SIMON FRASER UNIVERSITY

Speaking for the Salmon

Workshop Proceedings

A Community Workshop to Review Preliminary Results of 2003 Studies on Sea Lice and Salmon in the Broughton Archipelago Area of British Columbia

Inner Coast Natural Resource Centre
331 Larch Street, Alert Bay, BC,
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WORKSHOP HOSTS

The ***Centre for Coastal Studies at Simon Fraser University*** is the home of the *Linking Science and Local Knowledge: Building Capacity for Integrated and Sustainable Management of Coastal Resources* node which is one of three nodes of the national Ocean Management Research Network (OMRN) from SSHRC/DFO Joint Initiatives. The main objective of this node is to link scientific knowledge with local knowledge for improved, sustainable oceans and coastal management, and to assist Fisheries and Oceans Canada with an ecosystem approach to ocean resource management.

The ***Inner Coast Natural Resource Centre*** is an association with membership of 22 organizations comprised of educational institutions, First Nations, Business Groups, Non-Profit Societies, and Senior Governments having interest in Northern Vancouver Island and its natural resources, culture, and communities. The Mission of the ICNRC is to provide a forum for North Island Communities that recognizes, enhances and sustains social, cultural, economic, and environmental values. By sharing the wisdom of the elders and the historical perspectives of the residents with the research and academic communities we hope to provide the information tools that will promote, encourage, and support responsible and accountable decisions in partnerships with First Nations and other governments, communities, local organizations, business, and industry.

ACKNOWLEDGEMENTS

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Thanks to all presenters who shared their research and perspectives in an effort to better understand the sea lice issue in British Columbia.

We also gratefully acknowledge the financial support from the Linking Science with Local Knowledge: Building Capacity for Integrated and Sustainable Management of Coastal Resources (LSLK) Node of the Oceans Management Research Network.

The OMRN is a national network of cross-disciplinary and multisectoral research nodes dedicated to oceans management. The OMRN is, in part, a response to the Oceans Act, serving as a research instrument to advance the implementation of Canada's Oceans Strategy.

This report is the fourteenth in the Speaking for the Salmon Series. For information about past and future Speaking for the Salmon projects, please visit our website at: http://www.sfu.ca/cstudies/science/salmon.htm.

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Several scientific studies on sea lice and salmon have been conducted in the Broughton Archipelago and Central Coast areas of British Columbia in 2003. To foster a two-way exchange of scientific and local knowledge, this workshop was hosted by the Centre for Coastal Studies at Simon Fraser University and the Inner Coast Natural Resource Centre to examine the preliminary results from these recent studies in an effort to make recommendations for action and to identify areas for further research on these issues in a timely manner.

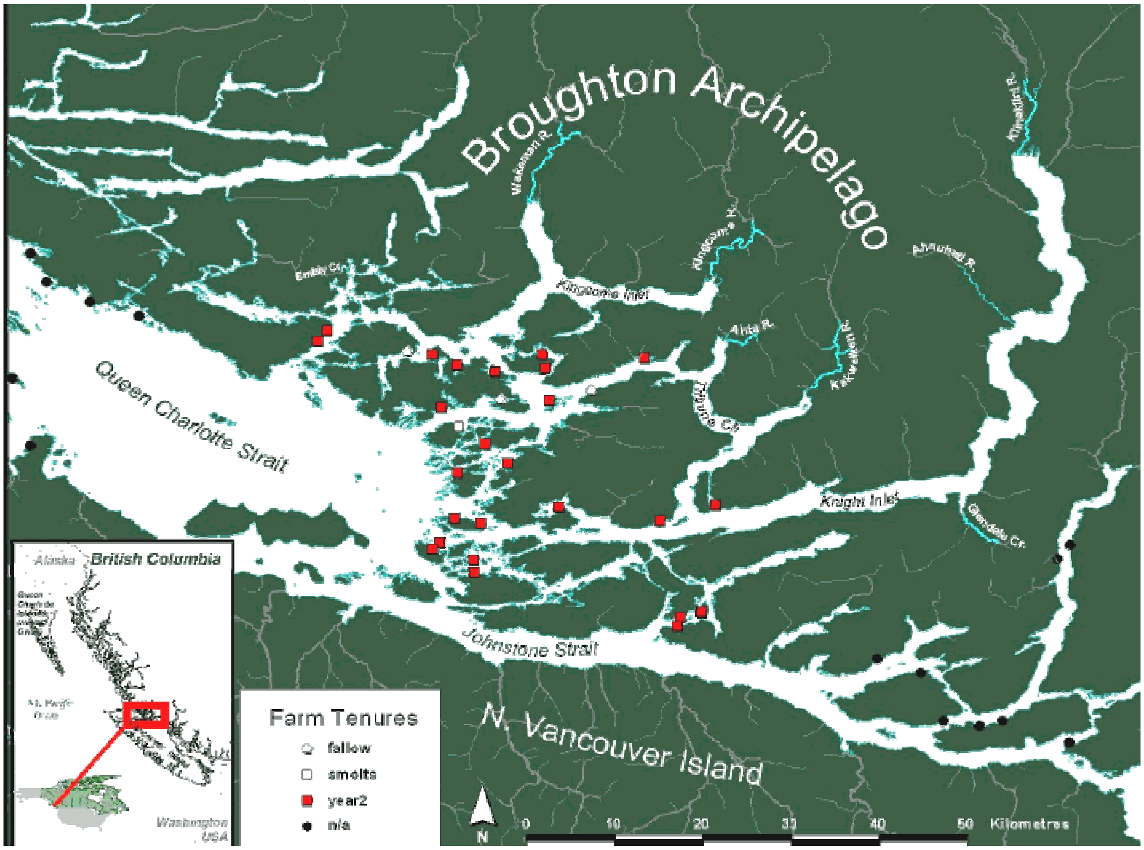

Figure 1. Broughton Archipelago, BC.

STATUS OF THE PINK SALMON ACTION PLAN

John Pringle, Manager, MEHSD, Fisheries and Oceans Canada, Sidney

A brief history of the involvement of the Department of Fisheries and Oceans in sea lice infestation of salmon was described. DFO has been examining fish health issues for salmon since 1960. A seminal paper, published in 1964 (Parker and Margolis 1964) was the first to report on an infestation of pink salmon with sea lice. In 1993/1994 a number of salmon farms in the Bay of Fundy, NB, reported sea lice infestations of Atlantic salmon. This was followed by a Science Strategic Funds (SSF) study on sea lice and Atlantic salmon from 1993 – 1997. In 2000, a study was implemented at St. Andrews Biological Station, NB, to determine the effectiveness of the therapeutant SLICE in controlling sea lice infections in Atlantic salmon; this work is ongoing. In 2003 the Pink Salmon Action Plan was conducted in the Broughton Archipelago, BC directed by DFO.

The objectives of the Pink Salmon Action Plan were to: monitor abundance and distribution of juvenile salmon in and adjacent to the Broughton Archipelago; and, to quantify temporal and spatial differences in prevalence and intensity of sea lice infections, where *prevalence* is the percentage of juvenile salmon that are infected with sea lice, and *intensity* is the number of sea lice on each infected fish.

There were three parts to the 2003 study: freshwater monitoring under the direction of Gordon McEachen, marine monitoring under the direction of Brent Hargreaves, and parasitology under the direction of Simon Jones. The scientific coordinator was John Pringle. The Plan was announced in February 2003, and the team was out in the field in the Broughton Archipelago in early March 2003.

The freshwater studies have been completed and a draft report has been submitted. The analysis of the marine monitoring results is underway. Part of the Plan includes communication of results to the public. This has been accomplished by planned discussions among the communities of the Broughton Archipelago, weekly data summaries posted on the DFO website, welcoming of observers including visits from the Pacific Fisheries Resource Conservation Council (PFRCC) and First Nations personnel to the site of the field studies, and the current workshop in Alert Bay.

Several associated studies were also conducted and the results of these studies will be reported in this workshop. They include a study of the distribution of infectious stages of sea lice in the water column (Moira Galbraith), a study of sea lice and juvenile and adult salmon beyond the Broughton Archipelago (Dick Beamish), and a survey of sea lice infestation on adult salmon ranging from Oregon to Alaska (Marc Trudel).

The complete results of the Pink Salmon Action Plan will be reported through the DFO peer review process, the Pacific Scientific Advice Review Committee (PSARC) at a meeting planned for late March. The questions that will be addressed (these are preliminary) are: What were the migration routes of juvenile pink and chum salmon through the Broughton Archipelago and down Knight Inlet in 2003? (this paper will be presented by Brent Hargreaves, senior author), and What was the temporal and spatial distribution of pink and chum salmon infected with *Lepeoptheirus* and *Caligus* species of sea lice, and what were the sizes of infected salmon and the life history stage of the sea lice present? (this paper will be presented by Simon Jones, senior author).

What are the next steps?

Q. What is next?
A. The PSARC process will dictate how long this study will be and what happens next.

Q. Is there a way for input to what happens in 2004?
A. We have not invited anyone to participate yet. We will come back to communicate in early March.

Q. The pilot study and model development usually takes 4-5 years.
A. The next step is to look at what should be done - this meeting will be a start to that process.

Q. First Nations have not been involved – we want to be.
A. We have been here in your community, allowing you to provide feedback. We have come out of our way and will come back in a few months when we have more to discuss.

PSARC Process

Q. I have been to a PSARC meeting before. I was an 'observer' only. Is there a way to get the critiques (information) in advance so that we know what will be discussed?

A. The PSARC meetings are observer-only scientific meetings. You have to be a scientist to have access to the information before the meeting. It is a confidential process and until the papers are approved they are not accessible to the public. There is a deliberation process following the presentation where there may be some changes recommended – once these changes have been completed then the document is upgraded to a research document and is released.

Comment from participant: First Nations may not have scientific degrees but they have knowledge about the resource.

Comment from participant: I will release my data regardless of whether it is published or not. There is a need for mutual respect. That applies to industry as well – they should share their data.

A. We ask industry to share data. Working papers are different from data. We do make this available and the data transparency issue will be included in the recommendations.

A. PSARC is designed for DFO management decisions. It is a formal process which allows us to have our data peer-reviewed and published in scientific journals.

PRELIMINARY OBSERVATIONS ON JUVENILE SALMONIDS AND THEIR SEA LICE INFECTIONS
Brent Hargreaves, Research Scientist, Salmon Section, Fisheries and Oceans Canada, Nanaimo

The presentation discussed the methods used and preliminary findings of the marine component of the Pink Salmon Action Plan that was developed in February 2003 in response to concerns over pink salmon and sea lice in the Broughton Archipelago. The objectives for this part of the Plan were: to monitor the abundance and distribution and try to discern the migration routes of juvenile pink salmon throughout the Broughton Archipelago and Knight Inlet; to examine marine timing – that is, when pink salmon juveniles migrate out and through the Broughton and how long they reside there; and, to quantify the temporal and spatial differences and the prevalence and intensity of sea lice infestations of juvenile pink and chum salmon.

The resources that were put toward the marine monitoring program included: $700,000 funding from DFO, DFO staff and two vessels, three First Nations vessels and crews, three biologists (on a rotating basis) from the Province of BC, and one person from each of Heritage Aquaculture and Stolt Seafoods. There were a total of 35 participants involved in this project.

The Pacific Salmon Action Plan was announced on February 20, 2003. Sampling began in the Broughton on March 2 and in Knight Inlet on March 10. The delay was due to the time required to identify the sampling sites. Fishing was conducted for 12 – 14 hours per day, 5 days per week from the initiation of the project in March until sampling was completed in both areas in mid-June.

Weekly sampling of fish was conducted at 105 sites in 11 different geographic zones (designated A – K) throughout the Broughton Archipelago and Knight Inlet. Sampling locations were flagged for repeat samplings. Samples were obtained using both purse seines and beach seines. Purse seine samples were obtained using the vessel, the *Walker Rock* in the Tribune Channel to Wells Pass area, with the same crew throughout the project. Purse seining in Knight Inlet was

Methods

Q. Are tides an advantage?
A. We have not looked at tides and the ecology of the marine environment (e.g., tides, salinity, temperature, moons). It was not possible to control for tides in the way that we sampled.
Comment: Tribune was the way that the fish traveled due to tides, which would account for why there was a low number of fish at one of the sampling sites (E).

conducted by charter seine vessels (mostly First Nation crewed). Beach seine sampling was conducted using an 18-foot Boston Whaler (Tribune to Wells), or rigid hull zodiac (Knight Inlet) and nets with the same size bunt mesh as the purse seine. Each sampling session resulted in 30 fish being individually bagged, and frozen; salinity and temperature were also recorded for most sites. At the end of each week samples were transported via cooler to the Pacific Biological Station where they were held in a freezer for analysis (length and weight of fish, sea lice counts and species identification). A total of 1,472 sets were made; 477 beach and 348 purse seine sets in the Broughton, and 362 beach and 285 purse seine sets in Knight Inlet. There was a difference between purse and beach seines with respect to numbers and size of fish; beach seines were more effective in catching pink salmon juveniles – purse seines caught fewer, larger fish. Total numbers of salmon caught were: 64,135 pink and 43,497 chum salmon for the Broughton; 9,889 pink and 64,329 chum salmon for Knight Inlet. The catch per unit effort was constant throughout the study.

Results

Q. Why was there a spike in abundance at the area labeled F?
A. This could have been due to a combination of the runs there, both local and those migrating past.

Q. Why is the abundance at B so high? This does not make sense.
A. Early in the season you know where to find the fish. As the study progresses you do not know where to find the fish (once they have started their out-migration). As time goes on there will also be a mortality factor.

Q. Is it possible to detect the fish that enter from the rivers at area K?
A. No, not without marking. You could tell by size increase and could resample. The fish will get bigger by the week. The information from genetics at the moment is not good enough to be able to distinguish between the stocks.

Q. Zone K is of concern. You cannot genetically analyze this – so is there a way to tell whether the smolts are coming from Kingcome or other systems in Johnstone Strait. Something seems to be going on at that area – is it geographic, i.e. a rearing area for a number of different stocks? Where do those fish come from?
A. We could genetically test, but even to get good information regarding stocks is difficult. We do not have the baseline data to match it to, and the process of dye marking is too expensive.

Q. This is very difficult to interpret. Is there an electronic tag that could be used to show which route the fish are taking?
A. You could dye mark the fish so that you know if they are the same fish.

Abundance patterns: Abundance patterns differed for pink and chum between the Broughton and Knight Inlet samples and in terms of early abundance, peak abundance and variability of timing and abundance patterns, with greater variability generally observed for chum.

Juvenile migration routes: In 2003 all farms were fallowed in March along a main migration corridor in the Broughton to protect juvenile pink salmon. The question is: Was this necessary and/or effective, and should fallowing be required again? The objective of this project was to determine if there is evidence that most of the fish actually out-migrate through the Tribune Channel – Wells Pass corridor. Preliminary findings indicate that it is not apparent that most of the salmon, both pink and chum are in fact using that corridor. It may be that the fish migrate out through all the access corridors. We are examining the

possibility that the fish come down Knight Inlet and change directions and eventually filter out through the Broughton.

Size of fish: Plotting the average length against time allowed us to assess growth patterns for pink and chum juveniles. Early on during the sampling there was very little difference between the size of fish caught in beach seine compared with purse seine sets. By early April significant differences (up to 20 mm in length) were observed, with larger fish being caught in purse seine samples. This is true for both pink and chum salmon. The pinks in Knight Inlet were typically bigger than the pinks in the Broughton at any given time – this can be explained in part by the earlier arrival of the fish into salt water. The same was also true for chum salmon. It may be possible to use fish size and size distribution as indicators of migration route. Without actually tagging the fish, this may be the only way to assess whether the Knight Inlet fish 'turn the corner' (into Tribune Channel) and enter the Broughton.

Sea lice infection: Preliminary data show that the infection rates for both pink and chum salmon are substantially lower for fish sampled in Knight Inlet compared with fish sampled in the Broughton. (See also presentation by Simon Jones.)

There is an ongoing statistical analysis program in place to assist in the interpretation of these data. They will be examining the significance of the data for both pink and chum salmon with respect to migration routes and observed patterns of infection. There are also a large number of samples of other species (herring, stickleback, coho salmon, etc.) that need to be analyzed.

A participant commented on the size of data set and potential difficulties in analyzing and interpreting it. A graphic simulation model was suggested to test the hypothesis. Q. Is there anything about the behaviour or colouration of the infected fish that would make them more or less likely to be in the sub-sample ? Do sea lice voluntarily leave fish when in the net, or get abraded off?

A. When using the net we are not selecting the sample fish based on colour. The only time fish were specifically removed were when they appeared 'odd'. Generally, colouration made no difference. We did sample randomly. We did not analyze for scars, and did not see the sea lice jumping off – nor did we find them on the net.

Comment from participant: The research methods were good, we took care to make sure the project was carried out properly and the project created good relationships. There is more information to come and I hope that First Nations and local people are part of that.

Comment: We cannot be concerned with one spot – we need to be concerned with the whole area.

CALIGID COPEPODS ON JUVENILE SALMONIDS AND SOME NON-SALMONIDS IN THE BROUGHTON ARCHIPELAGO

Simon Jones, Fish Health Research Scientist, Fisheries and Oceans Canada, Nanaimo

In British Columbia the two most common species of sea lice are *Lepeophtheirus salmonis* and *Caligus clemensi.* Sea lice are parasitic copepods from the family Caligidae. The life cycle of these caligid copepods is complex with 10 life history stages. The first two stages are the *nauplius* form which then moults to the one *copepodid* stage, all free-swimming and non-

feeding. It is the *copepodid* stage where the louse is adapted to find the fish host. The *copepodid* stage moults to go through four *chalimus* stages, which are attached and feeding on the fish, but non-motile. From *chalimus* there is a first and second stage of pre-adult and then a final adult stage, which are all feeding and motile stages.

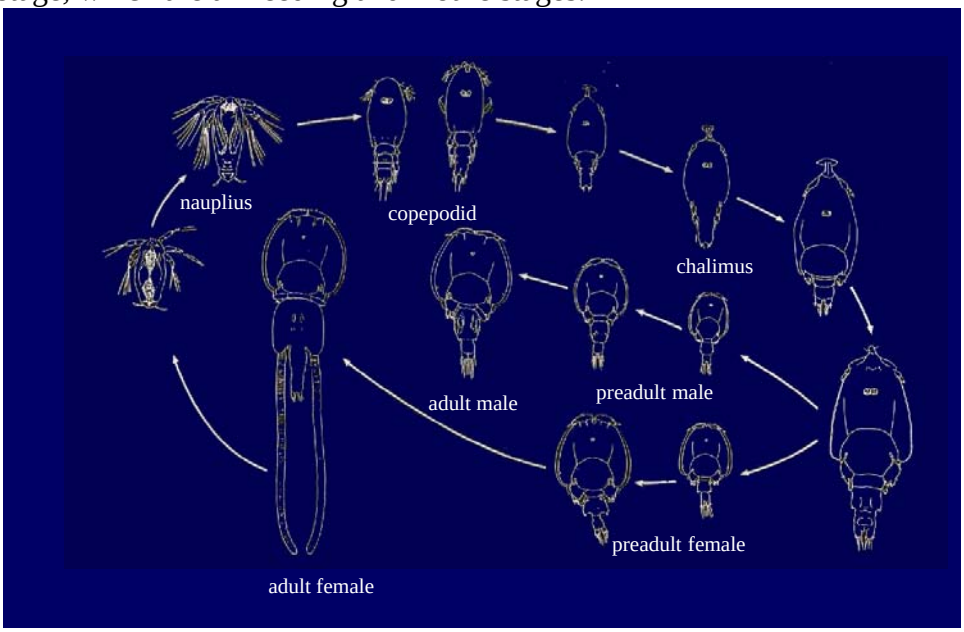

Figure 2. Life cycle of salmon lice. Source: Proceedings of the Summit of Scientists on Sea Lice, Continuing Studies in Science, Simon Fraser University, July 2002.

There are a number of factors that can influence the abundance and distribution of the lice, at all stages. The early *nauplii* stages will be most affected by water temperature and salinity, currents and predators. Host density, water temperature, salinity and predators affect the *copepodid* stage. The tolerance of the host, and abundance of the host and predators will affect the parasitic forms of *chalimus*, pre-adult and adult stages.

The presence of sea lice in British Columbia waters is part of a naturally occurring parasitic infection process. Parasites and disease occur naturally in healthy ecosystems, and the relationship between parasite and host is the result of a long period of adaptation and evolution. Typically a balance exists where the parasite does not cause disease or death to the fish host. When there is an imbalance you will see disease or

Q. Did you look at the condition factor in these fish (different sizes, visible marks, etc.)?
A. We collected length and weight data for all fish, and also collected the condition factor (body length divided by weight). Using this data as a base, we are then able to determine mass weight gain. These data are still under analysis.

Q. What is the biological significance of the lice load?
A. There is no question that if you overload fish in a laboratory, you will kill them. Those that died were the smallest fish. This may be a predisposition in the population. Many fish did not die, which was also observed in the Finstad study (Norwegian study with Atlantic salmon). In some fish it would be lethal, in some it would not. How do you compare Atlantic salmon to the Pacific species?

Q. You cannot estimate the effect of lice from these sort of data. For example, fish with the largest amount of lice are probably those that are in the best condition – because the lice have not killed the fish. Are there any plans for DFO to do experimental work on this problem?
A. There is some key work that needs to be analyzed. We need collaboration.

mortality of the host, where the fish is unable to defend itself, or the parasite is able to overcome the defenses of the fish. It is under these circumstances that you start to see disease in the population or increase in the parasite numbers. Within any given population, due to genetic disposition, some individuals are at greater risk of infection than are others.

To date in BC there has been no systematic surveillance of juvenile salmon for sea lice. The objective of this study was to measure prevalence and intensity of *Lepeophtheirus* and *Caligus* over time and space throughout the Broughton Archipelago and Knight Inlet, BC.

Beach seine and purse seine samples were taken weekly from March 2 to June 18, 2003 at 105 sites in the Broughton Archipelago and Knight Inlet, BC. All fish were bagged, labeled and frozen for later analysis. Fish and sea lice species, along with lice life cycle stage were determined for all samples. Caligid species were distinguished using body and appendage morphology and frontal filament morphology. Prevalence (percentage of fish with lice) and intensity (average number of lice per fish) were recorded for pink salmon, chum salmon and sticklebacks.

Q. There was variation in sea lice infestation rates. If we look at the geographical distribution of infestation rates then we may find useful data.
A. Areas E, H and K are the outmost regions and had the highest prevalence and intensity. The effects from Caligus and Lepeophtheirus were not the same.

Q. Were there pockets of intensity?
A. There were sample events that showed heavier infestation.

Q. You found no damage on the fish?
A. No large areas of discolouration – only the attachment holes.

Q. Have you looked at the effects of salinity on the development of lice?
A. We have not analyzed this yet. It is well described in the European literature. This is one of the many environmental variables to be examined.

Q. Are these gravid females that are on the sticklebacks?
A. We have so little data for the sticklebacks. They may be a potential source.

Preliminary results for all Caligid copepods (both *Lepeophtheirus* and *Caligus*) show that 27.9% of pink and 28.3% of chum salmon juveniles captured in the beach seine were infected with sea lice. For purse seine captured juveniles the prevalence of sea lice was 16.6% and 23.7% for pink and chum salmon respectively. Intensity of infection for beach seine was 1.67 and 2.22 for pink and chum juvenile salmon, respectively, whereas for purse seine intensity of infection for pink and chum juvenile were 1.44 and 2.05 respectively. Prevalence of sea lice on species other than salmonids was also examined. Early analysis shows that sticklebacks are the single most affected species with a prevalence of 55.4% for beach seine and 63.1% for purse seine and intensity of 5.6 lice/fish for beach seine and 6.5 lice/fish for purse seine. The study was not designed to quantify the number of sticklebacks in the area, but they were abundant and infected with sea lice throughout the entire study area. This observation had not been made previously.

The second part of the study focused on identification of sea lice species. For the Broughton Archipelago a total of 3,071 lice were collected from juvenile pink and chum salmon. For pink salmon 61.5% and 63.6% of the lice collected from beach seine and purse seine catches, respectively, were *Caligus* species, while prevalence of *Lepeophtheirus* species accounted for

38.5% beach seine and 36.4% purse seine. The same pattern was observed for chum salmon with 70.9% beach seine and 78.4% purse seine *Caligus* species present, with *Lepeophtheirus* present on 29.1% beach seine and 21.6% purse seine catches.

Part three of the study looked at the distribution of various stages of the sea lice, for both sea lice species, on pink and chum salmon. *Lepeophtheirus* adult stages comprised 40% of the total lice collected with varying degrees of abundance of the *chalimus* stages. This is in contrast to what was observed with *Caligus*, for both pink and chum salmon, where 70-75% of *Caligus* were the first two stages of *chalimus*, with only 10% in the adult stage. There were no *Caligus* copepodids found.

In conclusion, of over 18,000 juvenile Pacific salmon examined, 15% of pink salmon were infected with *Caligus*, and 9% with *Lepeophtheirus*; 20% of chum salmon were infected with *Caligus* and 7% with *Lepeophtheirus*. 90% of the *Caligus* and 60% *Lepeophtheirus* were from the *chalimus* stage with 10% *Caligus* and 40% *Lepeophtheirus* from the motile (pre-adult and adult) stage. Intensity of infection showed that total lice per fish averaged 1.6 for pink, 2.2 for chum and 6.4 for sticklebacks. There was no clear pattern observed of damage associated with the chalimus, pre-adult and adult lice present on the fish. Statistical analysis will be done to test for differences between geographic zones and clusters of sites over time. Further work will look at spatial and temporal variation using evidence in differences in size (length and weight) and condition between infected and uninfected fish. Additional work will be done to determine if there is a difference between fish infected with *Caligus* and those infected with *Lepeophtheirus*.

Q. We know that we have less farmed salmon in the water because of fallowing– would this be a contributing factor?
A. If they are not in the water then they would be less likely to contribute. We do not know if the stickleback data are normal, or if any of this is normal. This needs to be added to a database and we need to repeat this research.

Q. I thought that the main objective of this research was to see what effect fish farms have on lice infestation on pink salmon.
A. Yes, that is the long-term goal, but we have no database. We are building from time zero. This is ongoing work.

Comment: This was the objective, but you cannot look at normal conditions in a non-normal area/conditions. For this work on sea lice and salmon, we need controls and reference data.
A. Even if we were to generate data up the coast of BC there are other factors that come to play. We have collected data from other areas.

Comment: We need baseline studies. For this area it is too late, but there may be some hope in the Kitkatla region. We need to put monitoring/surveillance programs in place in advance of the farms.

Q. Were you given farm by farm data?
A. No, we do not have these data. We have had two meetings now and have asked for data and have not received it to date.

Comment: You seem to have said: "if less farmed fish then less contribution of lice", But we do not know the wild adult fish contribution.

Q. If we do not know the per farm data then how are you going to do the analysis?

MAINLAND INLET PINK- FRESHWATER MONITORING, JUVENILE AND ADULT ASSESSMENT

Pieter Van Will, Research Technician, Conservation Management, Fisheries and Oceans Canada, Port Hardy

The intent of this project was to conduct juvenile salmon (especially pink salmon) out-migration population and migration timing assessments on 4 key indicator systems in Area 12: Kakweikan River (Thompson Sound), Glendale River (lower Knight Inlet), KlinaKlini River (head of Knight Inlet), and Devereaux Creek (alias Mussel Creek – tributary to the KlinaKlini; head of Knight Inlet). Rotary screw traps (RSTs) and/or inclined plane traps were deployed in all 4 systems in an attempt to capture a representative portion of out-migrating juvenile salmon. The intent of the study was to determine the numbers of juvenile salmon (especially pinks) leaving these systems and, by extension, to determine the adult population of the contributing brood year (2001). Out-migration timing, juvenile fish health (condition) and environmental measurements were also assessed.

The following table (prepared by the editors) summarizes the 2003 trapping program results for pink juveniles at the four study locations:

Location	Study Duration	# Pk Juv. Caught	Est Total Juvenile Production	Peak Out-migration Period	Comments
Klinaklini R.	Mar 15–May 21	80	Unknown	Mar 30–Apr 6	Low catch, ice problems, no trap efficiency index possible – low confidence
Devereaux C.	Mar 6 – May 22	5,037	333,358	Mar 11-Apr 1	Good catch at start of program, ice problems and data gaps. No trap efficiency index possible – low confidence
Glendale C.	Mar 6-May 8	26,633	496,455	Feb ?-Apr 7	Large catches at start of program may indicate mid-February migration. Difficulties with mark/recapture and trap efficiency index – medium confidence.
Kakweikan R.	Mar 6-May 1	1,088	Unknown	Mar 13-Apr 7	Relatively few fish caught. Problems with mark/recapture and trap placement – no trap efficiency index possible – low confidence.

Trap-based estimates of juvenile out-migrant populations of other species (chum, coho, chinook) were somewhat more successful at Devereaux Creek and Glendale River. The results for these species will be reported elsewhere.

Recommendations for improvement to the juvenile downstream trapping program include:

- Earlier start to the program (especially Glendale, where warmer temperatures from Tom Brown Lake appear to result in earlier emergence/out-migration of pinks, especially from the spawning channel)
- Improved methods to determine trap efficiency indices (mark recapture very difficult with fragile pink fry)

- Klinaklini and Kakweikan trapping sites/methods should be re-assessed to ensure continuity, ability to index traps and increased data confidence.

Adult Salmon Escapement Program (Fall 2003)

In-season adult escapement enumeration activities for 2003 (which is an "off year" for pinks) focused on 11 major stream systems, which typically account for the majority of escapement (pink salmon) to the Mainland Inlets of Area 12. Some "minimal" interception of escapement to these systems was expected as a result of Fraser River directed fisheries. There were no (Mainland Inlet) *directed* commercial fisheries in 2003.

The immediate question arose as to what was meant by "directed fisheries"? Why is the sport fishery in the Mainland not considered a 'directed fishery' (regardless of species) – do you have catch numbers for this fishery? Why is it that the recreational fishery is not also closed (i.e. to mouth of the inlets) if conservation is the issue?"

Escapement enumeration consisted of over flights, stream walks, and estimation using "Area under the Curve" calculations. (Explanation of methodology given, includes live and dead adult fish observed and assumed instream residence time and a calculation of total spawning population.)

In general, adult pink salmon escapements to the 11 systems studied (in DFO Statistical Area 12) reflected that there were lower than expected returns (*viz a viz* the brood year) in the "Bond/Knight" area, but these were "within the historic variability seen with these stocks". There was a "slight improvement (to anticipated returns) in the Kingcome/Wakeman area". Preliminary estimates of 2003 pink salmon escapement (and brood year comparisons) are summarized in the following table:

System	2003 Preliminary Escapement	Recruits/Spawner	2001 Brood Year Escapement
Embley	42	0.28	150
Kingcome	375	0.34	1100
Wakeman	2570	2.70	947
Area Total	2987 (+36%)	1.36	2197
Ahnuhati	4262	1.50	2800
Ahta	1126	0.05	22000
Glendale	161876	0.12	1350000
Kakweikan	13888	0.14	96000
Klinaklini	4455	0.27	16538
Kwalate	43	0.04	1200
Lull	77	0.004	17000
Viner	16	0.05	350
Area Total	185743 (-88%)	0.12	1505888
Combined Total	188730 (-88%)*	0.12	1508085

As observed in the above table, preliminary 2003 pink escapements indicate a decline of 88% from the 2001 brood year. By comparison, (odd year) pink escapements for the whole "study area" and Stat. Areas 7 – 9 showed a similar decline of 80% from the brood year.

Recommendations for improvement to the adult escapement program include:

- Need to expand aerial survey program, to increase coverage and frequency in Kingcome/Wakeman area
- Need to calibrate aerial estimates with a known population (e.g. fence counts or manned channel counts such as Glendale and Kakweikan)
- Need to assess in more detail the average residence time of Mainland Inlet pink salmon.

Q. What happened to the 2002 Kakweikan run and why didn't you get juvenile data (in spring 2003)?
A. The low juvenile catch was mostly a function of trap placement and the inability to establish trapping efficiency.

Q. Did you solicit local knowledge (that might have improved the freshwater program) – if not, are you planning to?
A. No – it would be wise in terms of trap placement.

Q. You surveyed some Broughton rivers to detemine numbers of fry/smolts from the spawn of autumn 2002. Regarding Kakweikan, we cannot say what numbers there were in Kakweikan (and others). Is this surveying going to continue in 2004?

SEA LICE MONITORING IN THE BROUGHTON ARCHIPELAGO

Joanne Constantine, Fish Health Veterinarian, BC Ministry of Agriculture Food and Fisheries

In February 2003 the British Columbia Ministry of Agriculture Food and Fisheries (MAFF) developed the Broughton Archipelago Sea Lice Action Plan in response to concerns expressed that the 2002 low returns of pink salmon to the Broughton Archipelago was the result of sea lice infestation. The objective of the action plan was to develop a monitoring program to document the average number of the sea lice *Lepeophtheirus salmonis* on Atlantic salmon farms and work with industry to form management plans to minimize the levels of lice during the migration of Pacific salmon smolts, including pink salmon.

All 16 farms in the Broughton Archipelago region were required to report lice levels every two weeks from January to June 2003. Of these farms 14 contained fish at the time of the study. Three pens from each farm were sampled, one standard pen and two random pens, with a minimum of 20 fish sampled per pen. Fish were anesthetized and systematically evaluated for lice. All lice were counted and categorized into life stage. The numbers of motile and gravid lice were enumerated for each fish. Gravid lice are defined as mature female lice with or without egg strings. Motile lice include gravid female lice as well as pre-adult and adult lice, male or female. In addition to data from the Industry Monitoring Program, MAFF also carried out randomly selected farm audits from those farms active in the Broughton Archipelago. Approximately 25% of the industry sites were sampled every two weeks from March to June,

Q. We want clarity on the data on sea lice infestations on individual farms. Is there any way to access data about what has gone on in the past?
A. The reason why there was no program in place is because there was no problem previously.
Comment from participant representing the Province of BC: We only required the companies to submit data beginning last year. Prior to that it was up to the company to submit this information. The Province does not have the authority to force the industry to provide this data.

Comment: Last year's data has not been fully analyzed and time is running out. We need to get this out now – the fishing are coming out soon. Last year's data are not being made available to the DFO statistician.

2003. Historical data, from January to March 2003, were provided to MAFF by industry as part of the Interim Monitoring Protocol. All records and calculations were standardized to allow for cumulative data. All data were evaluated using arithmetic means.

Average numbers of gravid and motile *L. salmonis* per fish (broken down by age class) were reported from January to March 2003. The average numbers of motile lice varied according to size class; the average number of motile lice per fish for 2-3 kg fish ranged from a high of 4.74 in January to 0.19 in March; typically, 7 kg (or greater) fish had a larger number of lice, ranging from 8.69 to 10.68. This supports the trend of seeing the greatest numbers of sea lice on fish that have been in salt water the longest. The industry monitoring data from April to June showed that there was a decrease in the number of both gravid and motile lice. There was SLICE treatment of the 2-3 kg fish during the study that decreased the average motile lice level to 0.15 in April and 0.07 in May.

Effects of SLICE

Q. When are the studies on SLICE going to be conducted?

A. Some studies are underway on spot prawn and crab. There have been a lot of studies on invermectin. SLICE is formulated for fish.

Q. Once the fish eat SLICE and the lice die, what does this do for human consumption? There have been studies in Norway relating to adverse effects of the reproductive ability of clams. Does this have anything to do with SLICE?

A. There have been studies done on SLICE and it is safe for crabs. In those studies the crabs had to be *fed* SLICE in order for there to be an effect.

Comparisons were done to determine if the industry was providing similar data to those recorded from audit sites. Comparisons looked at pen levels and total site counts to determine if they were significantly different. The first test compared the 30 fish audit sites to the 60 industry reported sites. Two of the 25 counts were significantly different ($p<0.05$) with industry provided site averages being higher than the audit site averages. The second test looked at whether there was a difference with the 30 audit fish to the overall count of 90 fish (30 audit fish and 60 industry reported fish). There was no significant difference between these means. There was no trend to indicate a change in the averages, and all numbers provided by industry were accurate.

Based on data obtained from the 2003 study, the Sea Lice Monitoring Program will continue, with expansion to the entire industry coast-wide. Action levels will remain in place in 2004 dictating that if a farm reaches a total of *three* motile lice during the time of smolt migration then all farms in the area will be evaluated and it will be determined what action will be taken. For 2004, in the Broughton Archipelago area, 16 of the 18 farms will have 2-3 kg fish during pink salmon migration time, and MAFF will be looking at strategic treatment of this group to try to maintain low levels of lice on the farms. In 2004 *Caligus* species will also be added to the data set.

For further information on MAFF Sea Lice Monitoring Program please visit
http://www.agf.gov.bc.ca/fisheries/health/sealice_BA_monitoring.htm

Q. Are you concluding that fallowing did not accomplish much and this will not be included in the policy for 2004?
A. We are not looking at fallowing – you will have to talk to DFO. It is *Lepeophtheirus* that we are looking at. We still have to risk manage the farms.

Q. The province cannot force treatment on the farms can they?
A. Vets look at the lice numbers.

Q Will they treat the brood stock?
A. They did treat the brood stock.

Q. When are the 2-3 kg fish treated? April?
A. For the 2-3 kg fish, the number of sea lice present was high in January and then it dropped in February and March.
Q. I was worried about out-migration in regards to the European levels?
A. No, the numbers were well below the European levels.

Q. What does this mean? Where are the raw data? I am frustrated with the website not providing enough information. We need the raw data to examine; you cannot base anything on 'means'.
A. There are only 14 farms, and there is not a lot of data to look at. There may be variation. The runts are averaged into the pen data. We are not providing raw data at this time.

Q. What is the biological meaning of 3 motile lice?
A. There are many factors involved, including health, treatment efficacy. We take an arc approach. We need to react better on a real time basis. The '3' motile lice comes from studies in Norway.

Q. You have taken a look at farms and you have told us what you have seen. In spite of what you have seen on the farms, what is the interaction with sea lice and farmed and wild salmon? Have you any way of telling this? Is there any way you can compare your findings with the situation 5 – 10 years ago, or are these data available?
A. I have not seen a significant spike in treatment. In terms of performance, this varies yearly as it does in the wild. This has not been an issue.
Comment from Province of BC Participant: We have initiated monitoring for all farms and so now we collect data coast-wide

Comment: Whatever information you have from prior years, it has been shown that there are more rigorous and effective operations in recent years. The danger to smolts has been reduced. We cannot draw conclusions yet - we need the DFO data. Even though there is rigorous testing we still do not know if it has been reduced from previous years.

SEA LICE RESEARCH IN THE BROUGHTON – YEAR 3 UPDATE

Alexandra Morton, R.P. Biologist, Raincoast Research

The summer of 2003 marks the third year of the presenter's sea lice field research program in the Broughton Archipelago. In 2001 field studies covered a large area of the Broughton, including Knight and Kingcome Inlets. The intent was to find the 'outer edges' of sea lice infestation, and to map lice (*Lepeophtheirus*) distribution and incidence on juvenile pink salmon.

The 2002 and 2003 sampling program was reduced from the large coverage area studies in 2001, to fewer specific sites in the Broughton Archipelago region. In the 2002 research program 20 juvenile pink salmon were collected from each of six sample sites (sites near farms and control sites well removed from farms). In addition, samples of juvenile pink and chum salmon from Prince Rupert, Bella Bella, Smith and Rivers Inlets were examined for sea lice and numbers of lice (all attached stages) were documented. For the Broughton region, fewer sea lice were observed than in 2001. None were observed in the other sample sites except near the salmon farms in Bella Bella.

Some of the salmon farms in the Broughton Archipelago were fallowed during pink salmon out-migration times in 2003. The intent of the 2003 study therefore was to examine the impact of fallowing salmon farms along the pink salmon out-migration route. Six sites were tested in the Broughton; 3 were near salmon farms that were sampled previously. The other 3 sites were designed to serve as controls (i.e. farms not fallowed); however these results were not reliable because some of the farms had treated their salmon with SLICE and as a result the numbers of attached lice apparently decreased ten-fold (or more). It is interesting to note that the numbers of lice per fish observed in non-farm sites are consistent with the preliminary numbers reported in the 2003 DFO juvenile seine study (see abstract for Brent Hargreaves). Generally, it appears that there are more lice near farms than at sites well removed from farms.

When assessing prevalence of sea lice on salmon it is important to look at the incidence of all life stages of lice (*copepodid* to adult), not just adult lice. Higher incidence of younger life stages may indicate proximity to site(s) of infestation. In 2001 and 2002 (prior to the fallowing of 2003) there were higher numbers of younger lice life stages (*copepodid* and *chalimus*) whereas the reverse was noted in 2003 with higher numbers of adult compared with younger stages.

The question : What is the 'normal' pink juvenile migration route(s)"? was discussed at length.

Sites sampled in 2003 included sites near farms that were not fallowed in 2001 and 2002, but were fallowed in 2003. It was not possible to correlate the data collected near the farms that were stocked in 2003 given that information on SLICE treatments and lice loadings at those farms was not made available. It appears that juvenile pinks coming out of Knight inlet (no farms) became infected shortly after they passed the first farm (Sargeauent Pass – northeast end of Tribune Channel). The current meters deployed by DFO and Stolt Seafarms in 2003 show that particles (included lice *nauplii*) can

Q. How do you explain the reversal from high levels of juvenile lice found in 2001 and 2002 to high levels of adult lice found on juvenile pinks in 2003? They would have to have encountered the point of infection about 30 days prior to have developed to adults. How fast/slow do the juvenile pinks move? What is the source of infection?

A. It appears as if the juvenile pinks move out of the inlets fairly quickly and then mill around in the Broughton area (Fife and Wells Pass area) for quite some time (they are still around in late August and up to 12 grams in weight). The fallowed routes are not sealed off from current-borne sources of infection that might be quite distant.

Q. If the timing of the adult pinks (in the Broughton) does not coincide with the onset of infection then what is the source – could it be rearing chinook?

A. There don't seem to be many chinook around anymore. Other more likely wild sources could be coho or cutthroat (maybe Dolly Varden Char). It would be interesting to look at the lice loads on other species.

move as much as 10 km in one tide, so that fallowing a particular site does not preclude infection from active sites some distance away.

Q. You mention that Knight Inlet pink juveniles 'turn right' into Tribune Channel – are you sure it is because of currents? Would looking at currents be a better idea than just going by fish sizes?
A. Our study was not designed to look at currents. Tracking fish size is a good idea as well.

Q. Directed to a 'Namgis elder. Is one year of current studies enough to determine the current patterns in the Broughton/Mainland Inlet area?
A. I have lived here and fished that area all my life and still the current (tide direction) changes from year to year surprise me. It all depends on how much snow there has been and the influence of run-off from Knight (especially) and Kingcome Inlets. Sometimes (during heavy run-off periods) the surface current in Tribune Channel runs West all the time no matter what the tide is doing.

Lice incidence on juvenile pinks at the Glacier Falls site (Tribune Channel) was significantly lower (10%) in 2003 compared with 2002. This farm had been fallowed for 8 months. By contrast, fish sampled near the Wicklow Point site (Wells Passage), which had been fallowed only one week prior to the arrival of naïve juvenile pink salmon, had three times the numbers of lice than Glacier Falls, and showed less of a decrease (20%) in numbers of lice (all life stages) from 2002. Pinks sampled near the Wicklow Point site also had a relatively higher incidence of *copepodid* and *chalimus* stages compared to fish sampled at the Glacier Falls site. It was noted that in Scotland, farms are fallowed at least 30 days prior to the arrival of naïve fish being re-stocked; therefore, the short fallowing period at Wicklow Point could account for the higher incidence encountered – that is, there could have been *nauplii* still present after the adult farm fish were harvested the previous week.

The question of how many lice per gram of juvenile pink salmon is lethal remains unanswered. Given their very small size (< 0.5gm in April), even *one* louse per fish could be lethal if the 1.6 lice/gram lethal values found in Europe apply. The question of lethal loading must be examined. A containment system for juvenile pink salmon (with and without lice) was devised in an attempt to answer this question. Environmental problems and the very few fish held did not yield any conclusive data. Generally, mortalities appeared to be significantly higher among those fish with lice attached and the condition factor was lower in the infected fish than in the non-infected control group. Further, it was interesting to note that juvenile pinks eat the lice (especially gravid females) off each other when held in such containment in high density.

Although others have reported seeing no lesions associated with the presence of attached lice, most of the fish examined with gravid female *L. salmonis* in this study show the presence of double rows of holes where lice have attached. These appear to be associated with the "grabbers" (pinchers) present on two of the legs of gravid female lice that are used to hold on to the fish. The flesh of juvenile pinks around the point of 'tether' attachment of *chalimus* stages appears pinched and eaten within the (feeding) range of the non-motile *chalimus* stage louse on its tether.

Other work in 2003 was aimed at identifying potential sources of lice infection (other than farms). It is highly unlikely that wild adult salmon returning to local streams to spawn are a vector for lice transfer to juvenile pink salmon in April through June, since the first returning wild adult salmon do not appear in approaches to the Broughton until mid-July. In August, fifty

Q. Did you count *Caligus* as well as *Lepeophtheirus*?
A. Yes. There were more *Caligus* on herring and stickleback than on pinks. Less *Caligus* were encountered in Wells Pass.

Q. How do you explain the lesions (and lice 'hook marks') you see when DFO observed none?
A. (DFO): 30% of the lice on juvenile fish were *Caligus* and there were very few adult *Lepeophtheirus*. We did not see lesions on any of the 270 fish examined.
A. All the lesions (including paired perforations) observed were associated with *Lepeophtheirus*. Scientists in Norway say they have never seen the "tracks" I described and I sent pictures. I think the 30+ gram Atlantic salmonids (there) have tougher skin. This may highlight the extreme susceptibility of pinks and chums to death by one louse or more.

Comment: Scales (and skin) are closely connected to secondary circulation systems in fish – perforating that barrier could increase the osmotic challenge and lead to weakness or death.

Comment: If juvenile pinks (that you held) are eating lice off other fish in the containment, they must be starving.
A. It took about 3 days before they would eat hatchery fish food – yes, they may have become quite hungry.

Q. If you are seeing 10 gravid female lice per adult pink salmon, is it possible that the immature lice stages observed are coming from other pinks?
A. That phenomenon is not reported in the literature.

Q. You think your obseravations indicate smolts with sea lice died; those without lived. And there has been a question raised about whether data from Europe (larger smolts) is applicable here. Does DFO or the Province have any plan to follow up on this?

adult pink salmon were caught by angling in Fife Sound, one of the main approach routes for wild salmon migrating into the Broughton. These fish averaged 10 gravid (female) lice per fish. They also had an unusually high incidence of *copepodid* stage lice, which may infer that they had just passed through an area where they were infected. Adult coho and sockeye salmon also had adult and *copepodid* lice stages. We found no rise in the number of newly settled lice when the adult wild pink salmon first appeared in Fife Sound.

In order to examine any potential relationships between salmon farms and lice on wild fish the farms have to report on what lice levels they encounter, when treatments (SLICE) are applied, and how many fish are affected and are held at each site. If fallowing is effective at reducing infestation rates on wild juvenile salmon (as the 2003 data would suggest), then all farms that might be connected to juvenile pink migration corridors (by virtue of ocean current patterns) must be fallowed, not just those that lie directly in the assumed migration pathway. Since Atlantic salmon require 18 months at sea this may mean that important wild rearing areas for pink and chum salmon may not be suitable for farming salmon if we wish to continue having pink and chum salmon return.

All results reported in this presentation are either currently under review or have been submitted for publication.

Q. MAFF is not in favour of fallowing and DFO is not providing leadership (precautionary approach) for 2004 – does fallowing work?
A. Fallowing appears to reduce the incidence of infestation but we need to understand more about oceanographic influences and juvenile migration routes – fallowing a few farms along a theoretical migration corridor is not enough if we really want to protect wild (pink) stocks.

Q. What other variables would you take into consideration when picking reference sites?
A. Location of pinks, salinity, currents, temperature, and wild salmon.

Q. There may be reference points already. Can there be analysis done with Simon Jones and Alexandra Morton's data?
A. What you need is a controlled experiment, instead of worrying so much about reference sites. If you knew the information before and after you would be able to make better comparisons.
A. (DFO) In Muchalat Inlet on West Coast Vancouver Island (Nootka Sound) we got information before the farm went in. We had 19 sites every week and sampled via beach seine. The first fish farm went in in August. It is hard to get ahead of the game.

Q. Should that not be a prerequisite? That is, before you are approved for a lease, you have to have at least 2 years of data.
A. (DFO). This is evolving.
Comment: It is hard to prove cause and effect
Comment: These farms have never been charged.

Q. Can you really establish reference (control) sites for these studies?
A. (DFO) There are too many environmental variables other than farm/no farm to establish reference sites.
A. There are other variables (temperature, salinity, currents) but we should be able to work around them. Maybe we need reference sites elsewhere on the coast where there are similar conditions. One of the challenges is that we do not know (are not told) how many fish and/or lice there are on the farms.

Comment: Very few chum are coming back: Are they being affected by the farms? The escapement is now less than 50.

Comment: There seems to be an inherent conflict to all of this. This is the first year any studies have been done and you cannot get cooperation from the province and industry.

Comment (First Nation): The moratorium should be re-instated as long as these (obvious) questions remain. We cannot afford to wait for all the science to be done while we watch the very basis of our existence disappear. We are not rocket scientists but we don't have to be to see the changes and losses of our heritage values since farms came in. In spite of all these negative impacts there are more farms, not less – there should be none.

Comment: If DFO is mandated to protect wild stocks and stands by its 'risk averse' policies then fallowing a small area is simply not good enough. DFO must take the lead (consistent with policy) and establish research priorities.

Q. Boats are going in and out; Why then was Brent Hargreaves so concerned about spreading disease.
A. There was a possibility of disease transfer and I was doing my best to eliminate that.

Suggestions for Future Work
David Groves, Sea Spring Salmon Farm Ltd.

Pink salmon dynamics appear to relate more to feed energy supply as a primary cause, with sea lice as opportunistic secondary agents, than to sea lice as primary cause of mortality.

We need to understand susceptibility of pink salmon to sea lice as function of feed availability. Smaller (and/or lower condition) fish appear to be more heavily infested in studies in the Broughton Archipelago to date. If there is under nutrition then there will be a greater proportion of small, compromised fish. In extreme situations (as was probably the case in Spring of 2001, following the very large 2000 escapement) the feed supply is virtually overwhelmed by high numbers of fry and a very high percentage are compromised (sea lice infestation very large numbers of compromised fish) and there is a population wash.

Suggestions for studies that need to be conducted include:
1. Calibration studies in wild to determine size dispersion and condition of smolts and fry, and growth rate to indicate nutritional adequacy; i.e. lower dispersion, higher condition and faster growth rate is indicative of nutritional adequacy.
2. Tank studies where pink fry are reared at different levels of ration intake (eg. 100%, 70%, 50%, 30% of full intake) followed by challenge with *copepodids*, and analyses of different size ranges re: lice infestation across the different ration level groups.

OBSERVATIONS ON SEA LICE PLANKTONIC STAGES

Moira Galbraith, Zooplankton Biologist, Fisheries and Oceans Canada, Sidney

The zooplankton sampling program was initiated by Fisheries and Oceans Canada to locate the planktonic forms, *naulplii* and *copepodid*, of sea lice species. The objective was to develop and evaluate quantitative sampling methods in the Broughton Archipelago, BC for infective planktonic stages (*nauplii* and *copepodid*) of sea lice species *Lepeophtheirus* and *Caligus*. Abundance and distribution patterns of the louse would assist in evaluating risk to host and identification of the parent source population in the Broughton Archipelago region.

Methods

Q. Did you observe diel vertical migration (DVM)?
A. Yes, but it appears to be smaller that what normal copepods do.

Q. What were the depth of tows? Were the plankton deeper during the day time?
A. We sampled in some areas that were 10 m, but if they are all hanging out at the bottom then they are benthic copepods. I did do some stratified tows (0-5 m, 5-10 m, 10-15 m, and some 20 m tows for curiosity). Of the samples that were taken barnacle nauplii made up almost 80%. These do not exhibit diel migration, they are very positive phototaxic organisms and stay near the surface both day and night.

Samples were taken from April to June, 2003 in the Broughton Archipelago. Sampling was done during rising tides, when the pressure would force the copepods to the surface. Temperature and salinity measurements were taken for all sites. In April,all sampling was conducted using horizontal tows. Overall, the number of sea lice sampled were very low. Over 450 m^3 of water was filtered through a 100 µm mesh net with a peak sample recorded of 0.23 copepodids/m^3. The majority of the sea lice in the samples were *Caligus* species, with very few *Lepeophtheirus*. In May, the sets were done in selected areas resulting in fewer sea lice samples. Three *Lepeophtheirus* copepodids

Q. Did you test salinities in the area?
A. We tried to do hauls in areas where there was the salt water/freshwater interface, and also test along the sheer on the SW side of the zone.

Q. What is the salinity in the SW zone?
A. 25 in Scotland and here it is 25-30.

Q. Did you sample in the farms?
A. No not in the farms. We did not think to ask beforehand. Stolt Seafarms has been very cooperative. This was a scrambled project. There wasn't time to plan well ahead. I would like to go into pens and take samples to establish presence/absence in pens.

Q. Did you do any night tows?
A. Yes. The only difference was that we only caught larval stages during the days. At night the hauls were as close as possible to the shore.

were sampled, no *Caligus* larval forms were observed, but a number of adult male *Caligus* were sampled. Adult male samples were always *Caligus* species and never *Lepeophtheirus*.

In June, based on studies done in Scotland, a new sampling method was added. Shore sweeps in Scotland have shown positive results with numerous planktonic sea lice being caught. Using modeling of tides and currents to locate the freshwater/saltwater layover, a highly productive feeding zone, it was predicted that the plankton would be found in these areas. Sampling produced no results, possibly due to the late timing of the experiment. A different sampling method, using net tows in areas where there is tidal wash, produced positive results in Scotland with 4-5 *copepodids*/m^3, whereas in the Broughton Archipelago no *copepodids* were found using this method, which was also attributed to the timing of the sampling.

In conclusion, comparison of the different methods used to locate larval stages of sea lice showed that horizontal net tows and shore sweeps were not always efficient. Light traps should be investigated further to see if sea lice will react. Tidal currents are useful to predict area of accumulation of the larval stages. Average flow patterns may be useful in places where the planktonic sea lice maintain their position within the Broughton. It is recommended that sampling start earlier in the year (February to March), and take place in conjunction with beach seine sampling. Identifying the overwintering vector for the sea lice would assist in locating the nauplii in February and March.

Sea Lice Life cycle

Q. What is the normal cycle in plankton; when do they peak (in terms of reproductive phase)?
A. The sea lice life cycle is 6 weeks (egg to adult). If the temperature and salinity are good then the cycle may be decreased to 5 weeks.

Q. If a host is present 365 days a year, then what effect does this have?
A. This does seem to have an effect. The pen may act as a barrier – what goes through may be a small amount. The mesh on the plankton haul was 100 µm, and 230 µm.

Q. In your opinion with respect to light traps, do the lamps on the farms have an effect?
A. They are not feeding, they may come to the light.
Q. Could you use the light to draw the lice and remove them?

IMPACT OF SEA LICE ON THE POPULATION DYNAMICS OF PACIFIC SALMON IN THE CENTRAL COAST REGION OF BRITISH COLUMBIA

Presented by:
Richard Beamish, Senior Scientist, Fisheries and Oceans Canada, Nanaimo

Participants in this research: R. Beamish, S. Dawe, R. Sweeting, E. Gordon, N. Ambers, A. Hurst, C. Neville, S. Jones, M. Trudel, S. Johnson, T. McDonald
Advisor: Z. Kabata

Preliminary Report:

This is a two year study that finishes when adult pink salmon return to Broughton area streams in 2004. The objective of this research was to 1) assess the impact of sea lice on the health and population dynamics of Pacific salmon in the Broughton Archipelago and Queen Charlotte Strait, and 2) to identify sources of natural infections of *Lepeophtheirus salmonis* in the Broughton Archipelago and Queen Charlotte Strait. This project was supported by the Science Council of British Columbia and Fisheries and Oceans Canada.

Previous studies have shown that smaller coho do not survive winter as well as larger coho. Scale growth, therefore, could be is an indicator of impact of sea lice at the population level if sea lice are causing sub-lethal effects by causing fish to grow slower. An hypothesis to explain natural levels of sea lice was that sea lice (*L. salmonis*) in the open ocean minimize their risk of extinction by moving into coastal waters in the summer where habitat area is smaller and host density is greater.

Trawl samples were taken in August and September of 2003 in the Broughton Archipelago and Queen Charlotte Strait, BC at 5 knots; 92 (30 minute) sets were taken, for a total of 406 km towed with a 15m x 32m net and 200,000,000 m^3 of water fished. 13,000 Pacific salmon were caught, comprised of 11,700 ocean age 0 juveniles and 1,300 adults.

Q. There is a very low incidence of scale and skin damage. What deductions would you make about those data?
A. That is it – virtually none. That is the only comment I can make.

Q. With regard to the skin, and the juvenile salmon and the red discolouration, it is never on juveniles and only on adults. Why would you select indices when we do not know if this happens? This haemorrahging could cause death. How can you separate skin damage and scale loss? Is that scientific?
A. This came from published papers. We made the criteria sensitive. I don't live to compare oceans: ie, the Atlantic and Pacific
Comment: But you are comparing adult effects to juveniles.

Comment: If the size of the pinks and chums was over 60 mm and you were sampling in August and September and finding 15-20 cm fish, then you were looking at the super athletes.

The first part of the study examined skin damage, scale loss and number of sea lice present on juvenile Pacific salmon. Skin damage was evaluated using a scale from 0 (zero damage) to 4 (lesions present, skin removed and muscle exposed or skin partially removed exposing necrotic tissue, hemorrhaging at margins of lesions). No lesions were recorded for juvenile Pacific salmon in the Broughton Archipelago, Queen Charlotte Strait, or Rivers and Smiths Inlet sets. Minimal skin damage was observed in all areas. There was no evidence of ill health. DNA analysis is preliminary, but indicated pink salmon juveniles were from local stocks.

The study quantified sea lice levels, on adult Pacific salmon, for all five species. This type of information had not been examined previously for a large ecosystem in BC. The results showed that the average prevalence of sea lice on adult fish exceeded 90%. The possibility exists that coho and chinook are the over-wintering vector for sea lice.

Preliminary conclusions for salmon sampled in the Broughton Archipelago and Queen Charlotte Strait in August and September of 2003, include: these are important rearing areas for juvenile Pacific salmon in August; adult Pacific salmon (all species) had a high prevalence of sea lice; and pink, chum and other species of juvenile Pacific salmon in Broughton Archipelago and Queen Charlotte Strait had no lesions, virtually no skin damage and appeared to be healthy.

Q. Relating to your hypothesis that the lice in the ocean are coming into the Broughton with the stocks – I would say that they do not have to since there are hosts there all year long.
A. This is possible. There has been very little work carried out on the cause of marine survival. There is a significant amount of mortality. Preliminary data shows that there is a significant amount of mortality in the final brood year. We will know more about this next year.

Q. Regarding the juvenile salmon abundance in the Broughton, what are the numbers?
A. We saw a lot of fish in the inlets, and now believe that inlets are very important for juvenile salmon. They appear to stay inshore longer than we thought. It is possible that juveniles stay long and we need to figure out the mechanism that is stopping them from migrating out. Is it a physiological change? Perhaps they can no longer tolerate low salinity so they must move to the open ocean.

Q. You specified Pacific salmon. Where there any escaped Atlantic salmon?
A. No other salmon, only a few Dollys. I submitted a proposal to Aquanet to look at this issue.

General comments

Q. Farms are starting to have an impact on marine resources. What is wrong with local and traditional knowledge – you should not just be doing studies on salmon. DFO should have this in their records.
A. This is the job of the PFRCC.
A. We cannot wait that long.

Q. There are implications to all of this data, and you have to look at it in that light. There is a high degree of uncertainty and you need to understand the relevance of that when making management decisions.
A. That is philosophical – that is, how the results are used by management. Once this (data) analysis is completed I will answer that. I am not ready to answer that yet.

Comment: It appears to me that you are looking at other problems and not dealing with the problems at hand. We need to hear from the farms.

Comment by John Fraser, Pacific Fisheries Resource Conservation Council

It was the conclusion of our work on the 1994 Fraser Sockeye Review Board that there was a lot that we did not know about salmon, and there was a need for more and better scientific work to be done. One of the recommendations that came out of this was the establishment of an independent conservation council (the Pacific Fisheries Resource Conservation Council (PFRCC)) to report to both levels of government and to the pubic, advising on the state and status of the stocks. This was done because we did not believe there was enough work being done in DFO to effectively make management decisions.

Since 1998 the PFRCC and others have said repeatedly to minister after minister, and in discussion with DFO officials, some senior and some middle rank, that there are not sufficient resources being given to the Department of Fisheries and Oceans to even begin to meet the needs of the wild fish populations on the west coast. We have also said that the decision to cut funding was made years ago by bean counters, which also affects the cuts that are being made now. What we have also said is that the people who were making the cuts to the Department were not fisheries experts and they did not know anything about what was going on out here, and what was needed. Anyone can cut funds - what takes skill is the ability to manage the resources in the Department in such a way that funds are not being taken from the programs that absolutely have to be carried out; or else the mandate of the Department is lost.

We have also said this: the Department is in an invidious position, and many of the people within the department have been put in an invidious position, because the decision was made to upgrade, increase, and augment the resources for the development of fish farms. A special Commission was created, headed by Mr. Bastien, who only reports directly to the Minister. What this did was make to it very hard to argue against him.

The concern over the number of fish farms was increasing. The Department was caught in a position of having to decide: Do we say anything about it, do we increase our work in this area, or are we expected to do this by our bureaucratic masters (because I think half the time politicians did not know exactly what was going on), or are we supposed to say nothing because that might limit the management of fish farms. We have said all of this before and we have said it to all the Ministers, including David Anderson.

In a recent meeting with the new Minister of Fisheries and Oceans, I first thanked him for the meeting as it was only a few days after his appointment. I said that we would like to help him, and secondly that there are a lot of people around who would like to help, in the PFRCC, the Department and elsewhere. I took the position of speaking very frankly with him. I did that because I did not think he would get what I was going to tell him after the briefing preparation had been watered down (so as not to upset the Minister too much). He listened to an overview (the best that I could give) about what has been going on out here for a long time, with regard to the state of the stocks, the state of the habitat, the whole Broughton Archipelago issue, and the consequences of the decline in the resources and scientific capacity of the Department to do what they are supposed to do. And also about the conflict, the inherent conflict; that is, whether the Department is going to promote aquaculture or look after the wild fish and the habitat.

I also went through the whole issue of our proposal to establish an aquaculture forum; a forum in which many of the issues that are being discussed in the present workshop would be addressed.

All of us have an enormous stake in the continuance in the Department of Fisheries and Oceans, and especially in the rejuvenation of its capacity to do the kinds of things that it is supposed to do. I have not even touched on the provincial government. The Province wants to push aquaculture, and they do. The provincial government within the last year have paid a great deal more attention to these issues that we are discussing.

Lastly, I want to say this. Everyone has been saying this over the past two days, and DFO has said this: one of the problems is that we are trying to do a very rushed thing. We are trying to catch up on a lot of work that should have been carried out before now. But for the first time in a lot of years, a sort of practical program is going on. Even on the provincial side there is effort. However, DFO is trying to do science in a rushed way. If we were wiser, then it would have been done sooner. This is a crash program that is going on. This has not taken place before.

Secondly, on the announcement from the provincial government that monitoring is going to take place on all of the farms up and down the coast, I could argue against their decision not to fallow farms in the Broughton during the upcoming 2004 pink outmigration. An important question is whether or not a corporation (ie. fish farm business) is in a situation (where there is an interaction with wild fish) that they should have the privilege of sitting on their information and not giving it to the public.

There are significant things that have happened over the past 18 months, but is this enough? The answer is *no*, and no one says that it is. It is absolutely essential, at least in the view of the PFRCC, that we have to influence our new Minister in every way possible. We cannot be treated like our conventional fishery of the wild fish, and its economic importance, does not matter.

Lawyers have a term "Time is of the essence". It means that you have reached a point of urgency. In my mind we have passed this point a long time ago. We are operating, as one always operates when you are trying to cope with an urgent and emergency issue, with insufficient resources, non-sufficient time to plan adequately, and having to pick up bits and pieces of information only to find out how much more we have to find out. That is the situation that we are in now.

To the First Nations, I say: Do not doubt that your anguish is shared by those of us who are non-First Nations.

There are a number of questions that I and others have submitted (see p. 27). What these questions are aimed at is that we have to take what we have learned here, from a scientific fact finding point of view, and not diminish the quality, but to try and figure out how it relates to what needs to be done in the future. We need to understand what needs to be done tomorrow. We need to put this into clear precise language and give it to the public. Ultimately we will get more funding to answer these questions if the public understands this information. We cannot do anything without the public.

SPECTRAL SENSITIVITY OF THE SEA LOUSE *LEPEOPHTHEIRUS SALMONIS*

Inigo Novales Flamarique, Professor, Biological Sciences, Simon Fraser University

This study was designed to assess the spectral sensitivity and functioning characteristics of the visual system of the sea louse *Lepeophtheirus salmonis*.

Two cameras connected to a computer tracked the free swimming *nauplii* in three dimensions. A special chamber was used in which filters and colours could be adjusted, and water velocity and sea lice life history stages (*nauplii*, *copepodid* and adult) were monitored. Sea lice responses to on/off light were monitored and recorded, with varying light intensity and colour.

Results demonstrated different patterns of response to light for *nauplii* (2-3 day) and *copepodid* (4-7 day) stages. *Nauplii* darted upward quickly in response to the light being turned 'off' and sank when the light was turned 'on'. Note that the *nauplii* stage does not attach. *Copepodids* swam up when the light was turned 'on' and sank when the light was turned 'off'.

Adult females showed upward responses to both the onset and the termination of the light stimulus, but the 'off' response for vertical movement was always higher than for the 'on' response.

Preliminary results were presented on the use of mitochondrial DNA sequences to differentiate between populations of *L. salmonis* in the west coast. Future research will study the variation of sea lice on wild and farmed salmon, and investigate the validity of potential cross-infection hypotheses.

TEMPORAL VARIATION OF SALMON LICE INFECTION AMONG JUVENILE AND ADULT PACIFIC SALMON ALONG THE WEST COAST OF NORTH AMERICA.

Marc Trudel, Research Scientist, Fisheries and Oceans Canada, Nanaimo

This study reported patterns of infection with the sea lice (*Lepeophtheirus salmonis*) on Pacific salmon collected in 2002 and 2003 in coastal waters (water <200 m) off Oregon, British Columbia and Alaska; 934 (30 minute) trawl sets were taken at 5 knots, with 14,685 fish examined. Limitations of this survey were identified: probability that sampling gear removes lice, only adults and pre-adult sea lice life history stages were counted, not every lice was identified, and samples had to be taken in water greater than 20 m deep. Sampling error was likely consistent across sites and periods which provided a qualitative picture of sea lice infection. The need to account for temporal and spatial variation by having multiple observation periods was presented.

Q. How did you define juveniles?
A. First year in the sea – no gonads.

Comment: That is a wide range.

Salmon lice were observed on all Pacific salmon species examined and from all areas surveyed. Infection rates varied significantly among species and life stages. The number of salmon lice infecting juvenile salmon rarely exceeded 5 lice per fish. The mean abundance of lice was generally below 0.2 lice per fish in juvenile salmon. The significant interaction between species and life stages indicated that the ranking of species

with respect to salmon louse infection varied between juvenile and adult salmon. This study also demonstrated that juvenile chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*Oncorhynchus kisutch*) overwintered on the west coast of Vancouver Island and Southeast Alaska. Coastal fish were infected with salmon lice throughout the year and therefore could contribute to the infection of salmon smolts migrating to sea during spring.

In conclusion, sea lice were found to be ubiquitous on the west coast of North America, with greater abundance on larger fish. Resident Pacific salmon can perpetuate the infection of sea lice during winter periods; however, the importance of this source of sea lice for out-migrating smolts is unknown. There did not seem to be a link between sea lice infection and salmon farms. Sea lice infection varied in time and space but was not synchronized with the host species. Future research should be focused on documenting Pacific salmon distribution and migration routes. A gentler sampling gear is needed to prevent removal of sea lice on the net. Background levels of sea lice infection, especially on returning adult and resident salmon, along with the source of sea lice infection need to be established. Also, the biological effects of sea lice infection on Pacific salmon need to be determined.

Comment: I have heard a lot of 'I don't knows'. You should have consulted fishermen, and you should have concentrated your effort in the Broughton Archipelago.

A. This is new informaiton. This was not designed as a sealice study, although I was able to collect sealice as part of the study. There is no inherent connection between sealice and salmon farms, but there may well be. There are juvenile fish that have sealice and have never been in contact with a farm. I have also been collecting samples from Stolt to do a chemical analysis.

ADDITIONAL (WRITTEN) QUESTIONS SUBMITTED BY WORKSHOP PARTICIPANTS

1. Sea Lice Biology

What are the ecological interactions between the two species of sea lice (*Caligus* and *Lepeophtheirus*), if any?

With regard to sea lice monitoring, why is the testing done differently now? They used to freeze the whole fish with as little handling as possible.

On observations made (DFO, Morton, other) what correlation was found between fish farms and lice on smolts in the Broughton?

Where are the fish between 3 and 7 kg? What are the infection rates on fish between 3 and 7 kg? What percentage of fish in each size category is present in the Broughton?

2. Effects of SLICE

What is the mode of toxic action?

It is a neurotoxin. How is it that it affects the nervous system in sea lice and not that of the host?

How is it that it cannot affect the surrounding ecosystem through transmission by faeces and lost food?

What is the degradation time for the neurotoxin?

How meaningful are Norwegian threshold levels (for Atlantic salmon) for local circumstances?
- in terms of lice levels requiring SLICE treatment (3 per fish)
- lice levels on wild fish likely to cause mortality (1.7 per fish)

3. Study Design

Why has DFO neglected to study the connection between sea lice and pink salmon and fish farms?

Why has Dr. Beamish conducted juvenile salmon-sealice studies independently of other DFO researchers involved in the Pink Salmon Action Plan? He looked at 150 mm juveniles and Dr. Hargreaves looked at 30-60 mm pink juveniles. Should DFO not coordinate their work and do integrated studies?

Are fisheries (DFO, Province) carrying out tests in other than the main seaward migration path- what about the other routes?

How can they say that they are *just now* learning about the life-cycle or learning what type of salmon are in the Broughton? What is DFO doing? Is it not their job to know?

What were the returns of pinks in Broughton rivers in the autumn of 2003 (in each river)?

4. Availability of Data

JoAnne Constantine seems to show that the operators diminished/controlled lice in pens. Is there any way we can see the difference in sea lice on farmed fish in 2003 and what may have been the case in the spring of 2001 (ie Morton's findings)?

Bud Graham says monitoring of fish farms has produced data and it will be made available to DFO - What form of information? Each farm? Will it be public?

Why do MAFF and the salmon farm industry refuse to release individual fish farm sea lice counts? Does the public interest not outweigh the right to privacy?

We trusted the fish farm industries when they moved into our area. They have the audacity to withhold data from us. And then they claim that they are cooperating. Can you tell me how you will get the farm industry to cooperate with the studies we want to be done?

What is the law: Is it forbidden for the Province to 1) demand the data (fish farms); and 2) release the data to the public? What is the law re: DFO?

5. What's next?

The PSARC Review process is expected to take place in March at the earliest. The pink salmon smolt out-migration will begin in early February.

Can the biological timelines be met by the bureaucratic timelines?

Given environmental variability from year to year (e.g., tidal, snowpack, flood conditions), is it possible to identify migratory routes for pink salmon smolts in the Broughton?

How can we expand (use) a single year's study to reflect the huge inter-annual spatial variability that stems from Knight Inlet physical oceanographic influences?

Why has the province decided on no fallowing for 2004 *before* this workshop and/or before PSARC?

There seems to have been fallowing, that is a corridor, in the spring of 2003. If there is no fallowed corridor in 2004 what will be the effect? Does anyone know?

Given the current snapshot of the Broughton is it possible to make scientifically-sound decisions with regard to pink salmon in the Broughton for 2004?

What is DFO proposing to do to address the pink salmon-sea lice issues in the Broughton for the 2004 season? Do they appreciate the urgency for an immediate Action Plan?

Do DFO and MAFF foresee having the staff and funding to do the needed studies, enforcement, and monitoring?

Before any new fish farm sites are approved do we have a database on these areas (whether clean areas or areas where there are *some* farms)?

Is the Pink Salmon Action Plan being continued into 2004? If so, when does it start and will it be observing sea lice in areas where there are no fish farms?

We recognize the urgency of the situation with regard to sea lice infestations in the Broughton Archipelago with special reference to the potential interactions with fish farms. The meeting should call on both provincial and federal governments to continue the research and monitoring focus of 2003 with the aim of developing a stronger knowledge-based management system.

WORKSHOP SYNOPSIS

Brian Riddell, Science Advisor, Pacific Fisheries Resource Conservation Council, Vancouver

During the past year significant effort has been directed in the Broughton Archipelago to understanding the abundance and distribution of juvenile salmonids and the presence of sea lice on salmon, both in natural and farm environments. Some of the analyses presented at the workshop involved preliminary data and/or incomplete analyses but two notable features are not likely to change: i) sea lice incidence and loads were substantially lower during 2003 than reported for the past two summers, and (ii) two species of sea lice were present (*Lepeophtheirus salmonis* and *Caligus clemensi*) with *C. clemensi* accounting for about 60% of the total lice counts (based on Department of Fisheries and Oceans assessments). These data were largely based on samples collected by beach and purse seines (DFO program) and dip nets (Raincoast Research). Trawl-based net sampling during August 2003 was also successful in capturing large numbers of small salmonids. These salmonids were substantially larger than those collected by seining and dip nets, but they also had low incidence and numbers of sea lice. Counts of lice from trawl gear were acknowledged to be minimal as damage to fish collected in trawl gear is more extensive than by the other gears. In both the DFO seining and trawl programs, the vast majority of small salmonids were described as "healthy" with no readily apparent external damage due to sea lice. These observations were in contrast to photographs shown of small pink and chum salmon collected during the dip-net sampling in Tribune Channel and Fife Sound (Raincoast Research).

The Provincial government implemented an audit program during 2003 to verify the numbers of sea lice reported by the companies on Atlantic salmon. Under an interim sampling protocol companies were required to sample their fish routinely for sea lice incidence and loads. These data were summarized as the *average numbers of lice within three size categories* and were posted on a provincial website. The independent audit program inspected sampling processes, conducted counts on additional fish, and verified species identification of the lice. Dr. Joanne Constantine (Veterinarian) reported very good consistency between the audit samples and those conducted by the companies.

Other presentations reported on:

a) Return of adult pink salmon to rivers in the Broughton Archipelago and Knight Inlet, plus surrounding geographic areas. DFO's assessment was that pink salmon returns generally declined in 2003 relative to 2001 but that reductions were within levels previously observed for pink salmon. Sampling of juvenile downstream migrations was also attempted in three streams but with very limited success. These studies did suggest however that emigration from freshwater during 2003 was quite early and likely to have been in late February and early March.

b) DFO Science Branch also attempted to locate planktonic larval stages of sea lice in the Broughton Archipelago. Little success could be reported from this first year of effort.

c) Dr. Inigo Novales Flamarique (Simon Fraser University) reported on the development of a proto-type light trap to collect planktonic stages of sea lice (to be tested in the Broughton in 2004) and early stages in the study of genetic markers in sea lice (using a highly variable portion

of the mitochondrial DNA). Differences between lice were detected but whether differences could be used as markers remains to be investigated.

d) DFO Science Branch, High Seas program reported on recent year studies of salmon in coastal waters (west coast of Vancouver Island north to the Bering Sea), and sampling for sea lice on these salmon.

Sea lice have undoubtedly never enjoyed such profile in west coast fisheries research, but after the first year of investigations many questions and concerns remain unanswered.

Issues or Highlights
This list of issues reflects my personal impressions of the presentations and discussions. Other people would likely have different perspectives, but I hope these capture the general concerns expressed by participants. (These concerns are noted in the questions and comments from participant highlighted throughout this document) I have listed these issues from higher to lesser priority.

1) While people tended to acknowledge the significant effort in 2003, there was a frustration that analyses could still not comment on the issues of salmon farms, sea lice, and wild Pacific salmon. These initial studies revealed that significant numbers of juvenile salmonids (not just pink salmon) utilize the Broughton Archipelago over several months and are susceptible to two species of sea lice. A significant point for consideration should be how to address peoples' expectations that wild salmonids will be protected while the studies of potential interactions between the farms, lice, and salmon progress. Studies in complex and dynamic marine ecosystems are not likely to be quickly resolved or meet people's concerns. A realistic expectation is that a few to several years maybe be required if similar studies continue in the future.

2) A serious issue of comparability of sample results has not been addressed. Samples of salmon and sea lice were collected by various gear types over a wide area and several months. Can, or should, the incidence of lice on salmon and the counts of lice be directly compared? Further, are we confident that the various groups conducting the counts are equally capable; if not, can the differences be corrected? These data processing questions certainly add to the debate when the results of differences between samples are discussed and are the type of experimental comparisons that could have been addressed. For example, while the incidence of sea lice on salmon sampled by dip nets (Raincoast Research) was very similar to the results from the DFO seining studies, the values are not comparable since one set of numbers only included *L. salmonis* lice but the DFO study included both species (and their results suggest 60% of the counts were *C. caligus*). The selectivity of gears to size or species of juvenile salmon, the impacts of sampling methods on lice counts, and variation between persons counting were not compared, and must be acknowledged when future comparisons are discussed.

3) How many sea lice could kill a juvenile Pacific salmon? Differing observations on the health of these small salmonids draws into question comparability of samples (as discussed above) and the extrapolation of Norwegian studies that suggested 1.6 sea lice per gram (wet weight) was lethal to Atlantic salmon and sea trout (others at the meeting pointed out that mortality actually

occurred at even lower loads in these studies). The point of issue in applying the Norwegian studies is that they were conducted on much larger fish but the results have been extrapolated to the much smaller Pacific salmon juveniles. Many of the pink and chum emigrants are a gram or less and carry sea lice loads that would imply mortality of these fish - but is the extrapolation appropriate? Although two studies of the lethality of sea lice to small Pacific salmon were to be conducted during 2003, neither of these studies were successful. This issue must be addressed if the sea lice loads observed in 2003 are to be properly interpreted. Lice loads in 2003 were much reduced relative to the past two years but the loads were frequently in the range of 1.6 lice per gram.

4) The availability of data on sea lice in salmon farms and the abundance of Atlantic salmon in the farms remains a contentious issue. The provincial government reports of counts conducted during 2003 were notable but several persons noted the need for these data by farm and fish, and stage of the lice. The publication of average loads by time period is not adequate for statistical analyses and will become a greater concern as analyses progress. At present, these data have not been made available and there remain concerns about the proprietary nature of the data.

5) A number of concerns were identified about experimental design and sampling procedures. Several times comments were made that sampling was not random, few studies used controls or had reference sites, and the major DFO study acknowledged that their method for data analysis has not yet been decided. There is clearly an onus on a scientific organization to apply sound experimental designs and statistical methods. However, when conducting large field programs, these standards can be difficult to maintain. The statistical methods and designs merit greater attention in future programs, particularly when inferences drawn from these studies could have significant effects on wild salmonids and/or the salmon farms.

6) How comparable are the results collected in 2003 with the situations during 2001 and 2002? Salmon loads in the farms during 2003 have been greatly reduced through marketing by the industry, fallowing of farms, and indirectly due to the IHN outbreaks. The industry has also treated for lice during 2003. Further, pink salmon abundance was likely greatly reduced, but this cannot be quantified. These differences should be considered when inferences are drawn concerning the 2003 studies and past situations. Various participants were also concerned with the indirect ecological effects of treatments (using SLICE) and the efficiency of this treatment in controlling sea lice numbers. The conditions on the farms will be different again in 2004 (essentially no large grow-out sized Atlantic salmon) and this again complicates studies of the farms and wild salmon.

7) Are there sufficient wild salmonids in the Broughton Archipelago during the winter that these salmon serve as over-wintering hosts for *L. salmonis*? Sampling of adult salmon during 2003 indicated the common presence of sea lice on these returning salmon. While this has been a common observation for years it has seldom been quantified. Further, Dick Beamish has hypothesized that this is a life history strategy of *L. salmonis* and is a means for this species to locate hosts for the planktonic lice phases. Adults return to coastal waters where densities of younger salmon are higher. This strategy, however, may also lead to sea lice on over-wintering salmonids and this could be a source of sea lice on juveniles in the following spring. Dr. Beamish proposed that these over-wintering hosts provide a source of sea lice to both farm and

wild salmon. While this suggestion is a viable hypothesis, the relative importance of these over-wintering hosts versus the sea lice on salmon in farms will remain unknown unless significantly more research is conducted. For example, what is the abundance of over-wintering salmonids, what is the lice load on these fish and do the lice reproduce in the over-wintering environment, and are the infectious stages of these lice present in the Archipelago when juvenile salmonids emigrate from freshwater?

8) An interesting side-bar in the presentations was introduced by Simon Jones. Dr. Jones described the number of species of sea lice and noted that they are all believed to have similar life histories. He commented on how salmon, sea lice, and the incidence of diseases exist in a balance in Nature. A successful parasite should not kill its host (directly or indirectly) or the parasite cannot complete a stage of its life cycle. In an evolutionary sense, these associations have developed over a long period of time and usually represent close associations between the parasite and its hosts. He also noted that periods of disease due to parasitic infections maybe indicative of stresses on the host which disrupts the balance and can result in mortality of the hosts. Subsequent presentations presented interesting examples of the specializations of the parasites and how they are adapted to a highly mobile host such as salmonids. Moira Galbraith presented photos of the appendages of the planktonic sea lice and the hooks and claspers used to attach to the host, and specialization of the rostrum in different species. Inigo Novales-Flamarique showed how different infectious stages of sea lice respond differently to light and this may provide a mechanism for placing these stages in light regimes used by the hosts. This close association of host and parasite should suggest that in consideration of the salmon farm and sea lice issues attention also needs to be paid to the ecological condition of the juvenile salmonids. Are the infections observed due to an unusual abundance of the infectious parasitic stages, or is the infection also resulting from stresses in the juvenile salmonids (e.g. Was there sufficient food present to support the abundance of salmonids present?).

Recommendations

Before presenting another list of needed activities, the issue of addressing peoples' expectations merits a comment. Many people are concerned for the protection of the wild salmonid and want to see progress in these studies so that we can determine whether or not the salmon farms pose an additional risk to the local salmonid populations. To be realistic, and honest, these studies will take time as the ecological conditions for the studies are highly dynamic and the parasite is difficult to study in Nature. This is surely one reason for the continued debates in Europe. In managing the issue of sea lice and salmon in the Broughton Archipelago, we should recognize that there is a shorter-term process issue of managing an uncertain biological problem and being sensitive to the expectations of the public that the local salmon populations are being protected. There is clearly a sense of frustration concerning progress in understanding the issue of salmon farming, sea lice, and potential impacts on wild salmonids. However, *if* progress or change will only proceed based on sound scientific results, then progress and change will take time - more time than many people will want, or possibly accept. The recommendations below are not intended to address this process issue, but managers must continue to recognize these immediate concerns while research continues to develop an understanding that may explain what people have observed, and indicate how to manage these conditions.

It is also worth clarifying the primary issue that generated the debates over salmon farms, sea lice, and decline in pink salmon abundance. Unlike some comments presented, sea lice are *not* considered to be uniquely associated with salmon farming - this has never been the issue. Sea lice are known to be widely associated with salmon in the sea. Researchers also agree that salmon farms do contribute sea lice to the natural environment but this is incremental to the natural production of the louse. The issue of salmon farms and sea lice more specifically concerns whether the sea lice from farms cause an incremental natural mortality to salmonids during their ocean phases. Concern for this was heightened for Pacific salmonids because sea lice had not been previously recognized on small, early ocean migrant, Pacific salmon. Simon Jones noted the absence of systematic data on these small fish but many, many studies of juvenile salmonids have been conducted and infections of sea lice have not been noted.

The points of contention then seem to be:
• Do salmon farms produce a significant portion of the sea lice on these juvenile salmonids?
• How do the sea lice on these small juveniles affect the juveniles, and can we understand the ecological dynamics of this interaction sufficiently so that wild salmonids can be protected?

I list these research topics from highest to lowest priority, but these are simply my personal opinion:

1) Studies of the impact on sea lice on juvenile salmonids. What is a lethal load of sea lice on a small, early ocean migrant, Pacific salmonid?

The data collected in 2003 cannot be fully assessed without an understanding of what the observed sea lice loads mean in terms of impacts on the small fish. I suggest therefore that it is critical that laboratory studies and enclosure studies be conducted to rigorously examine this issue. Laboratory studies will be necessary to control the exposures and loads of lice etc., and to monitor the effects on the salmonids. Laboratory facilities also provide the opportunity to challenge the juveniles (or stress them) in different environmental conditions to examine changes in the sensitivity of the salmonids to lice infections. Challenges could include feeding conditions, temperature variation, fish density, and other factors. I also suggest the use of enclosure studies in the natural environment so that indirect factors such as predation could be tested under more semi-natural conditions. I would recommend that the enclosure studies are secondary to the laboratory.

2) Studies of the life cycles of sea lice in salmon farms and the natural environment. Our understanding of juvenile salmonids may be more limited than desired, but our understanding of these sea lice is even less. For example, are sea lice in salmon farm conditions more productive than in the natural environment?

Aspects of this research could also be conducted in laboratories, but the availability of appropriate laboratory facilities and researchers is a serious question at this time.

The study of sea lice in open environments will present some serious challenges as Moira Galbraith demonstrated. There is be a serious need to develop sampling tools and design of monitoring programs to sample for sea lice stages - we may be able to collect samples, but can

we sample sea lice abundance quantitatively and representatively? Testing of Inigo Novales Flamariques' prototype light trap should receive high priority for this year.

In studying the different species and stages of sea lice, there must be more attention paid to ensuring comparable results from the various investigations. Direct sample comparisons and replicated laboratory comparisons are recommended.

The hypothesis that over-wintering salmonids in the Broughton Archipelago are sufficient or alternative hosts for spring infection of the juvenile salmonids could also be an aspect of this research topic. Without investigation, this remains a viable hypothesis that would depend on the abundance and distribution of the over-wintering hosts, residency of these hosts during critical periods that infective lice would have to be liberated, and what the lice loads are on these hosts.

3) Studies of the ecological interactions between salmon farms, sea lice, and juvenile salmonids. I recognize that this is a "motherhood" type research topic and that results will inherently be longer-term, but this is the issue that must ultimately be managed. The question is: Can we better address the issue with more directed and experimental approaches rather than continuing to repeat large scale (temporally and spatially) sampling programs?

Progress in this topic likely requires the involvement of the salmon farming industry and the farms within the Broughton Archipelago. The absence of data from the farms continues to be a source of concern (as noted above), and the ecology of sea lice within the farms is critical to an accurate understanding of this topic. An improved, co-operative working relationship with all involved is essential to fully investigate this topic.

Studies of the early marine ecology and growth dynamics of juvenile salmonids are also needed. These studies are the "natural environment" side of the interaction concerns. The timing of emigration, habitat usage, and growth and dispersal relationships are likely all involved in the exposure of juveniles to lice and to the impact of the lice. However, this topic will take substantial time to truly understand - and there may be highvariability between years. An important consideration then is whether all Parties involved could develop a management plan that is not dependent on a comprehensive understanding of these natural population dynamics? It may require an agreement to conduct an annual sampling program but it should not rely on or expect annual investigations of this topic.

The other "interaction" component is the treatment for sea lice on salmon farms. The impact of treatment would be considered in the studies of sea lice ecology and production within the farms. However, there was clearly continued concern for the efficacy of treatment for lice and the indirect effects of treatment chemicals in the natural environment. This issue has received study in Europe and investigations continue in Canada (for licensing of the treatments) but a monitoring program in British Columbia may be required before public confidence in these treatments is established.

4) Establishment of key indicator stocks of Pacific salmonids to be used in annual escapement surveys. Significant concern for the impact of sea lice infections has resulted from changes in spawning escapement levels. It has been important to maintain the methods used to

monitor spawning escapement in recent years, so that changes in escapements are not confounded with changes in methods. However, the methods used for monitoring pink salmon are not as rigorous as many of the other studies involved in this debate. It seems only responsible that increased rigour be applied to a few key populations that can be monitored annually with accuracy and confidence. These studies should not be limited to pink salmon.

In other stock assessment programs, key stocks usually also involve monitoring of juvenile production. While this would be desirable so that the freshwater sources of variation can be accounted for, I suggest that the juvenile monitoring should be secondary to ensuring accurate spawning escapement trends in the Broughton Archipelago and some "reference" sites outside of this area.

5) Increased consideration of the statistical analyses and experimental design is necessary. I certainly acknowledge that some of the investigations that were implemented in 2003 had to be quickly organized and implemented. However, several comments indicated concerns for the use of control or reference samples, the role of random sampling in making statistical inferences based on the samples collected, and the appropriateness of designs to address specific questions For example: Was the purse and beach seine program able to detect migration paths or assess the fallowing of certain salmon farms? Further, the analytical methods to be applied to the temporal and spatial data collected from the purse and beach seining has not been determined.

If more timely progress is to be made in understanding the dynamics of this issue, then more directed experimental investigations are necessary. These types of studies are more amenable to careful experimental design and statistical analysis. However, each program addressing this issue should pay particular attention to the statistical basis of their studies, as the inferences drawn from them could have significant consequence to the industry and/or the local environment and salmonids.

In conclusion, we should acknowledge that a major issue in continuing to make progress in this issue will be *the availability of funds and facilities and the commitment of researchers*.

The above list is only five topics but each involves substantial commitment of resources if they are to be addressed. The participants of this workshop should not be complacent about the funding required to conduct this work; a serious issue could be the development of a strategy for how to find and maintain a commitment to continue research in these topics and this area.

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