implementation of any mitigative measure, industry must be involved in the development and application of such measures.

**Recommendations**

The following are management and research recommendations to mitigate the potential harmful effects of salmon farming operations on the wild salmon stocks. The lists are partial with the expectation that other specific recommendations will be brought forward in the other papers presented to the workshop.

**Management**

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**Research**

1. Priority should be given to researching the tripoidization procedure as the most promising method of rendering farmed fish, and thereby potential escapees, reproductively sterile. Without sterilization the risks to the genetic integrity of the wild salmon stocks are significant from farmed escapees, even when the escapees are the offspring of strains derived from local stocks. As well, industry wishes to test and utilize strains of non-local origin, and ongoing research on transgenics is progressing towards their use in open cages on a production scale.

2. Genetic profiles of the existing strains of Atlantic salmon grown in Maine and eastern Canada should be created and testing procedures established to enable enforcement of introductions and transfers regulations.

**OPTIONS FOR CONTAINMENT OF FARMED ATLANTIC SALMON**
**Res. Doc. 98/165**

**Working Paper(s):** DFO Working Paper 98/97

## Recommendations taken from Rapporteur Report

**Research Recommendation**

1. Develop certification procedures for all aspects of cage facilities including regular inspections to ensure construction and maintenance standards are respected.

2. Develop certification and licensing procedures for workers and on-site managers.

3. Development of contigency measures.

# Recommendations taken from Paper:

### Conclusions

The potential exists for negative impacts on the genetic structure of wild Atlantic salmon populations where they interact with escaped farm conspecifics. Reductions in recruitment rates affecting population viability are expected as well as associated changes in population character.

The likelihood that the outcome of any interaction will be positive, with regard to population viability at least, is small. Wild salmon populations are genetically adapted to local environmental conditions and most genetic changes will reduce mean survival and reproductive success.

As the proportion of farm salmon and their adaptive differentiation from the wild population increases, the likelihood of a negative impact on population viability, and change in population character, increases. Natural selection can only be expected to prevent negative genetic changes in subsequent generations where proportions of farm salmon are relatively small. For populations already in decline this proportion will be smaller than for healthy populations.

Safe levels of farm escapes cannot be specified and the precautionary principle must be used to guide management. Where escapes cannot be eliminated, interactions should be minimized by minimizing numbers of escapes and their genetic differences with wild stocks and making them reproductively incompetent.

The capacity to accurately identify and quantify risk, and remedy impact, can be increased by empirical and theoretical research which takes advantage of developments in molecular biology which allow the specific genetic characteritzation of individual salmon and salmon populations. Future research should use these developments to monitor the inputs and outcomes of existing interactions and to develop a deeper understanding of the nature and extent of local adaptation in Atlantic salmon populations.

**USE OF TRIPLOID ATLANTIC SALMON (*SALMO SALAR*) FOR AQUACULTURE**
**Res. Doc. 98/166**

**Working Paper(s):** DFO Working Paper 98/98

# Recommendations taken from Rapporteur Report

### Research Recommendation

1. What are the optimum culture requirements for triploid Atlantic salmon? Research is required to:
   a. Determine environmental tolerances and optima regarding;
      - temperature
      - oxygen

- salinity
- nutritional requirements
- disease resistance

b. Remedy the problem of jaw deformities.

c. Determine ecological consequences of interactions of triploid salmon with wild salmon regarding;
   - migratory behaviour, especially in relation to freshwater homing
   - interactions with other species
   - potential life span of triploids and likely changes in ecological impacts with increasing size.

**Management Consideration**

1. All-female, triploid Atlantic salmon will effectively eliminate concerns about genetic impacts on wild salmon populations; however,

2. Performance of all-female Atlantic salmon has proven too variable for use by the aquaculture industry. Such variability in performance is a liability to aquaculture industry viability. Husbandry practices would have to be worked out to the extent of ensuring predictability of performance of triploid Atlantic salmon in order for this approach to be adopted by and financially justifiable to industry.

**Other**

Resource managers need to be aware that technologies imposed on the industry have serious economic implications to industry development and stability. Care should be taken when considering resource management options that the strategies being considered are in fact workable. Dictates that drive the industry to collapse do no one any good.

# Recommendations taken from Paper:

**Research Recommendations**

1. Although pilot-scale aquaculture results with triploids to date have not been good, they certainly have not been disastrous. In fact, if one accepts the suggestion (Benfey 1996b) that triploids should be considered as a "new species" for aquaculture development, then initial results with triploids are rather encouraging. Once optimum rearing conditions are determined for triploid Atlantic salmon, they may prove to be just as good as, if not better than, diploids as production fish for aquaculture. A general recommendation, therefore, is that research be conducted on determining the optimum culture requirements for triploid Atlantic salmon. More specifically, research is needed on determining environmental tolerances and optima (temperature, oxygen, salinity, etc.), nutritional requirements (energy, micronutrients, etc.), disease resistance, and behaviour (aggression, competition with diploids, etc.). The specific problem of lower jaw deformities must be addressed, but this likely relates to nutrition.

2. Although triploids are sterile, this does not preclude the fact that they may have unexpected ecological effects should they escape or be intentionally released into the environment. A second general recommendation is therefore that research be conducted on the ecological impacts of triploids in natural environments. More specifically, research is needed on migratory behaviour (especially in relation to freshwater homing), interaction with conspecific diploids and other species, and life history characteristics (e.g., lifespan). Although such research could perhaps be addressed through laboratory experiments, I would advocate some controlled releases of all-female triploids for a more comprehensive evaluation of ecological impacts. In light of regular escapes of diploid salmon from aquaculture facilities, I do not see any added risk from such an experiment.

3. It should be remembered that techniques other than induced triploidy can be used to sterilize fish, and that perhaps better methods are available to do this on a commercial scale with salmon. A final recommendation is, therefore, to support research directed towards the development of alternative methods for producing sterile salmon (and other species) for aquaculture.

### OPTIONS FOR CONTROLLING DISEASE AND IMPROVING THE HEALTH IN FARMED SALMON, AS A MEANS OF REDUCING RISKS POSED BY ESCAPES
**Res. Doc. 98-167**

**Working Paper(s):** DFO Working Paper 98/99

## Recommendations taken from Rapporteur Report

### Research Recommendation

1. We need to discover new and improved indicators of "stress" in farmed fish.

2. We need to determine the optimal and effective fallowing periods in farms in order to break disease cycles.

3. We need to determine stocking densities that are "ideal' for stress reduction.

4. We need to improve our diagnostic screening methods for diseases.

### Management Consideration

1. Improve upon disease prevention with methods that replace chemotherapy, e.g., further improvements in husbandry; increased fallowing and area management agreements.

2. Development of codes of good practice linked to QA schemes (verification of compliance).

### Conclusions

1. The movement of live fish, fish carcasses and equipment between areas carries the greatest risks of introducing new infectious agents and disease to an area. Several serious disease incidents in wild salmon populations have been directly associated with these.

2. Fish farms often carry elevated levels of locally endemic disease in their stocks, which are likely to transfer to the wild with any escaped fish. No serious disease incidents have been shown to be associated with the escape of such fish.

## Recommendations taken from Paper:

### Conclusion

1. The movement of live fish, fish carcasses and equipment between areas carries the greatest risks of introducing new infectious agents and disease to an area. Although the main risks linked to live fish movements have been identified and are being controlled by legislation, several serious disease incidents in wild salmon populations have been directly associated with these.

2. Fish farms often carry elevated levels of locally endemic disease in their stocks which are likely to transfer to the wild with any escaped fish. No serious disease incidents have been shown to be associated with the escape of such fish.

### Research Recommendation

1. There is a need for continual improvement in the diagnostic screening methods for infectious agents in live fish populations which are being moved between different areas, to further reduce the risk of the introduction of exotic diseases.

2. There is a need for improvement in disease prevention methods in fish farms to reduce the levels of infectious agents present and to progressively replace chemotherapy.

**FACTORS AFFECTING THE HEALTH OF FARMED AND WILD FISH POPULATIONS: A PERSPECTIVE FROM BRITISH COLUMBIA**
**Res. Doc. 98/168**

**Working Paper(s):** DFO Working Paper 98/100

## Recommendations taken from Rapporteur Report

### Research Consideration

Although not mentioned per se, there seems to be a need for more information on the impact of chronic and acute stress and the duration and impact of various stressor events.

### Management Consideration

1. There is a need for information on levels of disease organisms (pathogen identity, prevalence and location [geographic and by species]) in the Maritimes Region. Properly designed surveillance programs should be instituted, possibly based on that of the Pacific Region's large database on pathogen and parasites in pacific salmon (and the smaller database on other marine species).

### Management considerations listed in MS

1. *Regulations:*
    - regulations to help reduce the likelihood of importing exotic pathogens to the area.
    - site regulations that require a 3 km distance between salt water sites, and that sites not be within a certain 1 to 3 km of salmon bearing rivers.

2. *Husbandry:* Reducing stress in fish farms can be achieved by good predator control/ evasion strategies, reduced handling of the fish, and when handling is necessary, using extreme care.

3. *Vaccines, etc:* increase fish's resistance to pathogens through the use of vaccines and good nutrition (acquired resistance).

4. *Screening:* screening smolts before seawater entry or screening broodstock is a common practice used by fish farmers to reduce the prevalence of certain important pathogens.

5. *Water Control:* Hatcheries with well water have in general fewer pathogens than those using surface water, and some facilities have the ability to ozonate their surface water supply which reduces the pathogen contamination in incoming water.

6. *Removing Infected Fish*

7. *Year-class Separation:* Stocking fish as single year-classes at individual sites is very beneficial for reducing transmission of diseases at netpen farms.

8. *Fallowing*

9. *Densities.* Another method of reducing exposure to pathogens is reducing the stocking density in pens or tanks in an aquaculture facility.

## Recommendations taken from Paper:

### Consideration

Assessing the risk of increased disease in wild fish due to aquaculture activities with any significant precision is a very complicated task and requires much more information than is currently available. One must evaluate a number of factors which affect host, environment, and pathogen, and determine the way that these factors affect the interaction of these three elements to ascertain

whether disease occurs or not. Then one must evaluate whether a few diseased animals in the population will lead to a disease outbreak that will affect the population significantly. Each disease and each species needs to be assessed in each circumstance in order to make rational regulatory decisions. Nevertheless, reducing diseases on farms will certainly benefit the industry, and reduce the risk of transmission of such diseases to wild fishes, regardless of the real or perceived risk. Finally, it is crucial to remember that the fish reared in government hatcheries for release into the wild are cultured using similar husbandry technology and practice as those used for commercial aquaculture. The experiments by Salonius and Iwama (1993) were conducted on government hatchery salmon. The much needed research in this area will therefore serve management and policy decisions which will be relevant to natural stock enhancement as well as to the interactions between wild and salmon produced in netpens for food.