Speaking for the Salmon

Conveners Report

Scientists' Roundtable on Sea Lice and Salmon in the Broughton Archipelago Area of British Columbia

Morris J. Wosk Centre for Dialogue
Simon Fraser University, Vancouver, BC
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This report prepared by
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Linking Science and Local Knowledge Node of the
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THE ROUNDTABLE PROCESS

Twenty-five scientists including those conducting research on sea lice and pink salmon in the Broughton Archipelago, or with extensive knowledge of salmonids and (or) sea lice, came together in a one-day Roundtable meeting and discussed the subject of sea lice and pink salmon in the Broughton Archipelago. Participation in the Roundtable was by invitation and the event took place on November 18, 2004. A list of participants is found on page 10.

In keeping with the spirit of a Roundtable discussion, with the exception of the opening presentation by an invited speaker from Scotland, there were no formal presentations; rather, as the day's discussions evolved, data and observations were shared when appropriate and relevant to the topic under discussion. The Roundtable was chaired by the Honorable John Fraser, Chair of the Pacific Fisheries Resource Conservation Council.

What follows is a summary of the discussions. This report does not represent a unanimous consensus of the participants.

Statement of Agreement

Based on the weight of evidence approach, participants generally agreed on the following statements as a reflection of their understanding of the impact and significance of sea lice for wild salmon in BC:

1. Salmon farms contribute sea lice to wild fish.
2. In Central British Columbia there are more sea lice (*Lepeophtheirus* spp) on juvenile wild fish near farms.
3. Sea lice can kill juvenile fish, even at low infestation levels. The lethal load varies with environmental conditions, fish size and cumulative stress. Limited evidence suggests that levels that appear to be lethal are found near fish farms.
4. The risk factors (e.g., geographic, channel morphology, salinity and temperature, presence of large and healthy runs, size of wild salmon population) contribute variability to sea lice incidence and lethality.
5. There is suggestive evidence of population impacts.
6. Raw data (temperature, salinity, stocking density, sea lice incidence, treatment regimens) from fish farms are crucial to research and management and we need to be able to verify those data.

The weight of evidence came primarily from the current knowledge of salmon and sea lice in Europe, Atlantic Canada and the Broughton Archipelago shared in the day's discussions.

"The ICES workshop in Europe concluded that in Europe where there are salmon farms there are more sea lice."

"Norway had (and still has) a problem with sea lice. Scotland and Ireland and then eastern Canada were also faced with a sea lice problem when salmon aquaculture was introduced. Now, on the west coast we have a problem. This is not magic. Sea lice kill salmon."

Invited presentation
Margaret McKibben, Biologist and Field Station Manager, Loch Shieldaig Field Station, Scottish Freshwater Research Services

Sea lice in Loch Torridon, Western Scotland: planktonic distribution, interactions with sea trout, larval transport modelling and the impacts of fish farms.
M.A. McKibben, P.A. Gillibrand, D.W. Hay, S. Murray & M.J. Penston.

Sea trout, *Salmo trutta,* numbers on the west coast of Scotland have fallen over the last thirty years. This decline has been linked to reduced survival in the marine phase. Lice infection may have a detrimental impact on the survival of wild smolts soon after entering seawater. Plankton samples collected over the last five years from near shore and offshore sites have shown higher levels of sea lice copepodids in the second year of the salmon farm production cycle. Very high levels of sea lice copepodids were found in near shore areas (> 100 m^3). Such high levels of copepodids have not been recorded previously outside fish farm cages. The seasonal cycle of larval sea lice abundance in samples taken weekly for over three years closely matched the local fish farm production cycle and sea lice infestation rates on the farm.

A particle tracking model has been produced for Loch Torridon showing the movements of passive particles in the surface layer using simulated advection and diffuse currents. The model indicates that the area of highest risk is often several km from the source farm.

Early returning post smolt sea trout are a phenomenon that has been studied since the late 1980s. In the River Shieldaig in western Scotland a sea trout trap allowed a detailed study. The presence/absence of early returning post smolts and the level of sea lice infection was examined over five years and the results related to the stage of the local fish farm production cycle. The results indicate that early returning sea trout smolts with high numbers of sea lice are mainly seen in the second year of the production cycle and are very low in the first year of production when ovigerous lice levels on local salmon farms are zero.

Area Management Agreements: The Tripartite Working Group set up by the Scottish Executive initiated the formation of Area Management Agreements (AMA) along the west coast of Scotland with the aim of bringing together representatives of the aquaculture industry and wild fish interests and improving local fisheries management. A major target of the AMAs is to improve sea lice control and integrated pest management with the aim of reducing lice burdens on both farmed and wild fish.

All AMAs are voluntary. Data are shared within the AMA but subject to a confidentiality clause. The formation of the Loch Torridon Area Management Group has improved the study of sea lice in Loch Torridon. Before the formation of this group we were unaware of the levels of sea lice on the neighbouring fish farms during our sampling periods. Once we were able to exchange sea lice data with the fish farmers a greater understanding of the sea lice patterns of abundance and distribution was achieved.

Discussion following the presentation was centered on the apparent link between declines observed in sea trout returns with the introduction of salmon farming and cooperation of the salmon farming industry and the sharing of their information.

Although declines observed in sea trout numbers could be related to a number of factors including poor marine survival, poor management or climate change, Margaret McKibben stated that most Europeans have accepted the link between the onset of farming and the decline in wild sea trout. Their results clearly demonstrate: planktonic sea lice levels are significantly higher near the farms, and; the pattern of planktonic sea lice dispersal from these regions throughout the loch.

With respect to the cooperation of the salmon farming industry, the AMAs are a voluntary process and to date have been very effective. Through the AMAs industry is working towards synchronized treatment and synchronized fallowing. *"The farms have started talking to one another (they never used to). They started communicating amongst themselves and then with government and the public."*

What follows is a summary of the collective knowledge and experience of the participants that was shared during the discussions of the Roundtable. Comments in quotation marks were made by participants unless designated otherwise.

WHAT WE KNOW ABOUT SEA LICE AND SALMON*

> ** " Research results are always 'suggestive', never conclusive. Fault can be found with any individual study, whether in the laboratory or field. It is the weight of evidence from several studies combined that is important, and lets one conclude that sea lice transfer from farm to wild fish."*

Effects of fallowing
Results of a recent study (North American Journal of Fisheries Management, in press) show that there was a significant drop in sea lice loads on juvenile wild salmon sampled near three of the farms in the Broughton Archipelago that were fallowed in 2003. In 2004 the lice loads on wild juvenile salmon sampled at these sites increased significantly and substantially when these same farms were not fallowed.

The nature of parasitic diseases – sea lice infections in juvenile salmon
• Stress
When animals are stressed, for example confined in a small area in high densities (such as in salmon net cages), they are more prone to parasitic infection. Sea lice outbreaks are therefore to be expected on salmon farms.

When animals that are already stressed (such as smolting juvenile wild salmon) encounter additional stresses such as infection with sea lice, the impact can be lethal. The more factors contributing to this cumulative stress the more debilitated the organism becomes and the greater the chance that it will die.

Even if individual fish survive the lice infections this does not mean that they do not suffer from long term impacts of parasitism. They may be compromised in some other way (e.g., reduced capacity to avoid predation or reduced reproductive capacity).

• Knowledge of sea lice species and life cycle and damage to host
Two genera of sea lice are found on juvenile pink salmon in British Columbia, *Caligus* and *Lepeophtheirus*. In the Broughton Archipelago infestation is primarily by *Lepeophtheirus*.

There are conflicting reports of physical damage to the skin of the juveniles. Some report no significant damage to the skin. Others have observed puncture holes. Puncture holes contribute to cumulative stress, especially in terms of osmoregulation in already challenged smolts. In comparing the susceptibility of Atlantic salmon juveniles with pink salmon juveniles a participant commented

"Atlantic salmon are like armoured cars and therefore you do not see lesions. Pink salmon are coming out at around 3 cm with hardly any scales and are virtually naked. You can see the holes easily."

Therefore, you would expect *Lepeophtheirus* to have a greater impact on pink and chum salmon juveniles than on Atlantic salmon juveniles and hence the lethal load would be expected to be lower.

Report on sea lice collected in May 2004

Mick Burt, Professor Emeritus (Parasitology), Biology Department, University of New Brunswick

During a visit to the Broughton at the end of May, 2004, several samples of juvenile pink and chum salmon were collected as well as a number of sticklebacks. These were heavily infected with sea lice and were fixed in 70% ethanol and placed in vials for later identification of the attached sea lice. Half of the vials were given to Dr. Z. Kabata, the leading international authority on parasitic copepods, stationed at the Pacific Biological Station of Fisheries and Oceans, Canada. I retained the other half for later examination of the fish skin.

The prevalence of infection (number infected in relation to number examined) was high (95%; n = 40); the mean intensity of infection (average number of copepods on infected fish) was 3.34.

Dr. Kabata identified all the lice he examined as *Lepeophtheirus salmonis* (with one minor exception – an immature *Caligus* sp. on a stickleback). These were found on all species of fish:

Four sticklebacks: one with an ovigerous female; the rest with immature stages
Thirteen pink salmon: all stages present, from chalimus to adult males and females.
Three chum salmon: infected with chalimus and immature stages.

My examination of the fish skin, both at the time of collection and upon my return to UNB, showed paired lesions, consistent with the spacing of the copepod's maxillipeds used in attachment to the host. The attachment was observed in the field when I pulled some copepods off the infected pink salmon and saw the holes left in the skin.

The use of Condition Factor to measure impact of sea lice in juvenile salmon*

Results were reported indicating no significant impact of sea lice on juvenile pink salmon as measured by Condition Factor. Participants agreed that there is a disparity between these observations and what is logical (i.e., infestation with a parasite means reduced condition). This brings into question the use of Condition Factor as a suitable measure of fitness in juvenile pink salmon. For example, the possibility exists that fish with a high Condition Factor may be able to tolerate high sea lice loads whereas fish with a low Condition Factor may die with low lice levels. Further, there is the issue of timing and life cycle – smolts are growing rapidly and changing shape and condition factor measures do not take this into account. It is logical to conclude that Condition Factor is insensitive to long-term effects. In Scotland they do not use Condition Factor as a measure of fitness – the smolts are changing too fast – although it can be used for adult fish.

It was generally agreed that Condition Factor alone is not an appropriate tool to measure fitness in juvenile salmon and alternative tools, such as swimming trials, must be considered for assessing fitness. Experimental work is needed to determine what measures of condition are significant in determining sea lice impact on salmon.

* Condition Factor ($k = 100 \times \text{weight}/\text{length}^3$)

Lethal load

Evidence from field experiments that examined the relationship between sea lice load and mortality in pink salmon juveniles was shared with participants by Rick Routledge and Alexandra Morton (publication under review). Below is an abstract of the findings of this research.

Mortality rates for pink and chum salmon (*Oncorhynchus gorbuscha* and *keta*) infested with sea lice (*Lepeophtheirus salmonis*) in the Broughton Archipelago

Richard Routledge, Chair, Statistics and Actuarial Sciences, Simon Fraser University and
Alexandra Morton, R.P.Bio., Raincoast Research

Juvenile pink and chum salmon were collected in the Broughton Archipelago, measured, and examined for lice. Fish were sorted into groups of 60 by species and number of sea lice, and these groups were placed into 18, 189 and 132 l. flow-through barrels. The capture sites were situated 2.5 - 5 km distant from the barrels.

There were three consecutive trials. Sea lice categories and fish species compositions varied from series to series according to availability of wild fish and maturity and abundance of sea lice infestations in the vicinity of the holding facility. Within each set (statistical block) of 3-4 barrels, all were identically oriented with the individual barrels randomly sequenced. Because the facility did not allow four categories per set, categories were assigned to barrel sets according to an incomplete block design.

In each trial, significantly more fish died in the categories with sea lice than in the lice-free category. The majority of fish that died were infected with motile-stage sea lice, although some did die with chalimus III/IV stage sea lice. Fish condition factor at the time of sampling was not significantly related to sea lice infestation level. Yet for fish that died, the condition factor appeared to have declined rapidly prior to death from the distribution of values at time of capture. These observations indicate that short-term mortality of juvenile pink and chum salmon is increased by infestations of 1-3 sea lice, and that condition factor levels in sampled fish cannot be used to assess even short-term mortality from sea lice infestations.

In the ensuing discussion, participants noted the proportional relationship between effects of sea lice on juvenile pink salmon and size of the fish as well as the sea lice load considered to be lethal for juvenile Atlantic salmon (average size 10 g) that ranges from 0.7 – 1.4 lice per gram. The average weight of pink salmon smolts swimming past fish farms ranges from less than 0.5 g to greater than 2.0 g later in the migration season.

Evidence of impact of sea lice on pink salmon juveniles in the Broughton Archipelago
Discussion revolved around the disparity between two sets of results reporting on impact or lack of impact of sea lice on juvenile pink salmon in the Broughton Archipelago. It was agreed that both sets of results are real but there was no obvious reason for this disparity. *"What people are reporting is honest. They just do not fit."* These conflicting results from two studies that used similar scientific protocols reflect the difficulty in obtaining conclusive results over the short term (e.g., two or three years) from a complex ecosystem with significant inter-annual spatial and temporal variation. If information from studies such as these is to be meaningful then there will need to be a commitment to continuing this work over the long term.

"There are a lot of data on the table showing valid impacts of sea lice on salmonids. There is a failure to explain the variability. How long can we discuss the evidence before something cataclysmic happens?"

Another approach to studying this complicated question was described by Martin Krkosek.

Transmission dynamics of sea lice from farm to wild salmon and effects on wild salmon populations

Martin Krkosek, MSc Candidate, Depts of Mathematical & Statistical Sciences and Biological Sciences, University of Alberta

Understanding the impact of salmon farming via parasitic sea lice on wild salmon populations requires understanding of (1) how farmed salmon alter the natural transmission dynamics of lice; and (2) how novel transmission dynamics affect wild salmon populations. A mathematical modelling framework was developed that can integrate disparate field and experimental datasets to quantitatively assess both points (1) and (2). Preliminary data and analyses were presented that illustrate an application of the methods.

In ensuing discussion, considerable interest was expressed in the use of this model to predict the population impact of sea lice infestation on adult pink salmon returns. Further discussion focused on the advantages of using corroborative evidence from abundance patterns of copepodid stage lice that could be found by direct sampling of copepodids in regions around the fish farms.

Incidence of sea lice in areas without farms
Results of a recent published study show that the Broughton Archipelago has higher sea lice levels than in adjacent regions in Central BC where there are no salmon farms. There is also evidence that sea lice occur more frequently in areas with fish farms. A participant noted that in Alaska, with no fish farms, sea lice have not been observed on juvenile salmon in significant numbers.

On the north coast of BC, an area currently without salmon farms, most of the sea lice observed on pink salmon are *Caligus* spp (early stages). *Lepeophtheirus* spp. are rare and infestation is of low intensity.

"There is a geographic pattern of smolt occurrence on the coast. That knowledge would benefit both aquaculture and the wild salmon. On the north coast applications for the first farms are under review. We have to get to the place where we acknowledge that there is a potential problem."

WHAT WE DO NOT KNOW AND NEED TO KNOW

During the course of the day's discussions participants identified a number of gaps in our knowledge of sea lice and pink salmon in the Broughton Archipelago.

Salmon farm data
Participants stressed that open access to all salmon farm data is an absolute requirement. Without this information we do not have a 'control' for other research findings. Some companies have been more forthcoming in sharing their data than others; however, what is needed is all raw data, as opposed to averages, for all relevant factors from all the industry participants including species, incidence, life stage and fecundity, and treatment regimens. Similar to the work described for Scotland, we need to be able to correlate the planktonic stages of sea lice and their distribution with location of farms and routes taken by outmigrating smolts.

Sea lice life cycle and species interaction and life cycle of Pacific salmon
We do not fully understand the life cycles of both genera of sea lice species, *Caligus* and *Lepeophtheirus*. We need to know the spatial (geographic and planktonic) and temporal distributions of each species. We also need to know about the life cycle of Pacific salmon (*Oncorhynchus*) compared with Atlantic salmon

(*Salmo*). For example, pink salmon have a two year life cycle – is one age class more vulnerable to parasitic infection than the other? Does the fact that there are multiple hosts affect the degree of infestation? It was felt that much of this information may be available in the literature – we need a comprehensive review of available information.

Effect of fallowing
There is compelling evidence from Scotland with respect to reduction in sea lice infestation of juvenile salmonids as the result of fallowing practices. There is only one published study showing similar effects for the Broughton Archipelago. We need long-term (e.g., five year) studies to examine the effects of fallowing on sea lice infestation of out-migrating juvenile Pacific salmon. To date only one partial fallowing has occurred in this area – in 2003, approximately half of the 27 farms were fallowed.

We need to know if the fallowing of one channel benefited the Broughton Archipelago as a whole.

Effect of salinity, temperature and other risk factors
The fjords of BC, where juvenile salmon emerge and outmigrate, are complex ecosystems. There is a high degree of inter-annual variation for a number of the abiotic and biotic factors that contribute to stress in the outmigrating juvenile fish. We need comprehensive information on these risk factors so as to predict which temporal, spatial and environmental factors are likely to be the most significant contributors to the susceptibility of juvenile fish to infection.

Long-term impacts on pink salmon populations in the Broughton Archipelago
We need to examine the transferability of data from the findings in Europe and Atlantic Canada to the Pacific with regard to population impacts of sea lice infestation.

"Sea lice have always affected wild salmon, but intensive farming has increased the size of the problem. It is now one of the biggest issues for salmon aquaculture in many areas of Scotland."
Chapter 6, 6.88, Turning the Tide, T. Blundell, Royal Commission on Environmental Pollution's Report, December 7, 2004.

Two or three years of data are not sufficient to draw conclusions about the long-term effects of sea lice on pink salmon populations. There is much inter-annual variation. For example, the frequency of sea lice in a population can be dependent on environmental quality (e.g., if growth conditions are good then the load may not matter).

We need to approach the problem with laboratory studies and seek commitment for funding of long-term field studies. Studies such as those described by Rick Routledge and Alexandra Morton and Martin Krkosek should be given a high priority for financial support in 2005.

Planktonic distribution
We do not have sufficient information on louse planktonic distribution in the Broughton Archipelago. Plankton sampling was carried out in Summer 2003 and the results were not conclusive – there were very few lice and results were not correlated with sea lice abundance on farms. Plankton sampling was not conducted in 2004. Participants stressed that this information is important given the inter-annual variation. They stressed the need for future plankton distribution studies in the Broughton similar to those conducted in Loch Torridon in Scotland.

Sea lice treatment regimes
The ecological effects of the major therapeutant, SLICE, are unknown – this is still under review by Health Canada. Other approaches in controlling sea lice infections are worth pursuing. The use of immuno-stimulants as a prophylactic measure should be investigated.

Incidence of sea lice on wild fish and placement of salmon farms
We do not know if there are areas that have a natural abundance of sea lice. This information would assist in placement of farms in the future so that these areas could be avoided. Similarly there are areas that are critical to juvenile rearing which should be avoided. In addition, spatially there are areas that should be avoided (e.g., long narrow channels) in placement of new farms.

RECOMMENDATIONS FOR FUTURE RESEARCH

Participants stressed the **urgent** need for information and research plans. It is now December 2004 and the pink salmon will begin their out-migration in February or March 2005. The Chair advised participants to put aside the issue of available funding – if this information is critical, then the agencies should commit the funding for this research.

Participants identified the following specific research areas as being of high priority.

1. Study the impact of fallowing over at least a five year period. However, given the life cycle of the sea lice it may be difficult to begin these studies in 2005 unless immediate action is taken. It is imperative that plans be put in place now for 2006.
2. Continue monitoring of infections rates and escapement data, and collect baseline data. However, while this is important, monitoring can only document lice levels in relation to geography and time, and cannot be extrapolated to determine mortality.
3. Do laboratory and field studies similar to that described by Routledge and Morton to determine lethal loads and impact. Lethal loads will depend on a number of abiotic factors that can be manipulated under laboratory conditions.
4. Correlate this work with modeling of sea lice distribution such as described by Martin Krkosek. Investigate the transmission dynamics from farmed to wild fish and how these transmissions affect the wild salmon populations. Use this modeling as a tool for making predictions regarding population impacts of lice infestations.
5. Conduct planktonic distribution studies, using appropriate sampling methodology, in areas adjacent to salmon farms in the Broughton Archipelago similar to the previous work in 2003, and the work conducted in Loch Torridon, Scotland.
6. Determine how juvenile salmon behaviour is affected by lice load.
7. Conduct swim trials correlated with lice load as an alternative assessment of fitness.
8. As a means of understanding better the relationships between sea lice and juvenile salmon a review of all literature related to sea lice life cycles of both *Lepeophtheirus* and *Caligus* as well as of Pacific pink salmon life cycle should be conducted immediately. Determine what is known about the intensity, prevalence and occurrence of sea lice species in coastal BC.
9. Investigate the use of immuno-stimulants as an alternative (prophylactic) treatment for sea lice infections, thus potentially reducing the use of chemicals and antibiotics in the farms.
10. Determine what level of recruitment failure can be sustained for the pink salmon of the Broughton Archipelago to remain a viable and healthy population.

RECOMMENDATIONS FOR MANAGEMENT ACTIONS

Again participants stressed the **urgency** of taking immediate action. In the absence of conclusive information about the impacts of sea lice on the pink salmon runs in the Broughton Archipelago the Precautionary Approach should be invoked in some form given the weight of evidence that exists. We should take heed of the European experience that indicates that regulations can substantially reduce the impacts of sea lice on wild salmon.

Industry Collaboration and Area Management Agreements
It is critical to immediately gain access to all existing data of the salmon farming industry in the Broughton Archipelago. The cooperation of the industry is key to ensuring the co-existence of a sustainable aquaculture industry and healthy wild salmon stocks.

Fallowing should be strongly considered as a management option for reducing infestation rates on the 2005 outmigrating salmon; a fallowing action plan should be developed immediately.

We should put in place in British Columbia a system of Area Management Agreements similar to those described for Scotland. Some measures that succeeded in the Scottish experience include selecting sites that have the least impact on wild salmon and synchronized treatment of sea lice (fallowing and baths) to avoid re-infection. No single approach to understanding the problems or implementing solutions will suffice so it is crucial for industry, communities and government to work collaboratively on these plans.

Independent review
There should be an immediate **independent** comprehensive review of all sea lice and salmon related research. This would address some of the discrepancies between the results described during the Roundtable discussions. The terms of reference for such a review are as follows:

1. Involve all stakeholders
2. Document the level of public concern
3. Review the state of knowledge of lice (define the species) in particular on the Broughton Archipelago and extrapolate from it to the Broughton situation. Tap into presently unavailable data.
4. Arrive at an assessment of the sea lice risk to Broughton farmed and wild fish.
5. Define management actions for immediate implementation to counter risk.
6. Define science/monitoring programs to document impacts of the management actions, and to provide necessary new knowledge.

Policy for salmon farm expansion
Plans are underway for expansion of salmon aquaculture in other 'virgin' areas of the BC coast. It is proposed that policy for new farms be amended to include the provision of monitoring prior to approval for licensing. Monitoring of a proposed farm site should commence one to two years prior to the commencement of farming and up to five years after the introduction of the farm.

Funding
Funding for research into the sea lice and pink salmon issue in the Broughton Archipelago should be of the highest priority.

Invited Participants

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For information about other Speaking for the Salmon initiatives on sea lice and other topics visit our website at www.sfu.ca/cstudies/science/salmon.htm or contact us at

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