SFU SIMON FRASER UNIVERSITY
CONTINUING STUDIES

Speaking for the Salmon

PROCEEDINGS

Summit on Fraser River Sockeye Salmon: Understanding Stock Declines and Prospects for the Future

March 30–31, 2010

Edited by Patricia Gallaugher and Laurie Wood
Continuing Studies in Science and
Centre for Coastal Studies

Photographs: Craig Orr, Watershed Watch Salmon Society

Preface

A scientists' think tank met on December 7-8, 2009 to consider the causes for the unexpectedly low returns for Fraser River sockeye salmon in 2009. They examined these questions:

- Is marine/ocean survival the problem?
- What other factors must be considered to develop a better understanding of marine and freshwater survival?
- Do forecasts provide useful information to fisheries managers?
- How can we improve monitoring and management in a changing world?
- Where should research be focused?

Their findings were published in a statement, which is available in Appendix 2 or at our website: (http://www.sfu.ca/cstudies/science/adaptingtochange.htm).

This website also includes information about the scientists and some of the resource materials considered in their review.

The Summit on Fraser River Sockeye reviewed the findings of the think tank in relation to the questions that were posed and sought solutions to ensure survival of Fraser River sockeye for future generations.

Taking a life cycle stage approach, participants followed sockeye from their emergence from the gravel to the time they return as adults, to gain a detailed understanding of the challenges they face, and what can and should be done to ensure their survival for generations to come. What follows is a synthesis of the presentations and dialogue.

The Speaking for the Salmon Series examines issues impacting the survival of wild salmon in British Columbia. Programs in the series include workshops, think tanks, proceedings and video presentations. For more information, visit our website (http://www.sfu.ca/cstudies/science/salmon.htm).

ISBN 978-0-86491-315-9

Acknowledgements

We were fortunate to have a diverse and informed steering committee and wish to acknowledge the contributions of the following:

Mark Angelo, Chair, Pacific Fisheries Resource Conservation Council and Chair, Rivers Institute, BC Institute of Technology

Patricia Gallaugher, Director, Centre for Coastal Studies and Continuing Studies in Science, Simon Fraser University

Craig Orr, Executive Director, Watershed Watch Salmon Society

John Reynolds, Tom Buell Leadership Chair in Salmon Conservation, and Professor, Biological Sciences, Simon Fraser University

Brian Riddell, CEO, Pacific Salmon Foundation

Ernie Victor, Manager, Aboriginal Community Liaison, Fraser Basin Council

We also thank the presenters for volunteering their time and sharing their expertise and express our gratitude to the sponsors for making this project possible:

rivers institute at BCIT

BC Institute of Technology, Rivers Institute

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PART ONE – CHALLENGES TO SOCKEYE

INTRODUCTION

Report from the December Think Tank of Scientists

Introduction by:

Mark Angelo, Chair, Pacific Fisheries Resource Conservation Council

Presentations by:

Mike Lapointe, Chief Biologist, Pacific Salmon Commission

John Reynolds, Tom Buell Leadership Chair in Salmon Conservation, Simon Fraser University

John Henderson, Councillor, Weiwaikum Band and Member, BC First Nations Fisheries Council

MARK ANGELO, CHAIR, PACIFIC FISHERIES RESOURCE CONSERVATION COUNCIL

Salmon are an icon to most British Columbians. They are an important part of our culture, our history, and our environment. The events from this past summer caused a great deal of anxiety, concern and hardship for a lot of people. This is particularly unsettling in light of long-term trends showing significant declines over the past couple of decades. You have to remember, however, that we did have a sockeye salmon return of 16.5 million as recently as 1997. While we have had some banner years for other species such as pink salmon - almost 20 million pink salmon returned to the heart of the Fraser in 2009 - the overall trend for sockeye has clearly been down. 2009 was the most recent of several so-called 'missing salmon' events that have occurred over the past decade with the numbers hitting a 52-year low with only 1.4 million or less fish returning, a fraction of what we all expected.

Consequently, in light of public concern and as a follow up to the extensive media coverage last fall, there has been widespread interest in hearing from the science community about what the causal factors behind this poor return may have been. December's gathering of scientists in a two-day Think Tank at SFU was the first event to deliberate on this issue from a science perspective. Then in November a formal enquiry was launched by the federal government to look into the collapse of Fraser River sockeye stocks – to be headed by Judge Bruce Cohen. This will be a positive exercise and will certainly shed some additional light on the Fraser sockeye collapse that we all witnessed. However, given the lengthy timeframe for the enquiry, which will not conclude until the spring of 2011, there was overwhelming support for December's science think tank to go ahead. The response and interest that we saw in that event highlights the public's desire to try and seek consensus on possible causal factors while also formulating recommendations for

management actions and research initiatives that could be undertaken sooner rather than later.

There is public concern that little may be done over the next 18 months while the enquiry is underway - it would be unfortunate for British Columbians and for its sockeye stocks if that were to transpire. Gatherings like this one are timely and certainly relevant. On the limiting side, DFO employees have been instructed that they could not participate in events of this nature due to the launch of the enquiry. That is certainly unfortunate. However, every effort has been made to gather from the Department whatever pertinent data may exist so that they can be adequately considered by this group.

In our upcoming discussions we will systematically review the lifecycle stages for sockeye as well as possible factors that may have been a cause for mortality. Undoubtedly there will be some consensus and also some strong differences expressed. The key point to make is the fact that this issue is very complex and there is still much that we do not know. But when all is said and done I suspect there will be agreement on some key issues and given the importance of the topic and the urgency attached to it, a gathering of this nature can only be positive in the end.

Mike Lapointe, Chief Biologist, Pacific Salmon Commission

This presentation will cover four topics: pre-season forecasts, in-season management, some outcomes, and longer-term trends.

Preseason forecasts

The 2009 pre-season forecasts predicted 10.5 million sockeye and 17.5 million pink salmon to return to the Fraser River. However, forecasts are very uncertain. For example, for sockeye in 2009, there was a one in four chance of a return of less than 6 million, and a one in four chance of a return greater than 19 million. This amount of uncertainty is not unfamiliar for those of us who are intimately involved with Fraser management. However, this has not necessarily been communicated that well to the public.

One thing to note is that fisheries managers not only plan for the point (the 10.5 million number), but they also plan for a range of returns. As a result, there are scenarios of potential fisheries that are very low returns and there are scenarios that are at higher returns. Note that forecasts are not used to open fisheries - fisheries are not opened purely on the basis of an expectation that starts at the beginning of the year.

In-season management

In order to understand in-season management, it is important to understand something about the management objectives. Figure 1 describes the management objectives for the Fraser River Panel (a bilateral body involving the U.S.A. and Canada) that is involved with the management of Fraser River sockeye every summer. The Fraser Panel does not regulate all fisheries on Fraser sockeye; for example, they do not regulate the commercial fisheries in Johnstone Strait and they do not regulate First Nations Food, Societal and Ceremonial (FSC) fisheries. However, all fisheries

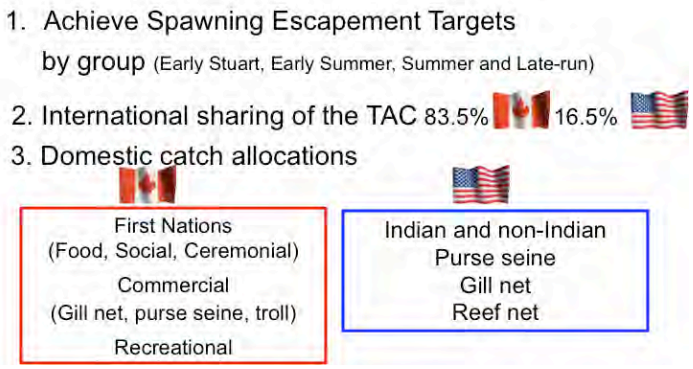

Figure 1. Fraser River Panel: management objectives.

are managed based on the same information and they share the objectives described in Figure 1.

The first objective is to achieve sockeye spawning escapement targets. These are grouped as follows: Early Stuart, Early Summer, Summer and Late-run. The second objective is to achieve the international shares of the Total Allowable Catch (TAC) as set out under the current treaty; Canada has an 83.5% share and the U.S.A. has a 16.5% share. In addition, there are domestic catch allocation objectives. In Canada these include the First Nations FSC fisheries in addition to the commercial (gill net, purse seine and troll) and recreational fisheries. In the USA there are treaty Indian fisheries and non-Indian fisheries; the non-Indian fisheries include purse seine, gillnet and reef net.

Components of the in-season assessments

Components of the in-season assessments are used every summer to tell us how many fish are actually coming back relative to the forecast. One component is test fishing - test fisheries are used to provide a very early indication of the abundance in marine areas. Another component is the acoustic program at Mission which monitors the upstream escapement, fish headed for the spawning grounds. DNA technology is used for genetic stock determination which tells us where these fish are headed when they are out in a mixed stock area; for example, if a sockeye is caught in Johnstone Strait, it is possible to determine what stream that fish is returning to. Finally, the scales of the fish are used to tell us how old the fish are.

Migration timing

Figure 2 shows the migration timing of Fraser sockeye where the daily abundance is described from June to September.

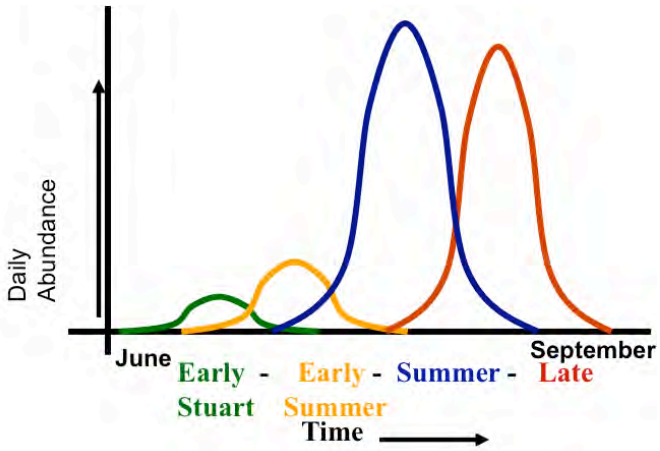

Figure 2. Migration timing of management groups.

This follows a very predictable pattern: the early Stuart runs come in first, typically with a much smaller abundance, then early Summer runs, typically the largest component, followed by the Late runs. This information helps us with our in-season decisions.

For example, the pre-season forecast for early Stuart for 2009 of 165,000 was spread over a 30-day period with a peak based on historical data (Figure 3).
In this plot, each of the blue bars represents the abundance of fish on a particular day passing a marine area, such as Juan de Fuca Strait. In this particular example we would expect to see about 10,000 fish passing the marine areas on July 4. The in-season management approach is to then compare this expectation with what actually returned.

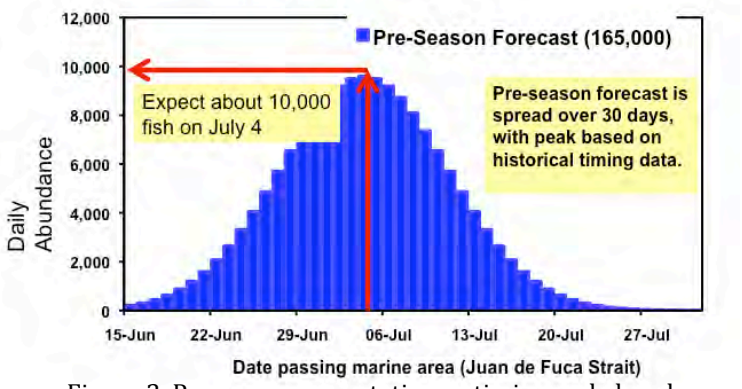

Figure 3. Pre-season expectations – timing and abundance.

In-season assessments

Figures 4 and 5 are plots of what actually returned in 2009. In Figure 4, the dotted line represents the expectation based on the pre-season forecast; the solid line represents the in-season assessments. For the early Stuart in 2009 what actually returned was about one half of what was forecast, 85,000 fish.

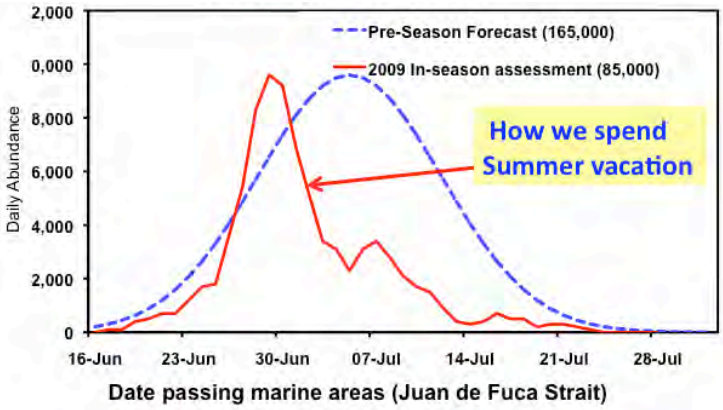

Figure 4. In-season assessments. 2009 Early Stuart sockeye migration.

What else can you learn from this graph? Note, for example, that the peak has shifted to the left at an earlier time than July 4th.

Figure 5 is the plot for the Summer runs. We were expecting about 8.7 million Summer-run sockeye and our in-season assessments indicated we had 644,000.

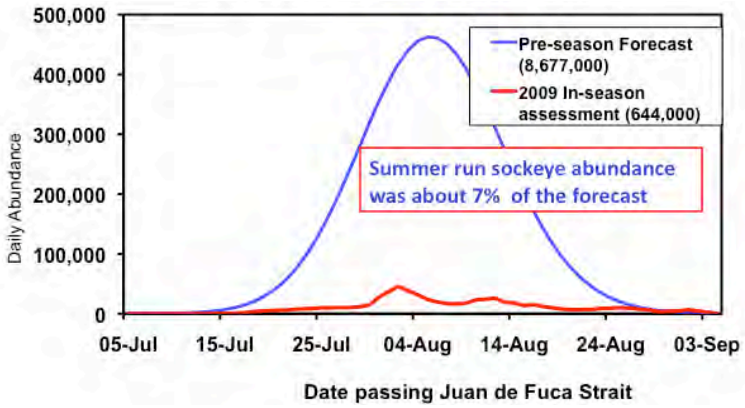

Figure 5. In-season assessments. 2009 Summer Run Sockeye

These plots are shown to the Fraser Panel about three times per week in-season. It was very clear to all the members of the Fraser River Panel that the Summer run was much less than we expected; in this case, the Summer run sockeye were about 7% of what was forecast.

2009 Outcomes

The pre-season forecast was 10.5 million, with a range from 3.5 to 37.6 million. The current post-season estimate is 1.5 million. This is the lowest return observed since 1947. There was a total catch of 124,000 Fraser sockeye, or about 8 % of the total return. That means that there was 92 % of the total return left for potential spawning escapement. Table 1 describes the 2009 Fraser sockeye spawning escapements.

Table 1. 2009 Sockeye spawning escapements by management group.

Management Group	2009 escapement (adults)	Average escapement (2009 cycle; 1953, 57, 61, ...2005)
Early Stuart	45,000	222,000
Early Summer	92,000	100,000
Summer	478,000	1,853,000
Late	441,000	139,000
Total:	**1,056,000**	**2,314,000**

The table shows the average figures on the cycle (four-year intervals). Early Stuart escapements were 45,000, well below the average of 222,000. Early Summer runs were slightly below average,

92,000 compared with 100,000. Summer runs were well below average with 478,000 compared with average returns of 1.8 million. Late runs were slightly more than average - this relates to the differences in the Harrison sockeye escapements (see page 12). In total the escapements were less than half of the average despite the fact that the run was the lowest since 1947.

The plot in Figure 6 represents a long-term pattern of Fraser River sockeye returns from 1893 – 1993, a full century of returns. The four-year intervals are highlighted. Note that the last point on the graph, 1993, was the largest return of Fraser sockeye in over 80 years, since the Hell's Gate slide (1913). In fact, the sum of the four years (in the green box) is as large as, or larger than, any four-year period in 10 years, even in the years prior to the Hell's Gate slide. The times have been shortened starting with 1952, which is a period when there are data by stock. Note the period of maximum abundance.

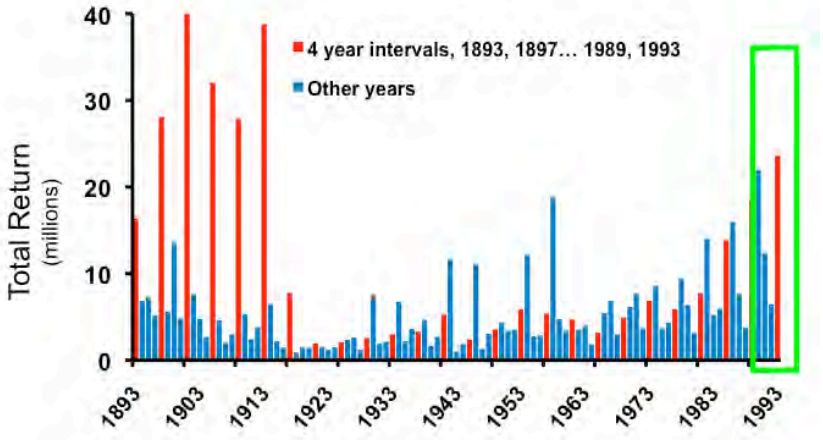

Figure 6. Long-term patterns in Fraser Sockeye returns, 1893 - 1993.

It should not be particularly concerning that there have been declines from an abundance that was an 80-year maximum. What is concerning, however, are the three low returns observed in the circle in Figure 7, including 2009. Those three returns are the lowest three-year returns since the 1920s.

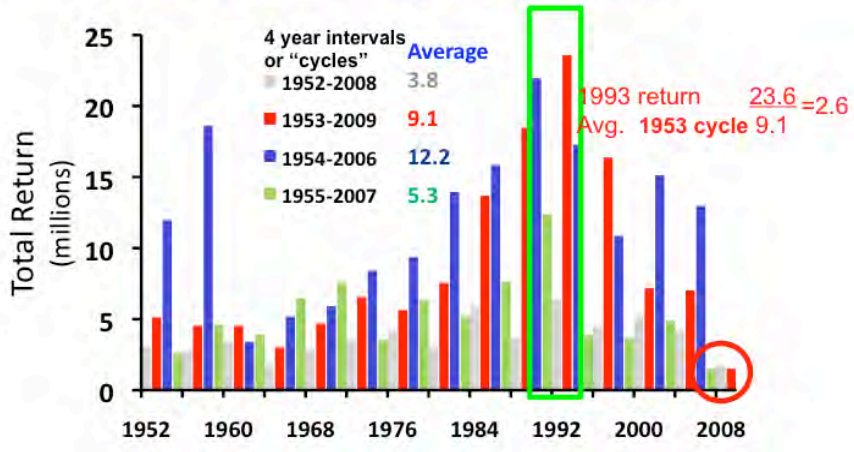

Figure 7. Long-term patterns in Fraser Sockeye returns, 1952 – 2009.

These four-year intervals have been highlighted in different colours and they all have different average abundances. The average returns are represented in the grey bar: 3.8, 9.1, 12.2 and 5.3.

This plot shows the trends and also takes into account these fluctuations. The return in each year was divided by the average on that cycle. For 1993, for example, the total return was 23.6 million and the average return on all the red bars is 9.1, resulting in a ratio of 2.6; that is 2.6 times the average return of the cycle.

Long-term trends

What is apparent then is that there has been a decline in returns (Figure 8). What has been happening?

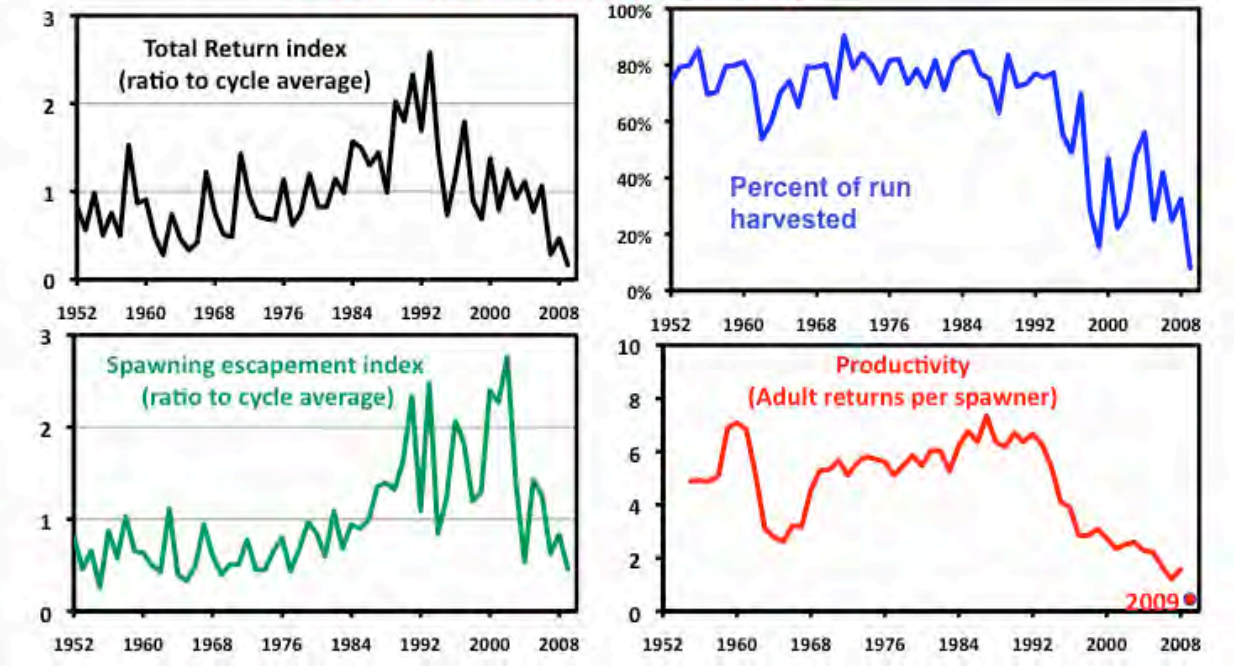

Figure 8. Long-term trends for Fraser sockeye (all stocks), 1952 - 2009. Total return index (upper left plot); percent of run harvested (upper right plot); spawning escapement index (lower left plot); productivity (lower right plot).

The upper right hand plot in Figure 8 shows the percentage of the run that has been harvested. Note that in the years prior to 1993 the harvesting rate was in the 60 – 80 % range. Since that time harvest rates have declined. In part this has been in response to declining abundance but it has also been due to some mixed stock fisheries constraints needed to protect particular stocks with conservation concerns (e.g. Cultus sockeye).

The lower left hand plot shows what has happened to the escapements over this period of time. It is plotted in the same way as the abundance; that is, the ratio to the average on each cycle. Therefore, runs are going down, the percentage of runs being harvested is going down, and escapements are going up.

What is causing this? The lower right plot represents productivity; the average returns per spawner. These are the returns that have come from a spawning abundance four years prior. Note that in 2009, the percent of the run harvested in 2005, the parent year that generated the 2009 return, was around 25 %. The escapement was about 1.5 times the average, about 3.3 million spawners in 2005. This was a very poor return rate, less than 0.5:1, which means there was a run of 1.5 million.

Implications for 2010 planning

We are currently doing the 2010 pre-season planning. This decline in productivity has already had an impact on that planning. First there is the pre-season forecast. Typically forecasts are based on assumptions of long-term average productivity. In fact, the 2009 forecast made that assumption. This year we have forecasted using three scenarios of productivity, the long-term average, the recent year average, and 2009. You can see the forecast based on the middle assumption, recent year average, in the Draft Integrated Fisheries Management Plan (IFMP) available on the DFO website at (www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/MPlans.htm). The second area where declining productivity has been examined in the pre-season planning is in the escapement policies. There is an escapement memo that provides some information in the same document, in Appendix 12 of the IFMP.

JOHN REYNOLDS, TOM BUELL LEADERSHIP CHAIR IN SALMON CONSERVATION, SIMON FRASER UNIVERSITY

Think Tank findings

At our think tank in December, the participants reviewed a great deal of information in a very short period of time (2 days). One graph particularly caught the attention of the participants – Figure 8 above. Here productivity refers to the adult returns per spawner. Note that while the 2009 return was way below the forecast, in fact it was on target, if we follow the trajectory down from the high returns of the early 1990s. This was a revelation to most of us, and it caused a great deal of concern. So, it is one thing to say that we had the worst return in history in 2009 – a disaster that clearly caught everyone's attention in the first place. But the think tank scientists were also very concerned about the longer term trend in declining productivity. We need to think about this when we consider options for management and monitoring strategies that will be robust against this trend in the future.

Note again that this declining trend occurred despite the strong reductions in fishing pressure over that period (Figure 8). In a statement of agreement, the think tank scientists suggested that fishing was not the cause of the poor returns in 2009 (www.sfu.ca/cstudies/science/adaptingtochange.htm). One could debate whether or not there was some legacy from the heavy fishing up to the 1990s; that is a question we certainly should consider especially if people have contrary views on this issue. But clearly the stocks built up in the early 1990s in the face of intense fishing pressure and yet the numbers came down after that even as the fishery was reduced.

The think tank examined the factors involved at the different lifecycle stages and noted where available information was incomplete. After two days of deliberation they agreed that, based on the weight of evidence available at the time, the problem of the poor returns in 2009 could most likely be attributed to what happened between the time when the fish left the lakes in the spring as one year-olds and their early survival at sea over the next few months. We know from a large number of other studies that this is the period when juvenile salmon are most vulnerable.

Naturally then, this early life history stage is the phase that came under our microscope most

intensely, but we were frustrated by the fact that it is also one of the stages in the life cycle that we know very little about. Therefore, although we spent most of our time on that phase, our conclusions were very preliminary.

Future research needs

The members of the think tank compiled some suggestions for future research. We pointed to the need to analyze existing data on the health and survival of the Fraser sockeye throughout the lifecycle, especially in the early marine stages. We also noted the need to compile historical data on the abundance and health of farmed salmon that the juveniles encounter along the migration route. These wild fish encountered a very high density of active salmon farms on their outward migration, from Campbell River northward. An epidemic, for example, not just of sea lice, but perhaps stemming from a virus or bacterium, could have been a contributing factor. The first way to find out if this was the case, would be to determine whether the farms themselves had any disease outbreaks at that time. We had no information on the history of diseases on farms to judge whether this would explain the long-term trend of declines; chronic disease transmission is something that should be looked into. Another research direction would be to expand studies of the timing and survival of the migrating juveniles, including in-river before they reach the sea and especially in the early marine environment when we traditionally lose track of them. Finally, we identified the need to compare populations to understand why some are faring better than others. Different stocks have different life histories, and different migration routes (for example, Chilko sockeye compared with Harrison sockeye).

Summary

In the short term we felt that even before the federal judicial enquiry is completed we must be prepared for the need for continued fisheries closures if the trend that we have seen in declining productivity continues. In addition, the think tank recommended additional precautionary measures such as experimentally removing farmed salmon from sockeye migration routes to see what happens. We also suggested that management agencies must take impacts of climate change into account to determine the degree to which the changes in ocean temperatures and in some cases in-river temperatures on the return migration are responsible for the trends over the past 15 years. These trends in declining productivity should be incorporated into forecasts. Finally, we concluded that we need to act now.

JOHN HENDERSON, COUNCILLOR, WEIWAIKUM BAND & MEMBER, BC FIRST NATIONS FISHERIES COUNCIL

Western science and First Nations largely operate in two solitudes. There are few people who can respectively bridge these divides. Also, First Nations and non-Native communities have to learn to work together and we have to do that in a manner that is respectful of the resources. Our elders view our traditional knowledge as something sacred and something to be kept and cared for. It is not always something that you can capture through a survey, map or chart. This makes it difficult for us to introduce our knowledge and history to a science-based forum such as this. From the experience of being involved over the past 32 years with the fishery as well as with First Nations people collectively, and representing them, I have come to understand where they have come from and how they have lived, and what they have seen.

This is a crisis. There are a lot of elders in our communities who have not had fish for the past three years and will not get fish again this year. This will impact the health of these communities. I sit on an advisory committee for health and have witnessed the impact this has had on our First Nations people - not eating the sustenance that they are used to.

How do we bring this resource back? If it means taking us out of the water again for another year, then that is what we have to live with. In general, First Nations would like to work more effectively with Western science. This is an important issue here.

We have talked to our elders about what is transpiring, and what they see as a problem in the future. In an average year in BC First Nations use almost one million Fraser sockeye for food and social and ceremonial purposes. Where are we going to get those fish when there is a crisis like this? We are starting programs so our younger generations can understand the importance of traditional food. How do we teach them about traditional food when it is not available to them? We are trying to entice the young people to come into the process, to learn not only about wildlife including fish, halibut, and clams, but also about what our old people ate and our traditional dietary system.

I have been a part of the fishing industry for almost my whole life and have seen the ups and downs of the fishing industry. When we talk about the importance of fish, our elders always said that Johnstone Strait never got any bigger; it is still the same size it always was. And the Fraser River is still the same size as it always was. However, the amount of fish that we are putting back into the river systems may have some bearing on where we are today. The spawning beds are still the same size but when I talk to my elder uncle he says that putting more fish in the river will sour the bottom – that is coming from a man that had a history of being a fisherman his whole life. This may help to explain what happened.

When I look back on it, I think our people were like scientists. We looked after the resource and it sustained us all of our lives. We have had fish traps that go back for thousands of years up and down the whole coast. Looking at the traditional information we are finding from the Comox area, we ask how could there be have been so many fish traps in one area? It must have been a food gathering area for all of our people. We are just now learning about this.

We talk about tides and the effects of tides and access; we discuss these points all the time; for example, how much time does it take a salmon to swim through Johnstone Strait? It has always been a point of discussion as to how fast those fish go. For example, if there is a 15-knot tide, then you have only three hours to fish. The rest of the time you are not fishing. And by the time a day goes by, those fish are gone. Over the past three years, with the limits that have been put in place, it has been impossible to fish the allocation until another three days. We have seen the structure of tides and the effect it has on all of us.

When we look at different species just in this past year in our territories, not the Fraser River, we have seen some of the largest returns on record, whether it be sockeye, chums, or pinks. We have counting fences in some of the rivers now, so that we can, as First Nations people, monitor the fish stocks. Over our lives we have also been taught that there are differences between species and between populations of the same species. Different stocks have different migration patterns. Some of the populations of sockeye stay in the river for two years, and others in the lakes.

Another example of great concern to First Nations people is Chinook salmon. In our territory,

we have an area called the Tyee Pool where fishers have been trolling for spring salmon and they have been doing this since the early 1920s. Over the years they have taken all the large fish. What is left to spawn? The broodstock are basically gone and every year the fish are getting smaller. The average fish is now 35 pounds or smaller compared to the 70 to 80 pound fish that we used to catch. This is true for all wildlife. If you take every large bull out of an elk herd, what is the success rate like for the future of the herd?

What is the reality in going forward into the future? If you don't look after the resource, then it will not come back. We need to monitor the amount of female sockeye that go up the river as compared to the males, for example. There are a lot of problems with temperatures of the water especially in the rivers, and with the impacts of all of the logging. In reality, we have a responsibility and an interest in a resource that supports us all. What hurts is that you can go to our communities and if we don't get any fish on the table over the next number of years, our way of life will be completely changed. We are going to have a hard time getting it back.

SECTION I
Fry Emergence and Migration to Sea

- **What is the "typical" life history of sockeye?**
- **What can we learn about sockeye diversity if we contrast typical lake rearing populations (Chilko) with atypical, non-lake rearing populations (Harrison Rapids)?**
- **How good are our data, and how do we know how many fish go to sea?**
- **What is the variation in freshwater productivity; is diversity important?**
- **What are the early challenges: how and what do we know about mortality during downstream migration?**
- **What are the general trends and issues related to freshwater sockeye stewardship?**

Presentations by:

Mike Lapointe, Chief Biologist, Pacific Salmon Commission

David Welch, Kintama Research Corporation

SALMON LIFECYCLE AND FRESHWATER PRODUCTIVITY

Mike Lapointe, Chief Biologist, Pacific Salmon Commission

Life cycle of the 2009 Fraser sockeye

Figure 1 describes the typical pattern of the Fraser sockeye life cycle in the context of the 2009 sockeye. In the fall of 2005 the fish that generated the 2009 return spawned. In the winter of 2005 these eggs overwintered from 2005 into 2006. Sometime in the late winter the fertilized eggs hatched into alevins with attached yolk sacs. At that point they were still in the gravel. The fry then emerged from the gravel and in the case of Fraser sockeye (in the spring of 2006), these fry migrated to a lake. Most Fraser sockeye spend one year in a lake. In the spring of 2007, the smolts left the lakes and migrated to the sea. The insert shows the path that most of the stocks likely followed. Usually, they migrate up the northern Inside Passage, along the Continental Shelf and then make a big circle. They came back after two winters at sea as four year olds, in 2009. This is a bit of an over-simplification; there are a few five year olds and three year olds (called Jacks) that are also produced. However, the predominant age of return is age four. Therefore,

if you are looking at a marine effect on the 2009 brood, then you are looking at an effect that would take place sometime between the spring of 2007 and their return time in the summer of 2009. If you are looking at a freshwater effect, then it could happen anywhere from 2005 through to 2006. By studying the life cycle of the 2009 sockeye you can get a feeling for where and when to look for certain effects on the returns. Incidentally, we do know exactly when these fish reached the ocean in 2007, the ocean temperature was a bit colder than normal in the period September-December of 2007 the approximate time of their arrival in the Gulf of Alaska as shown in map insert of Figure 1.

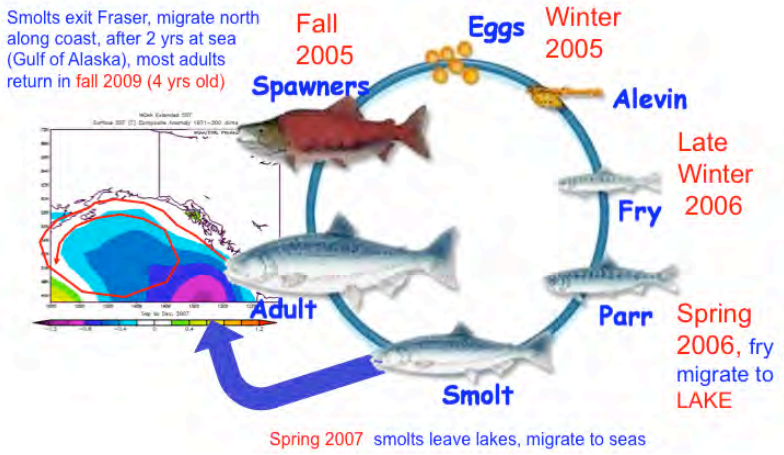

Figure 1. Fraser sockeye life cycle typical pattern.

Harrison sockeye

The reason we specifically focus on the Harrison sockeye is that they may provide some clues for us. The plots in Figure 2 represent the productivity for Harrison sockeye and total Fraser sockeye from 1952 – 2009. The productivity of the Harrison sockeye appears to be trending upwards during the same period with the total Fraser sockeye productivity trending downwards– that is why we want to examine the Harrison life history.

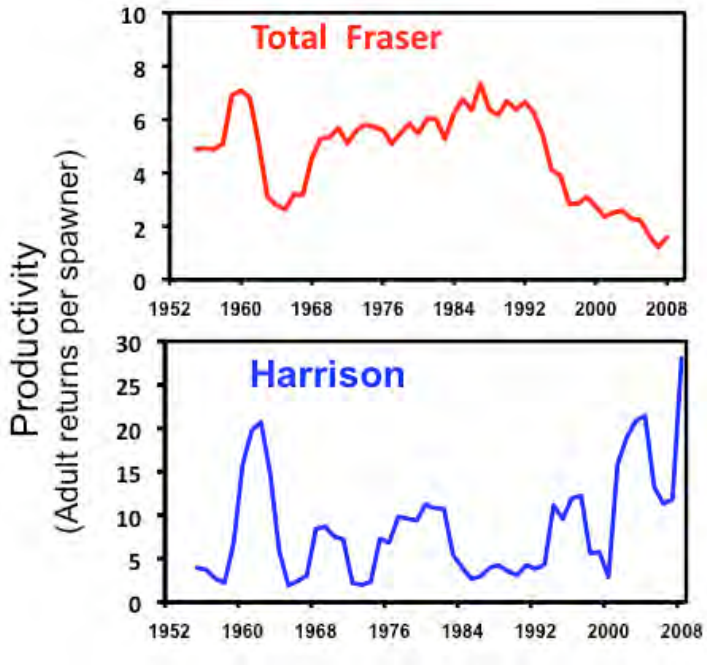

Figure 2. Comparison of Harrison & total Fraser productivity, 1952 – 2008.

Life history of Harrison sockeye

Table 1 compares the Harrison sockeye life history with the life history of most Fraser sockeye.

Table 1. Comparison of Harrison sockeye life history with the life history of most sockeye.

Life History	**Most Sockeye**	**Harrison**
Fry rearing	Lake (1 year)	Sloughs, estuary (few months)
Ocean entry	2 years	1 year after spawning
Ocean residence	2 years	2 **and** 3 years
Age at return	4 years	3 **and** 4 years
Ocean entry of 2009 return	2007	2007 for age 3 fish 2006 for age 4 fish

Note that instead of spending a year in the lake, the Harrison sockeye rear for a few months in Fraser sloughs in the estuary. They do not go up to a lake. In fact, there is a part of the Harrison River that has a rapid, fast, narrow stretch of the river, and most of the fish in the Harrison spawn below that area. One of the reasons why these fish may rear in sloughs is that the fry are not able to get through that rapid. Thus, instead of entering the ocean after spending two years in fresh water, the Harrison fish enter the ocean after approximately one year in fresh water. It may be nine or ten months, but it is a calendar year, one year after they hatch. These fish spend two and three years in the ocean instead of the usual two for Fraser sockeye. Harrison sockeye have two common ages that return - age three and age four. That means that the ocean entry of the 2009 return for Harrison would be 2007 for the age three fish but it would be 2006 for the age four fish. The returns for 2009 therefore had two different years of ocean entry.

Productivity of Harrison sockeye – 2009 returns

Table 2 describes the productivity of the 2009 returns of Harrison sockeye and of the total Fraser sockeye. For the total Fraser sockeye there were about 0.5 returns per spawner. For the Harrison, the returns were about 1.8 per spawner for those age three fish that entered the ocean in 2007 or approximately four times the returns per spawner for the total Fraser.

Table 2. Comparison of Harrison sockeye productivity with total Fraser sockeye productivity for 2009 return.

Year	**Total Fraser Sockeye**	**Harrison**
2007 Ocean entry	0.5 returns/spawner	1.8 (age 3 fish from 2009 return)
Smolt migration route	Most use Johnstone Strait	Some, perhaps most use Juan de Fuca Strait
2006 Ocean entry	3.0 returns/spawner	0.04 returns/spawner (age 4 from 2009 return & age 3 from 2008 return) 400,000 spawners (2005; 33 times average!)

What might be causing this pattern? One hypothesis that has been put forward is related to the differences in the migration route. It is thought that most Fraser sockeye head north en route to the ocean through Johnstone Strait. Some or perhaps most of the Harrison sockeye, on the other hand, use Juan de Fuca Strait. The differences in these migration routes, in addition to the life history differences, could potentially explain some of this pattern.

It is not that clean cut, however. Note that the returns per spawner were much better for the 2006 ocean entry year for Total Fraser sockeye - these are the fish that returned in 2008 where as the returns per spawner of the Harrison fish that entered the ocean in 2006 was very poor. Compare also the age-four fish from 2009 and the age-three fish from 2008. We are not sure if that particular year is a relevant comparison for marine effects on the Harrison, for the following reason. There were 400,000 spawners that generated that very poor return, which is 33 times the average. This was the largest escapement in history on the Harrison. It is possible, therefore, that that low returns per spawner for Harrison are the result of a freshwater effect. We simply do not know if this is true.

Methods for estimating juvenile abundance

There are three different methods that are used throughout the Fraser watershed to estimate juvenile abundance. Fry traps are used at three populations, Nadina and Gates and Weaver, which has artificial spawning channels. There also fry traps used at a few index streams at Early Stuart. Typically, there would be estimates of the number of fry migrating out and downstream to a lake, before the fish enter the lake. There are also some acoustic lake surveys. In this case boats go out and transect the very large lakes and get an estimate of the number of fry in the lake, usually in the fall prior to the spring out-migration. In the case of the 2009 return, this would have been the fall of 2006. Smolt weirs may also be used; at Chilko Lake for example, there has been a smolt weir in place since the 1950s. Chilko is the only population for which there is a long-time series of smolt estimates and numbers for smolts leaving the lake and prior to their downstream to the mouth of the Fraser.

Chilko and Quesnel sockeye

The circles on the map in Figure 3 show the location of the Chilko and Quesnel Lakes and rivers.

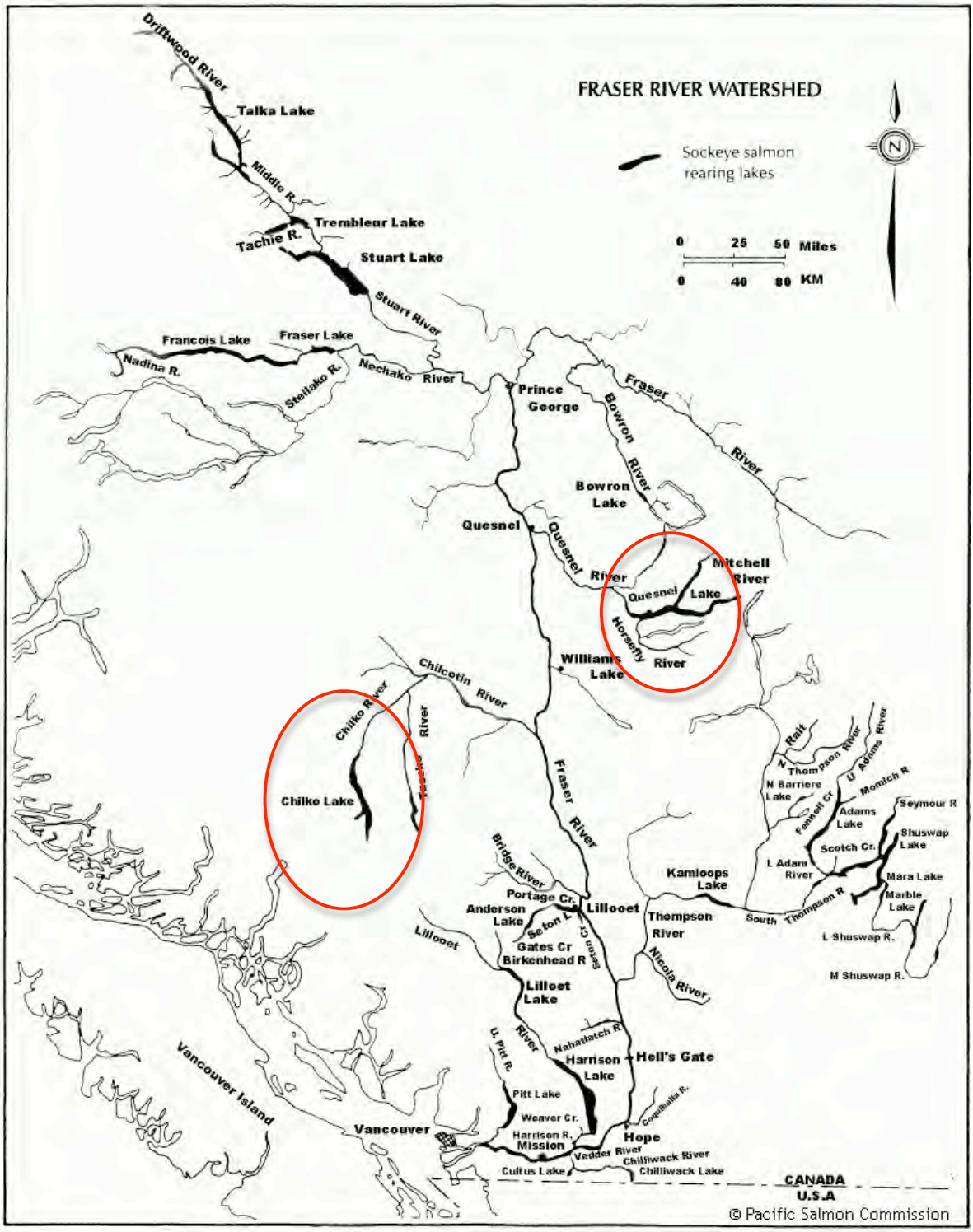

Figure 3. Map showing location of the Harrison and Quesnel sockeye systems.

There are several components to the Chilko sockeye smolt program. The weir is shown in the upper sections of Figure 4. It is about 0.5 km downstream from Chilko Lake and all the smolts that come out of the lake go through a funnel and are then directed into two small buildings. At the end of the funnel near the bottom of the river there is a window that controls the exit of smolts out of the lake (Figure 4, right section). Migration is primarily at night beginning around dusk when schools of smolts can be observed prior to exiting through the window opening and passing under the buildings. Inside each building there is a digital camera that points down and captures images such as the one in Figure 5. The image also records the date and time. These images are produced at regular intervals of about 10 minutes or so, recording each time the number of sockeye smolts that are migrating past the site. The rate is also measured.

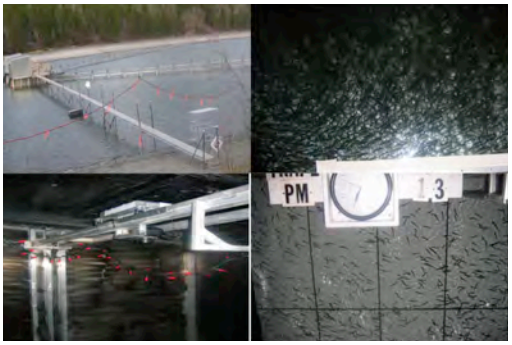

Figure 4. Chilko sockeye smolt program

The number obtained represents the number of smolts per unit time expanded for the time of the migration over the course of the evening.

The image in Figure 5 represents the Chilko smolt trap at one point in time in spring 2007. There were so many smolts on April 30 and a number of other days that the water was actually displaced. Clearly there were a lot of smolts coming out of the Chilko system in 2007.

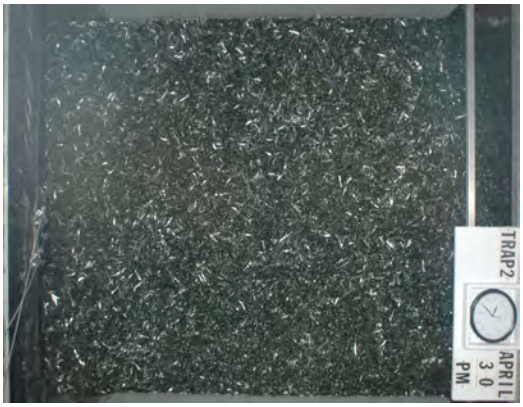

Figure 5. Digital image of the Chilko smolt trap in spring 2007.

The upper left plot in Figure 6 shows the smolt abundance data for Chilko from 1951 to 2007.

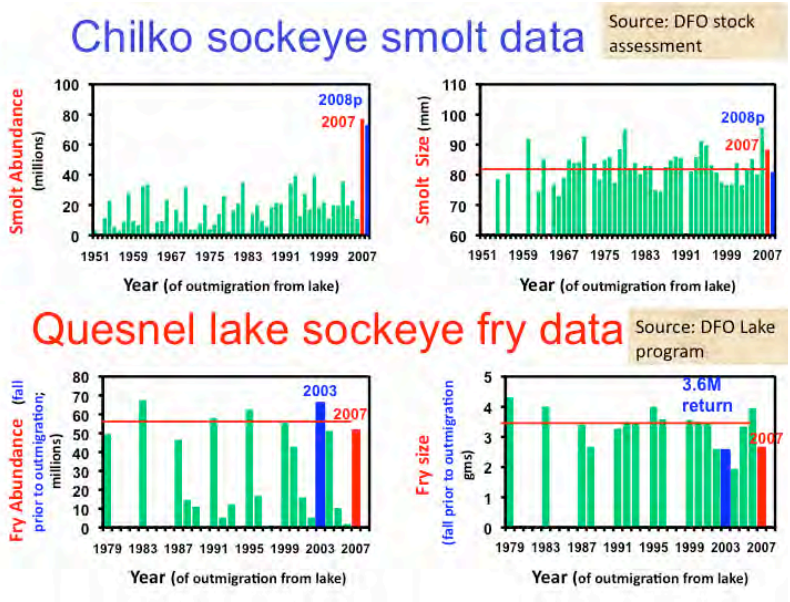

Figure 6. Smolt data for Chilko sockeye (upper panels) and Quesnel sockeye (lower panels).

In the earlier years the technology was less sophisticated. For example, in the 1950s single-lens reflex cameras with film were used and fish passed over white plywood boards and bright lights. But the photographic method has been used to estimate the number of smolts leaving Chilko lake throughout this period of time. Note the smolt abundances in 2007 that generated the 2009 return (approximately 77 million) and as well another year of large smolt abundances in 2008 (about 71 million). The 2008 smolts will

be coming back this summer, 2010. The smolt size is represented in the upper right plot in Figure 6. Note that not only were there a lot of smolts but also the smolt size was larger than average, about 80 mm.

The plots on the bottom of Figure 6 represent the data for Quesnel fry. Note that the abundance of fry in the lake in the fall of 2006 (2007 ocean entry year) was about 50 million. That is near the average abundance from the large spawning population years in this time series. The fry size was a bit below average but the previous spawning population year that entered the ocean in 2003, had similar sized fry and similar abundance of fry in the lake. However, the return from the 2003 ocean entry year was 3.6 million fish. Therefore, smaller than average fry size have generated reasonable returns in past years.

Why focus on the Chilko and Quesnel sockeye? The total Fraser forecast in 2009 was 10.5 million - Chilko and Quesnel accounted for 75 percent of that (Figure 7). Therefore, about 7.8 million of the total forecast was in these two stocks.

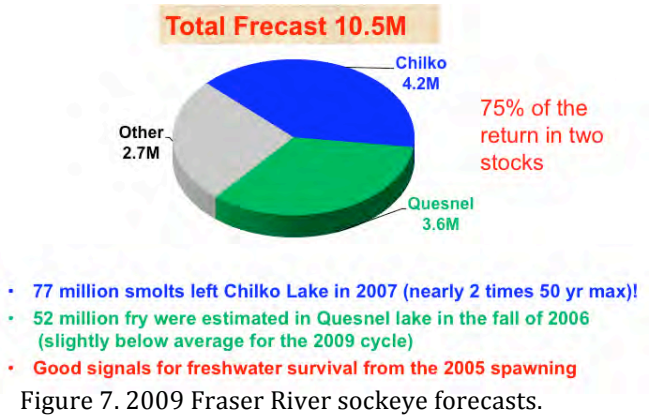

Figure 7. 2009 Fraser River sockeye forecasts.

That means that whatever was going to happen to Chilko and Quesnel was going to drive what happened to the overall Fraser forecast. 77 million smolts left Chilko Lake, nearly two times the previous 50-year maximum. We are not sure about what is going on in Chilko Lake but there appears to have been a dramatic increase in freshwater productivity in recent years. For the Quesnel sockeye, there were 52 million fry in the fall of 2006, slightly below average for the 2009 cycle. These figures represent relatively good signals for the freshwater survival of these two populations. Freshwater productivity estimates are available for six stocks. By "freshwater productivity" we mean the number of fry or smolts per female spawner. The results are summarized in Table 3. The results show below average numbers for the early Stuart and Gates systems, near average for Quesnel and Weaver, and above average for Nadina and Chilko. Note the results for the survival post-fry, the returns per fry, or the next stage. The numbers are below average for all six of populations.

Table 3. 2009 Productivity relative to average for freshwater and 'post-fry' stages.

Freshwater (fry or smolt/female)	**Post Fry** (returns/fry or smolt)
Below average:	**Below average:**
Early Stuart, Gates	Early Stuart, Chilko, Quesnel, Weaver, Nadina, and Gates
Near average:	
Quesnel, Weaver	
Above average:	
Nadina, Chilko	
No Juvenile data for other stocks	
Note: DFO concerns about fry data quality for Early Stuart, Gates?	

Changes to program implementation in recent years may have affected the fry estimates from the Gates and Early Stuart systems. There may also be some changes in methodology that could explain the results.

Table 4 describes what happened to the Chilko and Quesnel in terms of the 2009 returns. Only about 500,000 fish in total returned from this group of about 7 million. Clearly, if we did not get a return in Chilko and Quesnel, then we were not going to get a return to the total Fraser.

Table 4. 2009 Pre-season forecasts and post-season estimates for Chilko, Quesnel and the total Fraser.

Stock-group	Pre-season Forecast	Post-season estimate (prel).
Chilko	4,175,000	270,000
Quesnel	3,575,000	220,000
Total Sockeye	10,488,000	1,505,000

Sherlock's Theory

Sherlock's theory goes like this: Colonel Mustard did it in the ocean with a ___ ? Was it a rope? Perhaps. Perhaps it was a beer. What about Miss Scarlett? Is that her real hair? She looks a little suspicious. What about this Professor Plum? We just don't know the answer. (Figure 8)

Figure 8. Sherlock's Theory.

It appears that things are pointing towards the ocean mortality theory. However, there are some caveats to this idea that we should be aware of. The first one is that for the Chilko there are estimates of the number of fish leaving the lake but those fish still have 650 kilometres to swim down through the Chilcotin and the main stem Fraser before they get to the mouth of the river. Information for Chilko in 2007 about whether there was any mortality during that downstream migration is probably not available. For Quesnel, the last time there was a good estimate was in the fall of 2006. Therefore, we cannot rule out the possibility of additional mortality over another winter in the lake (nine months) or during their downstream migration.

David Welch, Kintama Research Corporation

In the 1990s when salmon survival was apparently decreasing in British Columbia, one of the questions that was asked was "*How do we actually address the question of where the problem occurs*"? The Pacific Ocean Shelf Tracking (POST) project array was our initial attempt at developing technology that would enable the observation of overall movements and survival of Pacific salmon. Cultus Lake sockeye, a Fraser River stock, was one of the major study populations used in the demonstration phase.

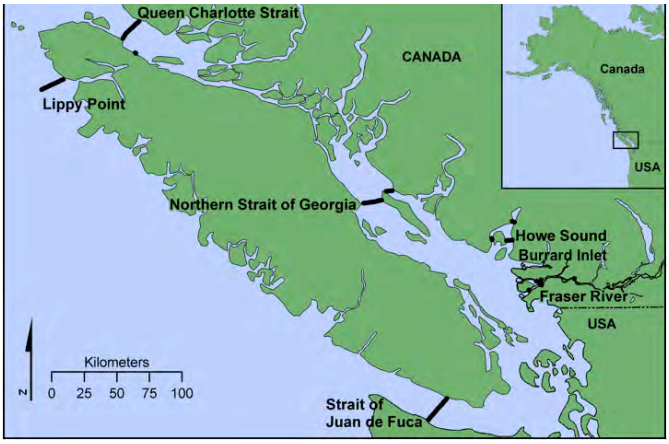

Figure 1. Southern British Columbia Pacific Ocean Shelf Tracking (POST) array.

The Southern BC POST array is shown in Figure 1. Essentially, the system consists of a series of seabed receivers sitting on the bottom of the ocean or in the river in precise geometries. Uniquely identifiable tags are surgically implanted into the fish

allowing us to track the movements of the fish over the receivers, both in the river and in the ocean. Sub-arrays (represented by black lines) are located in the lower Fraser River, northern Strait of Georgia, and just north of the the Broughton Archipelago in Queen Charlotte Strait. There is also a listening line in the Strait of Juan de Fuca and a sub-array or listening line at Lippy Point north of Quatsino Sound.

Figure 2 is a still representation from an animated figure showing the outmigration of the 2007 release of tagged fish from Cultus Lake (red). It also shows the overall array in the area around the Fraser River that the Cultus smolts went over. One sub-array that is very important is located in Alaska, at about the latitude of Icy Strait or Glacier Bay; none of the Cultus Lake sockeye have ever made it up that far. The tags that were implanted in these fish in 2004 through 2006 have a mean lifespan of about eight months operationally, so the smolts would have been observed in this area of Alaska if they had actually migrated that far.

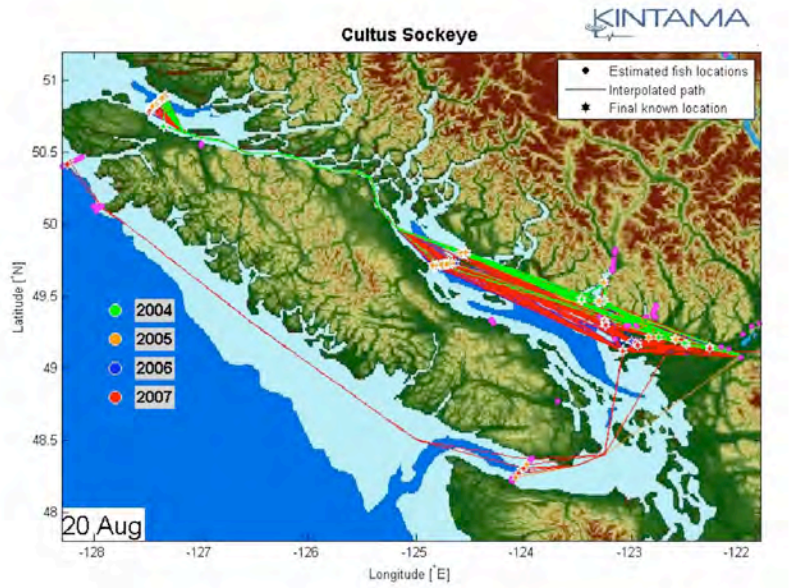

Figure 2. Outmigration of tagged sockeye smolts released from Cultus Lake in 2007.

It is clear from this information that the animals do go out of the Strait of Georgia quite rapidly, and given the speed at which we have observed them moving as well as their survival rates, they should have easily made it up to this area of Alaska. The fact that they did not does not necessarily indicate that they died but instead that they probably stopped their migration somewhere beyond the Queen Charlotte Strait sub-array.

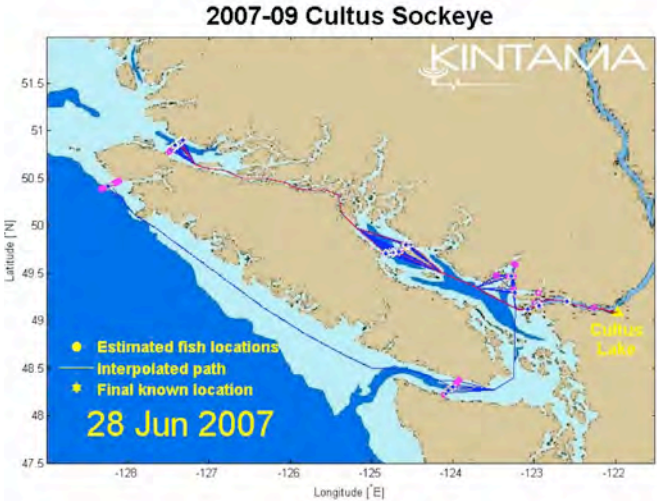

Figure 3. Outmigration of tagged sockeye smolts released from Cultus Lake in 2007. Smolts were implanted with specially programmed tags, which allowed monitoring both the smolt out-migration in 2007 & the return migration of adult sockeye in 2009.

Figure 3 shows a more detailed description of the outmigration of the 2007 Cultus Lake tagged sockeye smolts. The fish were counted at the mouth of the river, over the northern Strait of Georgia array, and then over the Queen Charlotte Strait array. Note that in 2007 six smolts initially migrated south through Juan de Fuca Strait. Two of those six fish survived to make it up to the Lippy Point line just north of Queen Charlotte Strait. The survival rate on the outer coast was the same as in the inner coast. Six is obviously a very small number but that is because so few fish go out in that direction. The two red dots on the animated version of this figure describing the smolt

outmigration show the two adults that are going to come back in 2009. The fish move through the Broughton Archipelago very rapidly and then go out over the Queen Charlotte Strait line quite quickly.

In 2007, special programming was used with larger tags than the ones used in 2005 and 2006, which provided enough battery power to potentially run for two time periods. The tags for 200 surgically implanted animals were turned on, on May 13 and 14 in 2007. The tags were then turned off to preserve battery power on June 27 and 28, about three or four days after the last fish was counted clearing out of the northern end of Strait of Georgia. Then in 2009, on July 26 and 27, the onboard clock in those tags turned them back on and started the tags transmitting again, so that if there were adult fish still alive to carry the tags back in they would be detected.

Figure 4 represents the observations from 2009 showing the detection in early August of one of the adult sockeye coming back in. This animal was first detected off the NW tip of Vancouver Island (Lippy Point), and then a few weeks later on the Juan de Fuca Strait sub-array. A second tagged adult is detected in Juan de Fuca Strait within a day of the first (but not previously at Lippy Point), so we have animated its migration path prior to Juan de Fuca Strait as coming directly in from the offshore, though this is a guess. The rate of movement actually slowed down after entering the Strait of Georgia, probably indicating a holding pattern off the mouth of the Fraser. The animals then went into the Fraser River successively passing over each of the receivers to as far as Mission, just below Cultus Lake, the location of the last receiver.

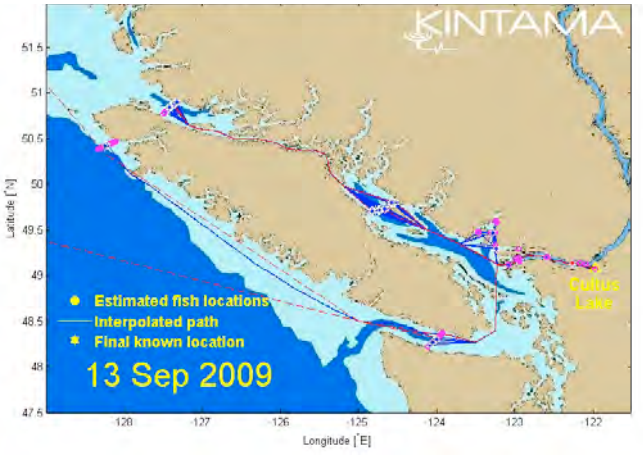

Figure 4. Adult return migration in 2009 of Cultus Lake sockeye smolts from 2007.

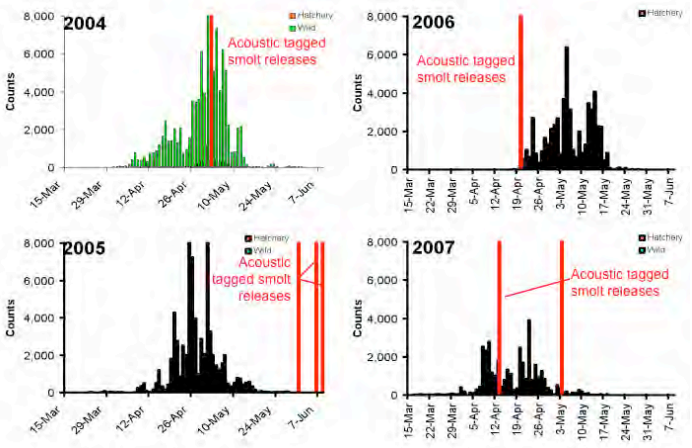

Figure 5. Cultus Lake sockeye smolt outmigration timing for 2004 – 2007.

Therefore, of the 200 tagged sockeye smolts that went out in 2007, two adults came back in 2009. These were hatchery smolts and thus larger than wild smolts.

Figure 5 shows the outmigration timing for the Cultus Lake smolts for 2004 - 2007. In 2004, the timing of the acoustic tag releases is represented as a red bar with the red and green smaller bars representing the timing of release or passage of the hatchery and wild smolts out of Cultus Lake. In 2005, technical problems resulting from a power failure at the hatchery resulted in the fish leaving about one month late. In 2006, at the start or during the run it was essentially all hatchery fish that went out. The brackets show the timing of the released tagged fish in 2007, corresponding to the migration of the hatchery and the wild smolts.

Figure 6 shows the overall estimates of survival for the 2007 fish, which returned as adults in 2009. Survival to the mouth of the Fraser River, through the Strait of Georgia and north through Johnstone Strait and up to Queen Charlotte Strait are represented in the plot on the left. In 2005, survival out of the river was extremely low but subsequent marine survival was high. (Very few fish actually made it out in 2005 probably because of the late release in the river.) In 2007, freshwater survival was stable, and there was very high survival in the Strait of Georgia and steady survival at the northern end. This does not mean that anything that happened in the northern end, such as to do with issues of sea lice or fish farms, was not a critical factor. It just means that it could have happened after that point, because the fish moved through quite quickly. The results do indicate that the mortality problem did not occur in the Strait of Georgia, as we shall see.

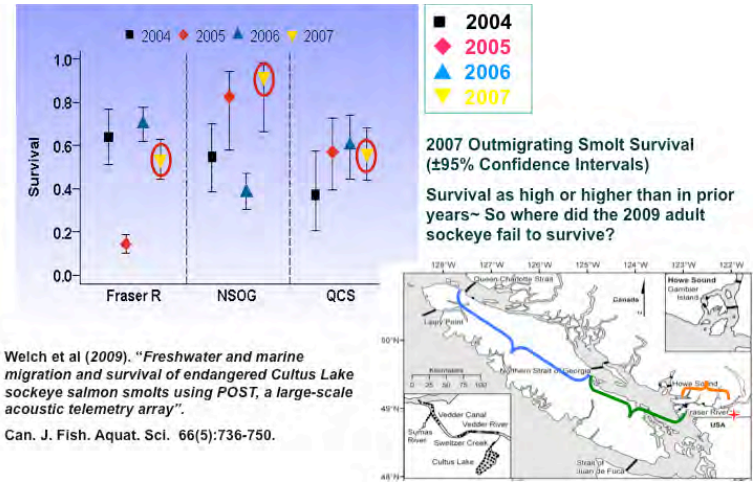

Figure 6. Survival rates for Cultus Lake Sockeye for 2004 – 2007 (±95% confidence intervals).

Table 1 summarizes this information. 200 acoustically tagged smolts were released in 2007. There was a 28% overall survival out to the north end of Vancouver Island and 1% (2) of the smolts survived to return in 2009. Preliminary data from DFO courtesy of Dr Mike Bradford for wild smolt survival for Cultus Lake in 2009 indicate a 1.4% smolt-to-adult survival rate. The question is: How well does that match with hatchery fish? Hatchery fry released in the lake from Sweltzer Creek showed a 1.3% smolt-to-adult survival rate, consistent with the wild progeny, while hatchery smolts kept in the hatchery and then released at Sweltzer Creek (similar to our tagged group) showed a 0.54% smolt-to-adult survival rate. So our 1% return rate of tagged adults is consistent with the run as a whole.

Table 1. Summary of survival rates for Cultus Lake sockeye released in 2007, returning in 2009.

- 200 acoustic-tagged smolts released in 2007
- 28% Survive to Leave SOG/Johnstone St. (~1in 4) (Welch et al (2009) Can J Fish Aquat Sci 66(5):736-75)
- ca. 1% of Smolts survive to return in 2009:
- Cultus Lake smolt-to-spawner survival*:(**DFO Cultus L Survival Estimates (Preliminary); Courtesy M. Bradford*)
  - Wild Smolt Survival: 1.4%
  - Hatchery Fry released in lake: 1.3%
  - Hatchery Smolts released at Sweltzer Creek: 0.54%
- ~1% Smolts survive to return in 2009, so:

1/100 SAR	=	1/4	x	1/25
Smolt to Adult Survival		*Fraser R & "Salish Sea" Survival*		*Outside "Salish Sea"*
		(28% & Stable)		

- Mortality "*beyond*" Salish Sea ~7.8 times mortality in Fraser River & Salish Sea
- Therefore, 2009 Fraser Sockeye collapse likely caused by mortality occurring beyond Fraser R/Strait of Georgia

Only 1% of the tagged fish returned in 2009; however, one in four fish survived migration out of the river and the Salish Sea. This means that only about one in 25 of those lucky survivors reaching the Queen Charlotte Strait line subsequently survived, indicating that the mortality beyond the Salish Sea was almost eight times more than the total mortality experienced in the river and within the Johnstone Strait area in 2007. This suggests that the collapse in 2009 likely occurred due to mortality occurring after the first month and a half of the outmigration, after the smolts pass the northern end of Vancouver Island. This is an important point, and is the first time that there have been data available to indicate how much mortality happens in the early part of the marine life history versus what follows later in the ocean life history.

In conclusion, it is clear that the 2009 sockeye failure is not a 'one-off' problem. It is a repeating problem going back to at least 1992. For example, in 1992, and again in 1994, there were 'missing' Early Stuart sockeye in-river. The cause was never determined. Then from 1996 – 2008, there were severe problems with late-run fish coming back. Late-run sockeye changed their behaviour, entered the river early, and died en route to the spawning ground—much like the problem for Early Stuart sockeye prior to the development of the "Late-Run" problem. We also know now that productivity of Fraser sockeye has been declining over about a 20-year period. In 2009 essentially all runs collapsed except for the Harrison run, which has a different migration timing. In my view, the problem in 2009 was clearly in the ocean, with most adults not surviving to return to the river, but the problems of the past 20 years have not yet been thought of as multiple surface manifestations of a single underlying problem.

DIALOGUE

The routes of adult returns

Alexandra Morton directed a question to David Welch: Given ocean temperatures offshore and in the Inside Passage, and the number of sockeye that migrated out through the Inside Passage, did it seem unusual to you that your only two returns came from the open Pacific? The fishermen tell me the fish come back the way they went out to sea and I don't know how true that is, particularly with the sockeye and the temperature issues. It seems extraordinary that those only two survivors came from the open Pacific and did not use the Inside Passage.

David Welch replied:
We always think we know a lot about what happens and then often when we get actual data it completely disagrees with our comfortable assumptions. Two fish only out of 200 returned so we can't really say too much. To me it is not unusual that both did exactly what we would have predicted them not to do which is come in through the outer coast. We would need to know the diversion rate for 2009.

Mike Lapointe added: The diversion rate was pretty even for the season, about half and half. We should note that Kees Groot in the 1980s tried to correlate the route of out-migration of the smolts with the route of return migration of the adults and whether they go through the inside or the outside. What he found was that there wasn't a relationship. That seemed to be a very consistent pattern for most of the Fraser stocks. I don't think we can put Harrison in that category for the smolts to go through the north. But the adults can come back 90% through Johnstone Strait or 90% through Juan de Fuca. It is quite variable and the two do not seem to be linked.

A participant commented:
As a fisherman, I would have made the assumption that the survival rates inside and outside would have been opposite. My perception is that fewer of the fish actually made it up through the Broughton and much fewer died from there to the adult return. Are there any data that we have from before we started seeing this problem as to what we would expect to see from the Queen Charlotte Sound to adult return? Do we have anything to compare it to?

David Welch: It is new information. I don't

think it was possible to make these types of measurements before the technology developed in the 2000s. It is also quite consistent with what we are seeing for many other species and stocks that we have been tagging. A lot of mortality still happens after the first month at sea.

Kees Groot:
You must have information on the speed of migration for the two legs that you measured there. Is there a difference from year to year and is there any relationship between the speed differences and the weather? In Babine Lake we found that smolts migrate faster on clear days and there was a direct relation with the hours of sunshine per day. I am not so sure if this holds in saltwater as well.

David Welch: I don't think we can actually answer that. These are averages over about a one-month period so I don't think we have the contrast and the data to be able to pickup any fine scale details relative to weather. One set of data from the Squamish River showed that the steelhead going down the Squamish, and the coho as well, migrated at night in the river and then seemed to stop during the day. But once they hit the ocean, very definitely there was no difference in the timing and they seemed to be migrating continuously.

Kees Groot:
What was the speed of migration? The optimum sustained swimming speed for the size?

David Welch: For all the fish that we are measuring it ranges from about one to two body lengths a second, averaging about one. That translates into about 20 to 25 km per day in the ocean.

Condition of fish

Arne Mooers:
Are there any data on the condition of the fish at any time along the migration?

Mike Lapointe: For the juveniles, about all we have is size. For the adults, there is a new research program that is looking at using genomics to look at some of the condition factors (see Willie Davidson, page 135). There is also extensive physiological sampling carried out in the Environmental Watch Program within DFO. But I don't know what the results are in terms of the adult condition for 2009.

About the data on survival rates in the marine environment

Andrew Wright directed a question to David Welch: I would like to challenge your numbers. As an engineer I notice that your mortality rate in the Salish Sea was one quarter of the stock and thereafter, one twenty-fifth. The one thing we are not balancing is the three quarters figure. If you turn it the other way around, that is, who died outbound but only over the first month or the duration in the Salish Sea, then I would guess that you would expect a much higher mortality in the ocean over the two or three year window because you have to factor in the time at sea. Therefore, if you are losing so many in the Salish on the outbound migration, are those fish being poorly conditioned so that when they hit the ocean that mortality rate is still dropping off very fast? To point to the open ocean as where something is going on, is perhaps a mistake because you are already seeing the beginnings of that mortality rate in the Salish Sea.

David Welch replied: The traditional view has been that the early marine survival rates or the mortality rates are much higher, so people have focused on the mortality rate which is undoubtedly higher during that first six weeks of out-migration. But the duration is relatively small. This is not to say that during periods of the high mortality rate you do not have potential sensitivity.

There are two points here. First, the survival rates, or the mortality rates, are relatively steady between years. The more important point is that there is still a great deal of mortality that happens after the fish pass the northern Strait of Georgia line. I am not putting the finger on the open ocean. I doubt very much that is the case. All of the work I used to do when I was with DFO (and still going on), says that the smolts are staying on the shelf.

At the start of the presentation, I alluded to the fact that we have not yet seen one Cultus Lake sockeye up at the north end in Alaska. They would make it there in about a month and a

half and potentially some of those tags would run until December for prior years; yet we have not yet seen one there. That indicates to me that either there is a large mortality that happens after they pass out of the Salish Sea system, or more likely, that they may be stopping.

My personal pet theory, for which we have no direct data, is that they are taking up residence in Queen Charlotte Sound. Just as birds migrate quickly and then they stop, my theory is that the fish stop in Queen Charlotte Sound. We have some data that suggest that this could be possible because some of the DNA work that we did from the trial surveys with Rivers and Smith Inlets sockeye indicated they were in disproportionately high abundance by the fall of the first year. Therefore, it looks like some of these stocks are staying in particular areas and that could explain why we are not picking them up off the Alaska line.

Certainly, the mortality rates are higher in the first period. It is just that the total amount of mortality still to come is many multiples of what is actually happened during the river and the Salish Sea migration period.

Andrew Wright:
My point is that if you factored in the mortality rate per time interval, then it is a two-year window and you would expect a lot lower survival. But in that short window when you are losing one in four or three quarters, whichever way you want to look at it, the question is are they carrying a burden from the Salish Sea onwards in the migration, such as poor gill conditions because they've been through annomina in the river, or any number of other stressors.

David Welch: It is important to remember that this technology measures the speed of movement and the survival to various points. It does not indicate how we interpret the data. Therefore, the data are essentially silent for anything that may have affected them in the river including questions about passage past fish farms. Because the fish are moving past so quickly if they encounter something that takes time to develop then we are not going to see it until after they have gone past.

Lacking information about the north arm of the Fraser

A participant (fisherman) directed a question to Mike Lapointe:
I represent the Fraser River Coalition and we do a lot of work in the north arm of the Fraser River. I wonder about the issue of smolts leaving the river.

The Fraser River Coalition has been looking at a lot of the water treatment plants, especially the one on Annacis Island. We believe that there are a number of new chemicals being put out by these sewage treatment plants directly into the Fraser River. As the Chilko smolts migrated down the river in 2007 there was a possibility of a tidal change in the mouth of the river that could have held those pollutants back in the river.

We are seeing the chemicals from Annacis now reaching right down into the north arm of the Fraser River. We know absolutely nothing about the north arm because nobody has done any research there. We know that approximately 11% to 18% of the water flow goes down to the north arm but we don't know how many smolts or fry go down there. And we don't know how many returning salmon migrate up the north arm. Could you please comment on this.

There was one study conducted by the Pacific Salmon Commission in 2001. It looked at potential causes of early upstream migration of late-run Fraser River sockeye. It did not look at smolts coming down the river. Some of the findings in this report are very alarming regarding the water treatment plants. Have any more studies been done? I can find no information regarding smolts moving down the river, passing through these large tidal areas of effluent from the treatment plants.

Mike Lapointe: I have seen only two reports and both were relating to the early upstream migration of adults, but not the smolts going out. We were looking for a trigger that might have caused these late-run fish to change their behaviour. From the findings in those reports, I believe that there were no clear conclusions about the potential triggers, but there was some information about the trends and various chemicals.

I know that the reports found compounds such as pharmaceuticals including endocrine disrupting compounds and a trend in a fire retardant chemical that was correlated in terms of its time pattern with the early upstream migration of Fraser sockeye. Both of those reports should be easy to access. Certainly you are right – there is a lot that we do not know. David Welch has receivers, listening lines, on both arms of the Fraser, so he might be able to comment on whether the smolts seem to be taking one arm or another. In terms of that detailed path, the only information we have is our test fisheries and there is no test fishery in the north arm.

David Welch: All the data for all populations are available on the POST website. From those data you can sort out what proportion of the fish are going down the two arms. I am almost sure that most of the adults coming back in the last year came in the main arm as opposed to the north arm but would need to verify that.

Can any of the mortality be attributed to the surgical implantation of tags?

Randall Peterman directed a question to David Welch: What is the possibility that there is some confounding of interpretation about the relative magnitude of mortality in the Strait of Georgia, compared to the period afterwards due to delayed mortality from the tagging process itself and the surgical implants?

David Welch: Surgical trials have been carried out on Thompson River coho, steelhead and spring Chinook, but not on Cultus Lake sockeye. There is some mortality from tagging but it is very small relative to what we expect or what we are measuring out in the sea. These are from fish held in the hatchery for up to eight months after they have been surgically implanted. This does not appear to have a large effect on our survival estimates out at sea. We are currently conducting a study with some colleagues at Oregon State University looking at saltwater challenges on tagged chinook. One of the questions is, if after about a month we put the surgically implanted fish into saltwater, do we see elevated mortality. From our knowledge currently, however, we don't see a lot of mortality happening that could explain the high mortality after the fish move out of the Salish Sea.

Randall Peterman:
My point was with respect to the delayed mortality that you are not able to estimate with your short-term experiments, looking at the tagging of fish or the tagged fish.

David Welch: My counterpoint to that is that when we hold fish in the hatcheries for up to eight months we do not see heavily elevated mortality. We do see a small amount of mortality that is due to tagging surgery, probably the drugs, and also some tag loss. We are also, of course, getting two out of 200 adults back, which is consistent with these observations. Very recently with our Sakinaw Lake sockeye tagging research, we have seen returns of five adult sockeye. The behaviour of those fish is very different from the Cultus Lake fish and all of the fish that have survived to come back as adults appear to have never left the Strait of Georgia during the time that the tags were operating.

Could marine mammals be affecting mortality rates?

John Henderson directed a question to David Welch: Do you take into consideration the numbers of predators that pass through Johnstone Strait and Queen Charlotte Sound? There appears to be an abundance of seals and sea lions in this area. Does that have an impact on survival rates and as well pattern changes to the migration paths?

David Welch: These tags will go into a predator and while they are in a predator, we will interpret it as if the animal was still migrating along. We generally expect hard parts such as bones to be cleared out of the predator within a few days. I am sure that some of the tags that we have picked up have actually been in a predator as opposed to in the animal that we implanted. We don't think that that should be a long-term problem, however, because the animals have pretty good mechanisms for getting rid of hard parts in their digestive system. I would guess that this would be a week at the most, but we haven't looked at it formally.

Getting clarification on the productivity numbers and survival rates

John Fraser:
At the end of the think tank statement, Adapting to Change, it states, "the weight of evidence suggests that the problem of reduced productivity occurred after the juvenile fish began their migration toward the sea." I take the words "reduced productivity" to mean they died or they were reduced in health. If I understood David Welch correctly, and he was referring to Cultus Lake sockeye smolts, he indicated that the collapse probably happened in the ocean after leaving the Fraser River. There isn't necessarily a contradiction here but those are two different approaches. Then if you look at the Harrison River there is something different. The public is understandably deeply concerned about what is going on but also confused about what all this means. Can you straighten that out.

David Welch:
In referring to Figure 6 (page 15) describing survival rates, the key point is that the out-migrating smolts that were tagged in 2007 had similar or higher survivals to the prior years in the Fraser River, Strait of Georgia and out through the Broughton Archipelago to Queen Charlotte Strait. So that gives us migration timing or speed of movement for these animals, but it also gives us the survival rates to those points. What we were seeing for the fish we tagged in 2007 is that the survival to the north end of Vancouver Island was as high or higher than in the preceding three years. Does that mean that the fish did not die because of events happening up to that point but expressed beyond that? We do not know.

We have a technical method now, for the first time, of looking at these measurements or looking at these questions and providing some hard numbers. They are suggesting that most of the mortality happens beyond Queen Charlotte Strait. Whether or not that is set up because of conditions that happened prior to that, we do not know. It is a big question to me why we did not detect any of these fish in the prior years when we used tags that ran for a much longer time. Why didn't they get up to Alaska? They should have. So I believe that they are stopping somewhere.

There is a big gap in our knowledge. Formerly, the gap was basically about when the fish left the lake. Now the gap is at the northern end of Queen Charlotte Strait. My personal view is that the mortality event that caused the problem likely occurred or was expressed somewhere beyond the Queen Charlotte Strait. The sea birds up there, for example, had very poor hatching success in 2007, suggesting that there may be a problem in Queen Charlotte Sound.

Mike Lapointe: To add a couple of points of clarification I would like to note that David was not part of the think tank deliberations, so this is actually the first time that people have seen this information, including the scientists from the think tank. Therefore, some of the conclusions that were made in December were based only on the information that was available at that time.

The think tank did have the information contained in Table 3 above, which can narrow it down to some time after the fry stage, but cannot get such a fine point as what we saw in David Welch's presentation today. A second point is that Cultus sockeye, as smolts, probably have the shortest out-migration distance of any of the sockeye in the Fraser watershed. The fish that David is tagging are larger than other Fraser stocks so we need to be careful about drawing an inference from Cultus sockeye with respect to the particular question that you raised.

Are any drugs administered to surgically implanted fish?

A participant asked:
Have the sockeye smolts that you are releasing been vaccinated? I understand that generally hatchery fish are vaccinated.

David Welch: None of the fish have been inoculated. Apparently DFO had a pretty rigorous broodstock screening program for the adults and as a result none of the fry or smolts were inoculated.

Participant:
Do you give them any type of medication when you're doing the operation?

David Welch: Based on our past surgical experience and the trials we do not even give

the fish antibiotics. The survival is extremely good as long as the surgery is carried out to a high standard. We try to minimize drugs, other than the anesthetic when we put them under to do the surgery.

What was the productivity for sockeye stocks other than the Fraser?

A PhD student directed a question to Mike Lapointe: What can you tell us about productivity, both recently and back through time, in other sockeye salmon populations in Southern BC or even in Washington State, such as the Lake Washington fish that also enter in the west coast of Vancouver Island?

Mike Lapointe: At the think tank, we did look at some of the patterns in other BC coast stocks, particularly focusing on 2009. It doesn't look like the pattern that we have seen of extremely low productivity in 2009 for Fraser stocks was observed in very many other sockeye populations in the south coast. Historically, the productivity of all salmon and Fraser sockeye are different, there is a very large variation, and so what you are asking is an important question. If we were able to tease some of those patterns out, not just for 2009 but for the longer timeframe, it might help us know where and when to look for causes. At the upcoming Pacific Salmon Commission workshop in June, we hope to gather some of those data and do some actual analysis prior to that.

What about hake?

A commercial fisherman directed a comment to Mike Lapointe:
We have not fished Fraser River sockeye for three years. I see the trend is pessimistic and there is a fairly pessimistic outlook for sockeye in the future. But being fishermen, we are born gamblers and I am wagering that the 2010 sockeye return is going to be larger than the 10 or 11 million that are predicted. In 2006 and 2007, there was a large amount of hake up there and generally the hake are caught on the west coast of Vancouver Island. In those two years in particular the hake fleet had to fish there and that is not their ideal place to fish hake, because they have to transport the fish a long way and hake is something that needs to be processed right away.

You could check with the Port Hardy DFO office to back up this observation. When I did test fishing in Barkley Sound the salmon technician told me that 95 % of the fish coming out of Barkley Sound were generally eaten by hake, and that was just a normal predation rate. Your presentation caused me to wonder about the role of hake. Obviously there would have been hake throughout history but they didn't cause this kind of decline. How would a salmon smolt or fry be able to escape such a large abundance of predators, especially for example, if they were carrying five to ten sea lice on their backs?

Mike Lapointe:
Hake are being monitored but I really am not familiar with the data.

2020 Clarification on Harrison sockeye smolts

Kees Groot directed a question to Mike Lapointe: You mentioned that many of the Harrison Lake fry go downstream now and stay for a year in saltwater. Are you referring to the fry that came out of Weaver Creek hatchery spawning channels that used to go into Harrison Lake?

Mike Lapointe: I believe that Harrison sockeye are spending a long period of time in Georgia Strait. The Harrison sockeye that I am referring to are a population that spawns in the Harrison River below Harrison Rapids, not the Weaver Creek spawning channel fish.

Kees Groot: What do you think are the mechanisms underlying the better survival of the juveniles in saltwater compared with the ones in freshwater? Is there any information of survival of the juveniles that stay in Harrison Lake and can you compare that with the saltwater fish?

Mike Lapointe: We do not have the level of detailed information to answer that question. The freshwater productivity phase that I am referring to is up until, in the case of Quesnel, the fall prior to out-migration. So we are not seeing that decline that we are seeing in the post-fry stage in these populations. But what is the mechanism?

We don't know.

SECTION II
Smolts Enter Nearshore Marine Environments

- **What stressors may be encountered?**

Presentations by:

Andrew Trites, Professor, Marine Mammal Research Unit, Fisheries Centre, University of British Columbia

Michael Price, M.Sc. Candidate, Biology, University of Victoria

Alexandra Morton, Director, Salmon Coast Field Station

MARINE MAMMAL PREDATION

Andrew Trites, Professor, Marine Mammal Research, Fisheries Centre, University of British Columbia

Following Mike Lapointe's presentation, I wonder if I am here to address the hypothesis that Colonel Mustard did it in the ocean with a harbour seal. We will see whether or not the evidence supports this. Anyone who has gone fishing for salmon could tell a good seal or sea lion story. In most people's minds, certainly in the collective memories of our lifetimes within this room, we know that harbour seals seem to be everywhere now. We are seeing a similar pattern a little further north of Georgia Strait with sea lions. This pattern seems to correlate in most people's minds with declines in salmon.

Harbour seal population in Strait of Georgia

The simple explanation is that there is more to this correlation than just coincidence. We clearly have the victim, the salmon, and the prime suspect in Georgia Strait in this case, the harbour seals. Harbour seals in Georgia Strait are currently at the highest density of seals anywhere in the world, and the population in Georgia Strait accounts for about 40% percent of the BC population of harbour seals. If we turn the clock back in time to when the Fisheries Act came into force to protect marine mammals, in this case putting an end to the culling and bounty on harbour seals, then the population in Georgia Strait went from close to 3,800, to ten times that many animals,

with an annual rate of increase of about 11.5 % per year. The numbers increased exponentially and then surprisingly in the mid-1990s, it hit a ceiling and the numbers have been constant ever since. The trend we see in Georgia Strait is similar to elsewhere in the province; that is, a rapid build up and then pretty much flat to stable.

Province-wide there are currently ~ 108,000 harbour seals. There is no doubt, therefore, that harbour seals are very much present. However, you have to look at when things stabilized and ask the question: Why did these populations stabilize? Prior to the most accurate counts that started with the Fisheries Act, there was information available about harbour seal numbers; for example, there are records of how many noses were turned in for the bounties and records of the numbers of pelts that were sold during the commercial harvest that started in the late 1800s. Going back in time, we can reconstruct the numbers of seals that were present. It turns out that in the period from 1875 up to about the start of the First World War, there was roughly the same number of seals as there are today. This leads us to conclude then that for marine mammals things seem to have come back to what was normal in the past.

Other marine mammals

Seals of course are not the only marine mammals present in Georgia Strait. There are at least 10 other species present, and while the harbour seal is the most abundant and most prevalent, there are also California sea lions, Dall's porpoises, Steller sea lions, Pacific white-sided dolphins, and harbour porpoises, all of which have salmon at some point on their menus and are preying on them to some extent. There are also killer whales, gray whales, minke whales and, over the last two years, there have been signs of elephant seals starting to breed at Race Rocks. It appears that things are coming back to the way the world once was.

Are marine mammals having an impact on sockeye salmon?

The question is: Is this having an impact on the salmon and in particular, the sockeye salmon and smolts? Our knowledge about diet, unfortunately, is fairly limited. There are a few records of stomach samples from the late 1950s and early 1960s, but diet was not really taken that seriously until 1980s, a point in time when it was no longer appropriate to shoot animals to see what that one meal was that they had on that one day. The system that is used now to collect information involves collection of fecal samples or scat. By cleaning that material, you can identify the bones that are present and with this information the species can be identified, although in some cases not down to the species level. Salmon have been particularly problematic. We can tell, for example, from the size of the bone if it is a smolt, or smolt-sized fish, or if it is an adult. But from the bones we have not yet been able to determine whether or not it is a sockeye, Chinook, coho or chum salmon. The bones are just too similar for that level of identification. Most recently we have been using DNA analysis, and it is now possible to determine the species of salmon eaten including some unexpected delicacies. We have found, for example, that in Alaska, some sea lions in the Aleutian Islands are eating Atlantic salmon. We would have never known that without the DNA technology.

Ultimately, it will be possible to determine the diet of harbour seals in terms of sockeye but that information is not currently available. However, we do have some information from the 1980s when the diet was intensively studied. About 3,000 diet samples were collected. from 58 sites around Georgia Strait. The primary item in their diet then was hake, and not salmon; during the late 1980s (and possibly also today) the diet of harbour seals in Georgia Strait consisted of 43% hake and 32% herring. That means that 75% of the harbour seal diet was not salmon. These data indicated that salmon only made up 4% of the diet at that time. An analysis of the size of the bones

in the stomach contents, showed that seals from only two of the 58 sites sampled had smolts in them. These two sites were Comox Harbour, from May to July, and Port Moody, from September to November. The scat samples that were collected near the Fraser River and Boundary Bay sites did not contain any significant numbers of small salmon.

The bulk of the diet of harbour seals, in terms of salmon, are adult fish. That is apparent when one observes the movements of seals. They tend to concentrate seasonally towards the river mouths where some of the larger runs are returning.

Finally, in addressing smolt predation, it is interesting to note the results of some recent research conducted in the Comox area where a graduate student coming back one night from a bar across the river, looked down and saw harbour seals in the river under the bridge. They were swimming belly up, side by side, like a virtual wall across the river. What the seals were doing, in fact, was using the lights and the shadow that the bridge created to feed on smolts coming out of the river. She could hear them slurping, as they were eating them. Scientists from DFO estimated that between 10 to 20 animals seemed to be responsible and from their calculations, just counting the numbers of swallows they could pick up, they estimated that they were eating around 140,000 chum, and 13,000 coho smolts. It is quite remarkable what the seals are capable of doing, although it is not clear whether or not they are just taking advantage of a man-made structure or if they could do this naturally elsewhere. Therefore, it is possible for harbour seals to adapt to find novel ways to feed on a food source that they may have not have accessed traditionally. In this case the seals were targetting chum and coho, and this observation ties into what was observed earlier in the 1980s in terms of Comox being one of the sites for eating smolts.

Summary

In conclusion, the seal numbers have returned to historic high values, and appear to be stable. Probably the reason why they are stable is correlated with killer whales. The transient form of the killer whale, which eats marine mammals, can typically be found on a daily basis now in the Strait of Georgia. As everyone knows, every killer whale needs one harbour seal a day to keep that doctor away and they appear to be consuming about one harbour seal per day, essentially what they need. That may be the factor that is keeping the harbour seal population in check. There are no signs of food stress. We see no signs that harbour seals are emaciated, or aborting pups or anything else that would suggest that they are having any kind of food problem that might force them to find some alternative food. Another point to note is that many people point to marine mammals as the cause of fish declines; yet they seem to have missed the fact that other fish consume more fish than marine mammals do. For example, hake are probably, in terms of a fish species, the largest predator of salmon smolts. Given that 43% of their diet could currently be hake similar to the 1980s, harbour seals may well have a net positive effect on salmon returns. In terms of the adult salmon that are taken by harbour seals, the estimates indicate that they only take about 2.8% of escapement. In the big picture, therefore, they are probably not having a huge negative effect on the sockeye stocks, but instead, they may actually be having a net positive effect, although this is a much more difficult thing to measure or demonstrate.

SEA LICE AND SOCKEYE SALMON

Michael Price, M.Sc. Candidate, Biology, University of Victoria

This presentation focuses on the early marine ecology of Fraser sockeye that I have researched since 2007. The objectives of this research included: an assessment of parasite levels on Fraser River sockeye and determination as to whether salmon farms are a contributing factor to the parasite levels; investigation of the migration patterns of these juvenile Fraser sockeye in terms of movement, sizes, stock proportions, and stock specific attributes; and an examination of their diet and health relative to parasite levels. This research was initiated as a broader investigation of juvenile pink and chum salmon and relative infection levels in multiple salmon farm regions in British Columbia.

Assessment of sea lice on pink and chum salmon

Figure 1 shows the location of the salmon farm regions in BC that were studied: Finlayson, Region A, the Broughton Archipelago, Region B, and the Discovery Islands or Georgia Strait, Region C. Sea lice levels on pink and chum salmon in each of these regions were compared to those in an area without salmon farms, located in Bella Bella.

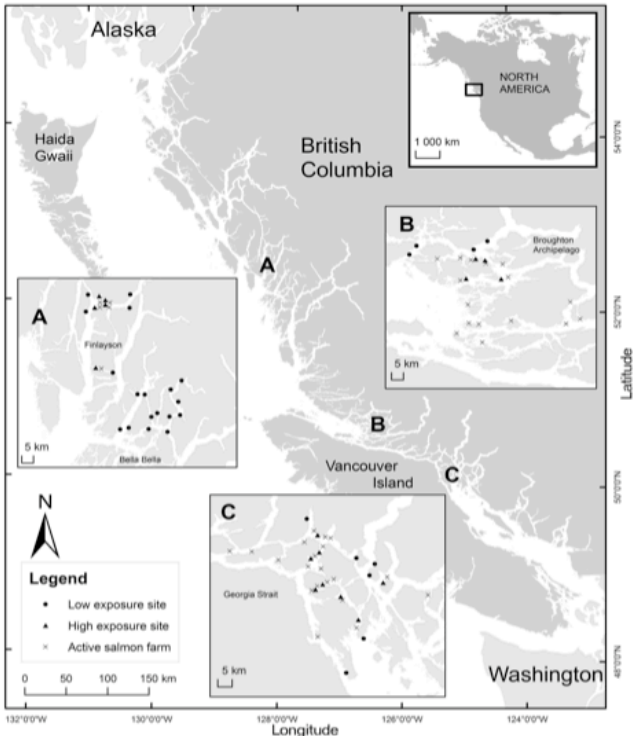

Figure 1. Map showing salmon farm study regions: Region A, Finlayson; Region B, the Broughton Archipelago; and Region C, the Discovery Islands or Georgia Strait examined during 2007-08.

The graph in Figure 2 shows the results of these studies: in Finlayson, the Broughton Archipelago and Georgia Strait, sea lice levels were highest near and downstream of salmon farms, and were lowest and most similar to the Bella Bella control study region at control sites in all regions except in Georgia Strait (where even control sites showed somewhat elevated levels of lice).

The abundance of sea lice also seemed to rise in concert with the amount of farmed salmon produced in a given region. For example, the lowest lice levels were observed in the Bella Bella region where no farmed salmon are produced. Alternatively, the highest sea lice levels were observed in the Georgia Strait region, which had the highest mean annual farm salmon production during these years. Although these data are for pink and chum salmon, if we consider these fishes as sentinel species, these data clearly show that salmon farms can elevate levels of sea lice (especially in the Georgia Strait), and may also be infecting Fraser River sockeye smolts migrating through the area.

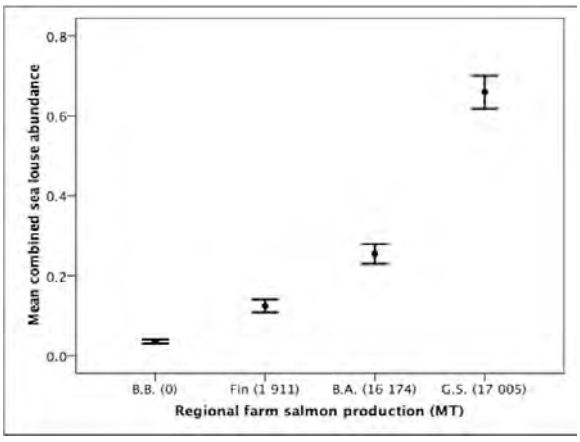

Figure 2. Combined Sea lice abundance on combined pink & chum salmon at Bella Bella, Finlayson, Broughton Archipelago, & Georgia Strait regions during 2007-2008.

Sea lice and sockeye salmon

The question is: Are sockeye as susceptible to louse infection as pink and chum salmon? Figure 3 shows the presumed migration patterns described by Mike Lapointe and the findings of Kees Groot (1987). Juvenile sockeye emerge from the Fraser River and primarily migrate north between the east coast of Vancouver Island and the mainland coast. Inevitably, they transit through the Discovery Islands' salmon farm corridor on route to the open ocean.

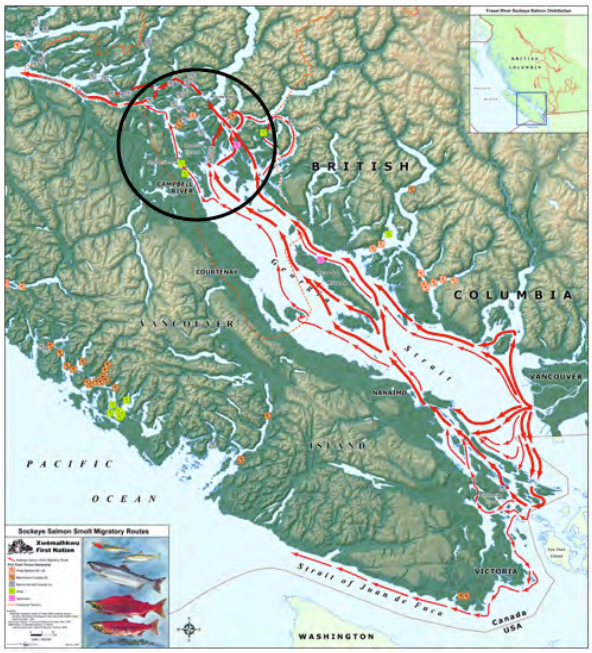

Figure 3. Presumed migration routes of juvenile sockeye salmon from the Fraser River.

As part of our pink and chum salmon research in the Discovery islands region during 2007 and 2008, we incidentally caught sockeye smolts; this then led to the current sockeye research project in this area. Figure 4 shows the Discovery Islands study region, with collection sites for sockeye from 2007 – 2009 denoted by black circles. Yellow circles represent active salmon farms. In addition to the farms, there are two processing facilities in the region that may be contributing factors to lice levels on the migrating sockeye (stars). The red arrows depict the migration of Fraser sockeye into the region.

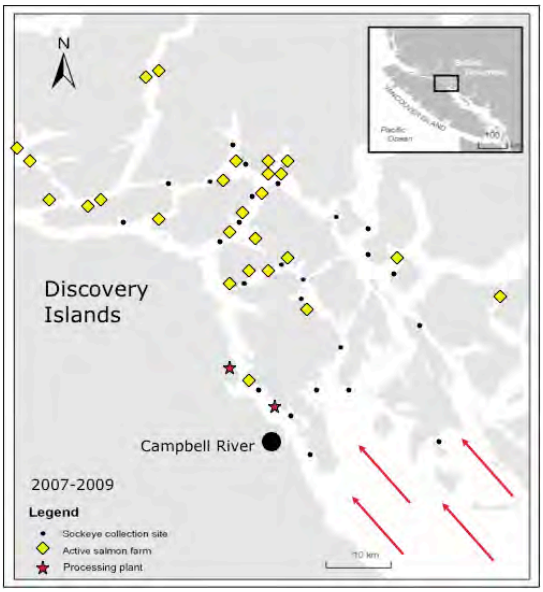

Figure 4. Map of the Discovery Islands study region showing collection sites for sockeye from 2007 – 2009 (black circles), active salmon farms (yellow circles), processing facilities (stars). The migration of Fraser sockeye into the region are denoted by red arrows.

Sampling procedure

Sampling methodology has differed slightly over the years. In 2007 and 2008 during the pink and chum study a 35-metre beach seine was used resulting in fish being caught close to the shore. This is easiest for pink and chum because they tend to migrate close to shore during the early marine migration. We were also able to catch sockeye in this region likely due to their large numbers and possibly also due to the region's narrow passageways. Surveys were conducted from late April until mid-June (the typical out-migration period for juvenile pink and chum salmon in this area) in 2007, and late April to the first week of July in 2008, targeting sockeye for those last few weeks once pink and chum were gone from the area. In 2009 we switched to a modified purse seine, which enabled us to more effectively catch sockeye where they tend to be, usually 30 to 100 metres offshore, or slightly further offshore in the open channels. In 2009 Fraser sockeye were targeted from the last week of May to mid-July, which seems to be the typical migration period for smolts through the Discovery Islands.

Results

Of the three salmonid species that were assessed in the Discovery Islands during 2007 and 2008 (pink, chum, and sockeye), sockeye were the most heavily infected with lice. However, there was a difference in the species of sea lice responsible for the infections. Whereas pink and chum were primarily infected by the salmon specific louse, *Lepeophtheirus salmonis*, sockeye tended to be infected with more generalist salmon louse species, *Caligus clemensi*. Although the *Caligus* spp. is thought to cause less mechanical damage to its host and is perhaps less lethal than the salmon specific louse *Lepeophtheirus salmonis*, there is minimal information available that describes the potential impacts that *Caligus* may have on sockeye or other juvenile salmonid.

Figure 5 describes region-wide parasite levels for both *Caligus clemensi* and *Lepeophtheirus salmonis* on juvenile sockeye salmon in 2007, 2008, and 2009.

		Caligus clemensi			*Lepeophtheirus salmonis*		
Year	No. of sockeye	Prevalence	Abundance	Maximum Intensity	Prevalence	Abundance	Maximum Intensity
2007	381	0.61	3.24	28	0.07	0.07	2
2008	510	0.62	1.73	21	0.21	0.30	5
2009	1422	0.90	5.20	41	0.06	0.08	3

Figure 5. Region-wide parasite levels for both *Caligus clemensi* & *Lepeophtheirus salmonis* on juvenile sockeye salmon in 2007, 2008, and 2009.

Note the differences in numbers of sockeye for each of the years, with the most fish being caught in 2009. This is likely more a reflection of learning where and when sockeye tend to be found rather than a measure of annual abundance or relative abundance among years. *C. clemensi* is the most infectious species for sockeye regardless of year. In terms of prevalence (the average number of fish infected with lice), the range was from 60% to 90%. The values for abundance, or the total number of lice given the total number of fish assessed, ranged from almost two to just over five lice per fish. Values for maximum intensity ranged from 20 to 40 lice per fish. Comparing these numbers to levels of infection of *L. salmonis*, the results in the latter case are an order of magnitude lower in every year.

Skeena sockeye salmon louse infection rates

The question arose: Are the levels of sea lice observed on sockeye smolts migrating through the Discovery Islands' salmon farm corridor the same as levels that would be found in the natural environment? Data were available for the 2007 out-migration year for the north coast, an area that does not have salmon farms, from research conducted by Alan Gottesfeld chief scientist of the Skeena Fisheries Commission. 369 sockeye were collected off British Columbia's north coast and assessed for sea lice; the majority of the sockeye assessed were genetically identified as being from the Skeena River.

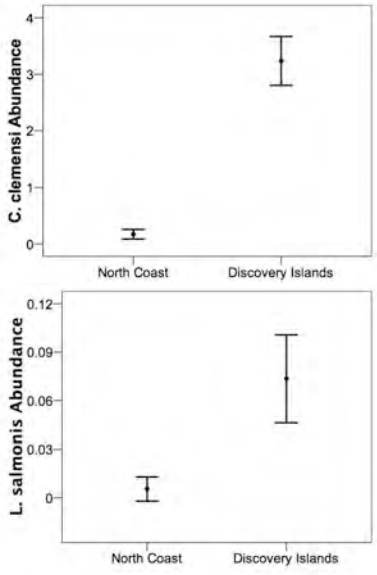

Figure 6a,b. Sea lice abundance (*Caligus clemensi* 6a; *Lepeophtheirus salmonis* 6b) on juvenile sockeye migrating along BC's north coast and Discovery Islands).

This provides not only a novel comparison of lice levels between regions, but it also enables a comparison between two of Canada's largest sockeye populations, originating from either the Fraser River or the Skeena River. The plot in Figure 6a shows the *C. clemensi* abundance levels for each region, indicating significant differences between the regions, with the lowest lice levels observed at the north coast site. Similarly, for *L. salmonis (*the salmon specific louse; Figure 6b), there were significant differences between regions with the lowest lice levels

among the north coast region.

Possible causes of sea lice infections of sockeye at the Discovery Islands sites

What then might be causing the higher levels observed among the Discovery Islands region? The presence and abundance of farmed salmon in the Discovery Islands is one potential factor, as has been shown for pink and chum salmon during the same years of study.

Figure 7 shows sea lice data for a select number of Marine Harvest salmon farms operating among the Discovery Islands during 2007 and 2008.

Note that both *Caligus* and *Lepeophtheirus spp.* were present on farmed salmon in both years, and specifically during the out-migration period for sockeye, as indicated in the grey shaded areas. There were also differences during these migration periods, with higher levels observed for *C. clemensi* in 2007 compared to 2009, and an opposite trend for *L. salmonis* in 2008 compared to 2007. Looking back at the region-wide parasite levels (Figure 5) there was a decrease in *C. clemensi* levels of >3 lice to <2 lice from 2007 to 2008, yet the opposite trend existed for *L salmonis,* which had higher levels in 2008, suggesting that salmon farms may be a contributing factor to lice levels on sockeye.

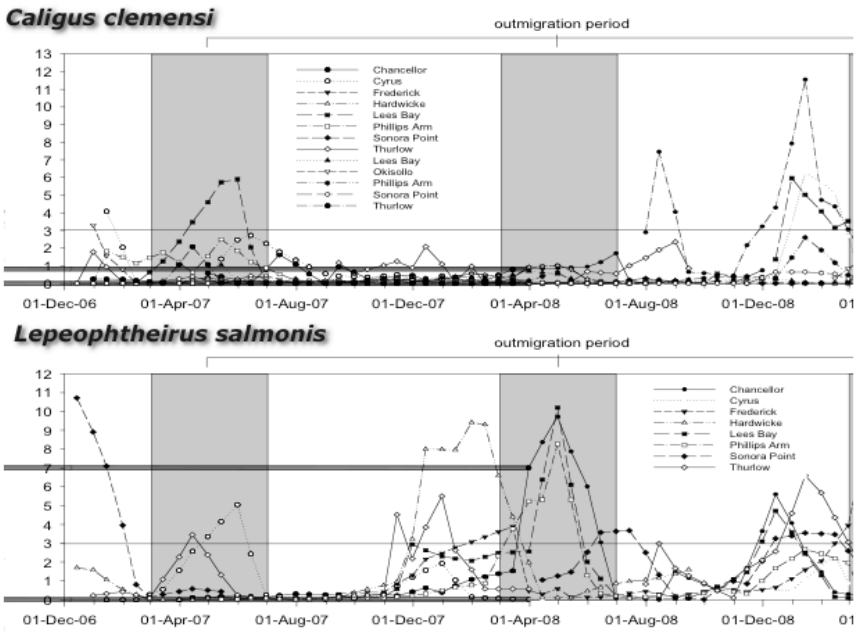

Figure 7. Average number of sea lice (*Caligus clemensi* – top; *Lepeophtheirus salmonis* – bottom) per farm salmon recorded bi-weekly on Marine Harvest salmon farms operating among the Discovery Islands during 2007-2008.

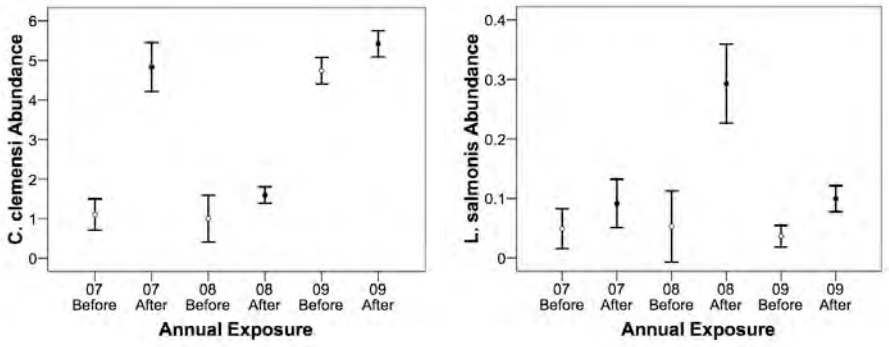

Figure 8a,b. Sea lice abundance (*Caligus clemensi* 8a; *Lepeophtheirus salmonis* 8b) on juvenile sockeye salmon at locations either before farms or after farms among the Discovery Islands from 2007-2009.

Focusing more specifically within the region and dividing it into southern and northern sites (or considering them in terms of Fraser sockeye before they pass farms and those that have passed farms), in terms of abundance, a notable increase was observed for those sockeye that had passed the farms (Figure 8).

In every year, sea lice abundance levels were higher for juvenile sockeye that had passed salmon farms compared to those that had not for both *C. clemensi* and *L. salmonis*. Again, these data

suggest that salmon farms are a probable source of lice on Fraser sockeye smolts.

We asked the question: Are these Fraser sockeye? How did we know they were not local stocks? Of the samples that were genetically identified in 2007, 40% were from the local Phillips Lake stock. These fish tended to be smaller and concentrated around Phillips Arm and Cordero Channel, and were only caught from late April to the first week of May. The other 60% of the samples were Fraser River sockeye that began to emerge in the region during the last week of May. In 2008, 99% of the sockeye that were genetically assessed were found to be from the Fraser River. Again, they emerged in the region in late May.

Conclusion

Based on our research findings to date, sockeye are the most highly infected juvenile salmonid species among the Discovery Islands. Fraser stocks may be the most at risk to louse infection due, in part, to their primary migration route through the Discovery Islands' salmon farm region. The threat of *Caligus* to Fraser sockeye remains relatively unknown; however, fish hosting 20 to 40 lice, as were observed, are unlikely to benefit from this infection. Further, the potential for disease transfer is probably the most urgent question we have and yet it, too, remains entirely unknown not only for Fraser sockeye but also for all wild salmonids. We are awaiting data from the genetic and dietary analyses of the 2009 samples.

SALMON FARM-ORIGIN PATHOGEN IMPACT ON FRASER SOCKEYE, A MATTER OF HOW GREAT, NOT IF

Alexandra Morton, Director Raincoast Research Society

What is the potential that salmon farm-origin pathogens have negatively impacted Fraser sockeye (*Oncorhychus nerka*)? Based on my observations and the scientific literature from British Columbia and Norway it is certain impact has occurred the only question is how much. A feedlot environment allowing open pathogen exchange with the wild environment will be continuously challenged with endemic bacteria, viruses and parasites. Once pathogens infect these anomalous captive populations, (500,000 to a million per farm), amplification is going to occur due to the absence of predators, lack of migration and high host density. Epidemics are extremely rare in wild salmon, because there are predators that attend every life stage of wild salmon and these serve to remove fish suffering from reduced fitness.

Bakke and Harris (1998) referred to salmon farms as pathogen culturing facilities. Johnsen and Jensen (1994) described the spread of furunculosis, a bacterial infection, into 70 wild Norwegian salmon rivers via salmon farms. Jarp et al. (1993) identified that one of the highest risk factors for furunculosis infection in enhancement hatcheries was fish farms on the migratory path of the enhanced salmon.

As a resident and biologist I observed several disease events in the Broughton Archipelago that suggested movement of bacterial infection between salmon farms and between salmon farms and wild salmon. In 1991, IBEC, one of the first farming corporations to be located in the Broughton Archipelago, placed Atlantic salmon infected with furunculosis into several of their farms. It became common knowledge through the community that these sites experienced large mortalities.

Shortly after the outbreak, Stolt Sea farms, a Norwegian company, bought the IBEC farms and in a meeting reported to the community that the bacterial infection originated in the farm fish hatchery (D. Blackburn, Stolt Sea farms pers. comm.). A small community Coho (*Oncorhynchus kisutch*) hatchery, the Scott Cove Hatchery, was sited east of one of the infected salmon farms at

Notice Point. Scott Cove Hatchery had a ten-year average broodstock mortality of 3%. However, in 1991 28% of the broodstock that had passed the infected salmon farms died of furunculosis. Fisheries and Oceans Canada (DFO) recommended the survivors be treated with the antibiotic, oxytetracycline. This worked well in stemming mortalities. Figure 1 is a map of Broughton Archipelago highlighting the farms that were infected with furunculosis. The line in the figure represents the adult Coho migration route and the round circle represents the hatchery.

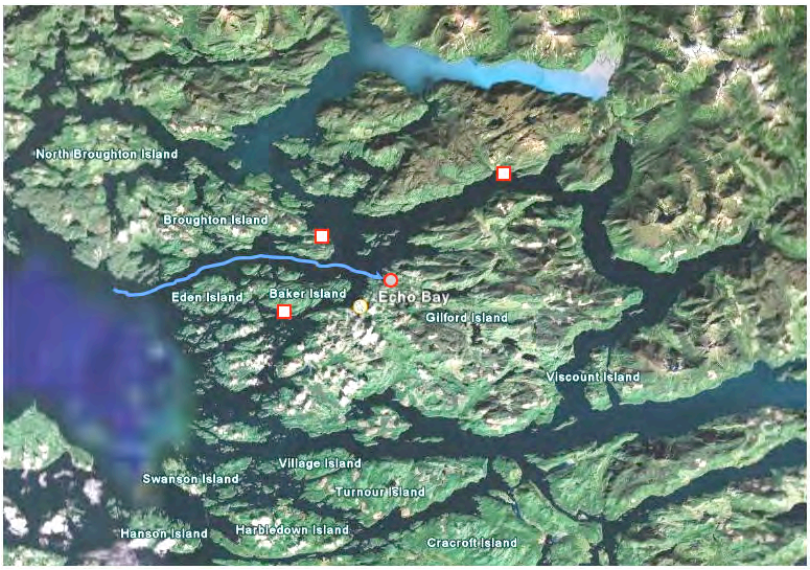

Figure 1. Map of the Broughton Archipelago highlighting the farms infected with furunculosis. Route of Coho (line); location of hatchery (circle).

DFO did not release the strain of furunculosis that infected the farm salmon so no confirmation was possible to determine if the hatchery and salmon farm strains were the same. However, in 1993 a similar series of events occurred, but this time the strain of furunculosis, introduced by a company named Scanmar, was resistant to all three antibiotics approved for use in salmon farms in British Columbia at that time. This strain of furunculosis spread within days to the nearby B.C. Packers farms (Needham, 1995). The Coho salmon that returned to the Scott Cove Hatchery in 1993 also experienced anomalously high mortality and were infected with a strain of furunculosis that was resistant to at least oxytetracycline. DFO examined pink salmon that had migrated past these salmon farms and found furunculosis in wild pink salmon (*Oncorhynchus gorbuscha*) from the Kakweikan River - but reported they lost the sample before they could test it for drug resistance. DFO refused further samples (D. Keiser, DFO pers. comm.)

One third of BC wild salmon migrate through the inside passage between Vancouver Island and the mainland in any given year (B. Riddell, PSF pers. comm.) particularly when there is warm water offshore. This means these salmon and steelhead stocks are exposed to effluent from approximately 70 salmon farm sites (http://www.livingoceans.org/files/Maps_Thumbnails/ff_bc_tenures_march2008.jpg).

Given the global escalating concern over impact of salmon farms on wild salmon stocks (Ford and Myers, 2008), placing numerous salmon farms in this area of high wild salmon traffic seems extremely high-risk fisheries management. The decline in productivity for sockeye beginning in the early 1990s (Statement from Think Tank scientists SFU Dec. 9 2009, Appendix 2) must trigger scientific investigation of the relationship between pathogen outbreaks in the salmon farms and Fraser sockeye productivity.

IHN outbreak in 2001

The first marine salmon farm IHN outbreak occurred in July/August 1992, in the Okisollo Channel in the Discovery Islands as the Fraser sockeye were migrating through this channel. (Minister of Environment, John Cashore, memo October 28, 1992). It was unknown prior to this date that IHN

outbreaks could occur in saltwater. These farm salmon were left in the ocean, even though hatchery policy in BC is to destroy IHN infected stock.

Saksida (2006) reports that in 2001 a salmon farm became infected with IHN in eastern Johnstone Strait. The virus spread rapidly to the neighbouring salmon farms. Then Atlantic salmon smolts in a transport vessel circulating ocean water through its hold became infected with IHN after passing the Johnstone Strait salmon farms. Shortly after they were placed in Simoom Sound, Broughton Archipelago, IHN was diagnosed and they were culled. A B.C. Supreme Court injunction (Feb. 8, 2002) barred these culled Atlantic salmon smolts from being off-loaded at a fish processing plant in Vancouver for fear of IHN transmission to Fraser River salmon stocks.

Figure 2. Salmon farm sites infected with IHN (red dots) in the 2001-3003 outbreak reported by Saksida (2006), excluding the infected farms in Clayoquot Sound. The yellow line represents movement of the Atlantic salmon smolts in transport vessels that became infected as they passed IHN infected salmon farms on route to being placed in sea pens. After these infected smolts entered the ocean, neighbouring salmon farms became infected.

According to Saksida (2006) another Atlantic salmon smolt shipment suffered a similar fate and were deposited in a salmon farm on the Central Coast. Then over a two year period 12 million farm salmon became infected with IHN in 21 salmon farms near the three original infectious sites and along the route of the smolt packing vessels. Clayoquot Sound on the west coast of Vancouver Island also became infected. Infectious farm salmon sites stretched from eastern Johnstone Strait to the Central Coast, where 1/3 of British Columbia's wild salmon migrate, including Fraser sockeye. (Figure 2) Management of this farm salmon outbreak was haphazard; some were culled, some resulted in mortalities so high rotting offal was visibly exiting the farm (pers. obs., Sir Edmund Bay) and others were left in the ocean (T. Needham, manager Heritage, Burdwood farm, pers. comm.).

Salmon farm sites infected with IHN in the 2001-3003 outbreak were reported by Saksida (2006), excluding the infected farms in Clayoquot Sound. The line represents movement of the Atlantic salmon smolts that became infected as they passed infected salmon farms on route to being placed in sea pens. After these infected smolts entered the ocean, neighbouring salmon farms became infected.

If transmission of IHN occurred within the minutes that the smolt packer passed the infected farms at a considerable distance of 10km or more as Saksida suggests, it is not reasonable to believe that the wild Fraser sockeye that also transited the area were not similarly infected. While the original source of the virus was almost certainly wild sockeye, IHN was not known to occur in saltwater prior to the 1992 Okisollo IHN outbreak (memo Armstrong MELP Dec. 17, 1992). In the wild, natural predation would have prevented 12 million IHN infected salmon in schools of 500,000 - 1,000,000 sited at intervals along hundreds of kilometre of the Fraser sockeye migration route.

"Quarantine"

I conducted a preliminary study of surface currents in the Broughton Archipelago and found movement of 0.5 - 10 km in six hours by the drifters. While Heritage Salmon wrote letters

communicating "quarantine," at their IHN infected Sir Edmund Bay site to restrict boat traffic, this did not address the much greater dispersal vector via marine currents. IHN transmission via seawater is confirmed (Traxler et al. 1993). Clearly, if there are elevated pathogen numbers in a salmon farm contained only with nets, these pathogens will pass through the nets, spread in the currents and challenge wild populations at unnatural levels and life-stages.

Infectious Salmon Anemia Risk

Infectious Salmon Anemia Virus (ISAV) was first detected in farmed Atlantic salmon in Norway in the 1980s and now occurs in every area of the world where Norwegian salmon farms operate except BC (http://www.thefishsite.com/articles/598/the-global-spread-of-infectious-salmon-anaemia). While open-ocean transmission via wild salmon stocks was argued for the North Atlantic spread of the virus, arrival of the current Norwegian strain of this flu-like virus in Chile suggests transmission via the salmon farming industry. In the opinion of a Norwegian scientist tracking ISAV around the world, British Columbia is "guaranteed" to get this infectious virus, if we do not already have it, because Atlantic salmon eggs are still being imported from the Atlantic (A. Nylund, U. Bergen pers. com.).

While the Canadian Minister of Fisheries and Oceans, Gail Shea writes "there is no strong evidence that ISAV is transmitted from adult to young via reproductive products…" (G. Shea Minister of Fisheries, letter March 11, 2009), Vike et al. January (2009) reports the opposite in "ISA virus in Chile: evidence of vertical transmission". Given that introduction of a novel, infectious, virulent salmon disease is an extremely undesirable and irreversible event Minister Shea may not be well informed enough to make this decision for all Canadians.

Sockeye returns - 2009 pattern

Summarizing the 2009 southern sockeye returns, - many Fraser stocks failed while the Harrison, Somass, Columbia and Okanagan stocks did well. An obvious consistent variable among the successful runs is lack of exposure to salmon farms. Tucker et al. (2009) never observed Harrison sockeye traveling north along the east Vancouver Island migratory corridor, but did find them in their first sea winter off the southwest coast of Vancouver Island, suggesting they migrated to the Pacific Ocean via Strait of Juan de Fuca where salmon farms do not occur. The Okanagan River is a tributary to the Columbia River which empties straight into the Pacific Ocean; thus it is unlikely these sockeye were exposed to the east Vancouver Island salmon farms. On the southwest coast of Vancouver the Somass River sockeye also thrived, entering the sea via Alberni Inlet where there are no salmon farms. Hayden Creek sockeye, however, did quite well, and they do enter saltwater within the east Vancouver Island corridor, near the north end. Examining these returns on a regional scale suggests a zone of impact from the Fraser River counting fences to the north end of the Discovery Islands.

In 2007, when the sockeye that failed to return in 2009 were out-migrating as smolts, some research was underway at the Salmon Coast Field Station in the Broughton Archipelago under the direction of Brendan Connors. In the late-May, early-June period, when Fraser sockeye would be passing the Broughton area, the fish collected for this project began to die. A bacterial swab showed that they were infected with Vibrio vulnificus. The disease on the fish was visible so the field crews became familiar with it and could see its occurrence was sudden and widespread. We had been sampling pink and chum (*Oncorhynchus keta*) salmon fry without sign of this disease since the beginning of March. Part of the sampling procedure involved recording visible anomalies and so the red speckles associated with the fish just prior to death would have been noted. How was the disease spreading? Could it have arrived with the northbound sockeye smolts that had passed the salmon farms? Was there a Vibrio outbreak on the salmon farms, did the Fraser

sockeye become vectors for this? Unfortunately, salmon farm disease information is not public information so these questions will remain unanswered but valid.

Research on sea lice infection rates on juvenile wild salmon in the Discovery Islands (Morton et al. 2008) observed high sea lice infections localized at salmon farms. This work is ongoing and *Caligus clemensi* is the dominant sea louse species found on sockeye near salmon farms in the Discovery Islands. Caligus is a generalist species found on farm salmon (http://www.marineharvestcanada.com/), herring and wild salmon. Because they are generalists they are more willing to transfer host to host than the salmon louse, *Lepeophtheirus salmonis*, making them a significant disease vector.

Sea lice/pathogens in effluent on Fraser sockeye habitat

Finally, in the map of the salmon farms presented by Michael Price (page 30) two processing plants were identified. High sea lice infection rates were recorded at those locations on juvenile salmon. Recently I received samples from the outfall from the more southern of the plants (Walcan) sited on Quadra Island, in Discovery Passage across from Campbell River. A plankton net was held over the end of the pipe to collect the sample (Figure 3).

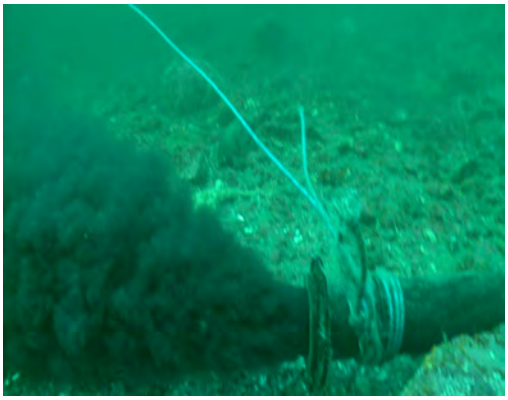

Figure 3. Farm salmon processing plant 12" out-fall pipe at 90', showing blood water (containing west Vancouver Island sea lice eggs) which appears black at this depth photo by Twyla Roscovich.

Under magnification the contents of the plankton net contained hundreds of hatching sea lice. These eggs originated from female lice attached to Atlantic salmon culled in Nootka Sound amid a sea louse outbreak that occurred despite treatment with the de-lousing drug SLICE® (Ministry Agriculture and Food correspondence). This raises the question about drug (SLICE®) resistance in sea lice. However, in addition blood will also carry viruses and bacteria and releasing farm salmon blood directly into the Fraser River salmon migratory corridor should be viewed as a significant disease vector. We know infectious diseases occur on salmon farms (Saksida 2006, http://www.al.gov.bc.ca/ahc/fish_health/index.htm). This effluent is discharging into crucial habitat used by Fraser sockeye at two of their most vulnerable life stages, saltwater entry and just prior to spawning. Aggravating this dynamic are the narrow confines of the passages of the Discovery Islands, reducing dilution.

If north-migrating Fraser sockeye smolts become infected with salmon farm-origin pathogens, it is unlikely they would die immediately. In that case farm-infected sockeye would become carriers exposing Rivers Inlet sockeye, Skeena sockeye and other sockeye stocks to the pathogens. This highlights the risk of salmon farms and farm salmon processing plants releasing effluent into the habitat of the highly migratory sockeye.

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DIALOGUE

Sockeye and sea lice levels

A participant directed a question to Michael Price:
Did you analyze the lice-loading on sockeye before they went past the Discovery Islands?

Michael Price:
Most of the sampling sites, especially in 2007 and 2008, were right in the Discovery Islands. Again, we were focusing specifically on pink and chum and the sockeye research was a piggyback study. In 2009 we tried to collect fish at the south end of Cortes Island, which is still within the Discovery Islands region. We think that might be a reason why we are seeing elevated levels even at what we consider to be control sites. This coming field season, we aim to follow the migration of Fraser sockeye even into the Gulf Islands and up through the Strait of Georgia, before they reach the Discovery Islands, to see how those lice levels change over time.

Potential for this type of sampling program

Mike Lapointe made the following comment:
This is in relation to the results of Michael Price where he showed the stock composition of Fraser sockeye for the last two years. The idea that you could go out there with a small boat, with a sampling design that is really designed to look at the distribution of sea lice on salmon, and get stock proportions that are representative relative to what you would expect in the brood year, to me, indicates that there is a potential opportunity to develop a very inexpensive sampling program. Potentially you could involve some academic researchers and students and get an index of sockeye passage over time with a different design. You would have to couple it, perhaps, with some tagging similar to the studies David Welch described, in order to get an abundance value. I think there is a very good opportunity to do basically the reverse of what we do with the adults when they come down through Johnstone Strait. There is great potential for this type of study.

A fisherman commented:
I agree with these comments. I was also very impressed with the level of detailed information with respect to the DNA in the smolt capture. I would like to suggest that if we could get more data sharing from everybody it would probably be beneficial.

Sea Lice and Herring

A participant (fisherman) directed a question to Michael Price:
Since the *Caligus* spp. is not a salmon specific louse, what is the main host that we would see in the environment for this louse?

Michael Price:
We think herring are a host. *Caligus* are certainly found on herring on the north coast and among the Discovery Islands. Any other pelagic fishes could also be hosts for *Caligus*. There is a spawning population of herring in the middle of Georgia Strait and it appears that stocks could migrate north to feeding grounds off Queen Charlotte Strait, going through Discovery Islands. Those herring would also pass salmon farms and they could also migrate south to feeding grounds off the southern west coast of Vancouver Island. The question is:

What came first? Herring could certainly be passing lice on to salmon farms and salmon farms could be passing lice on to herring. The transfer of *Caligus* to other fishes is also very likely because they are a generalist species and they will jump hosts quite readily.

Participant:
I have fished herring most of my life but I have never seen lice on the herring. I'll have to keep my eyes peeled now.

Michael Price:
And that is in the Strait of Georgia as well?

Participant:
Yes.

Michael Price:
We have seen low lice levels there. It could be one or two on a few herring, even near Bella Bella where there are no farms. Whether or not they are becoming elevated in salmon farm regions is still an outstanding question.

Dynamics of disease

Arne Mooers directed a question to Alexandra Morton: Do you know anything about the speed at which these diseases kill fish?

Alexandra Morton:
No, I don't at all.

What eats sea lice?

A participant asked:
Does anything eat sea lice?

Alexandra Morton:
We have seen stickleback eating sea lice and sometimes they eat them off themselves. Once the lice are free swimming they get eaten. As a larval organism, the naupli probably get eaten. They are very obvious, very brightly patterned and they go to the surface during the day. They are probably eaten but we do not have much data on that.

On sea lice and wild salmon to farmed salmon transfers

John Henderson:
We fished in these regions in the latter part of the 1960s and the 1970s, including the Broughton Archipelago and Kingcome Inlet, Thompson Sound, and Knight Inlet. The salmon then had sea lice on them and we had to scrub the lice off the hatch of the boat when we were kids. Are those lice different from the lice that we are talking about today?

Alexandra Morton:
They are the same lice. What happens is when the adult salmon come back in the fall, they go in the rivers and the sea lice die of freshwater. So the host dies and the lice die and there are very few adult salmon with lice on them near the shore where these little guys are first coming out. Then when the young salmon grow, they would get lice in about May or June when the next generation of adult wild salmon are coming in. By then, the young fish have scales on them which act like a coat of armour and the sea lice don't hurt them. The lice don't actually want to kill the fish because that is their whole planet. These are the same lice but now the fish farms hold very large populations of salmon stationary and so when the wild salmon come home, they infect them. Then the wild salmon go in the river and die and the farms brew the lice, because there are so many hosts. Now there are these huge populations of lice, literally in the order of billions, with larval lice coming out of each farm in the spring.

John Henderson:
If there were 10 million adult fish swimming through Johnstone Strait with sea lice could they transfer the lice onto other fish?

Alexandra Morton:
They definitely are transferring lice onto other fish. But the adults all go into the river and so in December through February there are not huge numbers of lice in the saltwater. They are transferring the lice to the farm fish, and then the farm fish are amplifying them and transferring them back to the wild juveniles.

John Henderson:
Are the cod and other species affected as well?

Alexandra Morton:
We are finding that Caligus is heavily infecting cod, pollock, and herring and all the fish farms are reporting the Caligus lice as well.

Processing farmed salmon near the Fraser River and spreading of disease

A fisherman participant directed a question to Alexandra Morton:
We understand that farmed fish from this area are moved down to the Fraser River for processing. This is of concern, especially when our fry and smolts are moving down the river. In the processing of these farmed fish, if they had diseases or if they were carrying lice or lice eggs, could that actually affect the smolts leaving the river?

Alexandra Morton:
This could definitely happen in terms of IHN and furunculosis which are found in freshwater. Also, if there is blood water pumping as happens at Walcan, then this is a definite possibility. But the lice should die in freshwater.

Participant:
There are three plants on the Fraser that discharge all guts and other material directly to the Fraser River.

Another participant asked:
Do you know if the discharging around the Walcan plant is an example of a company violating a permit or is it just an indication of permitting being perhaps not as strong as it should be?

Alexandra Morton:
I think it is both. They say that they have a 500 micron screen in place but we are finding hearts, gills, chunks of fish, and hundreds of scales which are much bigger than 0.5mm. The greater problem is that the blood water itself is going to go through – in this case there is not enough legal protection.

Fish Farms and poor chum returns in Nootka Sound

A fisherman commented:
Area "D" gillnetters fish in Nootka Sound and for 15 years had a consistent chum fishery with a total run size that averaged around 250,000. Nootka was then salmon farm free. They expanded fish farming there and right from the time they expanded it, the first juvenile fish that left the hatchery at Tlupana Inlet and the Conuma Hatchery showed very poor returns - only 10,000 or 15,000 to the hatchery. This is comparable to the declines in sockeye seen in the Fraser River, maybe even worse if you look at the percentages. The total run for the whole Esperanza Nootka area has been averaging 47,000, instead of 250,000, for the last three years since the farms have gone in, and another poor return is expected this year.

Access to fish farm data

John Fraser directed a question to Alexandra Morton:
You were saying with respect to sea lice and with respect to the transfer of disease that you have not been able to get data from the fish farms. The British Columbia Pacific Salmon Forum not only recommended, but said that fish farms must, because they operate in the public domain, release the data that researchers or the public are entitled to. Our recommendation was quite blunt.

Alexandra Morton:
An NGO has been trying to get the records from the Ministry of Agriculture and Lands on disease and what they know. However, the fish farm company said it would be bad for their business if the public knew what the diseases were. The commissioner ruled that the Ministry of Agriculture and Lands does have to turn these records over and they have until April 1, 2010 to appeal that decision. This is the first step but it only refers to part of the records. Given the trouble with the sockeye we will not know what the impact of the farms is until we have that information.

Another participant commented:
At the end of your presentation you said that at the end of the day we need to find out what is happening at these farms or it will always remain a question. It seems that it would be in the interests of the salmon farms to get ahead of any disease transmission issues, for their own purposes. Hopefully it is also in their interest to protect the wild stocks for a variety of other reasons. Apart from releasing records that the ministry would have, what other sort of issues would come up for you in terms of understanding exactly what is going on at the farms? Are you talking about things like the sources of their eggs or their planning around antibiotic use? What specific

recommendations do you have?

Alexandra Morton:
In 2003 the provincial government enacted the Pink Salmon Action Plan and they removed all farmed salmon from the major migration of pink salmon through the Broughton.

The productivity of that particular age class of pinks was higher than has ever been recorded. The fish farmers were, in fact, still farming in the Broughton, they were just not located on the major migration route. We have asked, including DFO, for this experiment to be repeated many times and it has not been.

I would say the next thing we need to do is reproduce that experiment in the Discovery Islands given that we have such a huge decline. From a scientific point of view, this would provide a lot of information; for those people that are tasked with trying to determine how many sockeye are going to come back, it would seem to be very important for them to have all the information. If, for example, they knew there was BKD on six farms and IHN on two and vibrio on one, and they knew what the survival rates of fish were when they are challenged with those diseases, they could figure that into their models. They should also know how many Atlantics are there, because there is also a big issue with by-catch.

Currently, I am charging Marine Harvest under the Fisheries Act for having juvenile pinks in the pens and I have seen photographs of juvenile sockeye in pens in Okisollo, a channel area.

One thing that stood out for me at the December think tank, was learning that in the last 10 years a number of new variables have come into play and this has made the work of estimating numbers of fish very difficult. It would be very good to know a lot of these things; however, given the late stage that we are at now, I think we should pull some farm fish out of the water right now.

Diet of marine mammals

Randall Peterman addressed a question to Andrew Trites:
You mentioned that the diet composition in the 1980s may or may not represent what it is now. In particular, what has been the change in the alternative prey for the seals such that there might be a higher relative composition of salmon in their diet than there was in the 1980s?

Andrew Trites:
In terms of the numbers of seals, the estimates I presented were from 1988 and that was getting close to when the population had reached its peak numbers. So we would perhaps have to multiply that by 20% to get it to where we are today. The numbers are based on the assumption that the data on the diet do hold. The work that generated these data in the 1980s was under the guidance of Michael Bigg, who is well known for his pinniped as well as killer whale research. Since then there has been relatively little attention focused on the Strait of Georgia. I believe that it is time to come back and do that research and for example, address questions related to hake. Is this species still as dominant as it appears to have been in the 1980s? Pollock is another species that has shown up in the diet of animals further south. Herring is probably one of the most important prey species and my understanding is that more recently herring have not been doing as well. Undoubtedly the animals are going to be shifting their diet in some way. It is definitely time to return and look at diet again, not just for sockeye, but also for some of the other species that we are concerned about. Certainly, our information is out of date and we are taking on faith that we can apply what we knew back in the 1980s to what is going on today.

Randall Peterman:
When you multiply out the number of predators by their daily consumption rate, even though a small composition of their diet might be salmon, is the total consumption of salmon substantial?

Andrew Trites:
Again, the estimates that were presented were obtained in 1988 and they were weighted by river mouth, in terms of where the scats were collected. In calculating consumption, we start with the individual animal and determine that the average harbour seal is eating just under 2kg per day, or about 700 kg per year. In

terms of total tonnage of fish that harbour seals are consuming, it worked out that time to be about 10,000 tons of which salmon made up about 400 tons. When I say that the average harbour seal is eating 700 kg per day, I am sure everyone in the room is thinking, "wow, what gluttons." However, I would encourage you each to weigh the bags of groceries that you take home, and don't forget to add in the water you pour out of your tap and drink and the coffee you consume, and I bet that you would all be shocked by just how much weight you consume each year.

Was traditional knowledge used to determine population size in the past?

A participant directed a question to Andrew Trites:
In terms of the comment that you made about the seals being about the same as 1875, around 108,000, was there possibly a connection there to the fact that that is when canneries first started taking large amounts of salmon? The connection might be related to the seal-culling programs that were put in place to support those canneries. Finally, how much traditional knowledge has been used to find out what the population might have been prior to that?

Andrew Trites:
Our understanding of how things were in the 1800s is pretty limited. The numbers that I presented were based on trying to reconstruct from numbers that were recorded and not just based on numbers of pelts that were listed. That is all we have to go on, but you or others might have other information. I do some work in Alaska with archeologists and they have really shifted my view about how the world once was. They look at it from many centuries and can see patterns and changes. If you have other information about traditional knowledge it would be very useful to bring it in. At this point this is all we have to go on.

In this session, we have addressed parasites and disease but we have only discussed part of the predation equation. The other part is predation caused by other fish, perhaps outside the Strait, or Humboldt squid. It would be useful, also, to keep in mind that there are more predators out there than just what we see on the surface.

Another participant:
Could you use the harbour seals as a way to look at how capable of survival the salmon are once they come out of the Discovery Islands? Can you look at their scat or the DNA samples of the animals that are preying on the salmon and learn something about the predation?

Andrew Trites:
From collecting fecal samples from pinniped seals and sea lions, we can now determine the species they are eating. We can even get down to being able to tell which run of salmon. But this still has to show up regularly enough to be measurable in a way that we can see some real differences over time and location. This is one way to monitor things; however, we are not finding enough salmon, at least so far, in the diets of any of the sea lions or harbour seals for it to serve as a long-term monitoring tool. But it is good for picking up things such as shifts in dominance of certain species over time and also by areas.

Threats to the Strait of Georgia

A participant commented:
This section of the program focuses on the lifecycle in the nearshore environment. The focus of the Georgia Strait Alliance is the Strait of Georgia. Sadly they have a laundry list of issues that includes habitat loss, sources of pollution, agricultural runoff, shoreline development and so on. I hope that this conversation continues, whether it is through this venue or the Cohen Enquiry, and that it also makes sure to look at those things. I believe that a lot of things are coming together to put pressure on sockeye and a lot of other species in the Strait of Georgia. When there are three million people living around an area and there is more ship traffic and more small oil spills and shoreline development, then there is a region that is very much under threat.

The problem is us

I grew up on Haida Gwaii and I currently live in Prince George and do some work for the Takla Lake First Nation in the upper watershed on the Driftwood, where a lot of these salmon originate.

We often sit in meetings with DFO. I note that

their history is quite limited going back only to around 1950. I suggest that we might want to look at DFO's historical records. Posted on their website, for example, is the 35th annual report from a fisheries officer in the early 20th century. He noted that 30 million sockeye were caught that year and were canned and he suggested there were another 30 million that could have been caught if the canneries had had the capacity to handle them. He said that the fishermen were limited that year and they could only do 20 minute sets because when they put their gillnets in they filled with fish so quickly, that they were losing nets. When we talk about the historical records of how many salmon have been there, I think it is a lot more than 40 million, probably in the range of 100 million, just in the early 1900s.

When we talk about what the diet of harbour seals was in the 1870s, as compared to now, I do not think that it is the seals that are the culprits. I think I might have the solution to what Colonel Mustard's culprit is and it is sitting in this room. It is you, me, and everyone else. I am learning a lot of information here that I will pass on to the constituency that I work for in the North, the Takla First Nation, who are asking, "Where are those salmon?" I don't necessarily think the mortality happened on the high seas. I sat in a forum in Kamloops last week and listened to one of the councilors talk about a mercury mine that was built in the 1940s that is still leeching mercury into Takla Lake.

When Mr. Anderson was the federal fisheries minister he put in place some very good programs that really looked at the freshwater environment and habitat and restoration. Moving into the ocean and laying the blame there makes it convenient for the Cohen Commission and other enquiries to go back and say, "Well, we can't figure it out because it is out there in the ocean." If we took a little closer look in the mirror, and I say that with all due respect for many people here, we might get a little bit closer to home on what the potential causes are, whether it is building fish farms in migration paths of wild salmon or whether it is putting three million people where the sockeye fry spend their time before migrating out.

I wanted to bring this perspective from the top of the watershed. I don't think that folks up there want to be hearing that we don't know what the problem is, and that it is out there in the ocean. I think they want to be hearing that it is you, me, and everyone else in this room flying around to all these meetings and affecting climate change and maybe causing record high stream temperatures along with some of the lowest snow packs ever. I am sorry that we have to move on to the high seas part of the cycle so soon.

Speaking for the Salmon

SECTION III
High Seas

- **Where and when do sockeye feed in the high seas?**
- **What are the recent survival and climate trends?**

Presentations by:

Sonia Batten, Sir Alister Hardy Foundation for Ocean Sciences, presented by David Welch, Kintama Research Corporation

Skip McKinnell, Deputy Executive Secretary, North Pacific Marine Science Organization

ZOOPLANKTON IN THE GULF OF ALASKA

Sonia Batten, Sir Alister Hardy Foundation for Ocean Sciences, presented by David Welch, Kintama Research Corporation

This presentation focuses on the large-scale, off-shelf picture of zooplankton, particularly in the Northeast Pacific and the Gulf of Alaska.

Continuous Plankton Recorder (CPR) surveys were conducted across the North Pacific from east to west and also north to south. The CPR is a simple mechanical device that may be towed behind commercial ships on their regular routes, collecting plankton samples over large distances (Figure 1).

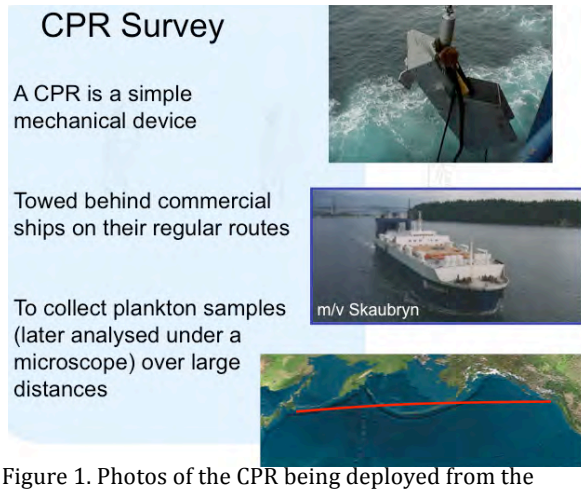

Figure 1. Photos of the CPR being deployed from the cargo ship 'Skaubryn' and the route it takes from Vancouver to Japan.

Microscopic analysis of the samples provides information on both species composition and plankton abundances. Because the surveys are conducted about five to six times a year, from the spring through to early fall, the information provides us with the seasonal progression of the plankton as well.

Zooplankton are the link between the physical environment and the higher trophic levels that depend on them. These are not necessarily plankton that the salmon, or in this case the sockeye, are feeding on, but they provide an indication of the overall changes in the oceanic environment. Ocean climate influences zooplankton (as a food source) in three main ways: quantity or abundance; timing, including when in the year and of what duration; and, composition or quality. Previous research has shown that oceanic plankton communities are not homogeneous.

Figure 2 shows the CPR sample coverage of the North East Pacific in June 2002, from the Aleutians to Japan and across. The dots represent the samples, which were taken during the day. The colour coding is based on the species composition. Changes in species composition occurred in similar locations for both plankton and seabirds.

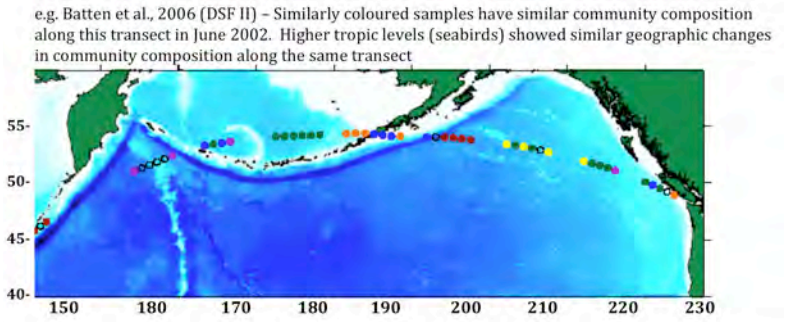

Figure 2. Results of an analysis comparing community composition of samples collected in June 2002. Daytime samples were compared and samples with similar species composition plotted in the same colour. The analysis was repeated for seabird observations. Changes in species composition occurred in similar locations for both plankton and seabirds.

Focusing now on the data that are relevant to the 2007 out-migrating sockeye smolts, Figure 3 shows the mean monthly zooplankton biomass from March to October for 2007, and the average mean monthly biomass from 2000 – 2009.

Note the very significant peak in 2007 in May followed by a very low abundance in June.

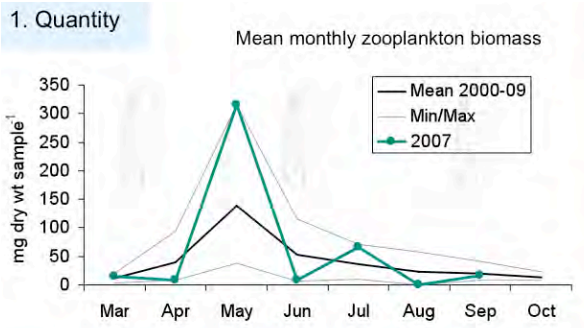

Figure 3. Estimated mean monthly mesozooplankton dry weight for 2007, compared to the min., max. and mean for 2000-2009.

The plots in Figure 4 represent data for one of the key plankton species, *Neocalanus plumchrus,* showing the timing as the median day in the year from 1999 to 2009. Note in Plot A, based on total biomass to give start middle and end of season, that in 2007 50% of the abundance occurred between day 120 and day 145. Plot A represents timing based on stage composition, and note that results for 2007 were not too anomalous, compared with 2005 and 2006.

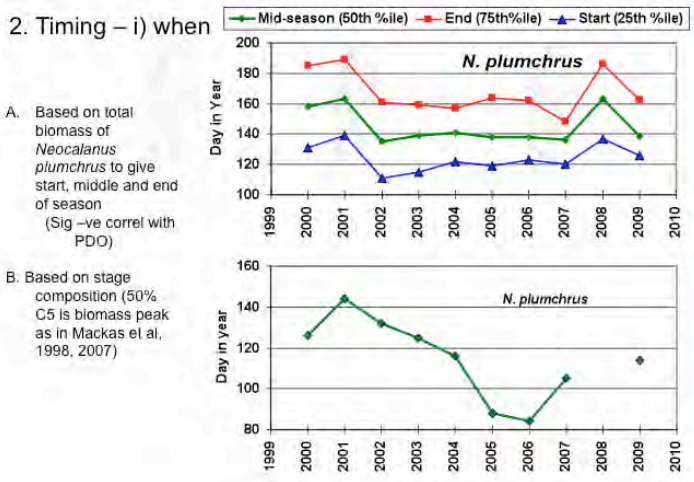

Figure 4. Timing of peak biomass of *Neocalanus plumchrus*. A. day of the year at which quantiles of cumulative abundance were reached. B. projected day of year at which peak biomass occurred based on stage composition.

Figure 5 shows the duration, or length of the season that the plankton are up in the surface and can be fed upon. Note that there is a general trend to a narrower season, especially in 2007; that is, the animals are in the surface layer for a shorter period of time.

Neocalanus is extremely important in the ocean ecology because they have a very high fat content and a lot of food value. This species is not necessarily what the sockeye are feeding on directly; however, everything will feed on *Neocalanus* and sockeye will likely be feeding a little higher up in the food chain. It is not clear what caused the narrowing of the season in 2007. It was not clearly related to either temperature or the PDO (Pacific Decadal Oscillation), although the coldest years tended to have the longest seasons.

Figure 6 is a Non-Metric Multidimensional Scaling (NMDS) plot of community composition in July and August of each year from 1997 – 2009. 2007 stands out as clearly unusual, mostly due to lower numbers of taxa. The *y* dimension is correlated significantly with temperature.

Figure 7 shows the proportion of the biomass according to species groups of plankton from 1997 to 2009. Again 2007 appears to be unusual in terms of the proportion of biomass for the various species, with relatively lower numbers of smaller copepods present.

The bottom plot indicates that small copepods are more important in warm years, and there is a positive correlation with summer temperature and PDO. In conclusion, there are strong ocean climate signals evident in zooplankton from year to year. Abundance, timing and community composition are all strongly linked to cold/warm, PDO-/+ phases.

The year 2007 saw unusually narrow

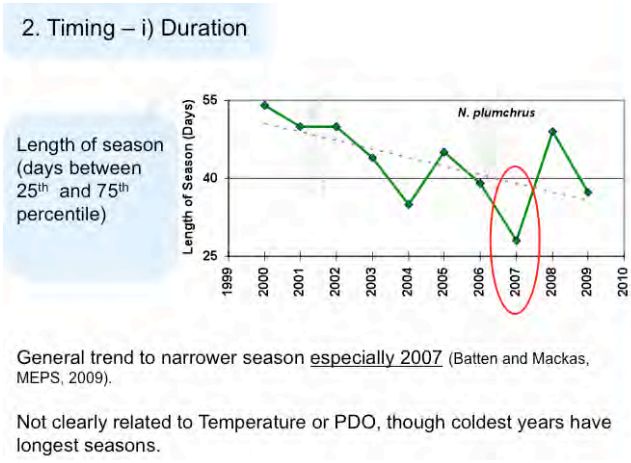

Figure 5. Duration of annual *N. plumchrus* cohort estimated as the number of days between the 25th and 75th quantile of abundance.

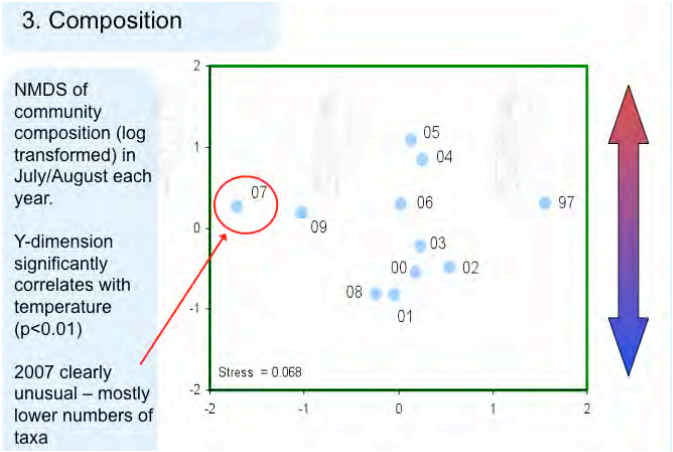

Figure 6. NMDS plot of zooplankton community composition in July/August of each year. Years plotting closest together have most similar community composition.

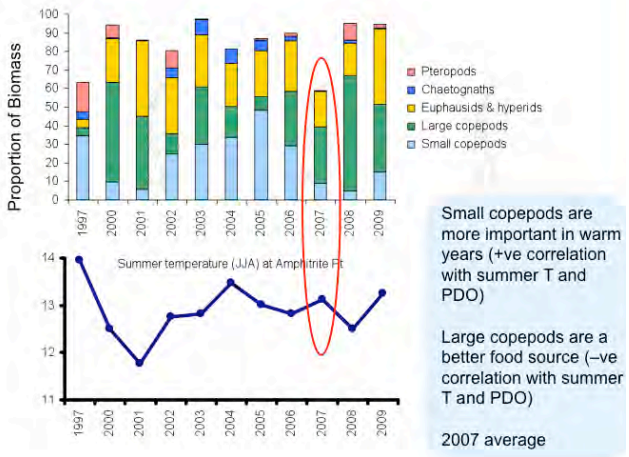

Figure 7. Proportion of summer biomass in broad taxonomic groups, together with local temperature at Amphitrite Point lighthouse (monthly means of daily observations).

peaks in spring biomass, with a very high May biomass, and low biomass in April and June. For a region just off the shelf, this is a very unusual peak, a very sharp peak of high abundance for a short period of time. The *N. plumchrus* season was the shortest in the time series. Finally, the summer 2007 community composition appeared to be unusual compared to other years.

FRASER RIVER SOCKEYE SALMON AT SEAS

Skip McKinnell, Deputy Executive Secretary, North Pacific Marine Science Organization

Little was known of the distribution of Pacific salmon on the high seas until after the Second World War when the International North Pacific Fisheries Commission was established. It provided a forum for internationally coordinated research of the North Pacific Ocean. As part of Canada's contribution to the research effort, the (now defunct) Fisheries Research Board of Canada established a North Pacific Survey beginning in 1956. The Board's activities included the deployment, annually, of several salmon fishing and oceanographic vessels to the northeastern Pacific. Fishing vessels used gillnets of varying sizes to learn about the species, abundance, distribution, diets, age, sex, and size of salmon on the high seas (to about 155°W). They also examined the abundance and diversity of the zooplankton community, while collecting information about sea surface temperature and salinity. A former navy frigate was reconfigured and deployed throughout the year to collect detailed hydrographic data throughout the Gulf of Alaska. Figure 1 shows a grid describing a typical summer of oceanographic surveys in 1957. All of this information was collected at a time before five billion hatchery salmon were released annually into in the North Pacific.

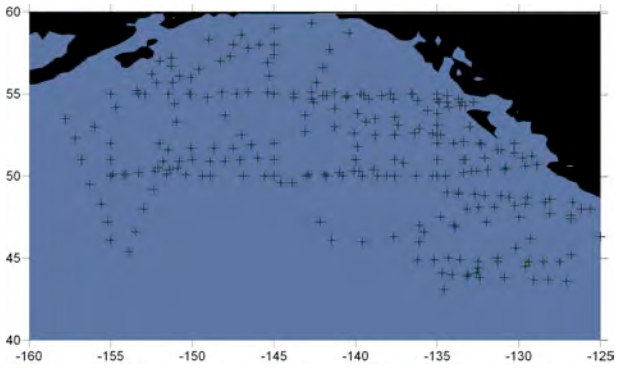

Figure 1. Fisheries Research Board of Canada oceanographic sampling in the summer of 1957.

High seas salmon tagging was conducted in earnest through to the mid-1960s to understand how salmon stocks of different origins intermingled at sea. The work resolved some longstanding uncertainties about their ocean-going biology. The program was curtailed significantly in the late 1960s leaving many unanswered questions. Tagging salmon on the high seas required the use of floating longlines because gillnets that were in common use did not provide researchers with live salmon. Hooks were baited with salted anchovy or herring that were attached to longline backbones and strung out behind the vessel. After a relatively short fishing time at twilight, the salmon that had been caught were taken on board, measured, tagged, a scale sample was taken, and they were returned to the sea. Recoveries of these tagged salmon provided information about the distributions of species and stocks on the high seas. Salmon tend to stay within the Subarctic region and are generally not found in the transition zone that separates the Subarctic from the Subtropical region. Figure 2 shows the record of the sockeye salmon tags recovered by this program from 1956 to 1990. Since 1990, only 4 tagged salmon have been recovered and reported

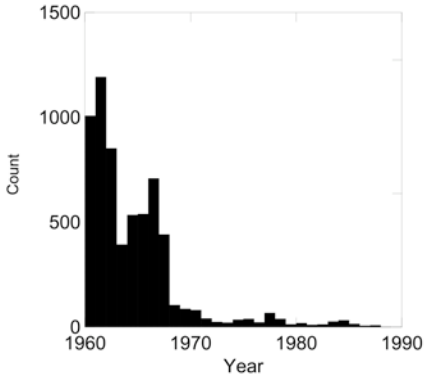

Figure 2. Numbers of sockeye salmon recovered with an external tag applied on the high seas (Database currently maintained by North Pacific Anadromous Fish Commission).

from BC salmon fisheries.

Figure 3 shows the tagging locations of sockeye salmon that were either caught in Fraser River salmon fisheries or found among the spawning adults. The red dots represent the fish that were tagged in the year they were caught in the fishery; that is, maturing fish coming home. The beige-coloured stars scattered among them represent fish that were tagged one year before returning to spawn. The yellow crosses along the Alaska coast represent sockeye tagged two years before they came home.

The distributions of the immature fish, determined from relatively few numbers of tags, are different from the maturing fish. Those with two more years to spend at sea are found only along the Alaskan coast. One juvenile sockeye salmon located near the Shumagin Islands at about 203°E longitude 55°N latitude (Fig. 3 – lower panel), reached that location by August 30th (tagging date). Note that Fraser River sockeye salmon with one more year at sea are more widely distributed and, on average, further west than the sockeye salmon in the eastern Gulf of Alaska which are on their way home.

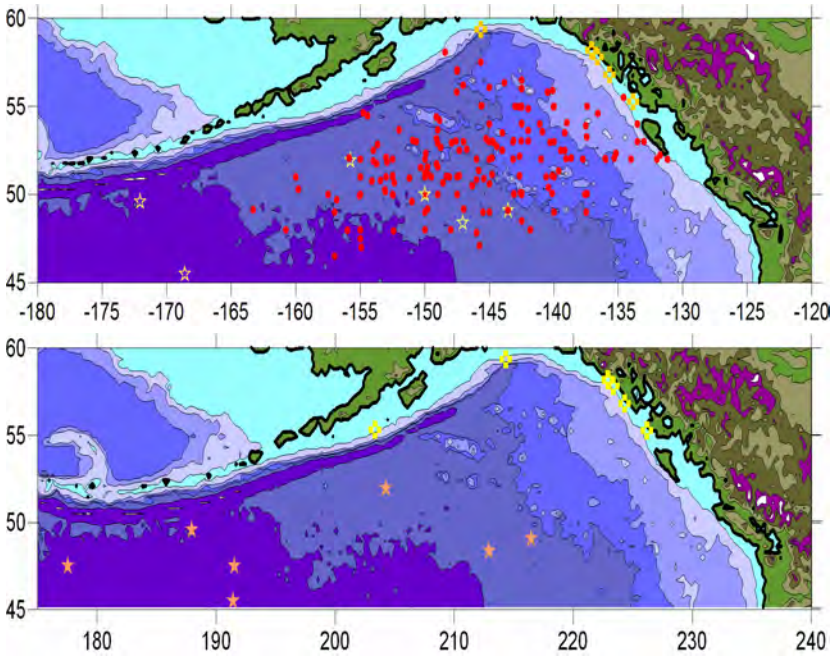

Figure 3. (upper) Sockeye salmon tagged on the high seas and recovered later in Fraser River salmon fisheries. Fish ages are indicated by different symbols; red= maturing fish, beige star= matured the year after tagging, yellow cross= matured two years after tagging. (lower) As in upper panel but with maturing fish removed. (Database currently maintained by North Pacific Anadromous Fish Commission).

The Fisheries Research Board of Canada made an outstanding contribution to the science of Pacific salmon and their habitat with the work they conducted on the high seas from 1956 to 1967. Much of the oceanographic work survived within the Department of Fisheries and Oceans as the current Line-P/Station-P cruises that are conducted regularly by the Institute of Ocean Sciences. However, studies of salmon on the high seas have largely disappeared in favour of continental shelf sampling programs. As a consequences, knowledge of where salmon go on the high seas is based on what was learned in the 1960s. Mind you, there is some advantage in delaying a return to the high seas. In the 1960s, it was necessary to tag fish in the hope that they would survive to return to the Fraser, be noticed in the catch, and be returned to the Research Board. In general only 3-4% of tagged salmon were recovered. Now, with the advancements in genetic stock identification techniques, genomics, and physiology, it is possible, to a certain extent, to understand sockeye salmon distribution and condition more readily, but it can't be done (yet) without someone going to the high seas.

Forecasting 2009 Chilko L. sockeye returns

The downstream migration in 2007 of more than 75 million sockeye salmon smolts from Chilko Lake alone gave rise to expectations of a fishery in 2009. Even when the worst marine survival

observed in history (till then) was applied to this level of smolt abundance, a small fishery could have been supported on the Chilko L. run alone.

Each spring since 1998, a multidisciplinary group of researchers who are interested in how the ocean affects Pacific salmon have met to review the state of the coastal ocean and to consider its consequences for Pacific salmon. In 2007, the group started an informal forecasting forum as a way of testing their hypotheses for what affects salmon survival along the North American west coast. Expectations were recorded annually and will be reviewed from time to time to understand which have performed better than others. My contribution is a forecast of returns of Chilko Lake sockeye salmon (Table 1).

Table 1. Forecast of returns of Chilko Lake sockeye salmon.

Return Year	Observed returns (,000)	McKinnell's outlook (,000)	Official forecast at P=0.5 (,000)
2007	322	< 560, maybe a lot less	1,700
2008	386	300-800	880
2009	245	1,000-3,000	4,100

Outlooks of Chilko Lake sockeye returns developed by the author in 2008 and 2007 (Table 1) were based on some simple ideas/hypotheses that are not particularly novel except for a consideration of a possible role for the ocean in adult morality. Warm ocean entry years are generally associated with poorer marine survival (Mueter et al. 2005). Recent work has shown that a warm surface ocean is an indicator of a suite of ecological changes in the coastal ocean environment and food web that are generally detrimental to salmon growth and survival. But when correlations of survival with sea surface temperatures (SST) are lagged to consider SSTs during the entire period when sockeye salmon are at sea, it appears that poor returns are equally likely in years where the Gulf of Alaska is cold in the return year.

The "cold return" part of this outlook centres on an (untested) hypothesis that a cold Gulf of Alaska is an indication of delayed/reduced biological productivity when maturing salmon need food the most (for growth, for maturation, for homeward migration, and for upriver migration and spawning). It entertains the (untested) hypothesis that salmon can die at sea if they don't have access to adequate food for these energetically demanding activities. So a cohort that faces a warmer coastal ocean on its outmigration and a colder Gulf of Alaska during its return year faces the worst combination.

Coho salmon that enter Georgia Strait in the same year as Chilko Lake sockeye salmon experience some of the same general conditions in Georgia Strait, and perhaps elsewhere, as Fraser River sockeye salmon but coho return to spawn one year earlier. Sharing the same general ocean entry location, coho survival in Georgia Strait may provide a leading indicator of sockeye salmon marine survival. In the range of years available, coho salmon marine survival seems to "explain" about 20% of Chilko Lake sockeye salmon marine survival so it is barely prognostic (Figure 4). But none of these ecological "associations" provide strong descriptive powers (account for large percentage of variance in returns) and even less predictive skill. The most reliable indicator over many years is simply the number of sockeye smolts that emigrated from Chilko Lake. So my previous outlooks were developed from a combination of these predictors. Unfortunately, the number that left the lake in 2007 and will return in 2009 was twice the previous observed maximum (PICES 2008), vastly exceeding anything observed in the past.

Of particular importance for the 2009 returns is the issue of density-dependent marine survival. Even in the historical data, models of adult returns versus smolt abundance favour some downward curvature at high smolt abundance. They provide a better fit of returns vs smolts (ln transformed) than a linear model. Of note, the scatter about the fitted model increases logarithmically implying that the least reliable outlooks of future returns from these data have tended to occur at high smolt abundance. Within the observed range of smolt abundances, as of February 2009, the years with the three largest numbers of smolts have all fallen significantly below any model expectations upon their return.

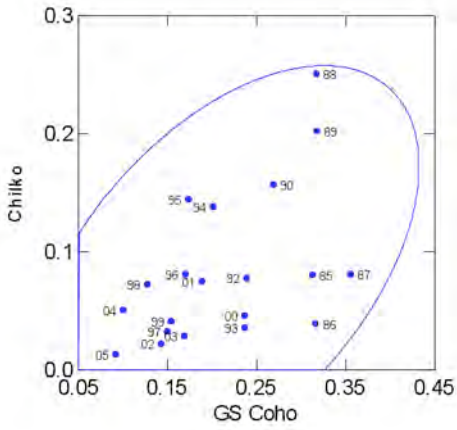

Figure 4. Smolt to adult survival of Chilko Lake sockeye salmon versus average marine survival of Georgia Strait coho salmon. Plot point labels indicate ocean entry years from 1985-2005. Both time series were square-root transformed. The ellipse indicates the x-y space where 95% of the joint data are anticipated to lie.

Taking this into consideration, I applied the worst marine survival observed to date (1.38% from the 2005 ocean entry year) to the 2007 smolt abundance. The result is about 1 million adults which I set as a lower bound on expected returns. Unlike the discussion in 2005 at our coastal salmon ecology meeting, we did not find 2007 to be particularly "unfriendly" to salmon survival when we met in early spring. The summer of 2007, however, became warmer than average along the west coast during July and August, and the winter of the 2009 return year was colder than average so I set my outlook for 2009 returns as poor marine survival.

It was consistent with lower than average marine survival that had been observed for coho in Georgia Strait for the 2007 ocean entry year. Marc Trudel also reported that growth and survival of juvenile salmon along the west coast was relatively low in 2007. While I did not feel that 2007 ocean entry years would be as bad as 2005, it could be sufficient to produce somewhere between 1-3 million adult returns in 2009. It did not. Only 245,000 Chilko Lake sockeye returned to spawn.

DIALOGUE

What proportion of Pacific salmon originate in hatcheries?

A participant posed the question:
I was quite surprised to find recently that 95% of Japan's commercial fisheries are from ranched salmon. I believe that Canada releases in the range of 600 to 700 million smolts from hatcheries. Are the five billion smolts in the North Pacific from hatcheries or salmon ranching?

Skip McKinnell:
Most of the Japanese and much of the Russian catches of pink salmon and chum salmon are of hatchery origin. The last five years have seen the highest average catches of Pacific salmon on record and that is mostly because of production in Asia.

David Welch:
The broader issue is that the decline in survival in British Columbia is really even more profound than it seems because during the last 20 years, while BC production for essentially all species was going down through the 1990s, overall production was

going up. So it is not only that we were losing in terms of salmon production, but also the fact that regions to the north were doing much better. Even 15 or 20 years ago I was quite concerned because it was said that whatever was happening in BC was accelerating compared to what was happening in other regions. I don't think that this is necessarily related to bad management, but rather that climatic change has made a significant impact, and we have been very slow to recognize this.

Comparing results of line-p cruises with CPR sampling

Randall Peterman directed a question to David Welch:
I wonder how the results for *Neocalanus*, and the other species for that matter, compared with the published work of Dave Mackas and the line-P transects done by DFO?

David Welch:
I believe that they match pretty well. Sonia Batten is co-author with Dave Mackas on some of the reports. The difficulty with the line-p cruises is that they happen only once or twice a year. The CPR routes are basically going through the same area but they are giving a much finer resolution to the seasonal cycle and the abundance than can be obtained off the line-p cruise. They are certainly not disagreeing.

What is the relationship between copepod abundance and marine survival?

Arne Mooers posed the question:
Is there a proposed mechanism for the relationship between, for instance, southern copepod abundance and marine survival?

David Welch:
The proposal is that in cold water years there is significantly more of the northern sub-arctic plankton. They are larger animals and have higher fat content so are a richer food source. They are probably feeding the bottom of the food chain. Ocean research conducted by DFO scientists shows that in some years there is much higher growth, higher fat content, and bigger fish. Also, surveys up the coast show that the fish in Southeast Alaska, coho, for example, in the 1990s were about twice as big as off the west coast of Vancouver Island. So it seems that there is a lot better feeding grounds in the north.

Skip McKinnell:
The interesting part of this is that juvenile salmon, certainly some of the species, switch away from copepods very early in their life histories. Chinook salmon more or less come out of the egg feeding on other fish. The question has always been: Is a bigger, fatter, more nutritional animal going to give rise to better survival? There is some research currently underway, where they are looking at the idea that these lipids actually move up through the food chain and that if the food chain is enriched at its very base that benefits the consumers on the way up.

Understanding the life cycle of the zooplankton

Andrew Wright addressed a question to David Welch:
In the chart you presented you showed that in April 2007 there was a very tight distribution in terms of production in the ocean, and then it went from an all-time high in April to a near collapse. Assuming the ocean conditions are such that they were really good that year and there was this big explosion of growth, if all the nutrients get burnt up by the plankton, what is the outfall when there are suddenly no more nutrients. If there was such a rapid consumption of the available inputs, what is the outfall in terms of ocean chemistry and feed if you go from boom to bust so hard and so fast?

David Welch:
In that particular case, there isn't one. What is happening is not that the animals are driving the ocean chemistry but rather you are observing how long they are up in the surface layer. They are a very robust food source, one of the major food sources at the bottom of the food chain, but they come up

and they stay on the surface layers and they over-winter and then they come up in the spring and they stay on the surface layer for a short period of time. Once they have gone through two or three molts, and they are through the last instars on the surface, they go down deep, 0.5km down. The rest of the life history is spent down, where the salmon are not present, and they breed and lay eggs at that point. And then this cycle repeats itself. Therefore, what is being shown there is that they were only in the surface for a very brief period of time, relative to other years. Compared with the timing data that we have from the sockeye migration from the tagging work, the copepods were already out of the surface layer and they were therefore unable to feed the food chain before any of the sockeye smolts would have made it out from the Fraser River.

Ocean and coastal temperatures in 2007 and 2008

A participant posed the question:
In terms of the relationship between zooplankton species composition and sea surface temperature what I took from presentations is that the 2008 temperatures were generally warm. But in Mike Lapointe's presentation earlier I thought he said that the ocean entry sea surface temperatures were generally cooler in 2008. Could you please clarify this.

Mike Lapointe:
In the open ocean when those fish arrived it should have been cooler than average. In the coastal ocean, and this is where there can be a bit of a disconnect, Skip McKinnell showed that it was warmer. These are two different regions.

David Welch:
But also to be clear, 2007 was the year the Fraser sockeye that failed to come back went out as smolts. 2008 was the coldest year in a long time along the coast. 2007 was not and you would have to say that there was nothing striking in the temperature record.

Skip McKinnell:
2007 featured generally cooler temperatures through the North Pacific. The only remarkable thing I can think about the ocean climate in 2007 was the reemergence in the fall of 2007, late September and October, of what is known as the PDO negative pattern, which features a cold west coast of North America and a warmer offshore central Pacific.

David Welch:
The breeding success of the sea birds near Triangle Island off the north end of Vancouver Island apparently collapsed in 2007 as well. That system is well beyond the Strait of Georgia system. I am not confident to speak to the details of what happened but certainly that is something that needs to be taken into account; that is, that other things did not necessarily do well in 2007.

Overlapping communities in the ocean

A fisherman participant addressed a question to David Welch:
It seems that there are distinct groups of zooplankton that we can observe as they tow these arrays across the great circle route; they showed up in the presentation as groups of colours. Then there appear to be overlapping communities of sea birds. What is missing in the food chain there; the sea birds aren't eating the zooplankton and they are not eating the salmon. But they are eating other species. So can we presume, then, that those other species are also grouped in communities? I was thinking that in the other presentation we saw the stocks aligning themselves in groups before they returned back to the ocean and I am seeing a relationship there between these groupings.

David Welch:
This is a very perceptive observation. I think you are right but we do not have the data to fully answer the question. What we know is that areas of the Gulf of Alaska tend to have regions with persistently different plankton communities, and the sea bird communities map on top of those. Some of those sea birds do feed on the larger plankton but many of

them feed on small squid or in fact I am sure that they would take a salmon smolt if they came across it. It is a community out there and there are different ecosystems in different areas. This is surprising because classically trained oceanographers or marine biologists would say everything is just mixing around and washing around with the currents. From my perspective, that is clearly not happening. What Skip adds to that mix with those graphs is information that suggests that different populations of sockeye are in different parts of the Gulf of Alaska.

Participant:
As commercial fishermen we sometimes struggle to understand how we could have a successful return to the north of us and a successful return to the south of us. But if you consider it from that aspect, and that the Columbia River fish might have been in a slightly different geographical area than the Fraser fish, then it makes it a little bit easier to understand.

David Welch:
As a professional scientist, I struggle with exactly the same thing.

Speaking for the Salmon

SECTION IV
The Return Migration

Presentations by:

Randall Peterman, Professor, School of Resource and Environmental Management, SFU
Mike Lapointe, Chief Biologist, Pacific Salmon Commission

Karl English, Past President, LGL Ltd.

Scott Hinch, Professor, Institute for Resources, Environment and Sustainability and Department of Forest Science, UBC

THE QUALITY OF PRE-SEASON FORECASTS OF ABUNDANCE OF ADULT SOCKEYE SALMON

Randall M. Peterman, Professor, School of Resource and Environmental Management, Simon Fraser University

This presentation will describe the pre-season forecasting methods used for sockeye salmon on the West Coast of North America and compare their performance using historical data. The presentation will close with some implications of these findings.

Background

The life cycle of sockeye salmon is well known. Spawners lay eggs in fresh water and then some fry survive to become juveniles (smolts), which migrate into the ocean (Figure 1). Some evidence of where smolts go in the ocean, based on past tagging studies, was provided in a previous presentation. These juveniles then face a series of mortality events in the ocean, and the resulting marine survival rate is highly variable across years. Survivors become adult recruits, sometimes also known as 'adult returns' or the 'run size'. These three terms are synonymous; they refer to the abundance that is estimated by pre-season forecasting methods. Adult recruits constitute the abundance prior to the onset of fishing, not after fishing. Harvest happens after that point, and

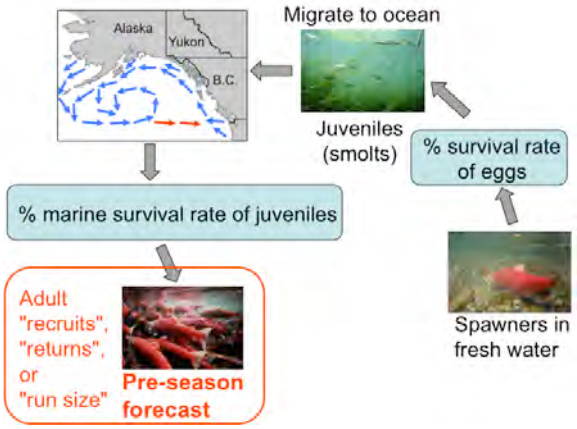

Figure 1. Life cycle of sockeye salmon.

those fish that are not harvested head upstream (Figure 2). Most of these fish make it to spawning grounds in most years.

The focus here is on the pre-season forecast, the estimate of abundance of recruits prior to the onset of fishing. Based on a large body of literature, there is strong evidence that for three species of salmon (pink, chum, and sockeye), marine survival rates is the dominant factor influencing year-to-year variability in survival rates from eggs to returns. This is a more important driver than variation in freshwater survival rates (Figure 3.)

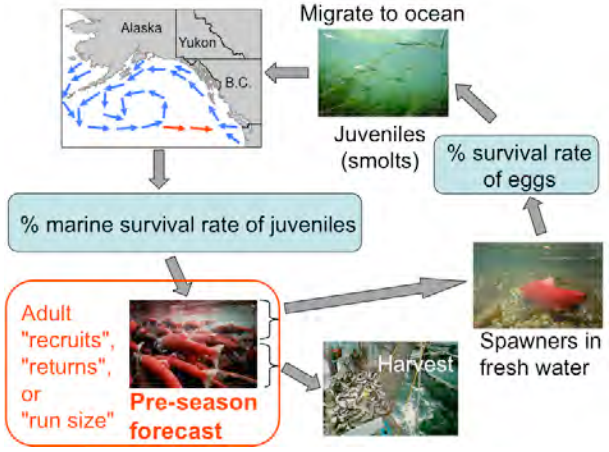

Figure 2. Harvest occurs after the forecasted adult run size.

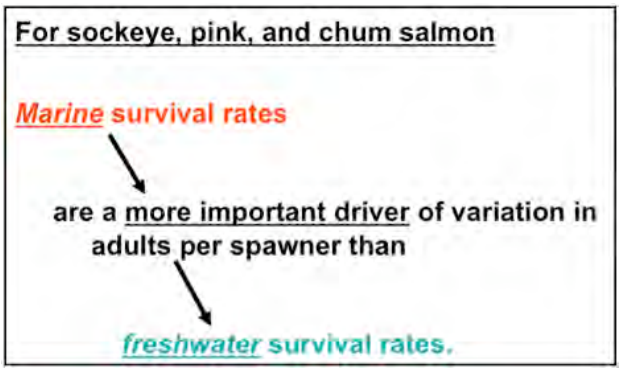

Figure 3. Marine survival rates are more important.

This is not to say that freshwater survival rates are not important. However, they do not have as dominant a role as variation in marine survival rates in affecting total adult recruitment.

The plot in Figure 4 shows survival rates of smolts in the ocean for a typical stock along the North American coast, the Chilko Lake sockeye. This is the only sockeye stock on the Fraser River system for which there are consistent smolt abundance estimates.

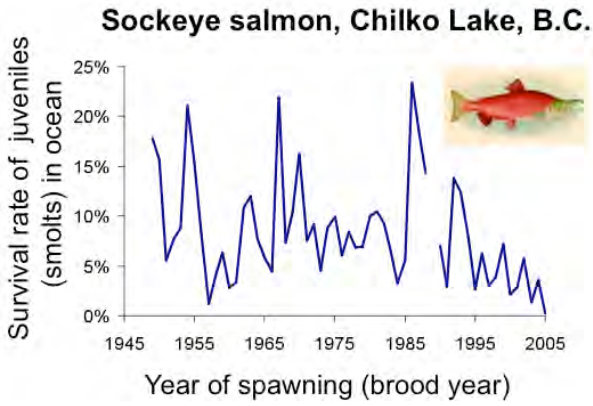

Figure 4. Survival rates of smolts to adults for Chilko sockeye.

Note that in the mid-1950s, values went from a high of greater than 20% survival rate down to a low of less than 2% survival rate over a short few years. Clearly, there is dramatic year-to-year variation in smolt-to-adult survival rate. Note also that those survival rates in the last decade have decreased substantially.

Forecasting methods

There are many types of models for forecasting adult salmon abundance in Alaska, Oregon, Washington, and B.C. (Table 1), but all salmon biologists tend to use similar approaches. The simplest methods are to forecast the same adult recruitment as occurred either in the previous year or four years ago. The latter model is an appropriate time frame for Fraser sockeye because of its predominant four-year life cycle. Another simple forecasting approach is to use a four-year moving average. These simple models do not require much biological knowledge.

Table 1. Sockeye pre-season forecasting models (11 types).

SIMPLE

1. Same adult returns as **last year**
2. Same adult returns as **four years ago**
3. Four-year **moving average**

BASED ON ABUNDANCE OF PARENTAL SPAWNERS OR JUVENILES

4. **Ricker** model
5. **Ricker** with autoregressive lag-1 variation
6. **Ricker** with sea-surface temperature (SST)
7. **Ricker mixed effects** model that includes SST and multiple stocks
8. **Kalman filter** version of Ricker model:
   The only model estimating changing underlying productivity (non- stationarity)
9. **Hybrid sibling** age-class
10. **Pink-sockeye** relationship using fish that entered the ocean in the same year (**Ricker-pink index**)
11. **Averaged forecast model** – average of forecasts of 4-year moving average and Kalman filter

The next group of models takes biological knowledge into account. For example, the Ricker model is the relationship between number of spawners and number of adult returns produced. There are three variations of this model that are commonly applied. One is the standard Ricker model (4). Another is a slightly more advanced statistical version of the Ricker model (5), and another one adds an index of ocean conditions encountered in early ocean life (model 6). The latter index is the coastal sea surface temperature (SST) encountered in the first four months of ocean life. SST is added as another independent variable to spawner abundance in the Ricker model to forecast returns.

Two new models have not yet been used by fisheries management agencies, but we nevertheless explored their performance. Model 7 is a more advanced version of the Ricker model that does not just use data one stock at a time to make a forecast, but instead uses data from a collection of stocks at the same time. If there were a strong environmental signal affecting a large area, then it should be reflected in multiple populations simultaneously. This model also includes sea surface temperature. Model 8 is a Kalman filter version of the Ricker model. This is a method that explicitly allows for changing productivity over time, unlike versions 4 - 7 of the Ricker model in Table 1. It is the only biologically based model that explicitly reflects changing underlying productivity, i.e., what scientists call “nonstationarity”. We used this model to allow for that change.

Finally, there are three other models that are sometimes used in various regions on the West Coast. The sibling model (9) forecasts the number of four-year-olds in a given year based on the number of three-year-olds that came back in the previous year (they are siblings because they are from the same cohort.) This model has been an important component of forecasting methods for Fraser River sockeye for many years; however, it has broken down in recent years in part due to changes in age structure. Model 10 asks: "Can we forecast the sockeye returns based on survival rates of the pink fry that went to sea in the same years as the sockeye smolts?" Even though juveniles of these two species are quite different in body size, this model allows for the possibility that they are subjected to similar ocean conditions. The final model (11) is an averaged forecast model, where the forecast is made based on the average of the two forecasts that are the most negatively correlated. This is one way of accounting for uncertainty about which forecasting models are the most appropriate.

How do forecasting models compare?

We compared these 11 forecasting models by looking at data on abundance of spawners and adult recruits for 37 sockeye populations ranging from Lake Washington in the south to western Bristol Bay, Alaska in the north (Figure 5). Black dots represent points of ocean entry of juveniles as they move from fresh water to salt water. It is important to note that not only were there 37 different populations, but on average, each stock had about 39 years of data on spawners and the resulting adult recruits.

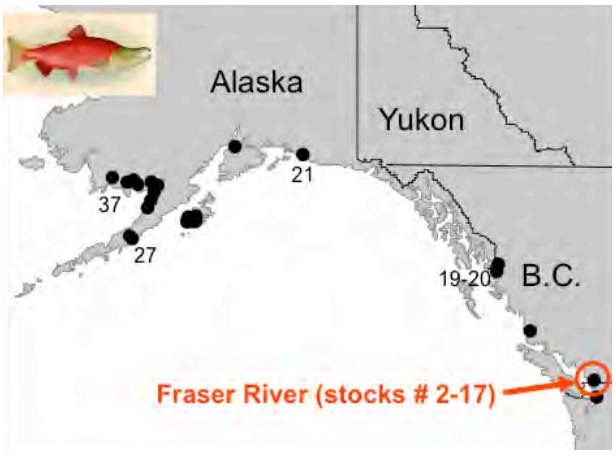

Figure 5. Locations of ocean-entry points for 37 sockeye salmon stocks, with an average of 39 years of data on spawners and adults.

We conducted a retrospective evaluation of each pre-season forecasting model and asked the question: "What if a particular model, for example number 5, had been used starting in 1960?" "How well would it have performed using only the data that were available up until 1960 to make a forecast for 1961?" We compared the 1961 forecast to actual returns in that year. We then added the actual returns from 1961 to the data set to re-estimate the parameters of that forecasting model, made a forecast for 1962, compared it with actual returns in 1962, and so on. We then calculated the annual forecasting errors, that is, the deviation between the actual forecast of that model and actual returns, for each historical year in the time series. This was done for all 37 salmon stocks, creating 1,081 'stock-years'. This process was then repeated for each of the 11 forecasting models.

Figure 6 shows a typical result of such a retrospective evaluation. This plot describes abundance of adult recruits for sockeye salmon in Ugashik River in Alaska from 1972 - 2000. The blue time series is what was actually observed. The red data series with square data points is what was forecast from one particular model. Note that in the 1980s, forecasts were far too low, sometimes a quarter of the actual return. The situation reversed in the late 1990s; forecasts were then far too high compared to actual returns. This variation among years, as well as the magnitude of deviation between observed and forecast, is common among populations that we examined.

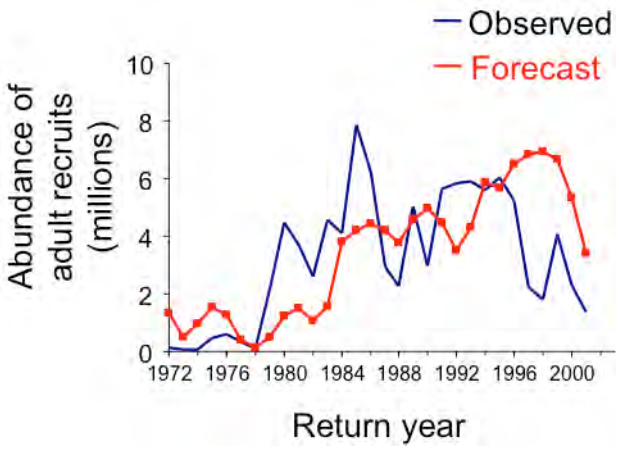

Figure 6. Sockeye salmon for the Ugashik River, Alaska. Forecasts are shown with square data points.

We ranked forecasting models based on three measures. One was bias. That is, on average over the long term, by how much does a model forecast tend to come out too high or too low compared to actual returns?

A second performance measure was the precision of the model from year to year. That is, one model's forecasts may be *above* the actual return by one million fish one year, *below* it by one million fish in the second year, and continue in that alternating pattern. This model's forecasts would be unbiased (i.e., averaging out to zero) but would be less precise than another model's forecasts that were off by only plus or minus 100,000 fish each year, for example. The third performance measure used a combination of both bias and precision for ranking.

Results

First, no single forecasting model turned out to be best across all 37 populations. Model rankings depended on which particular stocks were examined and on which ranking criterion was used, i.e., whether it was based on bias, precision, or the combination of those two. The second result was that the best models were those that put heavier weight on the most recent period, that is, the simple models, "like last year", "like four years ago", and "the moving average", as well as the Kalman filter model. This is an important result. Those methods that forecast based most heavily on the most recent information will pick up the kind of time trend and decreasing productivity that was described in the presentation by Mike Lapointe. Our third main result is shown in Figure 7; the *Y* axis represents the proportion of variation explained by the best stock-specific model. The *X* axis represents the 37 sockeye salmon stocks arranged left to right from Washington through to Western Alaska. B.C. stocks are stocks 2-20 on the left (in blue) and Alaska is 21-37 (in red). Note that the B.C. forecasting ability is similar to that in Alaska. In fact, if anything, for sockeye, it may be slightly better in B.C. There is also considerable variation among populations in the proportion of temporal variation in annual returns that we can forecast.

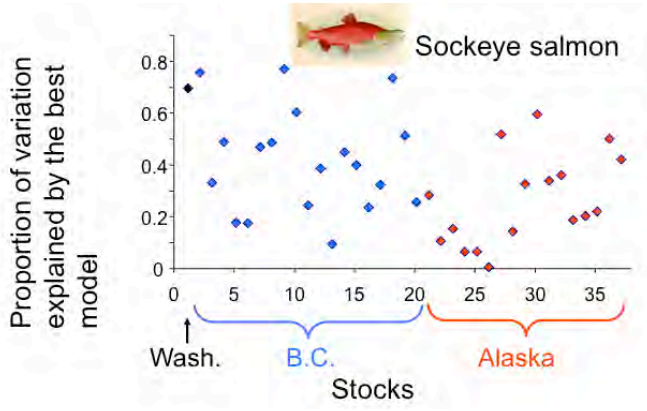

Figure 7. Effectiveness of forecasting in B.C. is not very different from Alaska.

The fourth result, observed in the dotted line across the graph in Figure 8, shows that, on average, we can only explain 36% of the variation from year to year in the 39-year time series, even with the best stock-specific forecasting model. That means that we cannot explain 64% of the variation from year to year in adult returns. People who expect excellent forecasts from salmon models are going to be disappointed (and already have been), yet these are the best forecasting models for each particular stock.

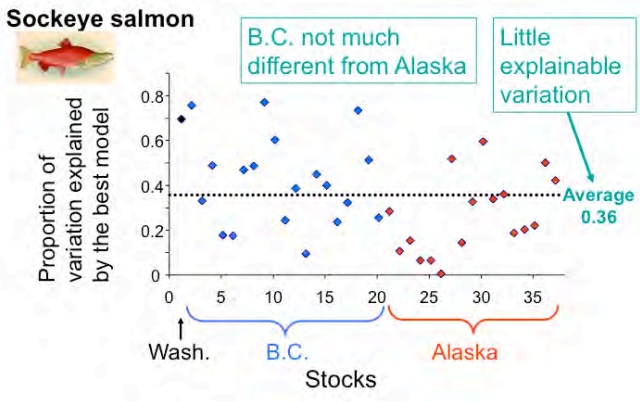

Figure 8. On average, there is little explainable variation for both B.C. and Alaska.

One key problem that we face in the Fraser River sockeye system is that the environment is not stationary. The graph in Figure 9 describes productivity of salmon. It is a composite of real and hypothetical data. This graph reflects qualitatively that there can be periods of low or high salmon productivity, as well as periods of increasing or decreasing productivity. This overall pattern is called a non-stationary environment; that is, it is not just a constant average condition with high year-to year variability around it.

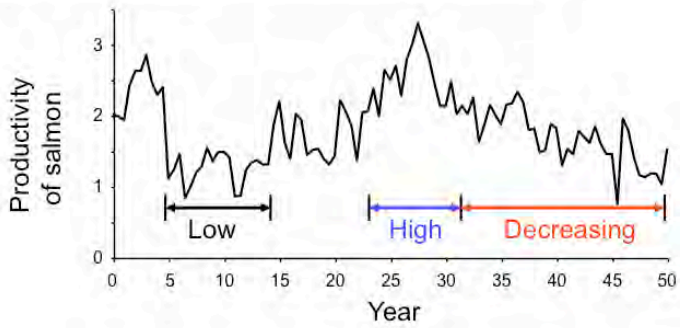

Figure 9. Key problem: Non-stationary environment.

Figure 10 is the same graph as presented in Mike Lapointe's presentation (page 62). For these Fraser River sockeye stocks, orange dots of increasing size in recent years reflect large decreases in salmon productivity, or recruits per spawner at a low abundance, compared to what the productivity used to be. This is a very important result.

These findings were produced by a Kalman filter method, which estimates the Ricker 'a' parameter, i.e., the maximum number of adults produced per spawner at very low spawner abundance with the density-dependent effect of spawner removed. Therefore, the decrease in

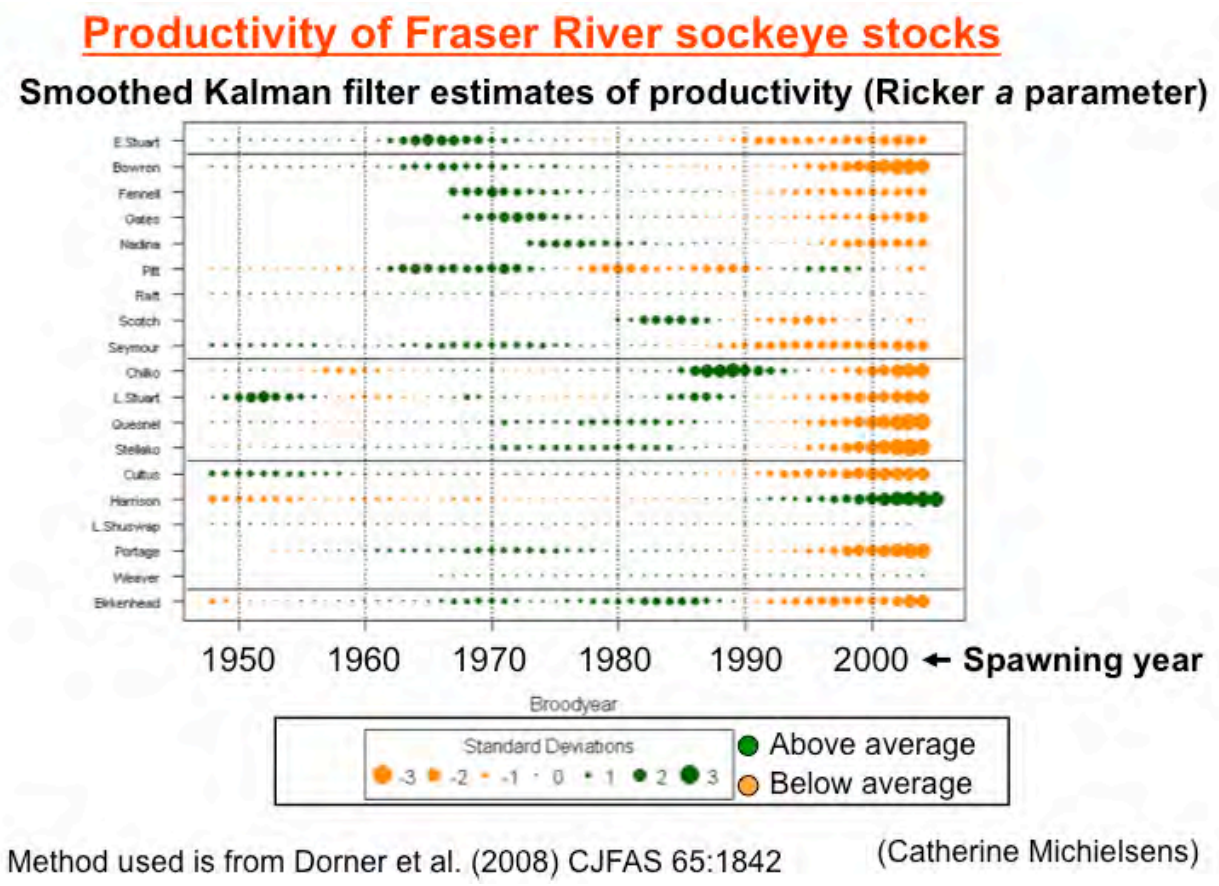

Figure 10. Productivity of Fraser River sockeye stocks; figure courtesy of Catherine Michielsens at the Pacific Salmon Commission.

productivity (recruits per spawner) is *not* due to increasing spawner abundance but is due to some other factor. This is a very serious trend from the standpoint of both conservation and management.

The non-stationarity in Figure 10 emphasizes two points. First, forecasters should ask: "How useful are old data?" Maybe they are not as useful as they would be if underlying conditions had not shifted. Second, forecasters for Fraser River sockeye should be using methods that take into account the recent decreasing trend. This point is consistent with our second result from comparing the 11 types of forecasting models for sockeye salmon, i.e., forecasting methods that performed best actually placed greatest weight on the most recent data.

What are the implications of these results?

These results have three important implications. First, pre-season forecasts are, on average, not going to be as good as many people would like them to be. Therefore, we should continue to improve in-season monitoring and updating of estimates of abundance. Furthermore, we should be thorough and take uncertainties in forecasts of abundance into account in decision making.

The second implication is that interested parties need to be more realistic and lower expectations about the accuracy of pre-season forecasts. Most people tend to place too much weight on the single best forecast estimate and do not recognize forecasting uncertainty. An analogy with weather forecasting is useful here. Weather forecasters say that for any locale like Vancouver, forecasts beyond five *days* are poor, and there is a decrease in the reliability of forecasts even between one and five days. In comparison, biologists are trying to forecast the return of salmon *two years* after they leave freshwater. In addition, unlike weather forecasters who have thousands of observations on which to base their forecasts, salmon biologists have at most a few dozen observations. It is therefore impressive that salmon forecasting methods work as well as they do, and explain on average 36% of year-to-year variation in adult sockeye salmon abundance.

We need to recognize the situation for what it is. Salmon migrate into a proverbial black box, only in this case it is a blue box, the ocean. The population of juveniles experiences some marine survival rate that we cannot estimate until surviving adults appear in coastal waters and we start harvesting them and/or estimating their abundance at Mission or on spawning grounds. Therefore, it is not surprising that there is a very large year-to-year variation in forecasting errors and that we do not really know each year how ocean processes affect salmon.

A final implication is that we need to understand that there is a huge amount of uncertainty in these forecasts, and everyone who uses this information should take these uncertainties seriously -- users of salmon, managers, the public who have expectations about forecasts, and most especially the media.

FRASER SOCKEYE STOCKS - PRODUCTIVITY CHANGES

Mike Lapointe, Chief Biologist, Pacific Salmon Commission

This presentation provides more information on the productivity changes shown in the former presentation where we examined the total Fraser productivity changes. However, there is a lot of diversity between stocks and it is important that the pattern be examined across all the stocks in the watershed. This presentation will also briefly describe some upstream migration challenges that will be described later in more detail by Karl English (page 66) and Scott Hinch (page 78).

Figure 1 represents the plot of productivity for the total Fraser sockeye from 1952 to 2009. Productivity is the total returns of all stocks combined divided by the total spawners four years prior. This represents the average productivity for all stocks of Fraser sockeye. Because of the way this average is calculated, small stocks could be doing well or poorly but that will not significantly affect the average. Conversely, trends observed for the very large populations will drive the overall trend quite significantly. It is important to note also that this represents a four-year average; it is not a 'dot to dot' line connecting each year's returns per spawner. The line has been smoothed to describe the trend. Note that the 2009 data point is the actual returns per spawner, calculated in that way for 2009 only not an extension of the four-year average trend.

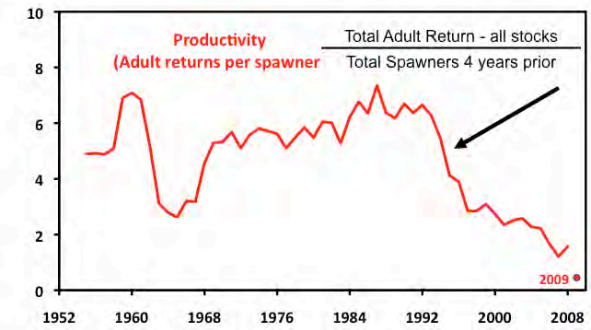

Figure 1. Productivity for the total Fraser sockeye from 1952 to 2009.

The question is: What is going on in individual stocks in the Fraser? The plots in Figure 2 represent the productivity for the Early Stuart and summer run management groups, where the summer runs are the most abundant component of the total runs. Note the similarity in the curves in the Summer run plot compared with the curve for the Total Fraser in Figure 1.

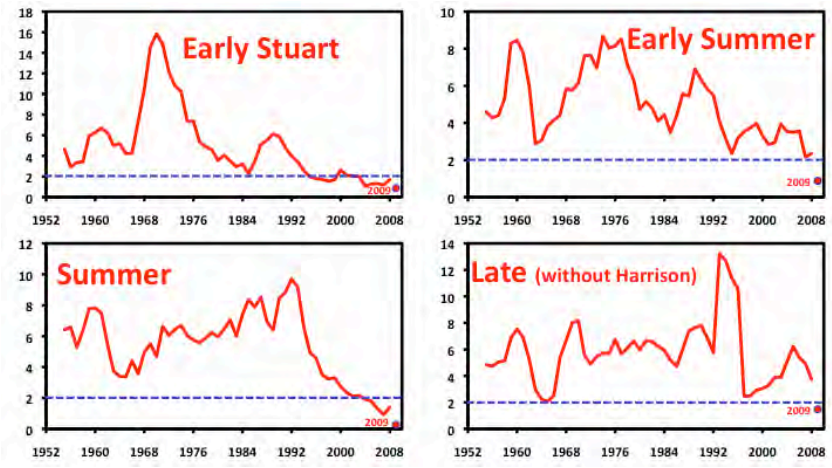

Figure 2. Productivity for management groups of summer run Fraser sockeye.

The summer runs are doing disproportionately poorly relative to other stocks, however. For example, note the plot for the early Stuart runs where there were very high values for productivity in the late 1960s (almost 16 to 1). (Note the blue dashed line representing two returns per spawner, inserted to adjust for differences in scale between the plots.) When this information is partitioned into smaller aggregates much more variation appears than was observed in the plots of the total Fraser. The Harrison data was taken out of the plot for the late summer runs – since the Harrison stocks are following a different trend, it is important to remove these data so that this trend does not drive the total trend for the late summer run populations.

The data presented in Figure 3 describe the trends and productivity in a different way. These data are for the Early Stuart populations with the circles representing productivity. The green colour represents productivity that is better than average and orange, poorer than average. The size of the circle is an indication of how much relatively better or poorer the productivity is relative to the average for Early Stuart.

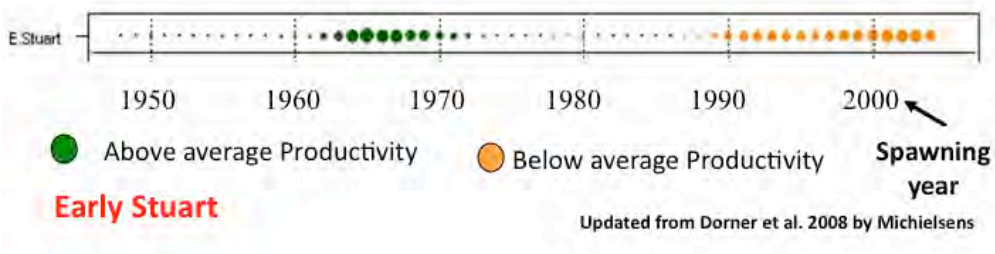

Figure 3. Stock specific trends in productivity for Early Stuart sockeye.

The years indicated represent the year of spawning; for example, the 2000 year of spawning corresponds to the 2004 year of returns for 4 yr old sockeye; the predominant age of return for Fraser sockeye. Note that there are some very consistent patterns appearing.

The plots in Figure 4 represent the same type of data for the other stocks in the Fraser, including the early summer, summer and late runs. In most cases information is presented for individual populations, although in some cases the data represent aggregates of populations.

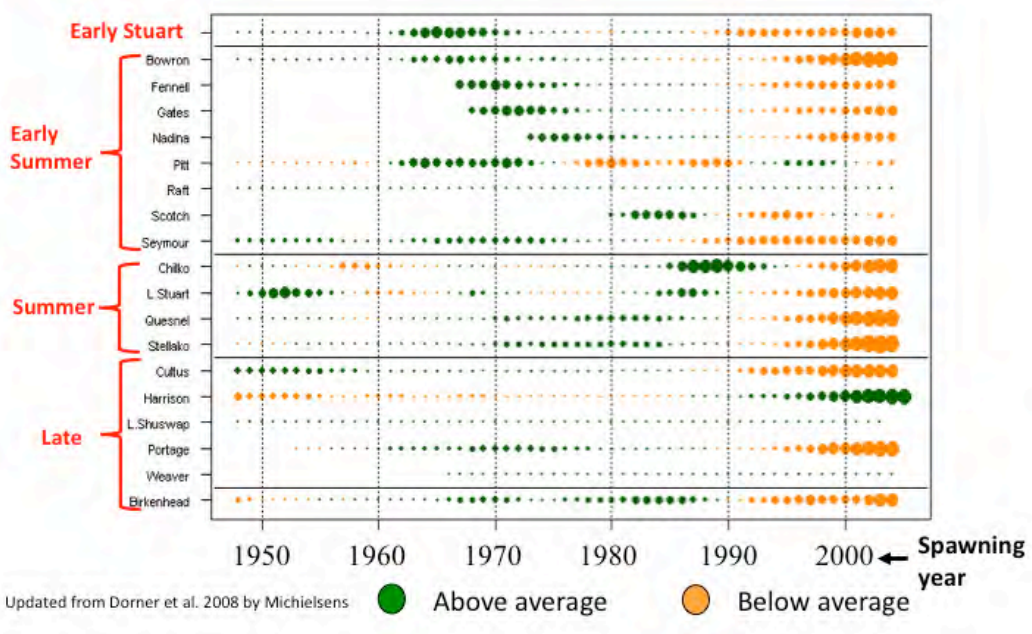

Figure 4. Stock specific trends in productivity for Fraser sockeye populations; Early Stuart, Early Summer, Summer and Late Summer runs.

Note the predominance of a significantly declining productivity for the four summer-run stocks. Then observe the data for the Harrison, keeping in mind the earlier description showing that the Harrison was increasing in productivity. Note here that the dots for the Harrison are becoming more green, and the size of the green dots is increasing, from around 1990 onwards. There were some populations for which we were not able to detect changes using this technique with no

strong evidence of declining productivity; for example, the Raff population and the Shuswap Lake runs that include the Adams River runs. Clearly, there is a lot of variation in the trends across these stocks and the changes in productivity do not all happen at the same time.

Perhaps there is a little bit of silver in this cloud - that is that the biggest declines, relative declines, seem to be occurring for the most part in the largest, most abundant populations, with a few exceptions. The Bowron Lake population, for example, is a fairly small stock and it is showing a dramatic decline. This is not a good sign. Many of the populations are showing declining productivity, but the consequences of rapid declines are more severe when they occur in less abundant stocks as opposed to more abundant stocks, because the less abundant stocks have a much shorter distance, in terms of abundance, to decline before they reach low abundance thresholds that might be difficult to rebuild from.

Warming of the Fraser River

The plots in Figure 5 show the temperatures in the Fraser taken near Hope for a number of periods, beginning with 1942 to 1969, then the period from 1970 to 1989 represented by the green line. The other two plots are of approximate ten-year periods; 1990 to 1999 in blue and 2000 to 2008 in red. This is a significant warming trend.

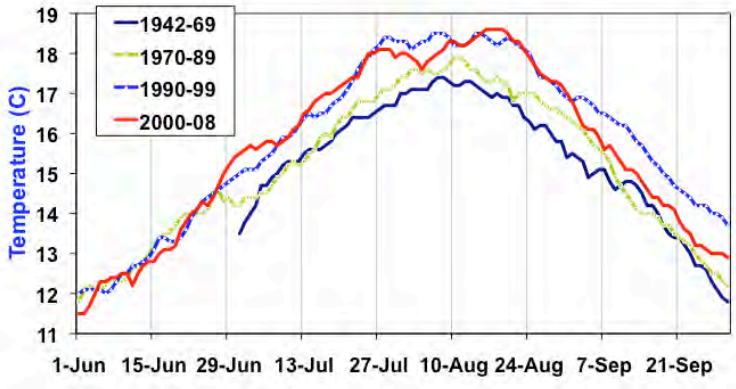

Figure 5. Fraser River temperature measured near Hope, BC from June through September from 1942 to 2008.

There are some data present in the Pacific Salmon Commission collection that tell us something about the effects of these warm temperatures. Every year the PSC goes through an exercise of calculating the 'difference between estimates'.

Figure 6 shows an example of these calculations for the summer run Fraser sockeye in 2009. The Mission escapement, in this case 616,000, was estimated and so was the catch up stream of Mission, in this case very small at 38,000. Rarely are there estimates available for en route losses. That means then that there was a potential spawning escapement of 578,000. This figure is then compared with what arrived on the spawning grounds, which in this case was 478,000. Therefore, there was a difference between estimates of 100,000 fish. The question is: How do these differences between estimates vary with temperature?

Impacts of warming Fraser
Summer-run Sockeye 2009
Differences between estimates

Mission escapement	616,000
- Catch upstream of Mission	38,000
- En-route losses	??????
= Potential Spawning escapement	578,000
Actual spawning escapement	478,000
Difference between estimates =	100,000

Figure 6. Impacts of warming Fraser Summer-run sockeye 2009. Differences between estimates.

The graph in Figure 7 describes the relationship between the difference between estimates and warmer river temperatures.

On the horizontal axis of the plot is the escapement that was expected based on the information at Mission; that is, the potential spawning escapement. On the vertical axis is the actual estimate of numbers of fish that reached the spawning grounds. The diagonal black line is the one to one line. That means that whenever a point falls on the line there are exactly the number of fish on the spawning grounds that were expected. The data points have been coded with different colours. Blue diamonds represent 'benign conditions'; that is when the temperatures were not anomalously high. The average temperature of those years during the time period when summer-run sockeye were migrating in the Fraser was about 17.3 °C. The purple squares represent the warm temperature years. In those years the average temperatures were greater than 18.5 ºC. Note that every one of the warm temperature years falls below the 1 to 1 line. Points above the 1 to 1 line indicate that more fish arrived upstream than were expected; points below the 1 to 1 line indicate that fewer fish arrived than were expected.

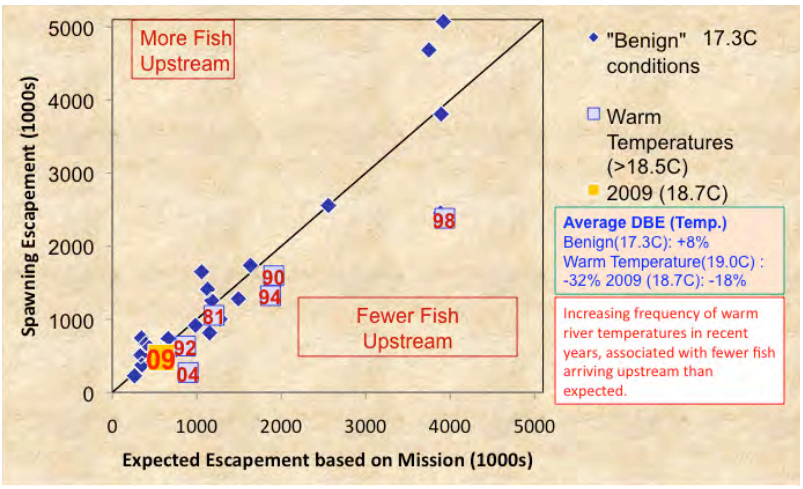

Figure 7. Relationship between difference between estimates and water temperature for Fraser summer run sockeye.

There is a very consistent pattern in all the warm years. A closer look at those years reveals that in each case there was an inquiry of some sort – 1992 (Pearse), 1994 (Fraser) and 2004 (Williams).

The chart on the right of Figure 7 shows average temperatures and differences between estimates for the years split out by temperature. In the benign years, on average, 8% more fish arrived on the spawning grounds than were expected. In the warm temperature years, the average was 32% less. 2009 was a relatively warm year but not the warmest year ever – it was 18.7% less. The point is that there have been more warm years in recent times with 8 of the 10 warmest years in the last 60 having occurred since 1990, and that has been associated with fewer than expected fish arriving upstream. It is not possible to tell if this is all due to en-route loss because there is a combination of estimates; whatever it is, however, it is related to temperature.

Management actions

What management actions are taken in response to the warming temperatures of the Fraser River? A factor called a 'management adjustment' is employed where the spawning escapement targets are increased to compensate for the expected difference. How does this work? Models are available that relate the historical differences to temperatures and flows in past years. Twice per week during the summer management receives 10-day forecasts of error conditions from the Environmental Watch Program at DFO. The forecasts are used to predict the expected difference based on historical data. The difference is then added to the escapement target. For example, in 2009 management added 280,000 fish to the escapement target to compensate for expected differences; in other words they removed 280,000 fish from the available harvest because of the warm temperatures that occurred.

COUNT ON SALMON PROJECT

Karl English, Past President, LGL Ltd.

This presentation focuses on the Count on Salmon Project. This project was initiated by the Pacific Salmon Foundation in 2007 with funding from the Fraser Salmon and Watershed Program and Pacific Salmon Commission with in-kind support from several Fraser River First Nations and Fisheries and Oceans, Canada. This talk includes a description of the goals and objectives of the project, the key results to date, and the plans for 2010. I would like to especially acknowledge the contributions of the Matsqui First Nation who contributed significantly to the fishwheel component of the project and all the other First Nations within the Fraser that are providing tag recoveries for the telemetry components of the project and their collaboration on the run reconstruction component.

Count on Salmon project

This project was built on the foundation of work conducted from 2002 to 2006 with the support of the Pacific Salmon Commission (PSC). The first question that was asked by the funders when we proposed this work was: Why focus on the last to stages in the salmon lifecycle? That is, stages 3 and 4 in Figure 1.

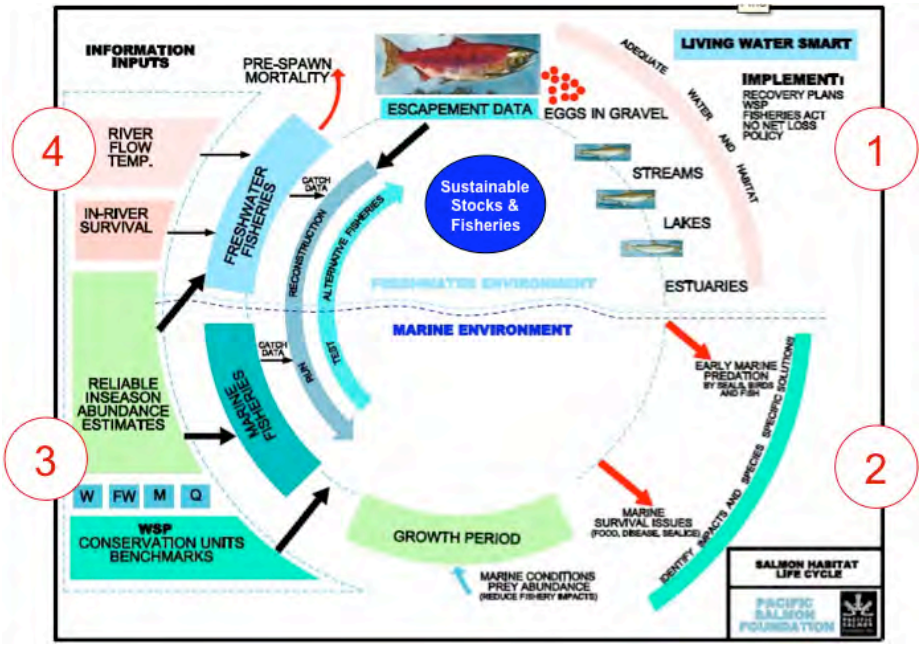

Figure 1. Lifecycle stages for sockeye salmon and areas of study.

The stages identified by number 1 was the primary focus for PSF efforts in the early years, including a lot of habitat restoration work. Several of the previous presentations have identified the marine environment (number 2) as a key determinant of returning abundance with many factors affecting marine survival rates for sockeye salmon. It is widely acknowledged that research to identify the determinants of salmon survival in marine waters is complex and expensive, and the degree to which human actions can alter marine survival rates is very limited. In contrast, improvements in the in-season data used to manage coastal and in-river fisheries, which occur during stages 3 and 4 of the salmon life cycle, will provide direct benefits for Fraser salmon stocks. Also, several earlier inquiries around 'missing' Fraser sockeye raised questions

about the Whonnock test fishery and the Mission hydroacoustic counts and the other fundamental building blocks that can drive in-season estimates. Several funding agencies (PSC and PSF) identified the need for more research to answer these questions and gain a better understand of the factors affecting in-river survival for Fraser sockeye (i.e. river flow, water temperatures and fisheries). The information generated by these kinds of studies can contribute to decisions about how to conduct fisheries more effectively such as by altering harvesting methods and minimizing harvest rates, with the ultimate goal of having healthy stocks and sustainable fisheries.

Project goals

The first goal of this project is aimed at improving the reliability of in-season estimates of abundance for Fraser salmon; for all Fraser salmon, not just sockeye. The second goal is to identify the times and locations of en-route losses for Fraser sockeye. Although the main focus is on Fraser sockeye, we will also be looking at some other species. Third, we will assess the relative impact of environmental conditions and fisheries on in-river survival of Fraser sockeye.

Objectives for 2007 - 2008

The studies conducted in 2007 and 2008 primarily focused on fishwheels as a mark-recapture platform in the lower Fraser to assess salmon returns. Another objective was to continue the en-route survival estimation that had been carried out in 2005 and 2006 in the lower river.

Three fishwheels were deployed at Mission, at one of the narrowest spots in the Fraser River in this region (about 480 metres wide), just downstream from the Mission hydroacoustic site. The purpose was to see if we could catch fish at this location. Because it was not as effective as we expected, in 2008 we considered an alternative site about 9km downstream from Mission at a narrow spot in the river. The reason for selecting this site was that there was flow along the shore most of the summer that meant there was enough current to drive the fishwheel. We also added a different design for the fishwheel, doubling the size of the earlier ones. Figure 2 presents a photograph of the large fishwheel used at the Crescent Island site, downstream from Mission.

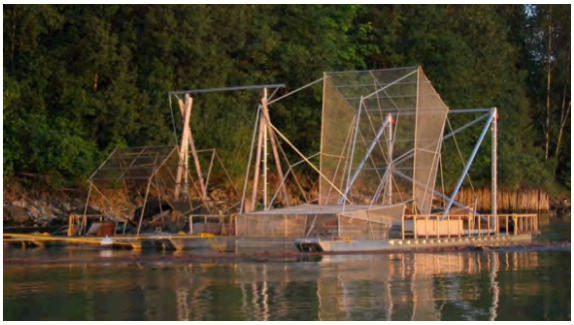

Figure 2. Large fishwheel at Crescent Island study site in 2008-2009.

The configuration was designed to move up and down with water levels because there is both tidal fluctuation and substantial variation in flow through the salmon migration period. The diagram in Figure 3 shows the floating shoreline abutment and weir that deflects the fish into water more than 10 ft. deep. A fishwheel, with 10 ft deep baskets, was positioned next to the abutment and the large fishwheel, with 20 ft deep baskets, was positioned next to the smaller

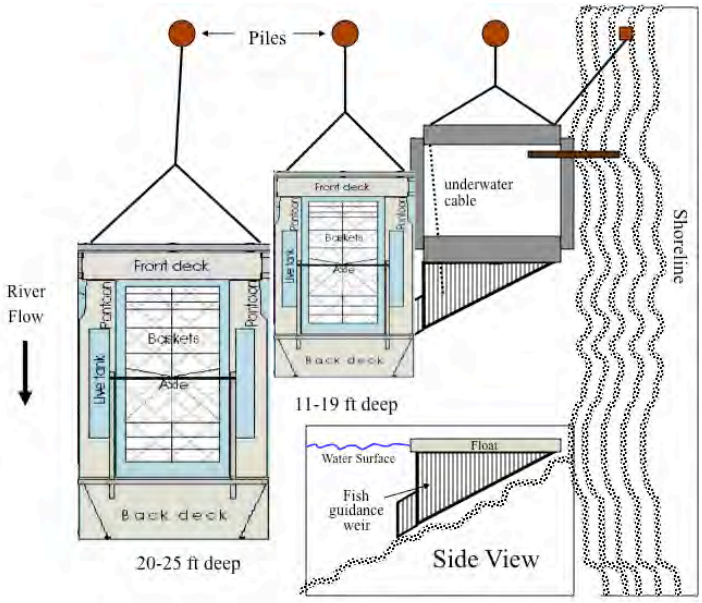

Figure 3. Diagram illustrating the floating shoreline abutment and two fishwheels at the Crescent Island study site.

fishwheel.

The plot in Figure 4 presents data for the sockeye salmon catch at the different wheels in 2007 compared with the PSC abundance estimates at the Mission counter (represented by the black line). The bars represent the proportion of the catch taken at each of the 3 fishwheels from June to September. Note that late in the season the catch represented a lower portion of the run compared with the Mission estimates. This is because of changes in flow and that is one of the reasons why we looked for a different site in 2008.

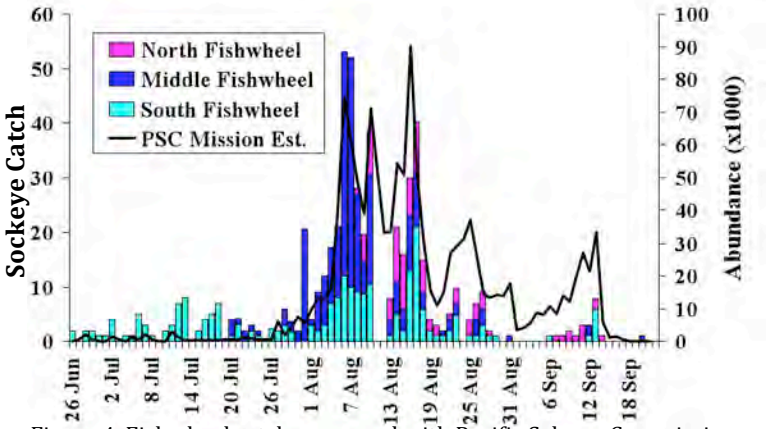

Figure 4. Fishwheel catch compared with Pacific Salmon Commission abundance estimates of sockeye salmon in 2007.

In 2008 two fishwheels were operated at the Mission bridge site and two other fishwheels were operated downstream at the Crescent Island site. Figures 5a and 5b show the catch for each of these fishwheels in 2008 compared with the PSC Mission estimates. Note that the larger wheel produced much better catches later in the season as well as a greater catch in total.

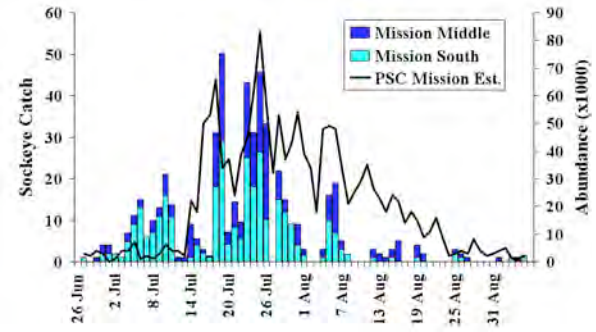

Figure 5a. Mision fishwheel catch compared with PSC estimates for sockeye salmon abundance in 2008.

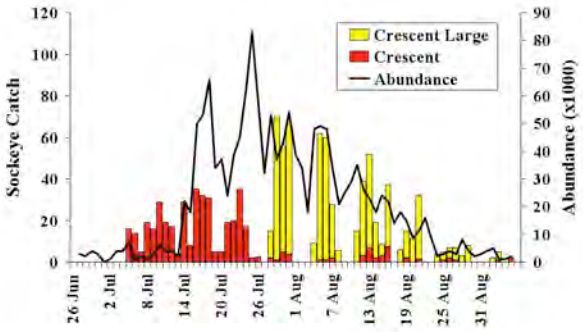

Figure 5 b. Crescent Island fishwheel catch compared with PSC estimates for sockeye salmon abundance in 2008.

Objectives for 2009

In 2009 we tested a new approach for estimating species composition by combining the information from the Crescent Island fishwheels with the information from the Whonnock test fishery and Mission hydroacoustic counts. We worked with the PSC to derive reliable in-season estimates of abundance at Mission for sockeye, Chinook and pink salmon. We also examined the in-river survival rates, migration rates, and impact of fisheries on in-river survival for sockeye and Chinook.

The graph in Figures 6a shows the catches in 2009. Although there were low catches later in the season there were much higher catches earlier on compared with total catches in the first year operating at the Mission bridge sites and the second year operating at Mission and Crescent Island sites. In each of those years there was almost the same amount of return, between 1.2 and 1.4 million sockeye. Therefore, the efficiency of the fishwheel operation was substantially higher in

2009 than in each of the previous two years (Figure 6b).

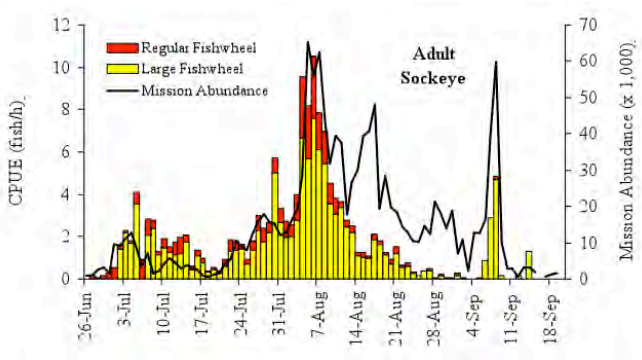

Figure 6a. Fishwheel CPUE (catch per unit effort) compared with PSC estimates for sockeye salmon abundance in 2009.

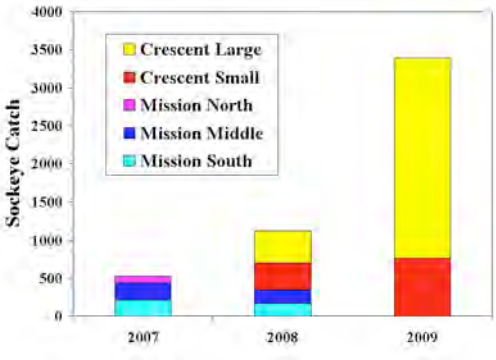

Figure 6b. Total number of sockeye caught by each fishwheel each year between 2007 and 2009.

Figure 7 describes the fishwheel catch by species in 2009. Note the abundance of pink salmon. These data are used to estimate species composition and to estimate sockeye abundance.

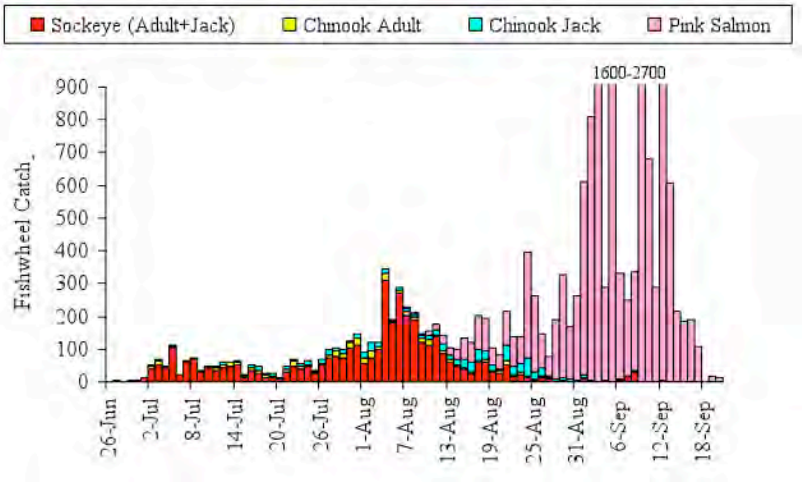

Figure 7. Fishwheel catch by species in 2009.

The three lines in the graph in Figure 8a compares the PSC sockeye abundance estimates in 2007 (grey bars) with the results derived using three different combinations of species composition (SC) estimates (Whonnock test fishery SC alone, the fishwheel SC alone, and the combination using fishwheel SC for nearshore hydroacoustic counts and the Whonnock test fishery SC for offshore counts.

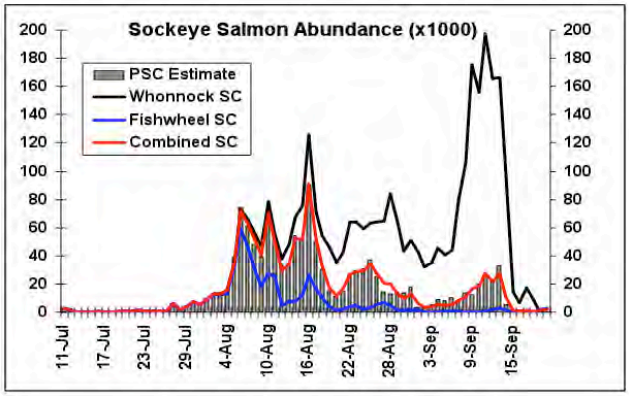

Figure 8a. Sockeye salmon abundance in 2007. Data determined from PSC estimate, Whonnock test fishery, fishwheel or a combination of Whonnock and fishwheel data.

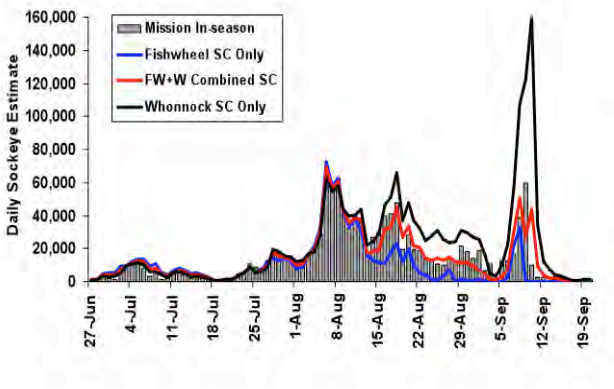

Figure 8b. Sockeye salmon abundance in 2009. Data determined from Mission in-season, fishwheel only, Whonnock test fishery only or a combination of Whonnock and fishwheel data.

Figure 8b shows the results for 2009. Note that in both years, sockeye abundance in August would be significant overestimates using Whonnock SC data alone while fishwheel SC data alone would result in underestimates. Estimates derived using both Whonnock and fishwheel SC estimates, as described above, produced the most defensible daily sockeye escapement estimates in 2009.

Telemetry Studies

Telemetry is another component of this project where radio tags are inserted in fish migrating upstream and the signals are detected by listening stations along the way. In Figure 9 the green circles identify stations along the river, blue circles indicate a variety of different release sites for the tagging, and yellow circles represent fishery recoveries.

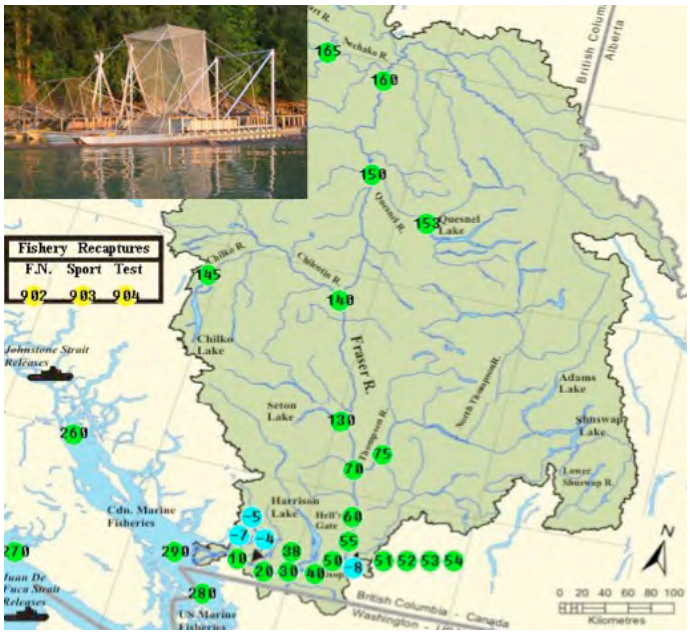

Figure 9. Telemetry study sites in the Fraser Watershed area from Mission to Stuart River.

This technology has been used to track the different populations each year, where DNA sample analyses provide information about the stocks. The different populations have been grouped into eight major groups: early Stuart, the summer runs (Chilko, Quesnel and Nechako), early Thompson, late Thompson, and Weaver and Birkenhead.

Figure 10a shows the location of the radio-tagged sockeye on 10 July 2009. Figure 10b shows their location on July 30. Note that Early Stuart fish (brown) are already at the spawning areas and the signals are indicating the beginning of the summer runs (Quesnel and Chilko fish in blue and some Nechako fish in grey). There were few early Thompson River fish (yellow) in 2009.

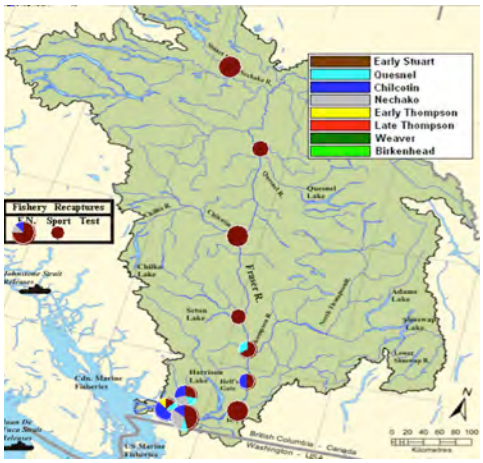

Figure 10 a. Location of Fraser sockeye salmon groups July 10, 2009.

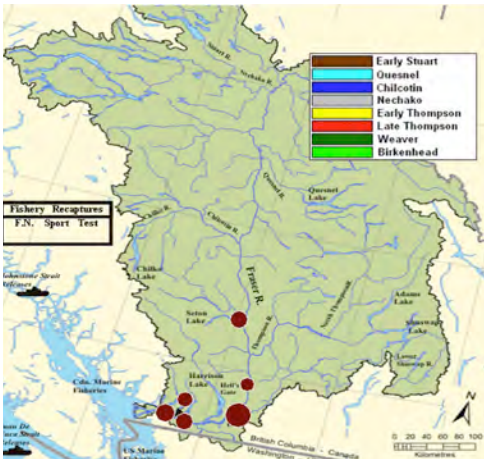

Figure 10b. Location of Fraser sockeye salmon groups July 30, 2009.

Figures 11a and 11b show the location of the summer and later summer populations in late August and at the end of the season, respectively.

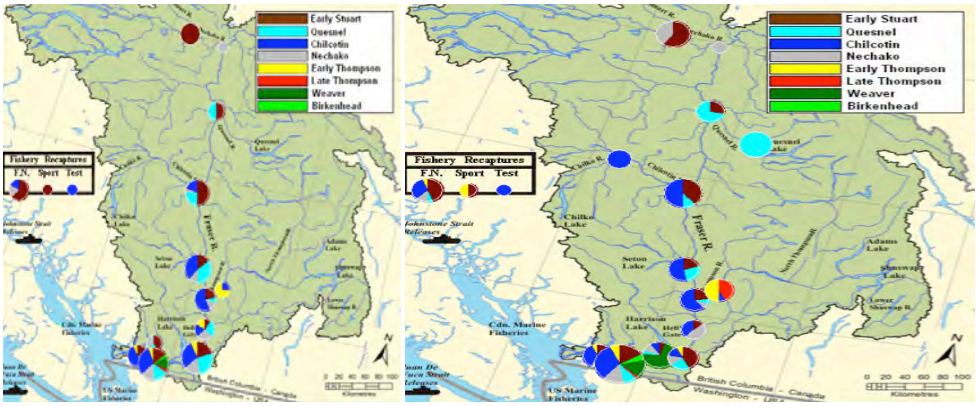

Figure 11a. Location of Fraser sockeye salmon groups August 22, 2009.

Figure 11b. Location of Fraser sockeye salmon groups October 20, 2009.

This technology also provides detailed information on fish movement and migration speed. Figure 12a compares the migration speeds in 2009 by reach and run-timing group. Note that the Early Stuart fish migrated from Mission to Quesnel at an average rate of > 40 km per day; this is an incredible pace, given that they have currents to battle against as well. Summer runs are a bit slower and the late runs are the slowest of the various timing groups. These comparisons can also be made between years. Figure 12b shows the migration speeds comparisons for summer run stocks from 2005 – 2009.

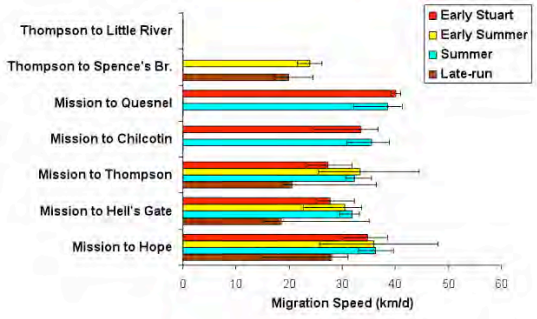

Figure 12a. Migration speeds by reach and run-timing groups for sockeye salmon in 2009.

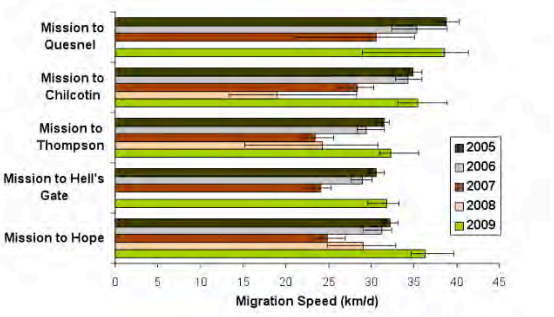

Figure 12b. Migration speed comparisons for summer-run sockeye salmon, 2005 – 2009.

Some of the variation between years can be accounted for by the method of capture used for tagging. For example, in 2005 and 2006 tangle nets were used whereas in 2008, 2009 and 2010 we were tagging out of the fishwheels. In 2009, the tagging procedure was adjusted, so fewer sockeye were tagged from overnight catches, and all fish were processed more rapidly and with less stress.

We can also learn about what is happening to individual fish. Figure 13 shows the pattern of sockeye that were tagged throughout the

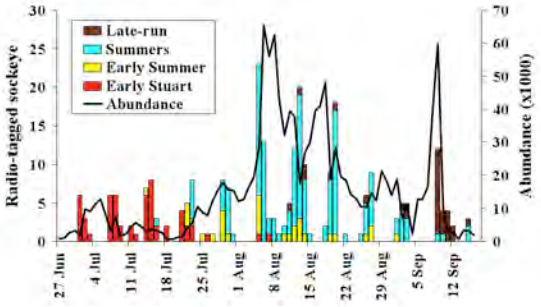

Figure 13. Radio-tagged sockeye salmon by timing groups compared with Mission abundance estimates, 2009.

2009 season. The goal is to tag each one of the groups and track them through the river. It is important that these are the same runs that the PSC Mission site counts.

We are also tracking these fish through each fishery. We can look at the timing of the catches and get information about what is removed from each of these groups (Figure 14). These are the best estimates we currently have of the daily harvest rates that occur relative to the tags. The main harvest period was during the latter part of the Early Stuart run in 2009 and it did not impact the later timing groups.

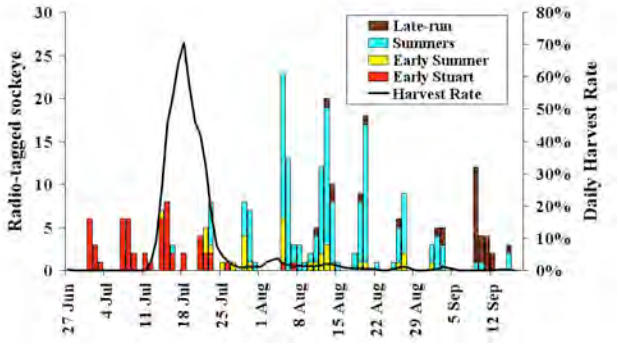

Figure 14. Radio-tagged sockeye by timing group and daily harvest rates from June to September, 2009.

Figure 15a describes what happened to the fish, showing the spawning fish (blue), enroute losses (grey), and the actual recoveries from fisheries (red).

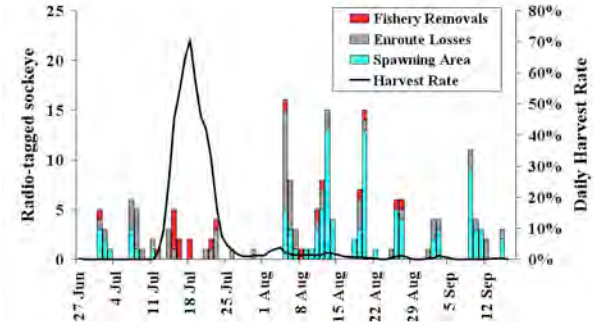

Figure 15a. Fate of radio-tagged sockeye and daily harvest rates by Mission passage date, 2009.

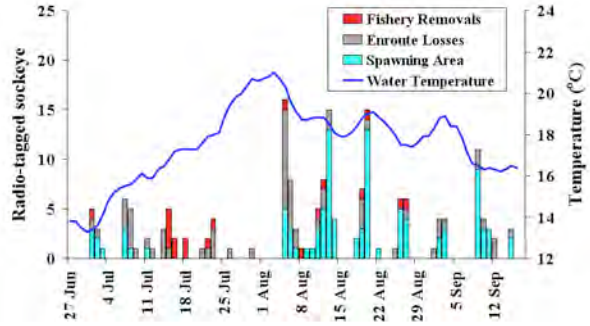

Figure 15b. Fate of radio-tagged sockeye and water temperature at Qualark by Mission passage, 2009.

Note that there was a period between mid-July and early August when very few of the fish detected passing the Qualark monitoring site made it to their spawning destination. Relatively high harvest rates during the first half of this period and high water temperatures (18-21°C) during the later half of this period were the most likely reasons for these results (Figure 15b). Typically when temperatures exceed 19 °C en-route losses increase and few of the radio-tagged fish make it to the spawning grounds.

Figure 16 shows the arrival timing for Early Stuart sockeye in 2009 at Chilcotin Junction and correlates this with water temperature. Note that all the successful migrants (blue) were detected passing the Chilcotin monitoring site before the period of rapid increase in temperature (22-26 July 2009). Stuart River temperatures exceeded 22 °C for several days in late-July, which is too hot for migrating sockeye salmon. Early Stuart sockeye that migrated past the Chilcotin Junction after 22 July did not make it to the spawning grounds.

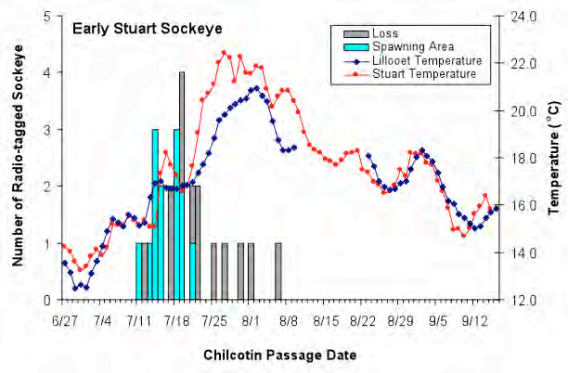

Figure 16. Early Stuart arrival timing at Chilcotin Junction, fate and water temperature.

Assessment of en-route losses for summer-run fish revealed similar results to other years. Figure 17 shows the final distribution of 143 radio-tagged summer-run sockeye in 2009. The area from Hell's Gate to Seton up to Kelly Creek, is where most of the en-route losses have consistently occurred for summer-run stocks in every year that sockeye radio-telemetry studies have been conducted.

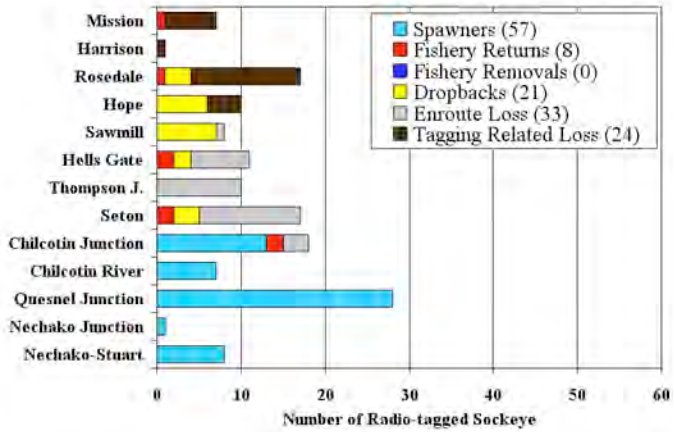

Figure 17. Final distribution of 143 radio-tagged summer-run sockeye, 2009.

Our data show that in most years en-route losses of summer-run fish were exposed to significantly higher temperatures than those that were detected in spawning areas. However, in some years (e.g. 2009) successful migrates experienced higher temperatures than the en-route losses in other years. Therefore, elevated water temperature alone does not determine the extent of en-route losses and it is likely that other factors such as fishing pressure and migration challenges (e.g. Hells Gate and Bridge River Rapids) combine with elevated water temperatures to produce the observed results.

Run Reconstruction Analysis

We are also integrating this information with the catch and escapement data for each of the Conservation Units (CUs) of Fraser sockeye with the goal of rebuilding and reconstructing stocks. The data for migration parameters provide information about run timing from Mission, fishery residence times and en-route losses from radio telemetry. Information about en-route losses is critical in order to determine the correct harvest rates for the different stocks; in some years as much as 60 – 80% of the fish entering the river have not made it to the spawning grounds. Figure 18 shows the harvest rates for 25 CUs for 2006. These are preliminary estimates of the in-river harvest rates, based on our run reconstruction analyses. They range from very low rates on the early Stuart and Chilliwack stocks (that do not go through many in-river fisheries) to higher rates on the summer runs.

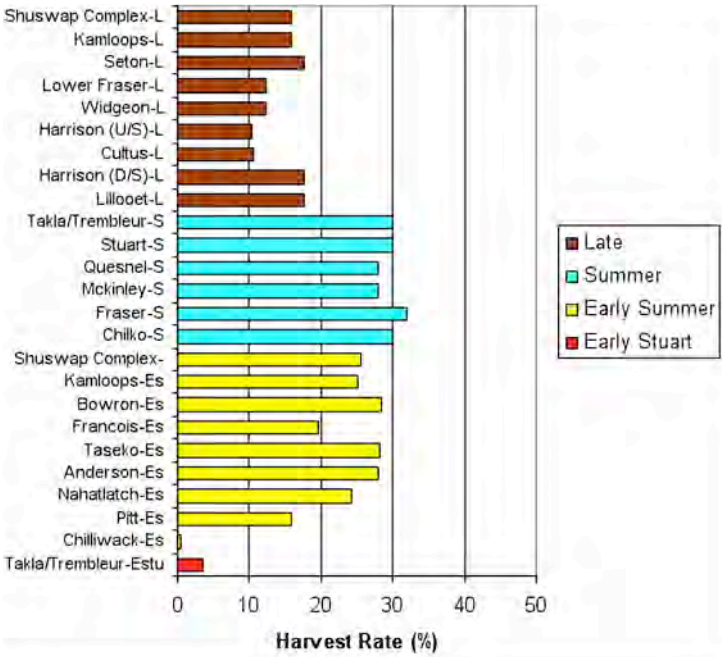

Figure 18. Sample run reconstruction results. Harvest rate by Conservation Units (CUs) for Fraser River fisheries in 2006.

Every stock is different; each has a different migration rate and is exposed to different fisheries. This is taken into account in these analyses.

Conclusions

Fishwheels

From the fishwheels at the Crescent Island site we have demonstrated that fishwheels can be an effective selective fishing gear in the lower Fraser River. Catch rates can be very high, particularly for pink salmon, and samples of near shore species composition are likely more reliable than those from other types of sampling gear that are less efficient. Fishwheels are not an effective gear for sampling species compositon in off-shore areas where drift gillnets are more effective. The combination of using the Whonnock gillnet test fishery data, the fishwheel data and the spatially stratified Mission hydroacoustic counts provides the data needed to produce a reliable estimate of escapement for sockeye. The Qualark hydroacoustic counts provide cross-verification of the Mission counts and will be a productive tool in the future.

En-route losses due to temperature

It is becoming very clear that there are significant en-route losses related to higher water temperatures during migration. We can identify the particular timing and locations of the river where these losses and migratory challenges are occurring.

Run reconstruction analysis

Finally, all catch, escapement, migration rate and en-route loss data need to be integrated into annual run reconstruction analysis to derive reliable run size and harvest rate estimates for Fraser sockeye CUs.

Plans for 2010

The Crescent Island fishwheel work will be continued, providing information about daily near-shore species composition, and collecting weekly DNA and biological samples. We will also be radio tagging Early Stuart sockeye caught in the lower Fraser fishwheels and tagging the other run-timing groups in marine waters where water temperature are much cooler than those for in-river locations in late July and August. We plan to continue the assessment of en-route losses and use additional fixed-station receivers, mobile tracking, and catch sampling data at key locations in the river to assess the reasons for en-route losses. We will also continue our work with First Nations, DFO, the PSC, and universities and other organizations, on sockeye run reconstruction analyses.

DIALOGUE

The value of the commercial fishery providing indicators of run size

A commercial fisherman participant posed the question:
It seems to me that there is a wealth of knowledge that has been lost due to the failure of our actual fisheries. I am speaking about them in an historical sense where there was a more reduced catch rate over a longer period of time in the marine approach areas, which we no longer have. And I was thinking about their value as indicators of run size; they were superior to our current system of sporadic test fishing and then mystery fish loss in the river and then counting fish on the spawning grounds. I challenge you that if we had found some way to keep a small commercial fishery operating through the decline, we would have been able to have a more accurate idea of what was coming back -- not two years in advance of the run, but certainly within a month or two in advance of the spawning. The commercial fishery itself is partly to blame. Perhaps we weren't flexible enough at the time and able to reduce our fleet down to a

small enough size where you would have a manageable impact while you were gathering data. But there is also some blame to be borne by the Department. They did not play a large enough leadership role and now there is such a large gap in the commercial fishery, that I am not sure whether we could get it started up again to provide the same tool. I challenge you learned folks: Wouldn't it be better if we had some steady data from the marine approach areas on a week to week basis?

Mike Lapointe:
First, you are right in that up until about 1994 when we had regular commercial fisheries every week, the relationship between the catch and those commercial fisheries was a very good predictor of abundance. Now that we have test fisheries, we are catching a much smaller fraction of the run and there will be a lot more variation in the predictions from those test fisheries.

You are also right about the flexibility to have those fisheries; for example, the best predictors were the seine fisheries in Johnstone Strait. The reason that those fisheries were good predictors is they moved about 60% of the run that was available to them over that six-day migration. One of the things that has limited the capacity to have those fisheries, of course, is the very high risk, particularly in this environment of declining returns. If we had been able to have small bite type fisheries with a smaller number of boats, then we might still have that continuous time series.

I suspect that five or ten vessels would probably do a much better job than one vessel would. But it is a challenge to fit those in, in the context of the current environment. In fact, there were times in the late 1990s when we actually recommended to the Fraser Panel that they increase the catch (we were calling them test fisheries at the time but they could have been caught by commercial fishermen) to improve the accuracy. The idea of improving the catch in a test fishery when very few people were going fishing was not particularly appealing to fishermen.

This could be very valuable if there were some innovative ways to do that. But it has to fit into the structure of the management in terms of allowable harvest and available commercial harvest, if it is a commercial fishery. That has been the major hindrance. I do see progress being made in terms of being able to structure fisheries in smaller ways and maybe there is a way there to get those regular fisheries happening again so as to have a regular predictive tool. This is what John Henderson was referring to when he was talking about the seaward fisheries and how if they don't get those fish in those first time periods, then the fish are gone.

For those people who are harvesting marine areas, whether they are First Nations or commercial, if they have to wait for the peak of that run to hit Mission, that may be a week later, and by that time, when that fishery is opened, those fish have swum past the area where, in an allocation sense, if there was a harvestable surplus they would have preferably been caught. It is definitely a challenge and a very good observation on your part.

A fisherman participant directed a question to Mike Lapointe:
Test fisheries are kill fisheries using a gillnet fishery in Juan de Fuca and gillnet and seine fisheries in Johnstone Strait. Last year we killed around 20,000 fish in these test fisheries. What are we going to do with test fisheries in the future? Are we going to have another large amount of sockeye killed in test fisheries or are we going to start thinking about a way of enumerating the fish coming in, using a different method?

Mike Lapointe:
Last year's catch of Fraser River sockeye in test fisheries was about 30,000 pieces. The gillnets are used primarily because some of these populations, particularly early Stuart, early summer and summer runs are fairly disbursed in their migration patterns. We find that we can get a much more consistent

index of abundance if we use a gillnet than if we use a seine. Once the summer runs arrive we do use purse seines and most of those fish are released with a small number being killed for samples or some other use. So it is the gillnet catch that accounts for much of the 30,000; the Juan de Fuca seine catch, for example, was around 900 sockeye last year. The only other way to gather the same information without killing these fish that I am aware of is with the use of marine hydroacoustics, and this is still at the experimental stage. Even marine hydroacoustics doesn't tell you (a) whether it is a sockeye, and (b) what stock it is.

When I am asked this question I turn the question back and say, "If we hadn't caught those 30,000 fish and we didn't have those in-season assessments, how might the fisheries have been conducted on that run with a ten million expectation? My argument is that 30,000 fish was an investment in the conservation of this resource and without that we might very well have been out there and caught a whole bunch of fish in commercial fisheries and then later be sitting here asking: Why did we fish so hard?

It would be good not to have to kill fish, but until we have another tool that we can use that can do as good a job or better, this is all we have. All we can do now is minimize the kill and we do that by releasing the seine-caught fish and trying to take only the number of fish that we need for samples.

Using jacks to predict returns

A fisherman participant directed a comment to Randall Peterman:
Before the 1950s fishermen used to do the enumerations every year in their way; that is, by looking at jack sockeye which are returning one year earlier. If for example I saw a lot of jack sockeye in the fish counter the year before, then I would plan to buy a new net for next year as I anticipated a very large run on the Fraser River. I want to note that fishermen in the past did have a way of predicting runs and some very successfully; we predicted the 1958 large run for example.

Randall Peterman:
What you are describing is the sibling model, where you forecast the number of age four next year as a function of the number year as they came back this year. This model has actually performed fairly well in the past but in recent years the age structure has changed dramatically such that the jack returns are not a good index of age fours.

Can we explain the decline in productivity and what will the future hold?

David Welch addressed a question to Mike Lapointe:
If you look at the productivity, it seems to have been declining since the early 1990s and this trend is still carrying on. You have broken it out by stock groupings or stocks in some cases and I still see the same thing although it is more variable for an individual population. Do you want to comment on that and the specification is what has driven it over that 20-year period when there have been fairly large cycles in climate? and, Where is it going to go in the future?

Mike Lapointe:
I think that is part of the reason that we are here. There have been a lot of changes going on since the 1990s. A lot of what is pulling down the plots in recent years can be attributed to two very extreme years, 2009 and 2007. But that does not necessarily help you decide what is going to happen in the future. I would point out that these are cyclical events. I don't think we are going to return to the kinds of productivity that we saw in the 1990s.

On the other hand, if you look at the Chilko marine survival rate this year it is four fish out of every thousand. The previous 50-year low was 12 fish out of a thousand. The recent year average is 50 fish out of a thousand and the long-term average is 90 fish out of a thousand. Therefore, while I am not suggesting that we are going to get back to 90 fish out of a thousand (or 9%) level, we do not have much farther to go down beyond

the 4 per thousand level. These extreme events then are really pulling down the productivity. I don't think it will get much worse, but I also don't think it is going to return to what we had before. What is causing this? I do not know.

A participant directed a question to Mike Lapointe: We have heard about differences between Harrison Rapids fish and the other stocks in the Fraser. Could you speak to any other variation in juvenile salmon ecology within the remaining 18 populations that you have long-term productivity estimates for?

Mike Lapointe: There is a huge diversity of populations in the Fraser. Three of the populations have spawning channels: Weaver Creek, Gates Creek and Nadina, so they obviously have a buffer on the freshwater side in terms of their productivity. Another population, Widgeon Slough, is actually not doing very well. But, probably half to two thirds of that population has a very similar life history to Harrison and, in fact, they spawn probably within around 3km of each other.

When we looked at the plots in my presentation and that of Randall, with the column and filter results by geographic region there was nothing that really jumped out in terms of differences. There are so many different sources of variation. The coastal populations like Birkenhead and Pitt do tend to produce more age-five fish and they are much more susceptible to coastal flooding. Those populations seem to have a strategy that is like bet hedging where they distribute their returns across two returns as opposed to one, probably in response to the sporadic influence of flooding.

We have to change the way we do forecasts.

A participant commented: One of the specific objectives in the program was to determine if forecasts provide useful information to fisheries managers. Randall Peterman answered this in part noting that about the best we can do is 36% accuracy. My hope is that this information gets communicated out a lot more widely. The analogy to weather forecasting is a really good one. Salmon forecasting results would not even show up on that graph because there are so many tools used for weather forecasting.

Mark Angelo started off this morning by saying that salmon are an icon. I made the point earlier that I think we know who Colonel Mustard's culprit is, it is 'us', and I know many people would agree with this. Why do we do forecasting? We do this for 'us' so we can go fishing. That is the simple truth.

The concern I have is that we say we have to kill fish for conservation. If we are doing the forecasts to go fishing, which is important as people have been doing this from time immemorial, then the forecasting that we base that on has to have a certain amount of accuracy. In a number of the plots in presentations we saw various populations, such as the Bowron, with significant trends of decline. But we don't really know about those populations.

Chilko and Cultus sockeye stocks come up because they are really the only lakes that we look at. We only look at a couple of the other stocks and then extrapolate those results out. Based on that observation, I would say that it is probably nearer to 1 – 2% percent in accuracy of forecasting. If we have been basing our forecasting on how many fish we can take, and if we have made errors because the fishing has gone on too long, then we have to take a very serious look at what we are trying to do here.

For those runs described by Mike Lapointe as a silver lining, we need to remember that there are people in the upper watershed that depend on them. For example the Klay-Klay [ph] people have had voluntary closures on the Bowron for years, and yet they depended on those fish for thousands of years. I believe that there is no silver lining. There are people who depend on the smaller populations that we generally never look at. Last year my brother-in-law who belongs to the Haida Nation got a total of seven fish, and that is on Haida Gwaii which is supposed to be a place of plenty.

I think we should point to the assumptions on which we base our pre-season forecasts. We should listen to the fishermen who are out there all the time. There is a huge base of knowledge, settler, culture, commercial fishermen and First Nations alike that could

help with this, not so much basing it on scientific models that are based on so many assumptions that it becomes a paper fish exercise.

When I lived in the Yukon I worked for the Na-Cho Nyak *Dun* First Nation. And an elder from Old Crow came down to the meetings that I was at with the Yukon Salmon Committee. Now, Fishing Branch River is a river to the northeast of Old Crow and it is called Fishing Branch River for a good reason. It used to have a huge run of chum on it and in the late 1990s and early 2000s that chum run collapsed. Throughout that same area, that community depends largely on the porcupine caribou herd that migrates back and forth. When that chum run collapsed, caribou biologists started to see a very large grizzly bear predation increase on the caribou herd. Because the chum had collapsed, the main food source for the grizzly bears was gone, so they had to go to the porcupine caribou. That does not fit into anyone's models because we don't look at this kind of information.

Finally I want to address the management adjustment that was added, the 100,000, and note that the one thing I never see in there is the bears' food? It is a huge proportion of the food. We would like to take a look at this. The whole way of forecasting has to change. We are only talking about one species of fish, sockeye. There are currently 70 people listed on DFO's Integrated Fisheries Management Plan. How much money was spent on that planning and how much money did commercial fishermen make in the last three years? I think there are more funds directed to building models than to actually protecting the fish.

A participant commented:
When I attended the International Fisheries Commission meeting in 1974, BC was a laughing stock in terms of salmon management, as we were managing fish by intercepting the stocks in the sea as compared to close to the river mouth. Other successful salmon nations managed close to the river mouth, making certain they have escapement first and then allow fishing to take place. BC has allowed our fishing industry to set the policies and standards. Maybe we need to step back and look again at how can we assure escapement first. Most of BC river systems have been depleted of salmon and we need to start rebuilding the stocks one river at a time. That can only happen if protection and escapement come first.

ADULT SOCKEYE SALMON: CHALLENGES TO COMPLETE THE JOURNEY AND SPAWN

Scott Hinch, Professor, Institute for Resources, Environment and Sustainability and Department of Forest Science, University of British Columbia

This presentation focuses on the following topics: ocean conditions matter for migrations; populations are unique, with an emphasis on a physiological perspective; entry timing and the relationship between physiological condition of fish and entry timing; and, warming temperatures and possible predictions under some scenarios of climate change.

Ocean conditions matter

The graph in Figure 1 shows the relationship between the terminal ocean weight of Early Stuart sockeye when they arrive at the mouth of the Fraser and the June-July zooplankton biomass measured at ocean Station 'P'. As Skip McKinnell mentioned above, it is difficult to get these types of information now because there is very little research conducted in the ocean.

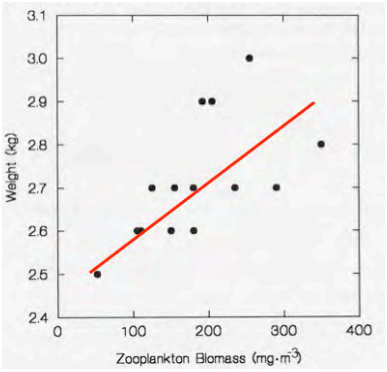

Figure 1. Relationship between terminal ocean weight of Early Stuart sockeye and June-July zooplankton biomass at ocean station P. The Pearson correlation was 0.615 (P= 0.019; n = 14, 1967-1989, inclusive) Hinch et al 1995.

Fraser sockeye starting up-river migrations tend to be heavier when ocean food is more abundant. This is important because

their weight at the start of the river migration is one factor that determines whether or not they are able to successfully migrate. Also, body weight is proportional to fecundity.

Another thing that tends to be overlooked is the role of energy in these fish. The graph in Figure 2 shows the relationship between sea surface temperature and the North Pacific Index of upwelling and the gross somatic energy content in the bodies of these fish. This is a very important component of stock-specific differences.

Note that there is a 20 – 25% difference in gross somatic energy between stocks at the beginning of the migration. Keep in mind that these fish stop eating some time before they get to freshwater so they are fueling their migration and development and spawning with their energy reserves. In constructing this graph we were able to import some historical data from the late 1950s and integrate it with some more recent data. Note that for Early Stuart (red dots) and Chilko (white dots) sockeye in years of the higher North Pacific Index values the fish come back with higher energy densities. Conversely, when sea surface temperatures are warmer, they come back with lower energy densities. Again, this is a reflection on the fact that what goes on in the open ocean, particularly during the final migration phase, is probably very important when it comes to energy density and that will affect river migration.

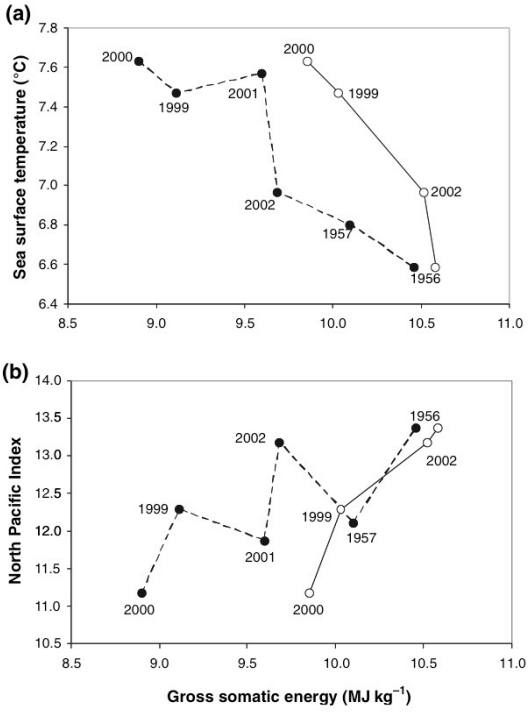

Figure 2. Body energy of Early Stuart (dark circles) and Chilko sockeye (open circles) at the onset of upriver migration in relation to sea surface temperatures (a) and North Pacific Index values (b) averaged over the last 6 months of ocean residence. Crossin et al 2004.

Populations are unique

Not surprisingly, salmon populations are unique in many different ways. We know, for example, that there are many Fraser stocks and a number of different Conservation Units (CUs). They migrate very different distances (100 – 1,200 km) to spawning areas and they have very different annual spawning abundances (100s to 1,000,000s). They also differ in terms of their physical characteristics, such as size and shape. In our studies on salmon we have examined energy density at the start of migration, fecundity, swimming performance as adults, and heart morphology and other characteristics in different stocks. The results of these studies provide a very compelling story that suggests that all of these things vary in such a way that suggests that they have specific adaptations for completing their river migration and spawning.

If you characterize these runs into different categories, difficult migrations, not so difficult and relatively easy migration, you will find that the adults that have long distance migrations or high elevation spawning areas share a suite of characteristics. They have relatively small torpedo-shaped bodies and high body energy at the beginning of migrations and they have few and small eggs in a relative sense. They have high maximum swimming speeds and they tend to have much more efficient hearts. They also have a large and broad metabolic scope. What this means is that these difficult migration stocks are built for high performance for energy conservation.

Assessing physiological parameters

One method of determining physiological traits in salmon is to expose them to swim tests. This occurs in swim flumes or tubes that operate like aquatic treadmills. The water is pushed through the tube or flume at speeds up to 2.0 to 2.5 m per second. These are closed systems so the oxygen consumption of the fish can be measured. These data allow us to develop curves such as in Figure 3.

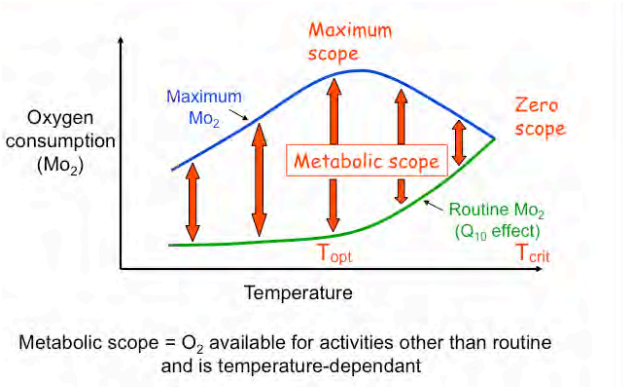

Figure 3. Metabolic scope in relation to temperature.

This graph shows the relationship between oxygen consumption by fish relative to water temperature. When a fish is at rest the value is referred to as the 'routine MO_2'. If the fish is forced to swim against the current as hard as it can then more oxygen would be consumed, and it would reach the value described as the 'maximum MO2'. The difference between the two curves is described as the metabolic scope; that is, the amount of oxygen in the blood that is available for activities other than routine. The graph also demonstrates that this value is temperature dependent. Note in the middle of the graph that there is a maximum relationship between metabolic scope and temperature and at the end the relationship is close to zero. These are described, respectively, as the temperature optimum, where they have the most scope for activity, and the critical temperature, where they can no longer swim.

These relationships can be developed for different stocks. Figure 4 shows the metabolic scope temperature profiles for three different Fraser salmon stocks: Gates Creek sockeye (summer run), Weaver Creek sockeye (late summer run) and Chehalis coho (fall-run).

Note that the optimum temperature (T_{opt}) and the critical temperature (T_{crit}) shift to the right from fall-run coho to the late-run sockeye and then they shift further to the right for the summer-run sockeye. These are the temperatures at which the fish would no longer be able to migrate. For Weaver Creek sockeye, that is around 20 °C, for fall-run coho it is around 17 °C, and for Gates Creek summer-run sockeye it is close to 25 °C. These are temperatures at which the fish are functionally dead. That is not to say that the previous temperatures are not going to be stressful and lethal as well - it just may take longer to kill the fish. Clearly then, T_{opt} and T_{crit} vary among stocks. This has been demonstrated with other stocks as well. It is important to note that there is actually a very narrow temperature range between these two measures; that is, there are only about 5 or 6 °C between what is the best and what is the worst.

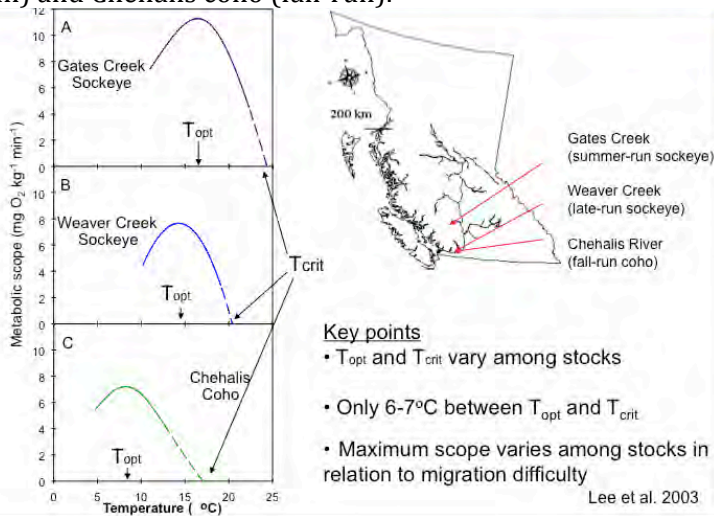

Figure 4. Metabolic scope temperature profiles for Fraser salmon stocks: Gates Creek sockeye, Weaver Creek sockeye and Chehalis coho.

This graph also shows that maximum metabolic scope varies among stocks in a way that is related to the migration difficulty. For fish that do not have to travel very far, such as the Chehalis coho or Weaver Creek sockeye, the scope is not as high as it is for fish that have to travel farther such as the Gates Creek sockeye that also have to deal with the Fraser Canyon and other rapids and obstructions. In this case, they need a much broader and higher metabolic scope to be able complete a successful migration.

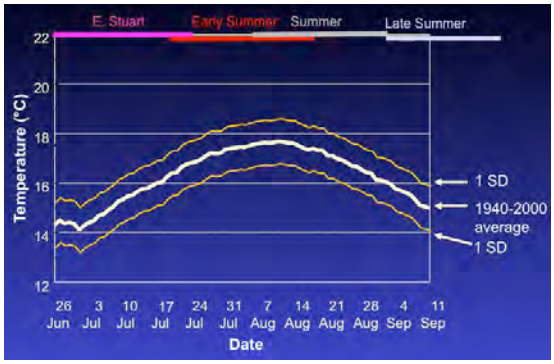

Figure 5. Historical Lower Fraser River thermal conditions, June to September, 1940 – 2000.

The question is: Why have the values for T_{opt} shifted to the right and why have the T_{crit} values shifted to the right? The answer to this question has a lot to do with what temperatures these stocks normally encounter, historically. The graph in Figure 5 is an historical thermograph for the Fraser River going from June to September from 1940 - 2000.

The run timing groups are added on the top horizontal axis. Note that the Early Stuart sockeye and late summer sockeye encountered lower temperatures, compared with the early summer and summer sockeye runs. We contend that these groups are adapted to dealing with these particular temperatures.

To convince you of this, observe the graphs in Figure 6. Here the historical temperature data is overlaid on the metabolic scope plots for each of the three stocks described above. The agreement between where the historic river temperatures fall and the metabolic scope is striking.

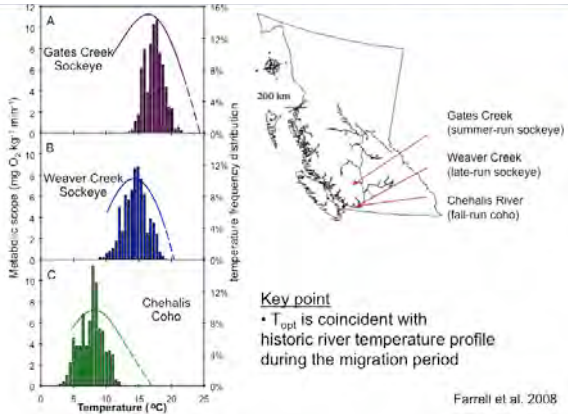

Figure 6. Metabolic scope temperature profiles for Fraser salmon stocks and historical lower Fraser River thermal conditions.

Entry timing and physiological condition

The main focus here is the early migration of late runs. This is a phenomenon that we have been studying for about five years. Since 1995 to the present, we have seen segments of all the late-run stocks migrating four to six weeks earlier than usual. They tend to migrate down the coast at typical times but the normal estuarine holding behaviour, which is what this four to six weeks is, seems to have disappeared or has shortened significantly. Correlated with this early migration has been extremely high mortality in freshwater.

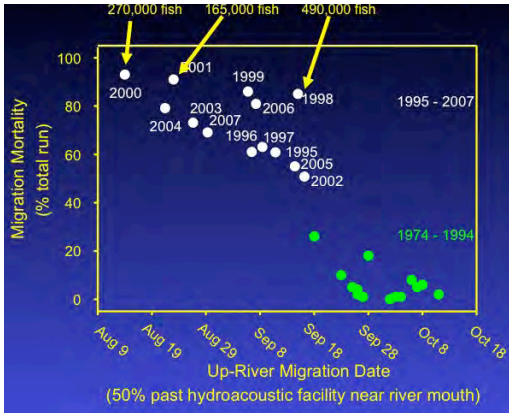

Figure 7. Migration mortality in relation to up-river migration date for Weaver Creek sockeye.

An example is provided in Figure 7, which shows the relationship between the up-river migration date and migration mortality for Weaver Creek late-run sockeye. With 50% of the population moving past the Mission hydroacoustic facility we can calculate the migration mortality as the percentage of the total run getting to the spawning

grounds.

In the early period from 1974 to 1994, there were relatively late migratory periods and relatively low migration mortality. In the recent period there have been much earlier migrations into the river for a significant proportion of the runs, and much higher mortality. In 2008 the migration mortality was close to 100% of the total run, and it was one of the earliest runs ever. Notably, this involves significant numbers of fish; in some years 200,000 to 500,000 fish.

A large inter-agency and inter-university program was instituted in 2002 focusing on the questions: Why are these fish migrating early? Why are they dying at such high levels in-river? and, What is the relevance to other runs and species?

Why are these fish migrating early?

Study methods

To answer this question, fish were sacrificed and sampled along the ocean and freshwater migratory routes for physiological and genomics information. In these studies a total of about 4,000 fish were sampled. Fish were also implanted with radio and acoustic telemetry tags and biopsy assessments were made on individual fish. Biopsy telemetry involves taking small blood and tissue samples before the fish are released. This provides a measure of condition so that the fate of an individual fish can be related to its condition subsequent to release. About 2,000 fish were tracked in this way. Temperature loggers (iButton) were also attached to each transmitter to provide a thermal trace on where the fish were tagged. Fish were tagged near Haida Gwaii, in Johnstone Strait, and in the Strait of Juan de Fuca and information was also obtained from other tagging programs in freshwater with Karl English. In addition a suite of swim performance and migration experiments were performed in the laboratory.

This work has been integrated with the work of POST (Pacific Ocean Shelf Tracking) (see David Welch, page 17). Figure 8 shows the location of the POST arrays, telemetry lines, stations and adult tagging sites, on the coast and in the Fraser. There are a series of radio receivers as well in the watershed so that although we were tagging with radio tags and you cannot detect these tags in marine environments, we were able to pick them up when they came into the freshwater. Acoustic tags can be detected immediately on the POST lines.

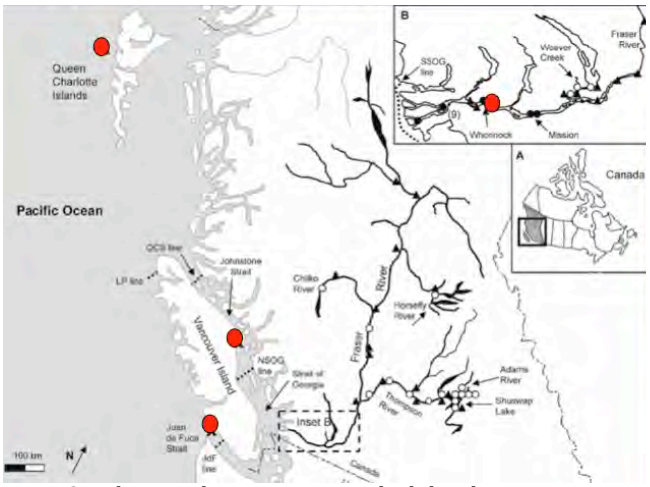

Figure 8. Telemetry lines, stations and adult salmon tagging sites for the Fraser salmon.

Results

The biopsy telemetry results revealed that early migrants are physiologically stressed; they have high levels of stress indicators. They are also more reproductively mature and in addition they have a dysfunctional ion regulatory system.

The reason for the early migration is not clear. There is evidence supporting environmental hypotheses including changes in upwelling in the open ocean and changes in salinity levels along the coast. There are also hypotheses that are supported by strict physiological interpretations and some behavioural hypotheses dealing with abundance changes in summer runs and how late

runs may be behaving more like summer runs. There is evidence to support all of these hypotheses.

Advanced maturation

Advanced maturation is a physiological signal that must have changed some time earlier in the lifecycle, not during the return migration along the coast. It probably happened in the open ocean or earlier during their outmigration. The fish are either changing internally as a result of something they experienced or there is something external that is causing them to start the maturation process earlier. We do not know the answer to this yet. One thing that is clear, however, is that en route mortality in the river is associated with higher than usual river temperatures.

Warming temperatures and climate change

You can think of thermal based mortality in a series of ways but it helps me to think about it in terms of things that kill fish quickly and things that kill them slowly (Figure 9).

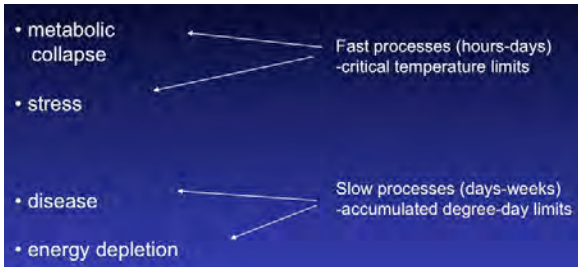

Figure 9. Potential causes of thermal-based salmon migration mortality.

The fast processes include things that would occur in hours to days, such as a metabolic collapse or physiological stress that can cause that to happen if it gets to critical levels. This information can be converted to critical temperature limits to give some insight into the relationships. The slower processes will occur over days to weeks. These can be measured through accumulated degree-day limits and those would be indications of disease and energy depletion, both of which could well be happening. In most years when we see fish dying, it can be due to a little of this and a little of that – it is difficult to tease the causes apart.

Building on the information presented in Figure 5, the graphs in Figure 10 show the metabolic scope for Gates Creek and Weaver Creek sockeye runs. What happens when we overlay a warm year on these graphs? The year 2004, the last big enquiry year, was a relatively warm year. When we lay on top of that the warm year temperature exposure what you see is that it exceeds the critical temperatures for the Weaver Creek run, and a significant portion of their run, but it does not do this for the Gates Creek run.

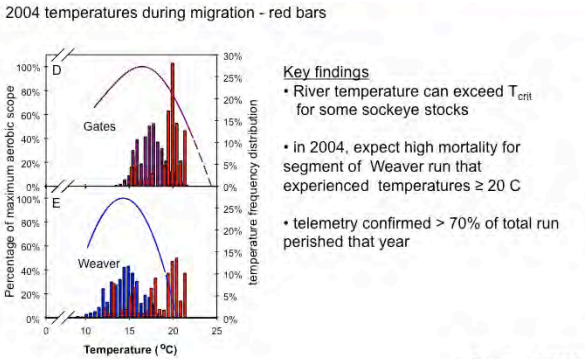

Figure 10. Maximum aerobic scope and temperature frequency distribution in relation to temperature in 2004 for Gates Creek and Weaver Creek sockeye (Farrell et al. 2008 Mathes et al. 2010).

What this tells us is that river temperatures can exceed the critical limit for some sockeye stocks in some years at some portions of their migration. In 2004, by looking at the data, you would have expected to see high mortality rates for that segment of the Weaver run. Based on the telemetry work we carried out on the Weaver Creek run that year we found that 70 % of the run perished after they were tagged in the Harrison River. This is not to say that that was the only cause of mortality. Temperatures close to the T_{crit} are going to be very stressful.

The question is: How stressful? The results of the laboratory holding experiments shed some light on this. In these studies, we collected fish when they came into the Fraser and brought them back

to the laboratory at the DFO Cultus Lake facility, and then held them in large tanks where we could simulate migration under different thermal and stress conditions.

Figure 11 shows the data from those types of experiments. The mortality is on the vertical axis and the number of days the fish were held is on the horizontal axis. This relationship was plotted for a number of different temperatures.

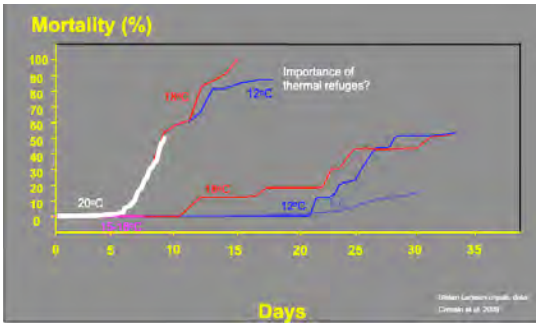

Figure 11. Results of laboratory experiments with late run sockeye showing mortality as a function of river migration duration at different thermal regimes (Larsson upub. Crossin et al. 2008).

The bar below the horizontal axis represents a typical river migration duration for a late-run sockeye. If the fish are held at 15 or 16 °C and then transferred to 8 °C water, they survive throughout the entire river migration duration. If the water is warmed slightly to 12 °C, there is no difference. However, if the fish are brought in at 15 °C and the water is then warmed to 18 °C, some mortality appears and by the end of the river migration the mortality rate may be as high as 20%. If the fish are held for even longer, enough time for them to have been on the spawning grounds for a few weeks, there would likely be further mortality. If the fish are brought in and put in 20 °C water immediately, after a week and a half, there is 50% mortality and even if they are cooled it does not change the trajectory for the mortality rate.

When we took some of the fish and serendipitously put them in a cold-water tank the mortality stopped (blue line). This led us to think about the importance of cold water refuges (see below).

Migratory Disease Issues

Fish are subjected to a number of diseases during their migration, including parasitic, bacterial and fungal infections, all of which are temperature dependent. In the years when temperature appears to have a stronger effect than in other years, even though it is the same temperature, it may well be related to the particular year and the particular diseases that occur in that year. In 2004 there was clear evidence of bacterial infections in returning fish, Columnaris disease being one of them. There were also fungal infections observed in migratory fish, particularly *Saprolegnia*, which normally does not appear until the spawning grounds. Columnaris was also observed in 2008 on Weaver Creek and Harrison sockeye.

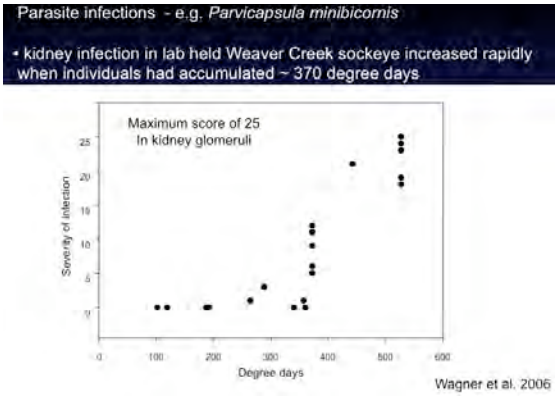

Figure 12. Severity of kidney infection in laboratory held Weaver Creek sockeye in relation to degree days.

Another parasite, *Parvicapsula minibicornis,* is a naturally occurring kidney parasite that is picked up by all migrating sockeye as they move into the lower Fraser River. It is an estuarine parasite that has an intermediate host. Figure 12 shows the results of our research to determine the severity of this infection in laboratory-held fish after they have been held for several days.

A degree-day represents the number of days multiplied by the number of degrees that the fish have been exposed to the temperature. Note the rapid increase in the severity of infection at about 370-degree days. That is the time when these fish would be getting onto the spawning grounds, if these were Weaver fish.

At the same time as we were conducting these studies, we brought fish back to the laboratory and looked at their cumulative mortality against degree-days (Figure 13). Again, the cumulative mortality increased significantly between 300 and 360 degree-days. If this was a real fish migrating, it would be the time when it would be getting to the spawning grounds. By about 500 degree-days the mortality is very high.

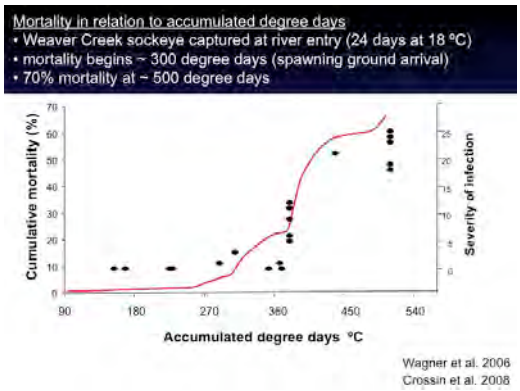

Figure 13. Cumulative mortality and severity of infection in relation to accumulated degree days for laboratory held Weaver Creek sockeye.

Note the concordance between the severity of infection and mortality rates. This suggests that thermally mediated diseases are playing a significant role in causing mortality as these fish move towards spawning grounds and they certainly play a role in fish that are dying on the spawning grounds.

The importance of cool-water refuges

The graph in Figure 14 represents the thermal experience of one Adams River sockeye in 2006, collected from its recovered temperature logger (iButton).

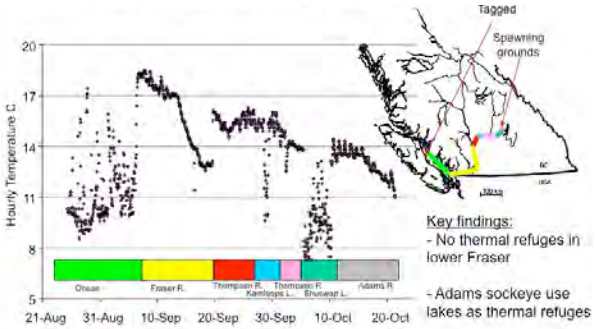

Figure 14. Thermal experience of an Adams sockeye from point of tagging to arrival on spawning grounds in 2006, as measured from a recovered temperature logger.

These data were collected from the one fish that was tagged in Johnstone Strait and was recovered on the spawning grounds. Note the wide range of temperatures the fish experienced in the ocean, in fact, almost across its complete metabolic scope. This would have occurred because it was encountering freshwater inputs as it was migrating and it could have been going deep. Information about the depth was not available. The temperature could also be influenced by tides. What we do know is that when the fish arrived at the Fraser River it had no choice but to come into water that was very warm compared to what it encountered just a day before. As it was migrating up river the fish experienced cooler temperatures because the river was cooling. Late run sockeye always encounter declining temperatures. When the fish got into Kamloops Lake, it went to the bottom of the lake. The same thing happened in Shuswap Lake, where it likely resided for a period of time. This suggests then that although there are no thermal refuges in the Fraser main stem, the Adams sockeye are using the lakes as a thermal refuge.

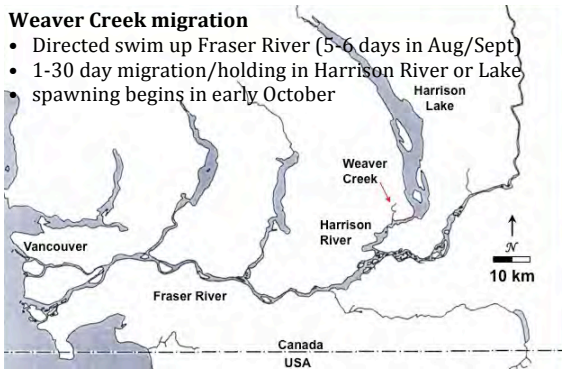

Figure 15. Map of Fraser River showing location of Weaver Creek and Harrison Lake.

You could say that they have to get through there anyway and maybe it is not a refuge, but just happenstance that they are passing through the bottom instead of the top. Another study was conducted with Weaver Creek sockeye. These fish have to migrate up the Fraser into the Harrison and fish that get there early may have to wait from 1 – 30 days in the Harrison River or move into Harrison Lake (Figure 15).

Those fish that move into Harrison Lake generally all go deep. These fish, however, do not have to go into the lake. They have a choice. They can stop on the Harrison River right in front of their home spawning area and wait there and have high temperatures. Or they can go into the lake, go deep to 80 to 120 metres, and experience temperatures of 8°C and spend 80% of their time down here.

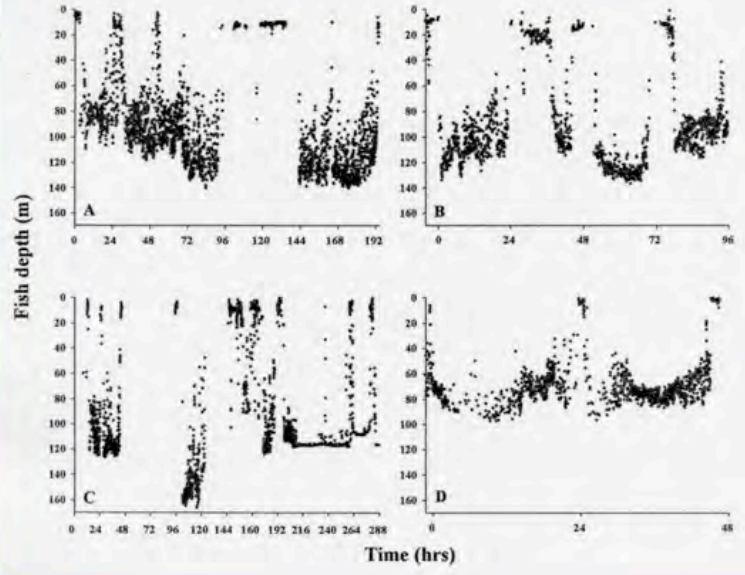

Figure 16. Hourly depth profiles for Weaver Creek sockeye 'holding' in Harrison Lake.

Figure 16 shows the hourly depth profiles for four Weaver sockeye 'holding' in Harrison Lake. Of all the early migrating fish in 2004 that came back to the Weaver, only those early migrants that went to the lake survived to reach the spawning grounds.

Clearly there are thermal issues for the Fraser River migration. To begin with, river temperatures are increasing. Since the 1940s, there has been about a 2% increase in peak summer water temperatures. Climate models predict another 2 °C warming. Recent years have had extreme (record) high temperatures. The graph in Figure 17 provides an example of that. Note that in 2004 significant portions of the average temperature data were above 18 °C.

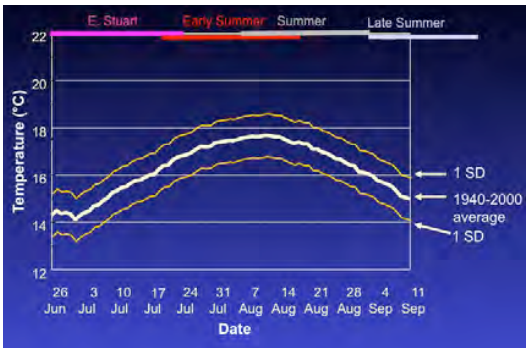

Figure 17. Historical Lower Fraser River thermal conditions from June to September compared with thermal conditions in 2004.

Also, late-run fish are now coming back much earlier, so that they are now not only experiencing warmer temperatures because of climate change, but they are also experiencing warmer temperature because for some reason they are coming into the river earlier and thus encountering 5 – 7 °C warmer temperatures than they once did.

With predictions that climate change will result in further increases in temperature, what does the future hold for Fraser sockeye? The graph in Figure 18 shows the predicted 60 to 80 year average temperature for the Fraser River between June and September. Note that the plot for 2004 temperatures seems to coincide with this average.

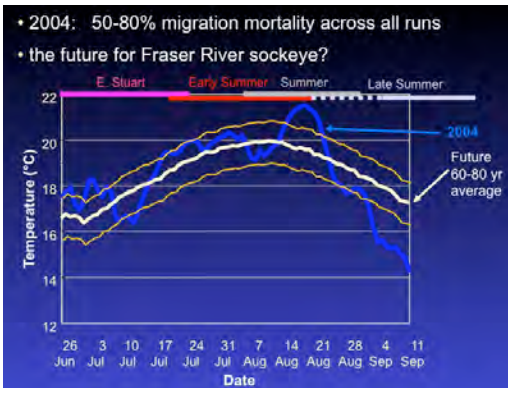

Figure 18. Predicted 60 to 80 year average temperature for the Fraser River between June and September.

Model Average Survival Analysis

Taking all the telemetry data together from 2002 to 2007 (minus 2004 when no telemetry data was available) a model average survival analysis was conducted. The data were collected from fish migrating up river carrying transmitters that were released in the ocean and returning to their natal watersheds. Figure 19 shows stock by stock what the relationships were with encountered temperature, based on known temperatures in the river at the time they were passing those sites.

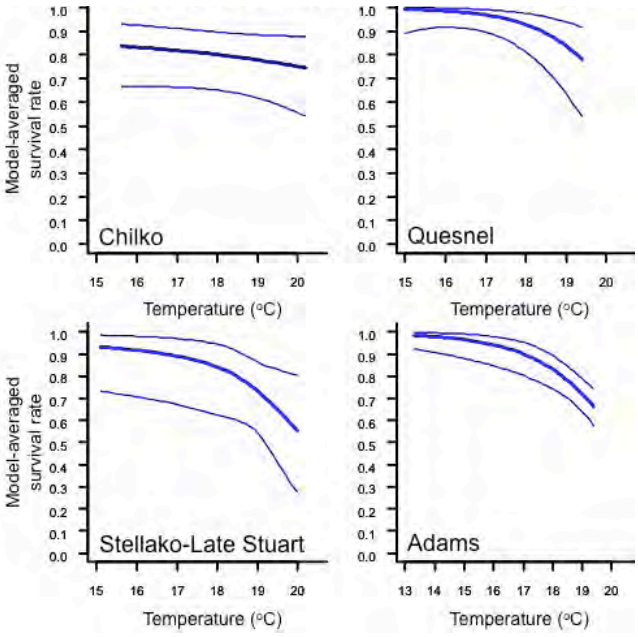

Figure 19. Survival rates (+/-CI) to natal rivers for Chilko, Quesnel, Stellako Late Stuart and Adams sockeye implanted with transmitters, in relation to encountered Fraser River temperature, 2002 – 2007 (Martins et al. 2010).

Note that there are stock-specific differences. Interestingly, Chilko runs appear to be relatively invariant to temperature changes, at least in the Fraser. These fish have the broadest metabolic scope of any of the sockeye stocks that we have studied in the Fraser. On the other hand, the Adams sockeye respond quite quickly to warmer temperatures and by 16 °C the survival rates decline relatively quickly. We do not have any data in the field above 20 °C because the fish are dying rapidly.

Any predictions we are going to make based on these data in relation to potential climate change effects are going to be quite conservative. We know from climate models that we are going to see a continued increase in temperature; summer runs are going to experience about a 2 °C warming. Late runs will experience about a 5 °C further warming if they maintain the early behaviour pattern. If they revert back to normal time behaviour, then they will not encounter much warming at all because they will be late enough in the season that the temperatures will not warm as much.

These temperature predictions can be applied to the survival rate data observed in Figure 19 and some predictions suggest that average survival rates will decline by about 15% in Quesnel and Stilako, but only by about 1 % in Adams, if they migrate back at their normal times, or by about 16% if they are early.

Summary

We can expect a warmer less productive Northeast Pacific Ocean in the future and a reduction in preferred thermal marine habitat. This will result in poor ocean survival. There will be smaller mature fish with less energy. There will be warmer river temperatures and more frequent extreme years as have been observed over the last decade. There will be high rates of river migration mortality. (see also Skip Mckinnell, page 48, David Welch, page 17, and Karl English, page 66)

However, these effects are going to be stock specific. Therefore knowing which stocks are going to be holding on, and which ones are going to have real trouble, will probably depend a lot on thermal refuges, if they are able to utilize those in their migration. Furthermore, a lot will depend

on the physiological critical limits of the stocks.

DIALOGUE

Effect of temperature on migration

A participant asked the question:
How fast do the fish travel up the river or do they slow down with the increasing temperatures? You indicated they can go up to 40 km per day. But when the temperature goes up, they probably go down to just a fraction of that and that means they are dying in the river.

Karl English:
For those fish that are migrating during the period of high temperature, the segment of the river that they are successfully migrating through is at a lower temperature. Once they get to the high temperature they basically stop and they don't get much further. That happened last year above the Chilcotin Junction, for example; very few made it to the station at Quesnel. We have no way of knowing how long they survived after they made it to the Chilcotin Junction and we know that they didn't make it to the next station.

Scott Hinch:
The fish have to slow down if they have reached their maximum scope. If they push it beyond that, then they start to accumulate lactic acid in their bodies and they are forced to slow down.

PART TWO – WHAT CAN WE DO?

SECTION V

Review of Day One and Recommendations for Action

- **Is marine/ocean survival the problem?**
- **What other factors must be considered to develop a better understanding of marine and freshwater survival?**
- **How can we improve monitoring, pre-season and in-season management in a changing world?**
- **Where should research be focused?**

Presentations by:

Mark Angelo, Chair, Pacific Fisheries Resource Conservation Council

John Reynolds, Tom Buell Leadership Chair in Salmon Conservation, Simon Fraser University

MARK ANGELO, CHAIR, PACIFIC FISHERIES RESOURCE CONSERVATION COUNCIL

Highlights of Day One presentations

There was a lot of very good material presented yesterday.

David Welch described his research with Cultus Lake sockeye and noted that he believes that the 2009 collapse was likely caused by mortality that occurred beyond the Fraser River and the Strait of Georgia ecosystem and beyond Queen Charlotte Strait.

As a follow up, however, Mike Lapointe cautioned that Cultus Lake fish have a shorter migration route and they are larger. So we have to be careful about expanding research findings on these fish to other sockeye stocks.

Andrew Trites described some fascinating results from his studies on harbour seals. We often assume that harbour seals are big predators of some salmon stocks. However, he noted that about 40% of the diet of harbour seals is hake, and also that hake are a major predator of salmon. In a broader sense, he made the point that seals may not be impacting salmon, generally. However, that is notwithstanding some specific examples that we are all aware of where large concentrations of seals have set up shop at the mouth of certain rivers.

Alexandra Morton gave an excellent presentation regarding whether or not lice are affecting Fraser sockeye. She said it was a question 'of degree' rather than 'if' and she emphasized that we have to learn about this, or it will always be a question.

Michael Price described his interesting results regarding lice infestation on sockeye in the Discovery Islands.

During the high-seas session, David Welch noted that in 2007 the plankton concentration in surface areas was occurring earlier and for a shorter period. Also, there was a significant spike and there appears to be a narrowing of the season.

Mike Lapointe described trends and productivity for Fraser River sockeye stocks. In referring to the data in one figure he noted that 17 of 18 stocks showed declines in productivity. This image, with so many orange dots, was very sobering.

Randall Peterman emphasized the importance of variation in marine survival rates and the fact that forecasting models cannot explain 64% of the variation we see. He noted that we must have lower expectations regarding the accuracy of forecasting.

Karl English described innovative monitoring and counting methods using fish wheels. Certainly this is providing excellent data and we can expect to see more of these types of studies in the future.

Scott Hinch demonstrated very clearly the impact of warmer water temperatures on mortality rates in sockeye. He highlighted the importance of cold water refuges and he talked about how effects related to climate change will be stock specific.

Endangered Rivers

We will now be moving into the freshwater part of the lifecycle and it is relevant to consider some information about endangered rivers in BC. A list of endangered rivers was recently published; the list of rivers described in the report is based on views of those who use and recreate on rivers, primarily the 100,000 members of the Outdoor Recreation Council, as well as the general public and those who manage rivers. It is a relatively accurate snapshot of the state of our waterways. A lot of what is in that list is very relevant to the discussions at this workshop.

The Kettle River

On the top of the list, tied for top spot, was the Kettle River in the southern Okanagan. This waterway is experiencing very low flows and high water temperatures as well as excessive water extraction. This is one of many rivers facing the same kinds of problems, not only in the Southern Okanagan region, but also on the east coast of Vancouver Island. Clearly, this ties in with the information Scott Hinch provided about the relationship between rates of mortality and high water temperatures.

The report also talks about the need for a water management plan, especially as many new proposals for additional extractions continue to come forward. It also highlights the need for

Water Act reform and modernization and notes that the current Water Act says nothing about maintaining healthy aquatic ecosystems and nothing about the needs of fish. There are many rivers that I can point to where there are significant problems with the excessive extraction of water, such as the Kettle, Coldwater, and Nicola Rivers, as well as the Salmon River in Langley.

The Sacred Headwaters

Another key issue that was highlighted in the report was the Sacred Headwaters. This is in an area of BC just south of the Spatsizi where the Skeena, Nass and Stikine Rivers originate. A very controversial coal bed methane project is being proposed for this area. I have seen many coal bed methane operations in Montana, Wyoming and North Dakota. They tend to produce a lot of what is called "product water"; that is, water that is high in salts and heavy metals. There have been a lot of unfortunate incidents in the past where that water found its way into surface water with very damaging effects for fish. In the Sacred Headwaters proposal, the proponents indicate that they will re-inject this water back into the earth. I can't help but worry, however, about how that will affect groundwater and the aquifer. The aquifer more often than not is tied to surface flows and ultimately that could impact the productivity of the three great salmon rivers that flow from that area. I believe that that we have to be much more proactive in protecting the great northern salmon rivers in our province. Another northern river, the Taku River, currently presents a great international salmon conservation opportunity with a land-use planning process now in place.

The Fraser River

The report also focused on the Fraser River, which has been in the top five of the endangered rivers list for 17 of 18 years. It is threatened by the more traditional problems pertaining to pollution and urbanization as well as sewage treatment plants, such as the Iona Treatment Plant where there is still only primary treatment. A lot of that effluent goes into the Strait of Georgia. If you really believe in looking at the Fraser as an ecosystem then that is very relevant because ultimately the small fish that leave the Fraser have to swim through that effluent. Right now Metro Vancouver is targeting 2030 for improvements to the treatment plants. I would like to think that they can do a lot better than that.

The report also describes the importance not only of habitat protection but also the important potential for habitat restoration on the lower part of the Fraser River. It describes issues related to the agricultural sector and the need to do even more in terms of promoting best management practices and engaging and encouraging more farmers to develop environmental farm plans. Unfortunately, only a very small percentage of farmers are participating in those activities.

The Heart of the Fraser

One of the most important issues highlighted in the report is focused on the 'Heart of the Fraser', an incredibly productive part of this great river between Hope and Mission. This is probably one of the most productive stretches of river found anywhere on earth. It sustains close to 30 species of fish, it sustains Canada's largest sturgeon population and it also sustains BC's largest single spawning run of salmon. When we think of the great runs of salmon of the Fraser most people think of the Adams River. However, the largest single spawning run takes place in the Heart of the Fraser; and it's the 20 million pink salmon that spawned there last fall.

However, the 'Heart of the Fraser' is very close to Greater Vancouver so it faces a lot of urbanization and industrial development pressures. Issues around agricultural expansion are also prevalent. From a fisheries point of view, there is a real need for a collaborative plan early on to ensure that we protect some of the great environmental values that exist here in the future. Groups such as the Nature Trust have been very helpful in raising funds to acquire a number of

key private properties for conservation purposes; properties that have very important fisheries and wildlife values. But there is still a lot of Crown Land in that corridor and there is an urgent need for a collaborative plan, sooner rather than later. When you think of the 'Heart of the Fraser', the Hope to Mission stretch of this great waterway, you cannot ignore the Harrison, which is part of that complex. The Harrison River is an incredible river and sockeye are actually doing well there. Once again, however, the Harrison faces significant development pressures and there is an important need to be proactive there as well. It was good to see the Harrison recognized as Canada's first salmon stronghold, an initiative that we are involved with jointly with the Wild Salmon Centre.

JOHN REYNOLDS, TOM BUELL LEADERSHIP CHAIR IN SALMON CONSERVATION, SIMON FRASER UNIVERSITY

The objective of this workshop is to understand stock declines and prospects for the future with respect to Fraser River sockeye.

During Day One, we discussed two themes related to stock declines. One was the poor returns of the sockeye in 2009. Clearly that is what caught a lot of people's attention. The other theme involved the causes of the longer-term declines in productivity since about 1993; this downward trajectory featured in many graphs.

Poor returns in 2009

A number of people embedded references to the poor returns in 2009 in their talks and some people took it on directly, looking for a smoking gun to understand what happened to those fish. Keeping in mind the highlights described by Mark Angelo above, I have identified a number of areas to focus on.

Ocean conditions

The poor returns do not seem to have been due to any clear signals in the temperature in the ocean, at least on the basis of the information we've seen so far. This issue was summarized by David Welch and it came up in other presentations and dialogue as well. Obviously, there is strong inter-annual variation, but I did not see any dramatic trends there. Also, it is difficult to interpret potential signals in the plankton, although there were some interesting trends presented from Sonia Batten's work. But I think the answer is that we still do not have anything we can put our fingers on.

Marine mammals

The poor returns of 2009 do not seem to have been due to anything unusual that the marine mammals did around that time period. Andrew Trites' presentation was very interesting, especially with respect to the hake story. It is so easy to point at a single predator such as seals and be mad at it. But then you need to ask: What else does that predator eat and does that prey species eat salmon? This can flip the whole logic around and lead to the realization that we might do more harm than good by targeting what seems like the obvious culprit. This seems to be a general message from food web analyses, which I've seen before in several other contexts around the world: as you go from simplistic predator-prey reasoning to wider food webs, you can end up reaching opposite conclusions about the importance of specific predators on species of interest. I thought that Andrew Trites provided a convincing illustration of that and the take home message

is that we should be cautious, as much as we may hate the seal that takes the fish off the end of our line.

Disease

Disease is a big issue. We did not get very far other than to note that as both Alexandra Morton and Michael Price pointed out there is certainly strong potential for a disease problem for these sockeye as they migrate past the gauntlet of farms in the Discovery Islands. To me this raises more questions than answers. We did not hear whether there was a specific disease outbreak in 2007 when the juveniles were outmigrating, but it would certainly help to have disease records from the industry to look into this. We also need to look at time periods prior to 2007, and consider what else might have been transmitted from farms or other sources in earlier years.

Juvenile survival

Beyond disease issues, there are many other factors that affect the survival of juvenile fish. The presentation by David Welch was quite striking in showing that survival of Cultus fish was not all that bad in terms of getting out of the Strait of Georgia, nor usually low in 2007. But as someone pointed out, they may still have died beyond the Strait as a result of problems that originated in the Strait. One other thing that I found interesting in the paper that David and his colleagues published from that research was how high some of the mortality was just in the freshwater phase. David answered queries about the potential for reduced survival due to the tags; as technology improves, this matter will be resolved. But the bottom line is that except for the POST tagging program, the down-river phase of migration is just as much of a black box as the ocean survival.

Therefore, unless DFO biologists and oceanographers have got something up their sleeves that they haven't been able to share with us because they were forbidden from attending our conference, I am not confident that we are suddenly going to come up with a magic answer to what happened in 2009. I suspect that there may not be a single smoking gun to explain what happened to those fish.

Declines over the long term

Beyond the 2009 issue, what concerns me more is the longer-term downward trend that we have seen over the last 15 years in productivity. The 2009 returns were bang-on where they should have been given the data from the years before that. We should have seen this coming.

Whether this decline in productivity has been due to various effects of climate change, disease, contaminants, or some other causes, I think we should pause and ask what we can do to manage and deal with something that we may never fully understand.

For example, we heard that different stocks have shown different trends over time. Mike Lapointe pointed this out, Scott Hinch showed it in his thermal tolerance work, and Skip McKinnell illustrated it with his work in the ocean. I take two messages from that. First, when some stocks, such as the Harrison fish, do reasonably well while others such as Chilko and Quesnel fish do badly, we have an opportunity to understand the biology behind their good or bad fortunes. Second, we need to implement management procedures that distinguish between stocks wherever possible, and which can deal with uncertainty.

Forecasts

Randall Peterman gave us a good reality check on forecasting. I suspect that forecasts are probably never going to get much better. We have to acknowledge that forecasts are imprecise. In fact, I often wonder why we do forecasts at all, but that seems to be a discussion no one is willing to have. I would like to compare the benefits of forecasting (e.g. economic, conservation, and sustainability) with the costs of forecasting, including potential improvements if these can be found. Yes, we want to know how to gear up for fishing and processing next year. But I do wonder how people can make serious fishing plans based on such imprecise information. I would focus more strongly on in-season forecasts since, as others pointed out, these are the basis for opening fisheries.

I hope that today when we talk about what we can do to move forward and the prospects for the future that we will keep these issues of inherent uncertainty in mind and not get too hung up on the details of the processes that caused a collapse in a particular year. Instead, perhaps we can ask about what methods we can use to be robust in our management and also what scientific information and long-term monitoring we would need to give the fish the best possible chance of meeting the challenges of the future.

DIALOGUE

Why do we do salmon forecasting?

Skip McKinnell:
First, we are unable to conduct experiments on the open ocean and the marine environment.

So as scientists one of the ways we have of learning is to use models of how the system works and then use these to make predictions. The prediction part is a way of testing our understanding. Typically research products like this do not get out into commercial applications until they have been tested. We are at the stage now scientifically of model building and developing understanding. Perhaps what has happened is that the application of this scientific exercise has been premature.

Humboldt squid

No one mentioned Humboldt squid in the discussion about predators. There were difficulties this year with the hake survey. They could not distinguish hake from Humboldt squid in the surveys because they give the same acoustic signal. The numbers of Humboldt squid that have been coming up the West Coast since 2004 are remarkable. Results of research on the diet of Humboldt squid on the west coast of the USA showed that for the most part salmon were not present. The one place they did find salmon in the diet was in the Strait of Juan de Fuca. Humboldt squid are in the Strait of Juan de Fuca in large abundance. This is a serious predator; it is large and capable of eating a lot of fish.

New approaches to forecasting

Randall Peterman made the point that the variation in returns is largely a function of what is going on with marine survival. In the model evaluations typically those of us who do not go to sea use sea-surface temperature to represent the ocean. However, we are learning to approach this in different ways; for example, the person who recently won

the forecasting award was a physiologist who measures blood hormones in coho. To me, that shows an advance in thinking about how we look at the ocean.

Enhancement of Fraser stocks and lake fertilization

A participant commented:
We have not heard anything about enhancement of sockeye salmon populations, whether it is spawning channels or lake fertilization. Could someone speak to their use, both past and present, in the Fraser and whether or not it can inform us in terms of the observed changes in productivity through time?

Mike Lapointe responded:
There are at least two different kinds of enhancement that have gone on in the Fraser. There are spawning channels for three populations: Gates, Weaver and Nadina. They began operations in either the late 1960s or early 1970s. In the case of Weaver and Gates, the primary motivation to put the channels in was the fact that both streams are subject to extensive flash flooding. By providing a stable habitat like a spawning channel they thought that it could help boost those populations. In the case of Nadina it was more related to boosting the productivity and taking advantage of the fact that they rear in Francoise Lake; this is a very large lake and it was thought that the lake habitat was underutilized. In terms of the impact of this type of enhancement, it tends to mask the ability to see the changes in the wild population; genetically you cannot tell them apart.

In terms of lake enrichment, the Chilko sockeye is one population that had a period of lake enrichment in the late 1980s. In fact, when I looked at the graph that Skip McKinnell showed in Figure 4, I wondered if those big high points were the years of lake fertilization. When we look at the Chilko data, if we are trying to understand what is happening with the wild population, we should probably remove those years from the time series, as there definitely was a benefit from the fertilization process. In the case of the Cultus population, a captive brood program and some hatchery rearing was put in place, and there have been for periods of time small-scale hatchery operations; for example, they have been exploring different rearing strategies in the Pitt River but there is no real sustained hatchery production there. That is another population that is subject to a lot of flooding.

There is also a spawning channel on the Horsefly, but is not utilized regularly, especially in the last few years, and there was a spawning channel for a brief period (8 – 10 years) at Chilko until it was decommissioned four or five years ago. The Chilko population is one of the few that migrate upstream to a lake. The reason it was decommissioned is that field staff were noticing that fry that were from the spawning downstream of the channel were actually getting sucked into the channel and ending up coming out at the bottom end and then making laps. (The spawning channel is on one side of the stream). These fry of course are very small when they are migrating upstream and they need to be right on the shore at Chilko to make it to the lake.

Returns to the Horsefly

A participant commented:
The channel in Horsefly was operating last year and I think it is generally scheduled not to operate on dominant and subdominant years. It was operated on very short notice – I operate it on behalf of DFO. The run was so low last year that we could not even fill the channel even though one million fish were expected back. The capacity of the channel is 22,000 sockeye. That is how bad the run was last year on the peak year of the Horsefly River.

Reduced capacity to do necessary science

Craig Orr:
While it is true that the Cohen Enquiry may not find a smoking gun, some people are hopeful that perhaps it will shed more light on our ability to understand what is going on with sockeye in British Columbia. We have seen a lot of changes since the productive days when scientists like Kees Groot worked for the Fisheries Research Board of Canada, and we have seen a very significant erosion of our capacity to do science on this coast. We have also seen erosion in our mandate around aquaculture science because the mandate is conflicted, in particular within Fisheries and Oceans. We need to see if the Cohen Enquiry can help us deal with some of those issues. I am concerned about our willingness and our mandate and our capacity now to do the research that is needed. Yesterday we heard about the Pacific Ocean Shelf Tracking program, which is providing excellent data, but this program is struggling for funding. Fisheries and Oceans do not have the money to pay for vessels for the sea lice monitoring work going on in the Broughton so this is offloaded onto industry and NGOs, in particular. The provincial government paid the lion's share of the costs of operating the vessels over the last few years and now that funding has stopped. And the Broughton is only a very small area. There is no comparable monitoring going on in Discovery Island areas where the sockeye first pass through.

My hope is that the Cohen Enquiry can examine those kinds of issues and recommend: "This is what you have to do, Canada, as a nation. If you really want salmon, you have to honour the Wild Salmon Policy. You have to put the capacity in place to study these things. It goes beyond trying to get disease records from the farms. It is about our ability to, as a nation, go out there and do the proper research and find out the answers to these questions." Perhaps we are holding our hopes too high for what the enquiry can do. After all, we have also had two reports from the Auditor General that have cited a conflict of interest in DFO in terms of promoting salmon farming and also protecting wild fish, and yet nothing has changed. As a group, we need to think about what we really want to see in the future, and whether there are the proper tools out there to do what we want.

Who is in charge of the data?

Arne Mooers posed the questions:
Is there currently a single place where all these data go? Is there anybody actually in charge of everything that we heard about yesterday? I say that because I saw the same graph in different versions and with different colours and with different levels of sophistication about four times and it was not clear whether there was anybody who had gathered it all together and then pieced it back out for people at this meeting, or whether that was actually the state of the data management. That may speak to how DFO used to do this, and now it is just piecemeal, or has it always been this way?

Mike Lapointe:
In term of the data sets there were three main sources that we used for the presentations yesterday: total returns, total spawning escapement, and the juvenile information. Up until about 1985, which was the year that the new Pacific Salmon Treaty was signed, all of those data were collected and held by the one agency, the International Pacific Salmon Fisheries Commission, predecessor to the PSC.

In 1985 this was split and the responsibility for most of the work that goes on in freshwater, virtually all of it, spawning escapements, juvenile work and so forth, was taken over by Canada, specifically the Department of Fisheries and Oceans. For the returns information, because it involves a combination of the escapement and the catch by stock estimates, our agency, the PSC, is responsible.

We have the tools - our in-season monitoring

gathers the catch information, and the genetic work is done in Canada, but is applied by us. Right now that total return escapement data set is jointly held with Canada. There is only one source of those data so we provide the data on the spawners and recruits to Canada when they do the forecast every year. Canada collects the escapement information and we generate the catch by stock information with the data from the two countries. The juvenile data are also held within Canada. Therefore, the data are in two different places but I wouldn't say that it is in a complete disarray, or not available. We provide the data to whoever asks for it.

Have any of the changes that have been implemented affected the way the system responds?

A participant commented:
I am pleased by that last question and I am surprised that some of these issues did not come up more in the yesterday's discussions. I also want to recognize that Mike Lapointe is an international employee and Canada is one of his bosses and so it could be difficult for Mike to be able to respond to some of these things.

I was around when the Pacific Salmon Treaty was negotiated with the United States and I recall the biggest fear that the commercial fishermen had with the signing of the agreement was that DFO would be taking over management control of Fraser River sockeye and pink salmon from the International Commission. I also know that at that time when that transfer of responsibility took place between the International Commission and the Government of Canada, we started to test the issue of cyclic dominance on the Fraser River. There were efforts to look at putting more fish on the spawning grounds in the non-dominant years to see whether we could actually even out the production across the cycles, rather than having one peak year and several smaller years in the four-year timeframe. We have also had major changes in the management paradigms because although the Mifflin Plan (1996) led to reductions in the commercial salmon fleet by 50%, we still have more capacity out there than we probably need in order to harvest under the new realities of the way we have to fish salmon and to implement the Wild Salmon Policy. As well, we have a new and better understanding of what our obligations are to First Nations. Trying to deliver food, social and ceremonial fish to First Nations has changed the way we manage our fisheries very dramatically.

However, the question is: Have any of those kinds of changes affected the way that the system is responding? Are we putting more fish on the ground than we should? Certainly, a lot of changes have occurred in management. What I did not hear yesterday, was discussion about how these changes in the management regime might have had an effect indirectly, or even a modest direct effect, on what might be happening to the productivity of the system?

Hatcheries and carrying capacity

Willie Davidson:
Hatcheries may actually be the elephant in the room that no one is talking about. Yesterday we heard that returns from Cultus Lake were 1.8% but the return from the Cultus Lake hatchery was 0.53%. That is only 30% as good a return as the wild stock. That should tell us something about the state of hatchery fish when they are released. I think we should also take a look at the enhancement programs, not just by looking at salmon. We are here to discuss sockeye salmon but I don't think we can discuss sockeye salmon without thinking about the other species that inhabit the same river systems. A graph that I have never seen, and would be interested to see, is one that shows the total returns compared with the total releases of all salmon in, for example the Fraser, from all hatcheries. Looking at all the different species of salmon that are pumped into the Fraser, sockeye are fairly small

compared to Chinook, pink, and chum. We have to ask ourselves the question: What is the carrying capacity of the Pacific? Are we (not just Canada, but also the US, Japan, and Russia) actually pumping out too many fish into the Pacific? Do we have any information about the carrying capacity and if not how do we get that information?

"No new knowledge is required, just action."

David Welch:
A couple of points stood out for me yesterday. One is related to the discussion following the viewing of *End of the Line*. One of the participants asked the respondent panel about the challenges of maximum sustainable yield and fisheries science and sustainability. Daniel Pauly had a rather telling response. He basically said that fisheries science does not do very well with sustainability and it does not do very well with ecosystem-based management. I would say that that is why it is called fisheries science - it looks at fish. This is an important point to consider when we begin to talk about conservation.

Another point came from the presentation of Randall Peterman where he noted that 39 years was a long time series of data in talking about salmon. But this is actually a short time series of data – it is only eight or nine lifecycles of a salmon. We heard John Henderson speaking about the First Nations view on long term where they talk about thousands and thousands of years of knowledge and information.

I am not really looking for a smoking gun – as one participant said yesterday, we know where the smoking gun is; it is sitting in this room. Looking at the graphs of productivity and the year of return, I tend to agree with Ken Wilson who said in another presentation: "It is not a collapse, it is a train wreck and it started in 1992." How did we not see this, and how can we sit here and say that last year was an anomaly? Some government scientists are saying that it was one-time-only event. It is not a one-time-only event. This was a collapse and it has been going on for a long time.

If you study the second graph (Figure 8, page 6) of fisheries effort it drives home the point. What population in the world can sustain for 40 years taking 80% of the population and expecting 20% to reproduce sustainably? For one First Nations community that I work with, located in the headwaters, they were only able to harvest 20 fish for their food, social and ceremonial needs. We don't have to look any further than those two graphs (Figure 8, page 6).

I also want to draw attention to a quote from the special viewing of *End of the Line* and the follow up comments of the respondent panel: "After decades in the wilderness, warning about the coming crisis, people are starting to sit up and pay attention. No new knowledge is required, just action." Action. There are many great individuals participating in this meeting that have been taking individual action over the years. That is where this is going to get solved. Fisheries science and salmon management is not a scientific exercise. Like it or not, it is a political exercise and that was made very clear at the special viewing part of the program yesterday. When we talk about conservation we have to address the questions: for whom? for what? by whose definition? and the big question, Why? There will never be a definitive answer.

Finally, when you ask one question, you end up with two more questions. You look for answers to those questions and you come up with four more questions. I would add one more objective to the program. The last question asks: Where should research be focused? I believe that there should be another objective that asks: Where should action be focused?

Were earlier forecasts more accurate?

A fisherman participant directed a question to Mike Lapointe:

The perception in the commercial fleet is that in the good old days the forecasts were much more accurate. Did you run across that when you were looking at the reviews of the general forecasting methods? Is it true that forecasts were more accurate pre-1985, for example, or has there always been this general uncertainty and we are just applying rose-coloured glasses when we look back?

Mike Lapointe:
I don't think it is necessarily true that the forecasts were more accurate then. They were biased in a different direction for a different reason. Prior to 1985, and this is substantiated by the information in the annual reports of the PSC, there was actually a template of fishing that was almost hardwired into the pre-season plan. What that meant was that in order to not have a fishery, they had to have a very extraordinary meeting. And to have governments in the middle of summer get together to have a meeting to discuss not having a fishery was an extraordinarily difficult thing. What that meant was that the forecasts actually tended to be directionally biased low, because it was much easier to add time than to take time away. In the last 15 years, however, there has been a directional bias in the opposite direction. Is that because there was intent to bias? No, it is because the forecasts have been assuming average productivity, yet the productivity has been declining. That is the reason that there is a change in the perception that forecasts were more accurate prior to 1985. In the past, it was exactly the right thing to do because, given the management structure, if you were too high you could not take fishing time away. That is what my take is on the history of the forecast pattern.

Participant:
And much easier to deal with the fleet in that fashion, as well.

Mike Lapointe:
Exactly. Much easier.

Ask: Who is in charge?

John Fraser:
When I was being trained as an infantry platoon commander, a senior warrant officer said, "Gentlemen, when you come upon a situation in which all is confusion, you ask: Who is in charge? If nobody knows, then you know what the problem is." That point was just raised by Dr. Arne Mooers.

One of the questions that we collectively have got to put on the front burner is: Who is in charge? I don't think you will be able to say who this is, that is, if being in charge means that you have authority and you have knowledge and you have an intimate association with the people and the resource that you are administering. It is an absolute disgrace that we are in this position and have been for quite a long time. It is not the blame of the people in this room and it is not the fault of a good many very decent and hardworking people within the Department of Fisheries and Oceans. But it is very definitely a political problem.

In my view, all of what we have been talking about has got to be raised up to the political level. Unless this happens, nothing much is going to happen; it will continue on so that a committee meets, and then moves on to another committee, and then another, so that when you ask who is in charge, nobody knows. This is not going to solve the problem.

Also, where is the provincial government at this meeting? The provincial government has an enormous responsibility for salmon and steelhead, for fish and for habitat. In the British Columbia Pacific Salmon Forum we pointed this out in very clear and blunt terms. You cannot manage and save the salmon on this coast unless *both* governments are involved. Where has that report gone? We did not provide a lot of options in our recommendations. Options, when you report to a government, is just another way of saying give them enough reasons to get out of doing anything.

It is absolutely urgent that everyone in this room and everybody we talk to understands that this is not going to get resolved until there is political action and you are not going to get political action until you can look someone right in the eye, and say, “All right, you are in charge. Now what are you going to do?”

SECTION VI

Putting a Value on Salmon – social, economic, ecological and cultural considerations

- **What does Fraser River Sockeye mean to society in broad social, cultural and economic terms?**
  - **Food, social and ceremonial fisheries**
  - **Commercial net fisheries and Recreational fisheries**
  - **Other social/cultural/economic/ecosystem services concerns**

Presentations by:

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Ken Wilson, Member, Canadian Caucus, Fraser Panel

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In 2005 at an earlier Speaking for the Salmon gathering, The Honourable David Anderson said,

> *"When you get into issues of spiritual value, managers in DFO may have many gifts but I do not see many of them in the pulpit. I would suggest that this is something that we must all get involved in… I do not think that this is a question of service to man. There are many spiritual aspects to protecting salmon and preserving this for future centuries and we are going to have to do a lot more in getting that message across. There are dollars flowing to BC from the federal treasury in fairly large amounts. There is no great problem there. The problem is that these dollars are not coming into science work in DFO or in general to DFO policies … There is not the feeling that somewhere or another this is really an 'in the heart of BC' desire."*

The issue here is about the prevailing value set and how that gets played out in political circles. What I discuss here is plural values: how one set of values is dominant in our current paradigm and yet how other sets of values are also critically important to this problem; and how we might better bring them out in order to enhance the reflection of those values and policy.

Ecosystem services

The concept of ecosystem services is important for several reasons. First it fits into the dominant paradigm of values with all the strengths and limitations that entails. But this concept of ecosystem services is exactly what the Honourable David Anderson referred to, in speaking about how salmon are not only about service to man or humans. Ecosystem services are the provision of things of benefit to people, by ecosystems, both directly and indirectly. This includes provisioning services, such as the provision of seafood, for example, provision of forage for livestock and fibre through timber (Figure 1).

Regulating services are more difficult to see than the provisioning services, which are often associated with ecosystem goods that are traded in markets and have dollar values associated with them. Regulating services are the continued state of ecosystems and the planet that allow for the opportunity for human life to thrive. These kinds of services are not generally recognized until things go wrong. They include the storage of carbon in many ecosystems that helps to mitigate against climate change, which has been implicated in the increase in both the incidence and rising magnitude of extreme events such as Hurricane Fran off the coast of Florida.

Figure 1. Ecosystem Services include provisioning, regulating, cultural and supporting.

Cultural services are the contributions by ecosystems to non-material benefits that people enjoy through interactions with ecosystems. That includes scientific inspiration, esthetic inspiration, spiritual values of all kinds as well as cultural identity and heritage. Then there are the supporting services and this is where the ecosystem services concept contributes the most because these are the services that are critically important, but through their indirect contribution. For example, pollination is important because it provides us with honey, but much more important because it provides a crucial process to the growing of agricultural crops. Without pollination by insect pollinators we would not have almonds or apples or pears or many other fruits, nuts, and seeds.

Salmon and ecosystem services

Pertaining to salmon in particular we can think of three of those master classes of ecosystem services as being really important. With respect to supporting services, salmon are critical in their contribution to nutrient cycling, and bringing nutrients from the freshwater ecosystems and even terrestrial ecosystems to the marine ecosystems and then back again. Salmon are also critical food for many other species, which are of value in various other ways. They provide several crucial provisioning services in the form of food, from all of subsistence fisheries, and recreational and commercial fisheries. And they are also thereby a source of income.

Cultural services of salmon are absolutely essential. They are very obvious and yet invisible: for example, the provision of cultural heritage, cultural identity, valued way of life through fishing, and sense of place.

Ecosystem services is a rich concept in allowing the expression of these various kinds of values. It makes ecosystem concerns much more real in an arena where human values predominate. And it recognizes the contribution of ecosystems in the form of natural capital alongside social capital, build capital, financial capital, and so on. That parallel kind of recognition is important, but there are limitations. Perhaps most importantly it connects the contributions to human well-being through an explicit characterization of ecosystem processes and functions. That allows ecosystem science to play a much more prominent and relevant role in decision making.

To sum it all, those three points mean that ecosystem services make some indirect ecological values visible. That is a very important contribution.

Limitations of the ecosystem services concept

On the flip side, in large part because of their conforming with the predominant value set, ecosystem services also have multiple limitations, one in the way that the concept treats all values as if they are market values and as if values are only measures of importance associated with benefits, when actually values are a much broader set of concerns than that. The services framework and the prevailing value set both also assume *individual* beneficiaries—that value is determined at the level of the individual and not at any higher levels. The ramifications are that the services framework, in the prevailing value set, ignores or suppresses certain important kinds of values: principles like equity, justice, fair restitution; and virtues such as the fact that we might only be good people if we are good stewards of our ecosystems. Then there are group values, values that are not held at the level of individuals, such as the notion of what would be an appropriate way for us to act as a society. These are values that have to be negotiated much more broadly at the level of society.

Intrinsic values

There are also intrinsic values, our egocentric or biocentric values, values that are held in nature itself and not only in our appreciation of them. The ecosystem services concept cannot capture these values in the sense that it is an anthropocentric concept. It only captures the *shadow* of these intrinsic values in the form of existence values; our *appreciation* of the fact that these things might have intrinsic value, as opposed to the contribution of these intrinsic values to what would make an appropriate decision.

Transformative values

Finally, there are transformative values. These are values whose principal contribution is in changing the way that we think and in even changing the way that we value things. They do not have value because we desire transformation; it does not have value until after our thinking has been transformed. An example of these kinds of values would be that life-altering experience of seeing salmon swimming upstream and leaping up rapids—that kind of a transforming experience is not one that is necessarily desired before it has been experienced. But after it has been experienced it is impossible to imagine how one might have thought about life before having seen that kind of spectacle.

In light of those pros of the ecosystem services framework and how they might contribute to the existing value set, the prevailing value set, and then also the limitations that come with that framework and the limitations of the prevailing set itself, I put forward a set of recommendations.

Recommendations

In terms of efforts at valuation, such as informing cost-benefit analysis, it is important to use a variety of approaches; that is, not only those that strive to represent market values and market-like values in the form of non-market valuation such as through travel cost method and hedonic value. Also important are methods borrowed from social sciences other than economics, that do not necessarily involve monetary values.

For decision making, it is important to include participatory deliberation, where some of these other concerns are brought forth and discussed, to make sure that they have equal or at least agreed upon consideration in light of all the other kinds of values, the market values that are expressed in easy dollar terms, for example.

Then it is important that when communicating these values, not to rely only on numbers and figures that are commensurate with dollars but also to use stories and to employ symbolic gestures. One kind of symbolic gesture is the naming of an official animal. I believe that this issue was raised years ago in

the Speaking for the Salmon series. At the moment as I understand it, BC's official fish is the bull trout. Why not salmon? How can it be the bull trout? That doesn't make sense to me.

Also, in any kind of debate about wild salmon, but especially insofar as wild salmon has been considered as a tradeoff basically against farmed salmon, it is important not to let market values dominate the conversation. These are only a very tiny subset of the values associated with salmon; market values, strictly speaking, do not even include those invisible ecological values. And even if we include those we are still going to be missing out on some critical contributions of salmon to society.

Summary

In summary, ecosystem services allow the possibility of expressing some of these indirect ecological values and making them visible. However, so far this concept has only been understood in market and market-like terms. We need to broaden beyond that, in part because of the danger of ignoring and suppressing other critical kinds of values. We can improve both valuation and decision making to better reflect intangible values. In the meantime, before valuation and decision making inherently reflect these other kinds of values, we need to engage. These values do not speak for themselves. They speak through others speaking, through getting active and through engaging.

To quote Carl Safina from Salmon Nation:

> *"Only a few wild animals symbolize the heart and soul of a region. Tigers in India, lions and elephants in Africa, kangaroos in Australia. In North America the buffalo of the Great Plains and the salmon of the Pacific Northwest supported economies, cultures and human self-identities. And though white settlers destroyed the buffalo in greed and in genocide against the Natives, they embraced the salmon. Immigrants, like, Native peoples, saw in salmon something deep, powerful, moving and valuable. Even if they approached the fish with less awe, less reverence and consequently less success than the Natives had for millennia. Think of the Northwest and salmon soon come to mind. Whether they represent your demons or salvation, salmon loom large here. Certain other animals still symbolize their regions but salmon are unique because their symbolic power and their ability to bestow significant economic and nutritional benefits on human culture have survived together to the 21st century. And this comprises the best hope in the struggle for salmon and the people who need and desire them."*

DIALOGUE

Is there a framework to use for these other valuations?

A participant asked:
Is there actually a framework for doing these other sorts of valuations?

Kai Chan:
There is no single framework for valuation that includes these other values. Willingness to pay, also called contingent valuation, assumes that people can construct a market in their minds; that is, they will imagine that there would be a market for whatever thing that they are being asked to value. But there are multiple types of valuation that might be employed. This is a rich topic for fleshing out for further research and also for bringing to bear what is already known into practice. What makes answering your question most difficult is that you have asked about valuation and about expressing some of these other values through that kind of a lens, where the lens is inherently buying into the economic framework. What really matters, however, is the way we make our decisions. The economic framework presumes that we should do valuation and the valuation should inform decision –making, whereas it is possible to come at it the other way around; that is, to ignore valuation and to jump straight to decision making, at which stage we can express some of these crucial values, but not through valuation.

What is an environmentalist?

A participant posed the question:

What is an environmentalist and does the concept or this definition serve us well?

Kai Chan:
To me, an environmentalist is someone who champions others whose home is in the natural environment - it could be the environment in general or it could be ecosystems or non-human organisms.

However, I don't know how helpful it is to designate people as environmentalists in the sense that it suggests that their motivation is other than human. It does, in some ways, marginalize the contributions of environmentalists to human well being by labeling them environmentalists because it suggests they are championing only for things that are not human.

What are the characteristics of those who are successful in communicating their culture?

A participant asked a question:
Thinking about how we determine the value of values, as a commercial fisherman growing up in the industry, we have been told for a number of years that the fishery needs to move farther up the river, which basically is going to put us out of the water in the marine approach areas. It seems as if there is a general lack of understanding about the values and the feelings of the culture that the commercial fishermen hold. From your experience, what is the best way to better inform the public or other stakeholders of the intrinsic value of your own life and your own way of life?

The communities that I grew up in and the people that made a living there by fishing are fading and those values have somehow become less valuable than other cultural values. From your research can you say who has been the most successful at communicating their cultural values and their intangible benefits and who do you see have been the least successful, and what are some characteristics of the most successful?

Kai Chan:
This is a great question but also one of the hardest that I could imagine. I don't know how to define success in that context, in the sense that some of the widest reaching communication also compromises in some ways the crucial part of the message. I don't want to get into judgments about success, but I will give you an example of one way of communicating those kinds of values that I think is especially effective.

A graduate student who worked with me recently arranged for a showing of the movie Red Gold. It was a full house and there was an enormous buzz in that room. Red Gold is a movie about salmon in Bristol Bay, Alaska. But it is about more than salmon; it is more about the fishermen whose livelihoods and ways of lives are at stake. It is a captivating story about some of those fishermen and how they are struggling with the dilemma about a proposed mine that threatens to end their way of life.

I can't think of a better way to express the value that people derive from that kind of an experience than by opening a window into that life through art, in this case a movie. In the language of transformative values, basically you are providing a moment, an experience, for transformation. It is not the same experience that you have when you are actually out there but it is a window into that and I think that is probably the most powerful way to communicate those kinds of values.

On environmentalism

A participant commented:
I would take issue with your very narrow definition of what an environmentalist is. I would say that an environmentalist is one who stands up for those that have no voice. But we have to stand up for everything, for the cultural values and all the other values. For example, we recognize the issues that are facing the fishermen, and we want to see people fishing.

If you are asking who has been the most successful, it certainly has not been those who have said the existence of salmon is the most important thing. We have managers who only look at use; they look at fishing plans above all else. They do not look at conservation. This has been the problem and that is why we are still talking about collapses. DFO is not managing for a future for salmon, certainly not for all stocks.

If we are going to really look at all values, then the importance of salmon to the ecosystem cannot be overemphasized. If we want to manage for the ecosystem, then we have to look at it in a very different way. I am not sure if DFO is capable of managing in a different way. What we do need, as John Fraser said, is to take political action on this because that is where the power lies, unfortunately. Under the Water Act the fish have no right to water. That tells you how much we value the fish and value the ecosystem. Therefore, we have to flip it all on its head. It is not a question that we have been monumentally unsuccessful in getting the attention that this fish and this icon of British Columbia deserves and for everybody to rise up and take action on this issue. It is that our current systems are failing and a new course has to be taken. If we don't change our course then we will end up where we are headed and we have seen where we have been headed since 1992, or even earlier.

Kai Chan:
It wasn't my intent to put forward a definition of environmentalism – I did this solely for the purpose of answering the question. The point is: What would make somebody an environmentalist compared to somebody who would not be considered an environmentalist? Certainly, environmentalists often champion many other things at the same time and often they champion the causes of those who cannot speak, in part because of, and in terms of, the benefits that they have for people. When I talked about the limitations, I was talking about the limitations of the term "environmentalist" and not of environmentalism, which does have many faces. So you and I do not disagree on this. Certainly, in many ways the systems are failing. But at the same time I would not agree that we have been wholly unsuccessful in championing the values of wild salmon. British Columbia's population in general is very much aware of some of the values of wild salmon. There is a widespread recognition of the importance of buying BC salmon, of buying wild salmon, that is just not present in many other places. And that can be attributed to the good hard work of lots of NGOs and environmentalists. It is just that we need to know how to build on this. I would say that there is definitely hope there.

Participant:
I would say that where we have not been successful is that we have not changed the course or the management paradigm at DFO and governments. We need a different mandate at the political level and one that actually cares and will manage. And until we do that, we are not being successful.

What steps can you take to address ecosystem services?

A participant posed the question:
In addressing ecosystem services, do you have any experience or recommendations on what are some of the first actual concrete steps that you can take? It is a wonderful concept to talk about and I think no one in the room would argue that salmon are not culturally valuable or valuable to ecosystems. But how do you actually start incorporating these ideas into top-down processes? Do you have to go through government and policy to start recognizing this? Or is it more the people who have to speak up for these values and the sort of work that is done at a bottom-up framework?

Kai Chan:
There is no one way to do this. I would say every which way. It seems pretty clear that the top-down approach is not going to be sufficient. It also seems very clear that just working from the bottom up and not actively trying to change from the top down, as the last participant was just speaking to, would also be limiting.

A participant posed the question:
When you are talking about value are you trying to assign a number to these values, like market value versus cultural value? How do you go about doing that?

Kai Chan:
Assigning a number would be the valuation part. But values do not have to be expressed through valuations. There are lots of different ways that one can assign valuations to values.

When will salmon be recognized as the official fish species for BC?

A participant commented:
Why are salmon not British Columbia's official species? Having worked with many species of fish in this province, I would say that actually the stickleback or coastal cutthroat trout deserve the recognition beyond salmon and that is not to disrespect the many salmon biologists who are in the room. But in regards to the toughest and the most resilient, we may need to look at the least charismatic species.

Iona Campagnolo:
One of the things I wanted to bring to people's attention is that there is a group of people present in this room and elsewhere who have worked for many years to make the salmon an official icon of British Columbia. The most recent push is about two years in length and we have been quietly told, although they will deny it at the top, to back off because salmon are too political and too divisive. I implore all of you who are useful in this room today to take up the cause, because it is realizable. Our present icons in addition to the bull trout are the Kermode bear, not at all political, the western red cedar, and the Stellar's jay. If you review the list of the rest of them you will see that the salmon has a legitimate place as an icon of this province and nothing less should be accepted.

PUTTING A VALUE ON SALMON

Ken Wilson, Member, Canadian Caucus, Fraser Panel

I'm not an economist; I'm a biologist and in that context my opinions about the value of salmon are no more or less important than those of everyone else in this room.

Bob's story

This is a story I call "Bob and the Loons". Bob is a retired economics professor and he fishes a lot. I fish with him on the same week each year, first week of June. We head off to Horse Lake with our fly rods and we go trout fishing. Horse Lake is infested with loons. Now I know that is a value judgment. I do like loons, but they harass fishermen; they steal the fish off your line – they are a little bit like flying seals, I guess.

What is the value of the trout in horse Lake? Bob and I spend hundreds of dollars to fish in Horse Lake and if we conduct our affairs appropriately we do not kill any trout. So anyone with even a tiny bit of arithmetic can see that by dividing the pounds of fish we take home by the cost of our trip, the fish in Horse Lake are infinitely valuable to Bob and me. And to be honest, that pretty much captures the way Bob and I feel about the fish in Horse Lake, although I know everything does have a price.

Bob was telling me a story as we were sitting in the boat fishing and loons were harassing us. He said, "You know, there's a study in Ontario that shows that the value of recreational property on lakes with loons is significantly higher than the value of recreational property on lakes without loons." And so we had a little talk and we decided that we could make our retirement fortune by buying up land on the shores of lakes with no loons, bringing loons in and then selling for a profit. But, of course, the joke, as most of you probably already realize, is that the reason some lakes have loons and some lakes don't have loons is that some lakes have fish and other lakes don't have fish. So I suppose the value of the property is really related to the value of the fish in the lake, not so much the value of the loons.

But to be fair, all of us probably know what loons are like and we have all probably sat around a campfire in the evening and listened to them, and consider it to be a valuable part of the experience of going fishing. So the loons can't be used to account for all the difference in the value of the property, but at the same time, loons are not a trivial consideration.

These values are intangible

I think that it is impossible to separate the value of the fish and the value of the loons and the value of the property. And because it is impossible, I know there is probably an economist working hard to do exactly that, probably ably supported by several biologists. However, they probably won't get there because as we have just heard, and I totally agree, many of these values are intangible. Many of our frustrations stem from the fact that we are trying to compare intangible benefits with clearly defined costs.

That is how the government decides whether to, for example, list Cultus Lake sockeye as an endangered species under SARA. They do a cost-benefit analysis and demonstrate to the satisfaction of anyone with even a minimum knowledge of mathematics that the cost of listing is enormous and the benefits of listing are small. Governments, as a rule, tend to do that. That is how they make their decisions. They set up a frame of reference that does not go too far into the tangibles and then run the numbers. This is because they are accountable to us, both as voters and as taxpayers.

Now, I am thrilled to hear that there is work being done to help us take the intangibles that we all care so much about and convert them into a more tangible part of the decision-making process. But at the end of the day what we are really being told is that this is political. It is about politics and about how you conduct your affairs as a citizen. We all make decisions about how we spend money and how we spend our time. We know that the way we make those decisions actually feeds back into the loop and affects the values of things. And it has political implications as well. I think one of our problems is that we have been reluctant to stand up for our values in a political sense and talk about things that are personal and private and even spiritual, and to argue that those values need to be incorporated in a very direct and meaningful way into the decisions that our politicians make.

To me, it is about standing up and having the courage to protect the things you value. It is about doing what you believe is right and not allowing yourself to be intimidated by a cost-benefit analysis that tells you that what you want is too expensive and that you are just being selfish.

DIALOGUE

You can't solve this with a calculator

Karl English:
After many years of working with Nisga'a, and being engaged in a number of battles with the federal and the provincial governments, the one thing that led to solutions was to look at where we shared values, not where we were conflicted on them. That is probably the only way around this problem. We constantly try to turn it into a mathematical equation where we are looking at tradeoffs between different values, but this is not something you can calculate with a calculator.

Everyone here shares the values of having an abundant salmon resource and feels the pain if there is not. If there is an abundance, then the issue of allocation arises and you have to address how you share under an abundant scenario. When it is not abundant, it is pretty simple – you have to let the fish spawn.

There have been good decisions made, at least in the past few years, to not go fishing when there are not enough fish to share. At that point it is not about whether it's worth this much to a sport fisherman, that much to a commercial fisherman, or this much to a Native fisherman for food or economic purposes - you just say there are not enough fish and we are not going to go fishing.

The problems all occur at the points between when you stop fishing and when there is an abundance of the resource and you have to determine how you share it. If we keep the focus on the systems to tell us when we need to back off, and where our values are in common, that is having a healthy resource, then we will get to where we all want to be down the road.

Are there examples of where framing has been changed around an issue and that led to concrete changes in policy and decision-making?

A participant posed the question:
How do you frame the issue? How does that affect the values in a society? If you look at this from an economic issue or from an ecosystem-based issue, you tend to segment people out in a culture and so you diminish the political power that you can put behind a particular issue.

Do you have any examples where framing has been changed around an issue and that moved it forward? I can think of social examples where people have tried to push an issue from one perspective and didn't get any traction. But then when they turned it into an equity issue, why is my neighbourhood treated differently from other neighbourhoods, for example, then they suddenly got the political attention and the change in policy that they needed. Do you have similar examples from the natural resource issues?

Kai Chan:
It is not so much about changing the values as changing the expression of those values. That is where framing really comes in. It is well-known that that is an important aspect of political dynamics. In this case, judging from the level of public opinion, I believe for the most part we are doing pretty well on salmon. There is broad public agreement about the values.

The problem is when it comes to the rubber hitting the road and the need for actual concrete changes in policy and management. That is when it is less clear what needs to be done and how we can use that public opinion to bring about those changes.

John Fraser:
I can provide some examples of action on the part of citizens resulting in action taken at the political level. David Anderson, when fisheries minister, took some very tough decisions. He stood up in front of very angry people and said, "Once upon a time there were a lot of fish out there. They aren't there now and the only way we're going to save them is that I have to stop you from catching what is left." That, in part, took an instinct about the values of growing up on this coast and understanding what an icon is, and understanding what salmon are and the interrelationship between salmon and so many of the other values that we have. This would not have happened if we had not had a fisheries minister at the time who had all those values instinctively within himself and had the political and morale courage to say what he did and to do what he did.

There are other examples. The Mulroney government and the former President Bush signed an accord on an attempt to eliminate, or to at least diminish significantly, acid rain. A cross party committee was formed and we had tremendous support from citizens in those parts of Ontario that were being impacted by acid rain resulting from a long-range disposition of pollutants. If there had not been that very widespread public support, coupled with people on both sides of the house who knew that it must be done, it would not have happened.

In the Maritimes a report from a DFO scientist said that if we continued to harvest the Atlantic salmon the way we were doing then we were going to eliminate these salmon on the east coast of Canada. Armed with that report, we did a tremendous amount of work, in partnership with the Atlantic Salmon Federation, the Miramichi Atlantic Salmon Federation and others, together with enormous public support, to finally go all the way against tremendous and very unpleasant opposition to end the commercial netting of Atlantic salmon. If that had not happened there would not be any Atlantic salmon today on the east coast of Canada. That was another case where many years of lobbying by citizens, on both sides of the border, brought about change. And that was the same with acid rain. We were able to engage the political side and get the political support and get it done.

Anyone who has lost hope that politicians cannot be persuaded needs these examples. However, you can't go just to one party or just to the government. Most of the times that we have actually got political action we have been able to involve people who happen to get

elected and who are in different parties but who are convinced that this needs to be done. Everyone here has an MP and an MLA. It does not matter what political party they are in. You should leave this meeting and you should get in touch with these people and tell them that these are the things we want you to talk about and we demand that you come back here in six weeks and tell us who you have talked to, and what you are doing. If we ever give up on believing that we have political power then we are not going to have a democracy. You can talk about values all you want in an undergraduate university course but it will just be that, talk. If you are going to solve these problems, you have got to know that ultimately you have to get to the politicians and you have to cross party lines and you must engage the public.

A participant commented: There are a lot of children out there that don't totally understand what salmon mean to British Columbia. And there are communities out there that don't even know that they have a salmon stream in their backyard. We were just at a school in Langley that had no idea that they had a salmon stream that was running right behind their school. And it was a great pleasure to enlighten them that there were actually salmon in there. Fortunately the fish were spawning just then so they actually were able to see this. This really changed how they feel about the place where they live. Kai mentioned that salmon is about place and talking to people. When you talk to people about their place you have to talk to them about their whole watershed and the rivers and streams that come to them and leave them.

SECTION VII
What Actions Can Be Taken Over the Short and Long Terms?

- **What stewardship and stock recovery initiatives are underway or needed?**

CASE STUDIES

Salmon Stronghold

Ken Beeson, Pacific Fisheries Resource Conservation Council

Water Conservation

Craig Orr, Executive Director, Watershed Watch Salmon Society

Contaminants and Sewage

Ken Ashley, Instructor, BC Institute of Technology

Change to Land-Based, Closed-Containment Aquaculture Systems

Andrew S. Wright, Save Our Salmon Conservation Foundation

SALMON STRONGHOLD

Ken Beeson, Pacific Fisheries Resource Conservation Council

The protection of Canada's wild Pacific salmon and steelhead requires innovative strategies to halt the declines in salmon populations and losses of biodiversity. This panel discussion is about reinforcing what's being done well, and offering different strategies.

Why do we need a new approach?

About two years ago, the members of the Pacific Fisheries Resource Conservation Council began investigating alternative salmon and steelhead habitat programs. They found that the North American Salmon Stronghold Partnership that was managed by the Wild Salmon Center in Portland appeared to hold considerable promise for its application in Canada.

There are obvious reasons to look for new salmon habitat solutions. In the uphill battle to safeguard British Columbia's wild salmon in the past two decades, crisis management has replaced prevention as the primary strategy. A fire-fighting mentality has come to prevail for salmon managers who have been

forced to deal after-the-fact with a constant series of wild salmon crashes and declines across many areas of the province.

At the same time, the funding for salmon conservation has become more severely rationed than ever. Government fisheries agencies have had to focus their dwindling resources towards coping with immediate weak-stock crises, and away from investments in prevention. The funding from conservation foundations and individual donors for salmon habitat also declined as the recession hit. As a result, the role of prevention and ability to apply risk management in salmon conservation lessened.

The Salmon Strongholds strategy is intended to shift the emphasis in salmon conservation onto measures that help avoid the increasingly severe productivity declines and conditions like those experienced last year in the Fraser River.

One of the main values in adopting the Salmon Stronghold approach in Canada could be to both strengthen existing habitat programs, like the Wild Salmon Policy, and establish a new strategic prevention initiative.

The Salmon Stronghold approach

The work of the North American Salmon Strongholds Partnership involves identifying and ranking the most important salmon and steelhead habitats, and supporting measures to ensure that these priority habitat areas are not left at risk. A Salmon Stronghold describes a watershed or basin or region where wild salmon are particularly strong and diverse and where the habitat has real and long-term potential to support thriving salmon species.

As I said, the Salmon Stronghold approach is essentially a preventive strategy to ensure thriving fish habitat and sound management exist to maintain three crucial components: abundance, productivity and diversity. It involves reinforcing the strengths and reducing the threats to wild salmon in geographical areas of special importance.

The investment in preventive measures in Salmon Strongholds could save millions of dollars that would otherwise be required for future restoration, stock rebuilding and emergency programs to deal with salmon stock crises.

Salmon Strongholds involve several voluntary and locally-based initiatives, in conjunction with government agency participation. A particular focus of Salmon Stronghold activity relevant to British Columbia is the purchase of land and property-rights arrangements, such as covenants and land set-asides, for areas with special significance or vulnerability for salmon.

Living Blueprint for B.C. Salmon Habitat

Many of the features of what is now described as the Salmon Strongholds approach were initially conceived by a group of prominent Canadian researchers and fisheries specialists and explained by them in the late 1990s. Their report entitled *Living Blueprint for B.C. Salmon Habitat* was prepared through the Pacific Salmon Foundation.

The authors of the *Blueprint* presented a compelling case for a shift in salmon habitat policy to become proactive instead of reactive. They were perceptive in the predictions of the severe climate change impacts on fish, competition for water resources, and urbanization effects -- all undermining the freshwater habitat of wild salmon.They emphasized the importance of carrying out a rigorous and science-based ranking of habitats -- including watersheds, basins and landscapes --- to measure their status in productivity and future sustainability. They called for a strategy that would give the highest priority in fisheries habitat management to the protection of the remaining crucial and significant salmon habitat.

Regrettably, the new habitat strategy suggested then by those experts was not adopted, primarily because of Canada's preoccupation with the Wild Salmon Policy's introduction and DFO's reliance on that Policy as the cornerstone of their future plans.

The North American Salmon Stronghold Partnership

Almost five years ago, the North American Salmon Stronghold Partnership was created in the Pacific northwest states by a volunteer network of individuals and organizations working from the same principles as those outlined in the document. The Salmon Stronghold partners -- including landowners, government agencies, scientists, NGO's, and First Nations -- are working in areas of California, Oregon, Washington and Idaho. They are involved in activities such as fish passage restoration, land exchanges, stock status assessments, regional planning, land set-asides for conservation, and non-development agreements for sensitive areas. They share their experience through an information and best-practices network, and are building towards coordinated coast-wide habitat activities.

Applying the Salmon Stronghold Concept in Canada

Last summer I produced a report for the PFRCC entitled *Applying the Salmon Stronghold Concept in Canada*. This report explained that Salmon Strongholds could offer a good fit with Canadian government programs and existing volunteer organizations, supplementing the initiatives of the Pacific Salmon Foundation and Living Rivers Trust Fund that have broad habitat restoration mandates. It explained that Salmon Strongholds could also represent ways to offset the perception of many British Columbians that there is unrelenting, unstoppable decline in the prospects of wild salmon.

The Harrison River

Based on that report, the PFRCC decided to test the Salmon Strongholds approach in Canada in a six-month pilot project in the Harrison River. That involved a joint effort by habitat scientists, government agencies, and the Chehalis First Nation. Together, they contributed to the scientific assessment of the area and salmon species, and began to identify opportunities for prevention initiatives. The PFRCC hoped that the Harrison River pilot project might lay the groundwork for Salmon Strongholds in other areas of British Columbia and Yukon.

The scientific assessment was coordinated by Gordon Ennis. Not surprisingly, Gordon found that the Harrison River scored exceptionally high marks from the perspectives of diversity, productivity and uniqueness of its wild salmon species. Consequently, this reiver was designated last month as Canada's first Salmon Stronghold. An upcoming meeting of stakeholders and interested groups is being organized to take the Harrison Salmon Stronghold into its implementation phase.

Moving forward in BC

The North American Salmon Strongholds Partnership was intended, from the start, to extend to Alaska and British Columbia. The involvement of Canadians and Canadian organizations in the Pacific Rim network of Salmon Strongholds presents a tangible way to advance salmon and steelhead conservation through joint initiatives and shared objectives.

The Wild Salmon Centre will be working with the PFRCC and other stakeholders to review the Stronghold Partnership's methodology of assessing Pacific salmon populations across the province to serve as a basis of identifying BC's Salmon Strongholds. They hope to obtain foundation funding this year to begin looking first at the Fraser River system.

The assessment in this proposed project would pull together the data and expert perspectives to fill a gap that has not been addressed in studies by other research or government agencies. It would provide an authoritative basis to establish priorities for investment in conservation efforts, and enable planning for long-term sustainability.

The designation of any further Salmon Strongholds in Canada will depend upon the findings of the comprehensive province-wide assessment. While there are some areas that, like the Harrison, may

seem to be obvious candidates, it will be important to provide a rigorous justification in each case. One of those future areas could be the Taku River system that might serve as a first international, shared-border Salmon Stronghold.

Conclusion

I just want to add two final comments. One is that Salmon Strongholds are not meant to replace or push aside any of the existing conservation programs. Salmon Strongholds are meant to attract new people and new sources of investment for salmon conservation, not to divert those away from current activities. Second, priority-setting and identification of areas of particular importance do not mean that other habitat should be ignored. The designation of Salmon Strongholds in Canada does not imply that other salmon watersheds or river systems should be overlooked in any way. In fact, the heightened public awareness created by Salmon Strongholds actually expands public understanding of the importance of protecting *all s*almon-producing ecosystems.

Salmon Strongholds could become a rallying point for more positive activity and new resources to combat salmon declines. The adoption of the Salmon Stronghold approach in Canada offers the opportunity for a renewal of hope and practical activities to protect Pacific salmon habitat.

If you would like more detailed information about Salmon Strongholds is available on the websites of the PFRCC and Wild Salmon Centre in Portland.

WATER CONSERVATION

Craig Orr, Executive Director, Watershed Watch Salmon Society

We have heard a lot about marine issues but we must also address watershed and habitat issues that might affect salmon. More and more we are recognizing the importance of freshwater and habitat for our salmon.

Facts about freshwater in BC

Here are a few facts about freshwater in BC. Right now fish and aquatic ecosystems enjoy no legal rights to water. Our Water Act is over 100 years old. It says nothing about fish and we do not have guaranteed in-stream flows, except in a few of the Hydro Water Use Plans. Water licensing decisions similarly ignore instream flow needs for fish. There are some guidelines around run-of-river projects but at this time there are no guaranteed in-stream flows for fish. Another obvious fact is that many streams are imperiled from too many water licenses and unregulated groundwater extraction. I believe that at the latest count there were 44,000 water licenses issued, and none of them, except for the new ones around run-of-river power, have expiry dates. We are clearly over-subscribed on many systems. We also have problems with unregulated groundwater extraction. At this point groundwater is not regulated except at flows above 75 litres per second, which is a huge amount. Finally, climate change and growth will only further impair aquatic ecosystem function and worsen water conflict.

Threats to freshwater systems in BC

Climate change

The graph in Figure 1 shows the observed and predicted (modeled) relationship between discharge from glaciers into streams in the Bridge River area over time, beginning in 2000. This is only one area in British Columbia and it is not necessarily symbolic of all other areas, but it does provide compelling evidence of the effects of climate change. It does not provide a very rosy picture

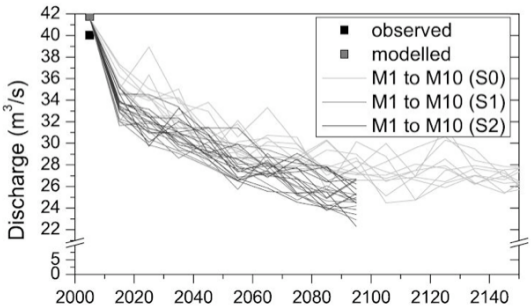


Figure 1. Evidence of climate change from observed and modeled declines in glacier-fed rivers near Bridge River, BC. (Stahl et al. 2009).

about the future stream flow available for salmon.

Run-of-river power projects

One significant concern at the moment is the number of river diversion projects, in place and proposed, for run-of-river power initiatives. Figure 2 shows a photograph of the Harrison project.

Figure 2. Construction impacts from project development, Harrison River BC.

These hydro projects are not small and have the potential for significant negative impact on salmon habitat; for example, the bypass tunnel at the Ashlu River is 7km long. In many systems these are very large projects and they are proposing to extract large amounts of water.

Figure 3 shows some of the projects that are proposed or in place along BC's South-central coast. Development at this scale is expected to result in major alterations of the hydrology of the systems, not necessarily affecting sockeye *per se* but obviously some of the resident fish. In some areas they may well affect sockeye in terms of stream use.

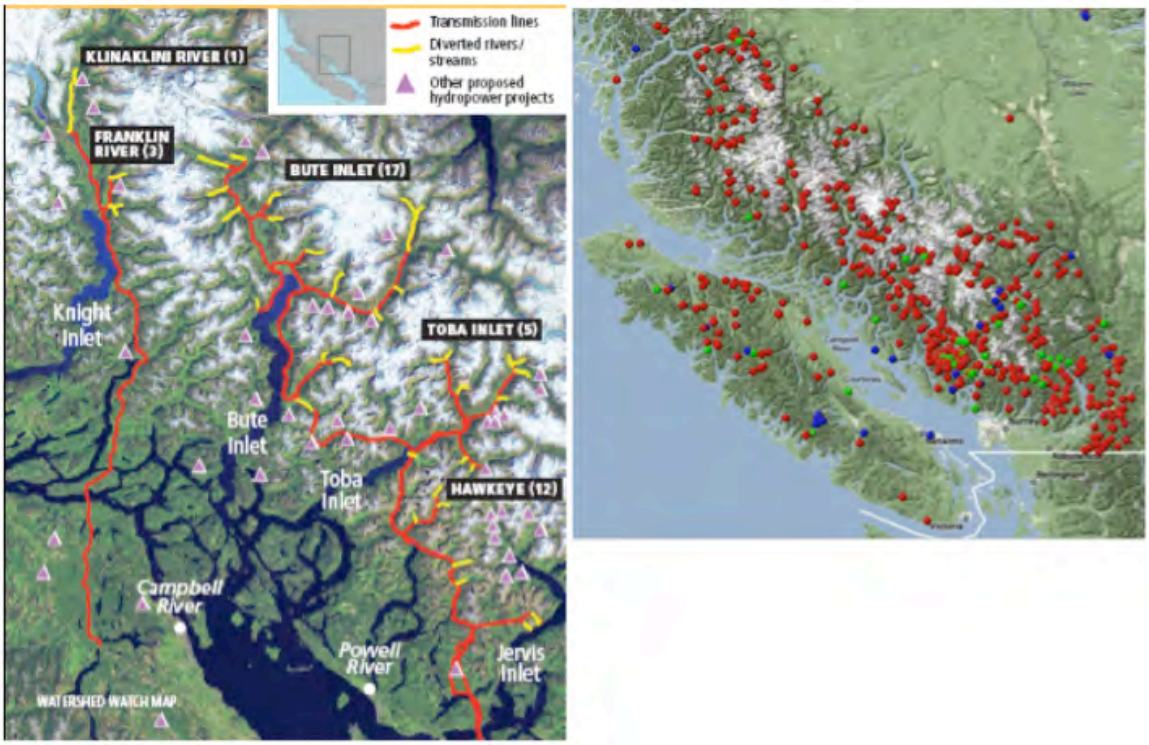


Figure 3. Locations of existing or proposed river diversion projects clustered in Knight, Bute and Toba Inlets, and map (www.ippwatch.info) of proposed or built projects in BC.

For instance, the Bute Inlet project is proposing to divert 17 rivers into 16 power houses, resulting in a major alteration of the area's hydrology. The map on the right of Figure 3 shows some of the proposed water applications around British Columbia. Note that they tend to be clustered in coastal areas and in other areas such as the Kootenays.

Groundwater

We are just now beginning to recognize the importance of groundwater, in particular to salmon. The small dark dots in Figure 4 are actually huge Nicola River Chinook salmon. The red line portrays a zone of influence from cool, influent groundwater.

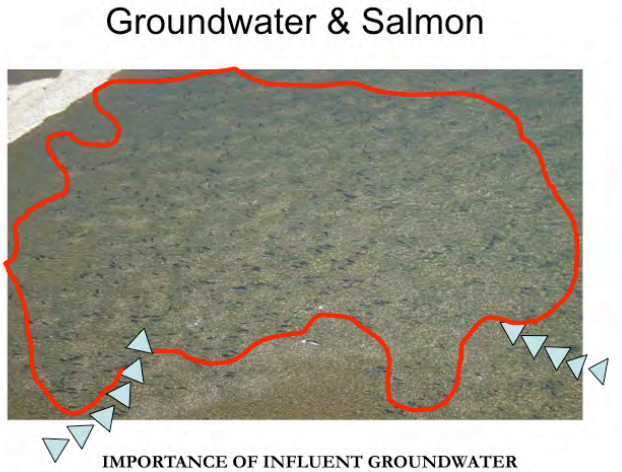


Figure 4. Aerial photo of thermally-challenged Nicola River Chinook. Spawning occurs in areas of influent groundwater.

We are learning that the value of groundwater to species like Chinook and coho is almost immeasurable. In fact, you can only find Chinook spawning in areas where there is influent groundwater in many of these streams. Unfortunately, however, if there is no protection of groundwater, then what we are doing now, since the surface water rights are fully subscribed or over-subscribed, is drilling wells right next to rivers and extracting water, without respecting the inter-connected nature of groundwater and surface water.

Again, it is becoming more and more evident that groundwater is important for maintaining the resilience of these systems by moderating flows and temperatures. Groundwater augments the flows in dry summer periods and keeps the temperatures to within the optimum critical levels described by Scott Hinch (page 78). In the wintertime groundwater prevents the ice from being frozen in these systems.

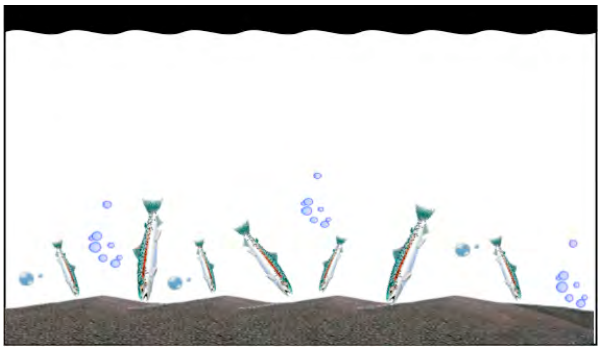


Figure 5. Juvenile coho salmon have been observed in temperature sensitive streams with their noses planted in the gravel above zones of cool, influent groundwater.

The cartoon in Figure 5 shows juvenile coho with their noses jammed in the gravel for the express purpose of surviving. They are trying to get the oxygenated water and particularly the coolness of the water coming up from the groundwater. This is based on some anecdotal observations that are currently being researched. This emphasizes the importance of some of these groundwater areas, for interior salmon in particular.

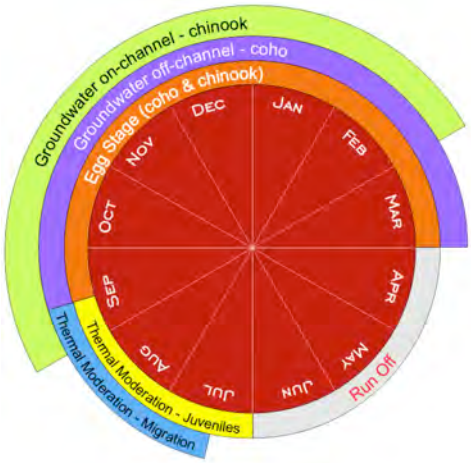


Figure 6. Groundwater provides thermal moderation for various species of salmon at different times of the year/life-cycle. Richard Bailey figure.

The chart in Figure 6 describes the importance off groundwater in providing thermal refugia for salmon. The months of the year are shown by the out bars where groundwater actually helps the salmon meet their various lifecycle requirements including the migration, the juvenile, and the egg stages. Thermal moderation for juveniles by groundwater from July through to September is absolutely critical.

How can we protect aquatic ecosystems?

Obviously, we need to look at guaranteed minimum flows in streams based on time of the year. Other flows are also important; for example, channel forming or flushing flows – it takes about 200 to 400 mean annual discharge flows to create these. We also have to acknowledge the connection between groundwater and surface water. In addition, we have to implement a rational planning process for renewable power production in BC if we want to see our fisheries resources maintained.

Furthermore, we need better management to ensure water for streams. Instream needs must be equal or higher in priority to other uses, and instream flow needs must be determined month by month both for valued fish species and life stages, as well as stream habitat maintenance. We must recognize the need to deal with trade-offs in the face of water scarcity and we must measure and regulate water withdrawals and ensure that water withdrawals for human needs do not compromise instream flows, even if this means limiting human use. And we can do that. There is a lot of information available from the Water Use Planning process. For example, the graph in Figure 7 shows maintenance flows, rearing flows, spawning passage flows and flushing flows that were measured for the Coquitlam River Water Use Plan, based on mean annual discharge.

The science is there. It is the will and the ability to do it that is lacking at this time. The concept of carrying capacity has been advanced for many years through ecology but we tend to ignore it when we start settling into areas, particularly arid areas where there is a limited amount of water. Certainly, we can do better at conserving water. There are some awareness tools available, including a publication on legal tools for First Nations.

Daily flows augmented by releases from Reservoir in a "wet" and "dry" year at Port Coquitlam (WS08MH002) in the Coquitlam River. Naturalized mad = 27 cms. Three conservative flow levels plotted. Assumes 2 cms release (Nov-May) and 3 cms (Jun-Oct).

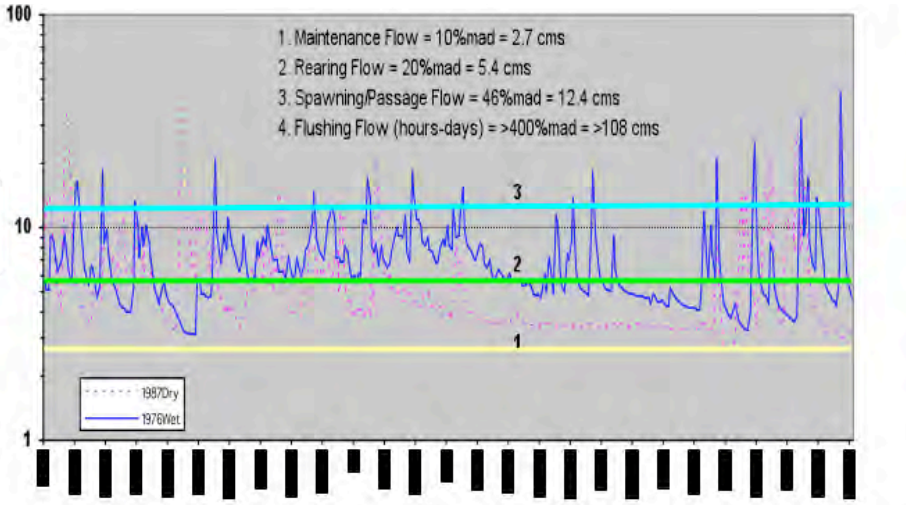


Figure 7. Water requirements for salmon are defined as maintenance flows, rearing flows, spawning passage flows and flushing flows, here measured for the Coquitlam River, based on mean annual river discharge.

Our best opportunity is going to be through Water Act modernization and the Living Water Smart program. This was announced two years ago by the provincial government, and the consultations around how we are going to look at modernizing the Water Act are just now beginning. The two themes that are of great importance to those who care about salmon are stream health and protecting groundwater.

CONTAMINANTS AND SEWAGE

Ken Ashley, Instructor, BC Institute of Technology

This presentation focuses on: emerging concerns about wastewater and removal efficiencies in wastewater treatment plants; the potential effect of wastewater in the Fraser on smolt migration; trends of PCB and PBDE levels observed in Strait of Georgia sediment cores, with a focus on one particular contaminant that Metro Vancouver is discharging into the Fraser River; and the effect of wastewater treatment plant discharges on Fraser River water quality.

Emerging concerns about wastewater

There is an emerging concern about wastewater and the array of chemicals that are being produced by society and usually end up going down the drain. Endocrine disruptors are of particular concern, and there is a large range of these compounds; for example, the compound Bisphenol A which led to a debate over plastic water bottles and the banning by Health Canada for some baby bottles. Another endocrine disruptor is Triclosan, a thyroid hormone mimicker that acts as an antibacterial agent. PCBs (polychlorinated biphenols), POPs (persistent organic pollutants) and fire retardants such as PBDEs (polybrominated diphenyl ethers) are other compounds of concern. Numerous pharmaceuticals, such as Viagra and Prozac that are also found in wastewater. The latest compounds of concern are nanoparticles, such as nanocarbon, nanotitanium and nanosilver. Nanosilver is now used by some washing machines to disinfect clothing (silver has been known since the Middle Ages to have antimicrobial activity). All of these compounds usually end up in the drain being discharged into either the marine or freshwater environment.

Take for example, Triclosan, an insidious antibacterial agent that is everywhere. It is found in many household and personal products including liquid hand and face soaps, toothpastes and mouthwashes, deodorants, cosmetics, shaving products and dish soaps and household cleansers. Figure 1 provides lists of some of these products.

Products Containing Triclosan (incomplete list)

Liquid Hand/Face Soaps:
Dial, Softsoap, Clearasil, Clean & Clear, pHisoderm, DermaKleen

Toothpastes & Mouthwashes:
Colgate Total, Reach Antibacterial Toothbrushes, Breeze Triclosan Mouthwash

Deodorants:
Old Spice High Endurance Stock Deodorant, Right Guard Sport Deodorant

Cosmetics:
Supre Cafe Bronzer, TotalSkinCare Makeup Kit, Garden Botanika Powder Foundation, Mavala Lip Base, Jason Natural Cosmetics, Blemish Cover Stock, Movate Skin Lightening Cream HQ, Paul Mitchell Detangler Comb, Revlon ColorStay LipShine Lipcolor, Dazzle

Shaving Products:
Gillette Complete Skin Care MultiGel Aerosol Shave Gel, Murad Acne Complex Kit, Diabet-x Cream, T.Taio sponges and wipes, Aveeno Therapeutic Shave Gel

Dish Soaps/Household Cleaners:
Dawn, Ajax, mop heads

Figure 1. Products containing the endocrine disruptor compound, Triclosan.

The chemical itself is an endocrine disruptor, very similar to thyroid hormone. Endocrine disruptors function at concentrations that are well below the normal ecotoxicological levels observed in the field; that is, concentrations much lower than milligrams or micrograms per litre levels. Most chemicals in the environment that mimic hormones in the body and that can have potential impacts on fish, wildlife and humans operate at much lower concentrations, in the parts per billion and parts per trillion ranges. To put that in a time perspective it would be like one second in 30,000 years. These are the

typical low concentrations of hormones found in mammals and fish. Table 1 provides a list of known endocrine disruptors in 2007.

Table 1. List of identified endocrine disruptor chemicals, 2007.

- 17 B-estradiol (normal female hormone)
- Ethinylestradiol (birth control pills)
- Surfactants such as nonylphenol and nonylphenol ethoxylates
- Triclosan (antimicrobial agent in household products)

Wastewater treatment

The question is: how effective are wastewater treatment plants at keeping these compounds out of marine and freshwater environments? The answer is that they are not; however, the efficiency of removal depends on the type of plant. In one study, only around half of the frequently detected compounds were reduced by 95% or more by activated sludge plants whereas less than 10% of the endocrine disruptors were reduced by 95% at trickling filter plants.

Primary treatment compared with secondary treatment

Primary treatment is a mainly mechanical process that removes between 30 – 40% of BOD (Biochemical Oxygen Demand) compounds and 50% of the TSS (Total Suspended Solids) compounds. Iona Island and Lions Gate Wastewater treatment plants are examples of these. Secondary treatment is a biological process that removes up to 90% of BOD and TSS compounds. Lulu Island, Annacis Island and Northwest Langley have these types of plants processing the wastewater before the effluent is released into the Fraser River.

Comparison of wastewater treatment plants

It is only recently that removal efficiency at wastewater treatment plants has been examined in more detail; comprehensive reviews were conducted by both Europe and the USA in 2007. The results of these reports indicate that trickling filter (TF)plants are very ineffective at removing a wide range of emerging contaminants and that biological nutrient removal (tertiary treatment) types of plants are the most effective. They showed that the highest removal efficiencies were in activated sludge plants (as WWTPs) because these have longer hydraulic residence time (HRT), longer solids contact time and a more diverse microbial community. Table 2 provides the results of the Europe 2007 study comparing different wastewater treatment designs.

Table 2. Effect of Wastewater Treatment Plant design; 2007 England study.

- Activated sludge WWTPs have higher removal efficiencies for most EDCs than most trickling filter plants
- Higher removal efficiency in AS WWTPs is due to (1) longer hydraulic contact time (2) longer solids contact time and (3) more diverse microbial community:
  - Activated Sludge WWTP ~ 5-20 hr HRT
  - Trickling Filter WWTP ~ 30 minute HRT
  - Biologically Aerated Filter ~ 15 – 60 minute HRT

Table 3. Effect of Wastewater Treatment Plant design: 2007 USA study.

- Highest (>90%) EDC removals were observed in:
  - AS plants with sludge age of 5 to 10 days and
  - AS plants with a nitrification/denitrification step
  - TF plants with additional tertiary biological step

  Note: Annacis/Lulu design (TF/SC) is not effective at removing EDCs

Results of the 2007 study conducted in the USA are presented in Table 3. Similar to the European study, they demonstrated that > 90 % of endocrine disruptor compounds (EDCs) are

removed in activated sludge plants, or trickling filter plants with an additional tertiary biological step. The largest wastewater treatment plant that releases effluent into the Fraser River, Annacis Island, has trickling filter treatment, but it is not effective at removing EDCs.

Effects of effluent on salmon migration

Recent research has show that incidents of sex-reversal in salmonids have been observed in the effluent plume. The presence of EDCs may also interfere with the typical olfactory imprinting process during early life cycle development stages in salmon.

There is a period when the smolts go through the parr-smolt transformation, where the thyroxin hormone levels become elevated in the blood. It is known that juvenile salmon detect the unique odour of their natal streams; this phenomenon is referred to as olfactory imprinting, and this is how salmon migrate to their natal stream once they return into the freshwater environment (in the open marine migration they are guided by magnetic compass and sun height). Evidence suggests that juvenile salmon 'imprint' odours of the streams on the way to the ocean during the parr-smolt transformation period. Elevated thyroxin levels stimulate neural development of the olfactory cells, and this facilitates olfactory imprinting. However, this process may be interrupted when the smolts move through effluent plumes containing Trislocan and other EDCs.

PCB and PBDE trends in Strait of Georgia sediment cores

Research has been conducted under the direction of scientists at the Institute of Ocean Science where sediment cores were obtained from the Strait of Georgia and examined for organochlorines, PCBs and PBDEs among other compounds. The presence of PBDEs is universal; for example, they are in your furniture cushions and in computer cases.

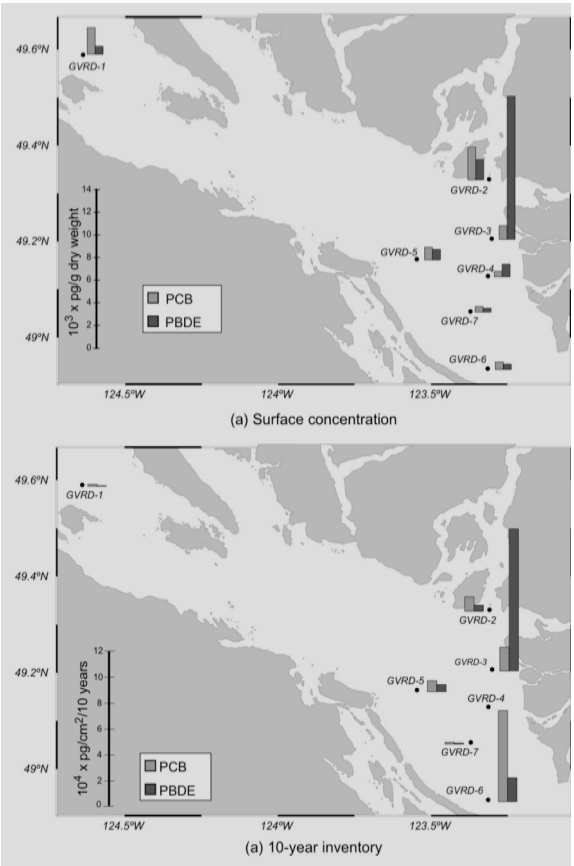


Figure 2. Strait of Georgia sediment core sites and trends in PCB and PSDE concentrations (Johannesen et al., 2008).

The sediment cores were taken from a number of sites in the Strait of Georgia, including a site close to the Iona wastewater treatment plant and one off Hornby Island. The map in Figure 2 shows the locations of the core sites. The heights of the bars at the right of the figure indicate the quantity of the compounds measured. Note the amounts of these compounds being discharged from the Iona wastewater treatment plant, measured after treatment.

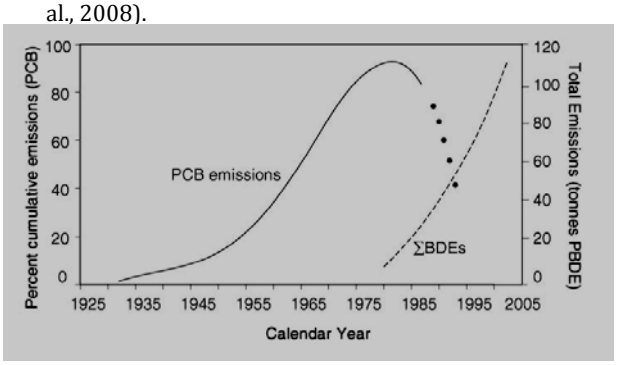


Figure 3. Emission histories of PCBs and PSDEs, in North America, 1930 – 2000 (Johannesen et al., 2008).

The graph in Figure 3 shows the North American emission trend for PCBs beginning in the 1930s when these compounds were first introduced. Note the significant decline that has

occurred since the mid-1970s when the use of PCBs was banned. However, the decline in these compounds has been replaced by a positive trend for polybrominated diphenyl ethers (PBDEs) since this time. PBCEs have not yet been banned and the levels have increased very significantly in the past 25 years. It seems that one problem has been replaced by another. Note that now when the tissues of dead killer whales are analyzed for the concentrations of PBDEs that are present this results in the whale carcasses being classified as toxic waste and they cannot be disposed of in normal ways (Figure 4).

The orca found dead on the Olympic Peninsula earlier this year carried a level of contaminants that was among the highest -- if not the highest -- ever measured in killer whales, laboratory tests show.

The 22-foot-long female orca was so full of polychlorinated biphenyls that when scientists first attempted to test her fat, the result was too high for the machines to read it.

Figure 4. May 7, 2002, report from Seattle Post-Intelligencer, Robert McLure.

Outfalls in Strait of Georgia

The map in Figure 5 demonstrates how many outfalls there are in the Strait of Georgia. In terms of pulp mills, there is one at Crofton near Duncan, Harmac in Nanaimo, Elk Falls near Campbell River and one each at Powell River and in Howe Sound. There are also outfalls from the Lions Gate wastewater treatment plant and the Iona plant, both of which have only primary treatment. The Annacis plant is the largest wastewater facility that Metro Vancouver has, serving around a million people. This secondary treatment plant uses the trickling filters design and is not particularly effective at getting rid of EDCs.

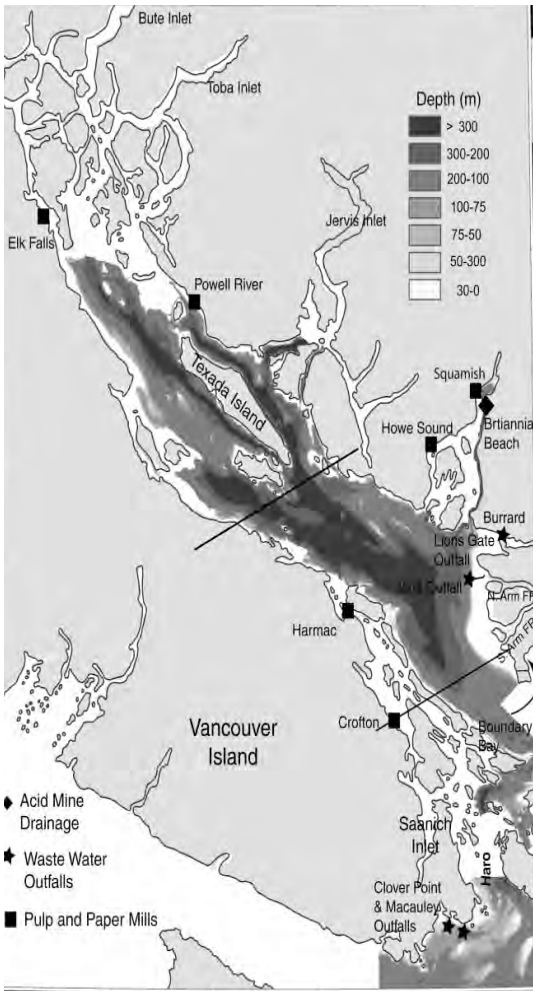


Figure 5. Outfalls in Strait of Georgia (B.J Burd et al. 2008).

The major issue, however, is ammonia and the Annacis wastewater treatment plant is known to be bad for ammonia (Figure 6).

The Annacis Island Wastewater Treatment Plant (WWTP) is the largest plant and provides secondary treatment to wastewater from approximately 1,000,000 people in parts of Burnaby, New Westminster, Port Moody, Port Coquitlam, Coquitlam, Pitt Meadows, Maple Ridge, Surrey, Delta, White Rock, City of Langley and Township of Langley.

Biosolids produced in 2006 (dry tonnes/24-34% solids concentration): 12,000
Biosolids type: Class A
Solids digestion process: Anaerobic thermophilic (55°C)

Ammonia Toxicity
pH 6 3,000:1
pH 7 300:1 $NH_3 <> NH_4^+$
pH 8 30:1
pH 9.5 1:1

Figure 6. Levels of ammonia in effluent from the Annacis Island Wastewater Treatment Plant.

Ammonia can be either in the NH_3 form or the NH_4^+ form. The form that kills fish is NH_3 since this molecule can pass through the gill membrane as it does not have a charge. The higher the pH of the water, the more toxic ammonia gets. Figure 7 shows

the relationship between ammonia and pH and includes data for the level of ammonia in effluent discharged from the plant (red dots). This demonstrates how close the effluent being discharged from the Annacis treatment plant is to killing salmon outright in the effluent at a pH value of around 7.5.

Figure 8 shows a typical chart that records data for a number of variables during routine monitoring at the Annacis Island wastewater treatment plant. The arrows show that in this record, there were 7 of 12 monthly failures of 96 hr LD50 (Lethal Dose, 50%) standard bioassay tests for ammonia in the Annacis effluent.

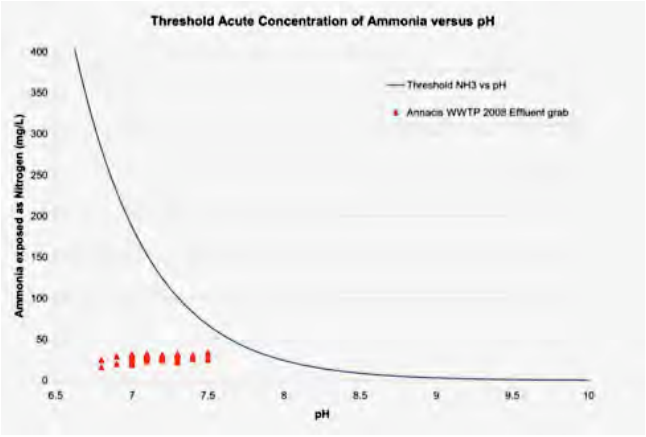


Figure 7. Annacis Island WWTP. Threshold acute concentration of ammonia versus pH (Wastewater The Greater Vancouver Sewerage & Drainage District Quality Control Annual Report 2008).

MONTH	Max. Inst.Flow Rate	Total Daily Effluent Flow (MLD)			Composite pH Average		Grab pH Average	Grab NH3 Average (mg/L)	96 hr LC50* (%v/v) FINAL EFFLUENT	
					RAW	FINAL	FINAL			
	(m3/sec)	Max.	Min.	Ave.	INF	EFF	EFF	FINAL EFF	Regular	Parallel CO2
JAN	11.9	850	457	554	7.3	7.5	7.1	24.6	>100	>100
FEB	9.7	665	441	524	7.2	7.5	7.2	25.0	>100	>100
MAR	8.9	540	441	469	7.2	7.6	7.2	26.9	74	~~>100~~
APR	7.8	586	417	449	7.2	7.7	7.1	29.0	79	~~>100~~
MAY	8.5	506	414	438	7.2	7.6	7.0	30.1	86	>100
JUN	9.4	509	400	436	7.2	7.6	7.1	30.7	>100	~~>100~~
JUL	7.0	441	400	412	7.2	7.6	7.2	30.7	86	>100
AUG	8.5	544	383	437	7.3	7.6	7.2	27.3	82	>100
SEP	7.0	458	415	429	7.2	7.6	7.1	27.9	74	~~>100~~
OCT	9.2	622	412	452	7.3	7.6	7.1	27.9	98	~~>100~~
NOV	11.8	804	449	558	7.3	7.6	7.2	23.5	>100	>100
DEC	10.9	681	429	541	7.3	7.7	7.2	24.4	>100	>100
# Samples	-	-	-	**366**	**349**	**358**	**63**	**55**	**14**	**14**
Maximum-Yr.	**11.9**	**850**	-	-	**7.5**	**7.9**	**7.5**	**33.9**	**>100**	**>100**
Minimum-Yr.	-	-	**383**	-	**7.0**	**7.2**	**6.8**	**16.1**	**72**	**>100**
Average-Yr.	-	-	-	**475**	**7.2**	**7.6**	**7.1**	**27.3**	**>90**	**>100**

7 of 12 monthly failures of 96 hr LC_{50} standard bioassay tests for ammonia in effluent

* LC50 results are reported as monthly average

MONTH	Conductivity (umhos/cm)		Ave Chloride (mg/L)	Ave Temp. (oC)	Ave. Chlorine (mg/L)	Ave. Residual Chlorine Final Effluent (mg/L)		Residual SO_2 (mg/L)	Fec. Coliform (MPN/100mL) Final	
	RAW	FINAL	FINAL	FINAL	FINAL			Effluent	Monthly	Max Geomean
	INF	EFF	EFF	EFF	EFF	Before SO2	After SO2	Outfall	Geomean	in month
JAN	507	577	66	12	-	-	-	-	-	-
FEB	490	554	48	13	-	-	-	-	-	-
MAR	505	587	50	13	-	1.07	<0.1	1.83	-	-
APR	540	636	70	15	2.9	1.02	<0.1	1.70	140	-
MAY	514	596	54	17	3.2	1.15	<0.1	1.86	54	76
JUN	497	574	54	19	3.2	1.20	<0.1	1.90	75	75
JUL	473	556	44	21	3.6	1.11	<0.1	2.66	739	2334
AUG	462	533	45	21	3.6	1.31	<0.1	2.88	1273	1114
SEP	459	532	45	20	3.7	1.35	<0.1	1.62	1171	1171
OCT	450	528	43	19	3.5	1.42	<0.1	1.78	53	2276
NOV	426	489	36	17	-	-	-	-	-	-
DEC	547	589	79	15	-	-	-	-	-	-
# Samples	**349**	**359**	**54**	**63**	**218**	**228**	**228**	**228**	**62**	**55**
Maximum-Yr.	**1140**	**971**	**165**	**22**	**4.2**	**1.9**	**<0.1**	**6.84**	**35000**	**2334**
Minimum-Yr.	**338**	**373**	**28**	**11**	**1.9**	**<0.1**	**<0.1**	**0.23**	**<20**	**22**
Average-Yr.	**488**	**562**	**54**	**17**	**3.4**	**<1.9**	**<0.1**	**2.06**	-	-
Geomean	-	-		-	-	-	-	-	**241**	**586**

(1) pH, Temperature, ammonia, Residual Chlorine(taken before and after dechlorination), Residual SO2, 96 hour LC50 and Coliform are determined on grab samples; all other parameters are determined on 24 hr. flow proportioned composite samples.
(2) Summer = Mar. 28 - Nov 14, 2008 inclusive: Chlorinated Effluent; Winter = Jan. 1 - Mar. 27, 2008 and Nov. 15 - Dec. 31, 2008: No Chlorination

Figure 8. Annacis Island WWTP. 2008 routine monitoring results and performance summary (Wastewater The Greater Vancouver Sewerage & Drainage District Quality Control Annual Report 2008).

The ammonia concentration for the Fraser River is determined using standard engineering equations as shown in Table 4. Taking the data for the ammonia concentration in effluent from the Annacis Island treatment plant of about 27 mg per litre of ammonia, then when the flows are low (1,000 m^3s^{-1}) in the Fraser River as in late February or early March there will be a concentration of about 0.16 mgl^{-1}, which is about one tenth of the lethal concentration. When the flows are higher (2,000 m^3s^{-1}) then the concentration of NH_3 is lower.

The point is that both the Annacis Island WWTP and the treatment plants at Lulu Island and Northwest Langley, are all discharging wastewater directly into the Fraser, and the effluent contains a considerable amount of ammonia.

The question is: Are we now at the point where the ammonia levels are exceeding sub-lethal concentrations for salmon?

Table 4. Ammonia concentration in the Fraser River under two different flow regimes.

(Flow 1 * Conc. 1) + (Flow 2 * Conc. 2) / Flow 1 + Flow 2)
For Fraser River in March, assume 1,500 m3/s, and 0.01 mg/L NH_3
For Annacis WWTP discharge in March = 469,000,000 L/d = 5.428 m3/s, and 26.9 mg/L NH_3
(1,500,000 * 0.01) + (5,428 * 26.9) / (1,500,000 + 5,428) = 0.11 mg/L at pH 7.1
At 1,000 m^3/s = 0.16 mg/L NH_3
At 2,000 m^3/s = 0.08 mg/L NH_3

Table 5. Average 30-day concentration of total ammonia nitrogen for protection of aquatic life (mgl^{-1} of Nitrogen)

pH	T = 7.0	T = 8.0	T = 9.0	T = 10.0	T = 11.0	T = 12.0	T = 13.0
6.5	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.6	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.7	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.8	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.9	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.0	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.1	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.2	1.90	1.88	1.86	1.85	1.83	1.81	1.80
7.3	1.90	1.88	1.86	1.85	1.83	1.82	1.80
7.4	1.90	1.88	1.87	1.85	1.83	1.82	1.80
7.5	**1.91**	**1.88**	**1.87**	**1.85**	**1.83**	**1.82**	**1.81**
7.6	1.91	1.89	1.87	1.85	1.84	1.82	1.81

Table 5 shows the effect of pH and temperature on ammonia toxicity. Toxicity increases with pH and temperature.

Finally, Figure 9 shows an example of an operational certificate that is required for monitoring chemicals in wastewater treatment effluent. Note that the analysis includes measures of a number of heavy metals and other metals. The concentration of cadmium is extremely high and should be investigated immediately. This information is stored in documents that are hard to access and it is unlikely that fisheries agencies are paying much attention to this information in current times.

				No. of times Criteria Exceeded												
Compliance Parameters	**Frequency**	**OC Limits**	**Max. Value for the Year**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Yr to Date**
Total Flow (MLD)	Daily	1050	850	0	0	0	0	0	0	0	0	0	0	0	0	0
cBOD (mg/L)*	3/week	45.0	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Suspended Solids (mg/L)	5/week	45.0	64	2	0	0	0	0	0	0	0	0	0	0	0	2 of 360
cBOD (Tonnes/Day)*	3/week	17.0	21.7**	1	0	0	0	0	0	0	0	0	0	0	0	1 of 105
Susp. Solids (tonnes/Day)	5/week	20.0	53.4	3	0	0	0	0	0	0	0	0	0	0	0	3 of 360
Chlorine Residual (mg/L)	Daily	<0.1	<0.1	0	0	0	0	0	0	0	0	0	0	0	0	0

* cBOD reported 1/week when COD are reported 5/week

**cBOD loading for secondary effluent was reported for Jan 14, 2008 during bypass

	OC	Sample	Year 2008		
Monitoring Parameters	**Frequency**	**Type**	**Maximum**	**Minimum**	**Average**
pH***	1/month	Grab	7.5	6.8	7.1
Toxicity, 96-hour LC_{50} (%V/V)	1/month	Grab	>100	72	>90
Ammonia (mg/L)***	1/week	Grab	33.9	16.1	26.8
Hardness (mg/L CaCO3)	1/month	Comp	54.9	33.5	43.7
COD (mg/L)*	5/week	Comp	89	39	81
Conductivity (*u* mhos/cm)	-	Grab	971	373	562
Temperature °C	1/month	Grab	22	11	17
Fecal Coliform MPN	1/Week	Grab	35,000	<20	1000****
Residual Chlorine (mg/L)	Daily	Grab	<0.1	<0.1	<0.1
Oil and Grease (mg/L)	-	Grab	<7	<5	<7
Phenol (mg/L)	1/month	Grab	<0.01	<0.01	<0.01
Aluminum, Total (mg/L)	1/month	Comp	0.20	0.08	0.12
Arsenic, Total (mg/L)	1/month	Comp	<0.001	<0.001	<0.001
Barium, Total (mg/L)	1/month	Comp	0.011	0.004	0.007
Boron, Total (mg/L)	1/month	Comp	0.20	0.13	0.18
Cadmium, Total (mg/L)	1/month	Comp	16.7	9.6	12.9
Chromium, Total (mg/L)	-	Comp	0.004	<0.001	<0.002
Cobalt, Total (mg/L)	1/month	Comp	0.001	<0.001	<0.001
Copper , Total (mg/L)	1/month	Comp	0.072	0.028	0.056
Iron, Total (mg/L)	1/month	Comp	0.90	0.48	0.70
Lead, Total (mg/L)	1/month	Comp	0.001	<0.001	<0.001
Manganese, Total (mg/L)	1/month	Comp	3.23	2.14	2.79
Mercury, Total (mg/L)	1/month	Comp	<0.00005	<0.00005	<0.00005
Molybdenum, Total (mg/L)	1/month	Comp	0.005	<0.002	<0.003
Nickel, Total (mg/L)	1/month	Comp	0.004	0.002	0.003
Selenium, Total (mg/L)	1/month	Comp	0.01	<0.01	<0.01
Silver, Total (mg/L)	1/month	Comp	<0.001	<0.001	<0.001
Zinc, Total (mg/L)	1/month	Comp	0.040	0.029	0.036

*** Minimum, Maximum and average values are calculated from all available weekly grab data.

**** Fecal Coliform results are monthly geomean values and are only done during the disinfection period under the new Operational Certificate.

Note 1. Toxicity requirements, April 23, 2004 Operational Certificate: If a fish bioassay toxicity test fails to meet or exceed a LC50 value of 100%, the permittee is required to conduct a Toxicity Identification Evaluation (TIE) study for the purpose of determining the probable cause of the failure.

Note 2: In calculating average results, all < or > signs are removed and the numbers are used in the calculations. The sign is added back to the calculated average value.

Figure 9. Annacis Island WWTP 2008 Annual Summary: Effluent quality (Wastewater The Greater Vancouver Sewerage & Drainage District Quality Control Annual Report 2008).

CHANGE TO LAND-BASED, CLOSED-CONTAINMENT AQUACULTURE

Andrew S. Wright, Member, Save Our Salmon Foundation

I am an engineer and so I can tell you how to measure short circuits at two decimal places at two gigahertz. But what does that have to do with salmon? The answer is that I am a passionate conservationist and I am looking for solutions to protect wild salmon. When we reflect on all the presentations at this meeting, from a systems perspective, I cannot help but think that if you think of the salmon cycle from eggs all the way to returning spawners, there are a phenomenal number of probabilistic events that can occur to impact the return of those salmon. Historically, salmon have been subjected to natural phenomena whether it is warm temperature years, ocean food conditions, or a number of other stressors that we have learned about. Over centuries, however, a carrying capacity has formed balancing the numbers of salmon with the ecosystem. It is only in the last two centuries that there have been systemic anthropogenic (downward) pressures on these stocks, from a variety of causes. One of those causes, I believe, happens to be salmon aquaculture and how it is practiced today in the Broughton Archipelago.

Our approach to wild salmon conservation

The Save our Salmon Foundation is a collection of engineers, entrepreneurs and conservation minded people who have teamed up to change public policy on salmon aquaculture. We are a solutions-based group of individuals, and closed containment is part of a suite of solutions that we bring to the table. This presentation is about closed containment as a solution for protecting wild salmon, a keystone species on the coast of BC. I want to leave you with one very clear thought: closed containment land-based salmon aquaculture is technically and economically viable.

Case Study: Swift Aquaculture

Figure 1 describes the Swift Aquaculture approach to salmon aquaculture. Based in Agassiz BC, Swift Aquaculture produces 10 tonnes of Coho every year. It is a polyculture system where the waste from the salmon feed crayfish and in turn the wastes from those two streams form feedstock for two organic crops, wasabi and garlic.

Figure 1. A case study for land-based aquaculture: Swift Aquaculture, Agassiz, BC.

However, the owner, a fish geneticist, and his wife, an animal nutritionist, will quite readily acknowledge that this flow through, rudimentary system is good as a hobby business but it is not scalable. The question is: How do you scale up this business?

Farm design

I believe that this is an engineering problem. Figure 2 summarizes my vision of the farm design. A tank is filled with fish. To survive, they will need heat, power, feed and water. To keep them alive concentrations of the

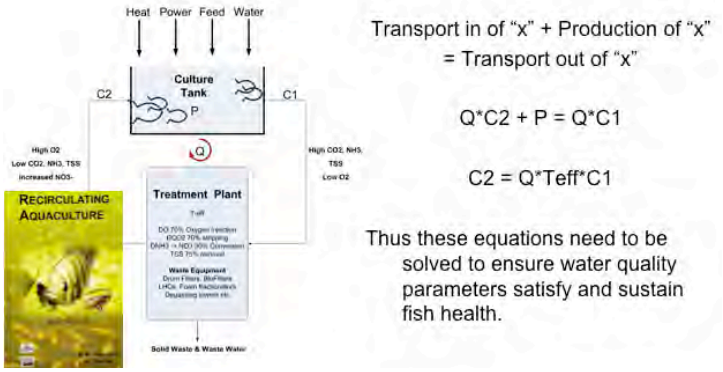


Figure 2. Farm design - solving the mass balance equation.

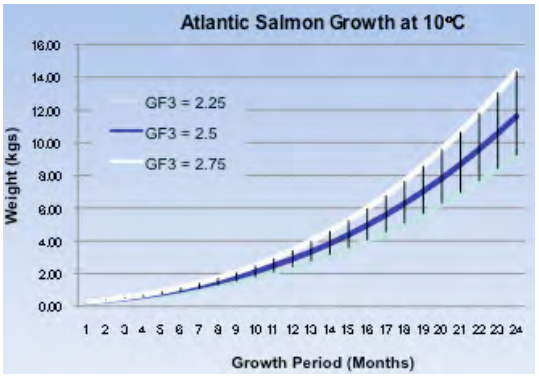
wastes from CO_2 to ammonia and solids will have to be removed and oxygen will need to be added.

A treatment plant will scrub the wastes and replenish and put back what once was there so the fish can continue to survive. To do this efficiently you have to apply the mass balance equations described above by Ken Ashley (page 118) and detailed extensively in *Recirculating Aquaculture*. Where does this equipment come from that will scrub CO_2, remove ammonia and re-oxygenate the water?

I found some of the answers to this question in a book, *Recirculating Aquaculture*, produced by the United States Department of Agriculture. The USDA has been running a recirculating aquaculture research program funded by $30 million for over 20 years. Every component and all the mathematical information you need to build a closed containment farm is documented in this book.

Fish biology drives the farm design

The biological requirements for fish husbandry and growth are described in Figure 3, including feed-conversion rates and oxygen requirements. The graph shows a typical growth curve for Atlantic salmon held at 10 °C.



Parameter	Empirical Value
Feed Conversion Rate	1.2x Current industry standard
kg O_2 Requirement f(feed, metabolism)	0.72x = 1.2 * 0.6 * total feed weight Feed conversion factor *O_2 consumption rate
kg CO_2 Production rate f(O_2, metabolism)	1.375 *x O_2 kg x O_2 consumption rate
kg NH_3 Production Rate f(feed, metabolism)	0.045x = 0.45 * 0.1 * total feed weight Protein content in feed * NH_3conversion rate
kg Total Suspended Solids Production f(feed)	0.25 * total feed weight Fraction of fed convertor to solid waste

Figure 3. Farm design. Factors related to fish biology. Graph shows a typical growth curve for Atlantic salmon held at 10°C.

Empirical values are presented for waste products including CO_2, ammonia and suspended solids.

Water quality targets for the farm design are presented in Figure 4, where specifications and requirements for a number of parameters including stocking density, temperature, dissolved O_2 and CO_2 and ammonia concentrations are listed.

Parameter	Specification / Requirement
Stocking Density	50 Kg/m^3
Water Temperature	14º-15º C
Dissolved Oxygen DO_2	15.0 mg/liter ingress 8.0 mg/liter egress
Dissolved Carbon dioxide DCO_2	6.35 mg/liter ingress 20.0 mg/liter egress
Ammonia Concentration NH_3	0.7 mg/liter ingress 1.0 mg/liter egress
Total Suspended Solids	2.5 mg/liter ingress 10.0 mg/liter egress
Salinity (optional)	10-11 ppt

Figure 4. Water quality targets for farm design.

Technologies for a working farm

Putting all this information together, how would you go from schematic diagrams of basic components all the way up to a working farm? The question is: Is this achievable?

I have found that all the necessary technology is available off the shelf – in the engineering world this is described as commercial off the shelf or COTS and all are available from multiple vendors. Some of these technologies can be seen in Figures 5a and 5b.

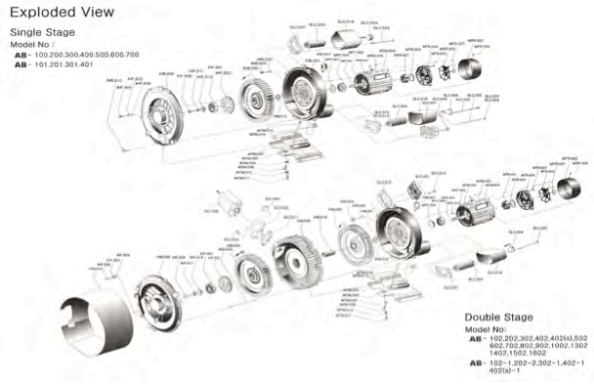


Figure 5a. Technologies required for an operating farm.

Figure 5b. Types of technology available as commercial off the shelf.

These include equipment such as drum filters to remove large solid wastes, CO_2 degassing towers, foam fractionators to remove very fine particles, and settling tanks. There is also the critical equipment that operates on the physical principles associated with Swiss cheese, which has a finite volume and close to an infinite surface area. For example, if you take a block of cheese and drill a hole through it, the surface area has increased but the volume has not changed. If you keep on doing this there will suddenly be habitat available for microbes to consume the ammonia and turn it into nitrate. These principles are applied to bio-filter design and to take a column of water and break it into the finest spray to blow air through it to strip/remove CO_2.

This looks promising. Then by solving the equations for the flow rates to remove the various wastes we found a route to save energy even further by having parallel processes rather than steady, sequential processes, so that each loop can be tuned, one for oxygen, one for CO_2, and one for waste removals (Figure 6).

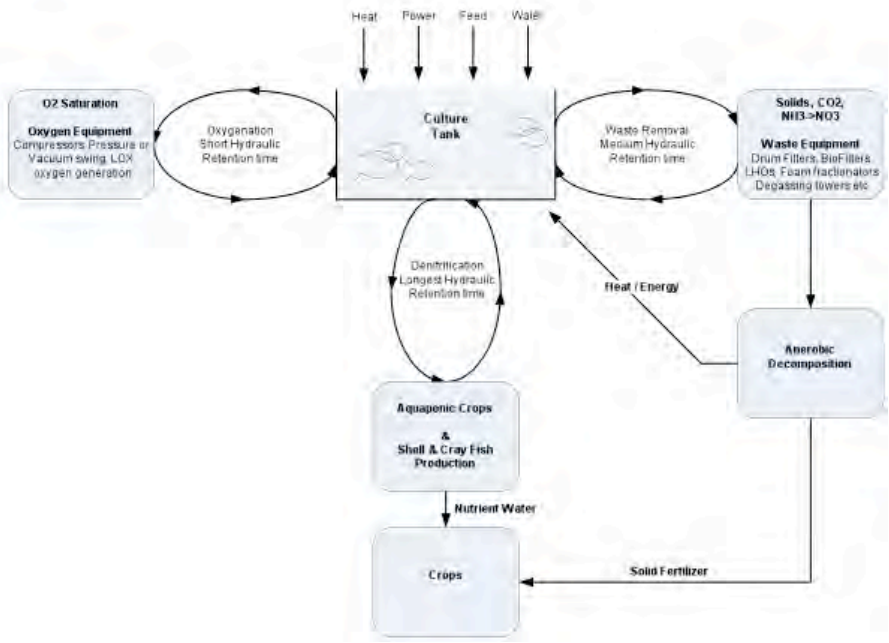


Figure 6. Basic Closed containment Farm Schematic.

Next we discovered the Akva Group Product Offering (Figure 7), supplied by a Norwegian group that has been commercially making and conducting turnkey solutions exactly

along the lines of our thinking. There are over 30 of these installations globally now used in aquaculture across a variety of species.

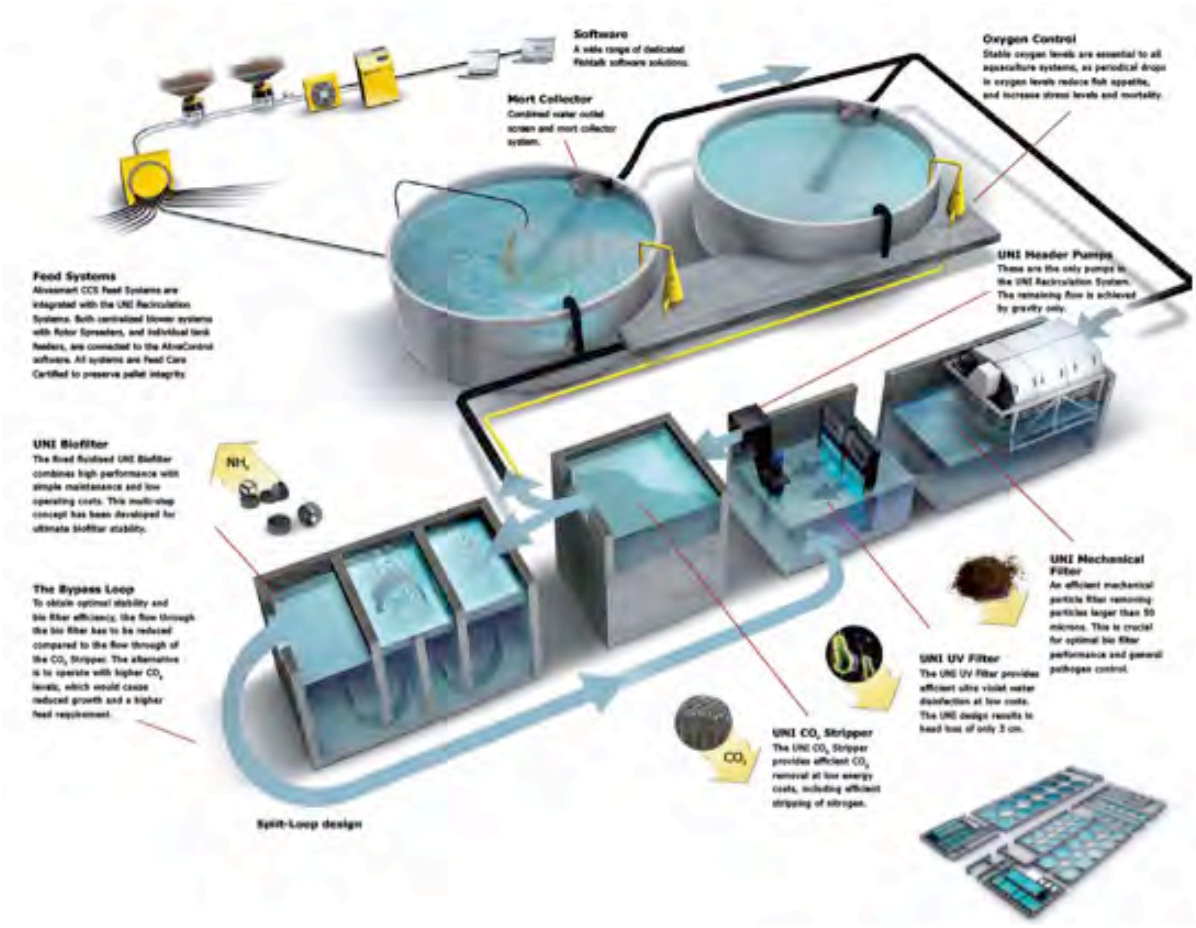


Figure 7. Akva Group Product Offering.

Content of farm waste

Waste from these farms is extremely rich in nitrates and solids and can be used as fertilizer. Currently, all that value is thrown into the ocean as waste. But in the future there can be integrated systems, where waste is the feedstock for a subsequent process. The liquid nitrate stream, for instance, is ideal for growing aquaponic crops. For example, 200 kg of fish alive in a tank produces enough waste to support the growth of 3,000 head of lettuce every six weeks - a huge amount of biomass waste that is not captured or utilized today. Solid waste is ideal for blending with agricultural waste to feed anaerobic digesters for energy and solid fertilizers. With a feed conversion ratio of 1.2 to 1 (that is, 1.2 kg dried pellets to 1 kg of wet protein), just over one quarter of a ton of waste is produced. Every ton of waste contains 500 to 2,000 kilowatt hours per ton of energy that can be captured in anaerobic decomposition. If this is blended with the carbohydrate-based waste as opposed to protein-based waste from typical farm waste, it will fall within the higher end of this range.

Farm design – construction and production

The chart in Figure 8a shows what a one thousand metric ton farm is going to cost you to build, about $12 million. Once it is up and running the operating costs will be about $6.5 million per year (Figure 8b).

Item	Unit basis	No required Module / Farm	100MT Module	1000MT Farm
Culture Tanks 200 M3	$100 / m3	10/100	$200,000	$2,000,000
Swirl Separators	$1000	$12,000	$12,000	$120,000
Oxygen injection cones	$4,400	10/100	$44,000	$444,000
Oxygen generators Triple Redundancy		3/3	$150,000	$574,275
CO2 Degassing Tower	$200/m3	1 / 10	$3,593	$35,935
Degassing Media	$400/m3	OPTIONAL	$7187	$71,870
Blowers	$11,000	2/20	$22,000	$220,000
Bio filter tank	$200/m3	1/10	$5,137	$51,370
Bio Media	$70/m3		$1,798	$17,979
Low Head Oxygenator			$2000	$20,000
Foam fractionators	$1500	10/100	$15,000	$150,000
Drum filters	$17,000	2/20	$34,000	$340,000
Settling tanks / Eco Trap			$10,000	$100,000
Pumps	$400 /HP	30/60 100HP/1000HP	$58,641	$586,409
Plumbing costs			$75,000	$750,000
CPU monitoring & control			$40,000	$400,000
UVc sterilization			$20,000	$200,000
Ozone sterilization			$40,000	$400,000
Robotic feeding system			$80,000	$800,000
Back Up Generators 2x redundant 1000kw/farm		2/2	$50,000	$300,000
Land prep			$10,000	$50,000
Land Purchase			$54,684	$546,845
Building construction			$400,000	$4,000,000
Total			**$1,286,041**	**$11,884,683**

Figure 8a. Economics – capital costs.

Line Item	Unit Costs	100 MT Module	1000MT Farm
Cost of Feed (Taplow)	$1.8/kg	$378,000	$3,780,000
Cost to Stocking	$2.00 /fish	$70,000	$70,000
Cost of Power	$0.07 kwh	$80,636	$806,358
Cost of Harvest	$0.5/kg	$17,500	$175,000
Cost of Mechanical Replacements	(includes uVC bulbs)	$22,000	$220,000
Cost of Labour	**Farm module** 3 FTE Workers 40k/yr PT manager @ 50% 100k/yr PT Mill Wright @ 50% 80k/yr PT Vet @ 50% 200k/yr **Farm** 8 FTE Workers 40k/yr 1 FTE manager 100k/yr 2 FTE Mill Wright 80k/yr 1 FTE Vet 200k/yr	$250,000	$780,000
Total Operating Costs		**~ $818,725**	**~ $6,467,246**

Figure 8b. Economics – operating costs.

Here is an interesting analysis of power costs. In this case the cost comes in at about 12%; that is only a 12% increase over costs for the existing net-pen industry. Note that in the process of designing such a farm, we made the assumption that failure was not an option. Therefore every pump and every piece of mechanics is replicated in our design, which puts an extra burden on the capital cost and it also elevates the power costs.

It turns out when you compare this work with the Akva design, our design is more than two times more consumptive of power. That puts the margin difference at only 6% over the existing industry.

Line Item	Unit Pricing	100 MT Module	1000MT Farm
Market Price of Fish	$8.25/kg	$825,000	$8,250,000
Market Price of Lettuce	$0.4/head	$284,932	$2,849,315
Market Price of Compost	$0.30/kg	$9,000	$90,000
Energy Cost Recovery		$	$
Total Revenue		**$1,118,932**	**$11,189,315**
Income from Fish After All Costs		**$225,140**	**$3,971,398**
Income All Crops After All Costs		**$519,071**	**$6,910,713**

Figure 9. Economics – summary of revenue.

The chart in Figure 9 describes projected revenues. With a capital expense of $12 million, yearly operating costs of $6 million, and if you sell fish only at a commodity pricing, then we predict a revenue of $11 million per year. If you also do fish aquaponics and composting, then the revenue could be more than $15 million per year. The income, after costs, would be between $5 million and $9 million, depending on the choices in terms of operating.

If you approach companies who are now in the marketplace asking for sustainable salmon you could likely charge a modest premium for this product and that would elevate the revenue even higher.

Conclusion

I believe that closed containment land-based salmon aquaculture is both technically and economically feasible. In the light of the discussions today, I would offer that one of the knobs that we can turn back in this big system of probabilistic natural variation and systemic anthropogenic negative pressures on salmon stocks, is to choose to invest in on-land, closed-containment aquaculture as a means of reducing pressure on stocks. Is it the only issue? No. Is it one we can control? Yes. Therefore, we have the luxury of making a choice. Who pays? The answer is "we pay." The choice is do we pay in the currency of wild salmon or do we pay in the currency of dollars to migrate our current industry to a higher plane of practice.

DIALOGUE

Do the contaminants in dredged sediment impact salmon?

A participant commented:
I understand that from time to time they dredge the sediment that accumulates from the rivers to assist with ship navigation. Is there any risk assessment on the impact of this dredging and the disposal at sea of the PCB/PBDE contaminated sediment on the life history of the salmon? That would go up the food chain to the top predators like resident orcas whose diet is 70 – 90% salmon.

Ken Ashley:
The dredging work windows are regulated around salmon passage migration. As far as I know, nobody is looking at those particular types of chemicals because of the expense involved; each sample costs at least $1,000.

Participant:
We have modeled the impact of this sediment and the compounds it contains using empirical data and a food-web model for PCBs showing how this contaminant is amplified in the food web.

It turns out that Chinook salmon, which comprise 70% of the diet of resident orcas, exceed two quality tissue guidelines. And for resident orcas, all the marine mammal thresholds that were tested are also exceeded. Perhaps we should be examining the impact of dredging material. PCB and PBDE compounds are highly hydrophobic and become linked to organic matter and also to lipids and so are stored in tissues. I believe that we should be studying the impact of the dredging process on the survival of salmon.

Ken Ashley:
There is a legacy of contaminants that are already out there and have been for at least a century. Wastewater treatment plants should be designed such that the continuing leakage does not get into the environment so it won't be contaminating the sediment in the future.

Participant:
Maybe new tools should be considered to look for assessing the impact in the future.

Disposal of wastewater

A participant directed a comment to Ken Ashley:
Anyone working with wastewater right now is working in the big river and ocean systems. Something that is coming up in the background is that they are starting to look at the small streams as somewhere to put wastewater treatment centres to augment the low summer flows and they are asking how we feel about having these facilities on many of our small streams. Keep in the back of your mind, when you note that the larger plants are not working, that the next place to put them is in the small streams.

A participant directed a comment to Ken Ashley: As someone who has been advocating for better wastewater treatment for the Georgia Strait Alliance for eight years, I sadly think about sewage much too often. Your presentation highlighted the fact that wastewater is pollution and there is an increasing amount of toxins that we need to be concerned about. Trying to ensure that those toxins do not get into the wastewater stream is important but once they are there we also need to manage them effectively. Currently Metro Vancouver is trying to finalize its liquid waste management plan and the waste management committee, contrary to what the staff proposed, agreed to upgrade the two primary plants in this region, Lions Gate and Iona, to secondary by 2020. This suggestion went to the board where the issue of money came up. The proposal has now gone to the finance committee twice and it is going to go forward again as they try to decide what to do with these big ticket items. Other levels of government are not stepping up to support Metro Vancouver in trying to do the right thing and upgrade these plants as soon as possible with the best technology. The federal government has just put in national wastewater standards so that finally in Canada, 30 years after the United States, we can have secondary treatment as a starting point for our wastewater. But they are not coming forward and putting money on the table to support communities to do this. This is very frustrating because as it stands it is looking likely that the Iona plant will continue to dump wastewater into the Strait of Georgia for another 20 years. There will be more and more chemicals released that will have cumulative impacts on our salmon and orcas, and on one of the most biodiverse parts of BC.

We certainly are a voice at the table - all of us need to be really pushing our federal and provincial governments to step up to help communities manage wastewater effectively. We want to do the right thing and we need the support to do it.

Ken Ashley:
It all comes down to dollars and the issue right now is that the Iona plant is outdated and needs to be rebuilt and it will cost about $1 billion. The Lions Gate plant is out of date, it is a fish killer, and to upgrade it will be about $0.5 billion. Annacis, Lulu and Northwest Langley plants all need significant midlife upgrades. If you add it all together, the cost is about $1.75 billion. The issue is that Metro is currently following a funding model where they want to pay everything off in a 15-year amortization period. This has gone to the finance committee twice and the liquid waste management panel has suggested that instead it be spread over 30 or 35 years. These are multigenerational facilities that will be here for a long time.

To follow up on John Fraser's comments, in order to enable politicians to do their job this time at the local government level, you need to talk to your city councilor or mayor who is on the Metro Vancouver wastewater management committee and tell them to adopt a 35-year amortization period and rebuild all of these starting at the same time and with the best available technology. If they get hung up on the 15-year amortization period, they will drag the upgrade out for 20 or 30 years.

A fisherman's perspective on pollutants in the Fraser

A participant commented:
I fish along the Fraser River and I watch these sewage treatment plants. I drift over their diffusers and it is not a very nice scene. There have been big changes in the past couple of years. More is coming out of these plants and birds are not feeding around the outfalls.

The whole issue here is that we have to listen to what other jurisdictions are telling us and we are not doing that. In my conversations with scientists who are dealing with wastewater on the Hudson River in New York, and the Columbia and Sacramento Rivers on the west coast, they could not believe that we do not have better sewage treatment on a salmon bearing river.

The scientists acknowledge that there are serious problems on the Columbia and Sacramento Rivers related to their salmon smolts as they outmigrate and then hit the perfect storm. The perfect storm happens on the Fraser. Fishermen can tell you about this – they know that the perfect storm is a combination of tides, rainfall, and the release of tons of pollutants from the sewage treatment plants into the river, and it all comes within one week of killing the smolts.

We have a plant in New Westminster that is filling the river with contaminants on neap tides all the way from Steveston, up to Douglas Island. There is no doubt in my mind that these contaminants could affect smolts coming down the river.

Ken Ashley is absolutely correct. We have to fix what we are doing wrong. Trickle filters are not working on secondary treatment now and the tides are pushing these contaminants as far as Douglas Island.

Ken Ashley:
I think that it is fair to say that Metro has just done the bare minimum that is necessary under the law. The current thinking today is to use best available technology rather than the least that you can do to just barely get over the regulatory limit. There needs to be a mindset change in this organization. Metro has a budget of $ 0.5 half-billion a year and 1,500 people, yet they do not have a single fisheries biologist working with them. This discharge is being dumped into the Fraser River, which is the most important salmon river in the world, but they don't see it that way.

John Fraser:
Ken Ashley's response is exactly what we need to hear and it is exactly what the politicians need to hear.

Integrating land-based aquaculture with agriculture

A participant directed a question to Andrew Wright:
Was the cost of land included in the total cost estimates?

Andrew Wright:
Land costs were included. The costs were calculated from quotes from agricultural specialists and were based on prime agricultural land in the Fraser Valley. It is a myth that closed containment aquaculture takes up a huge amount of land. To give you perspective, we have calculated that the whole of British Columbia's 100,000 metric ton industry as it stands today can be replaced by building a facility on land on 2.5 km^2. This is not a guess; we have determined this from detailed scaled drawings.

Participant: Perhaps land could be taken out of the ALR to for this.

Andrew Wright:
It could be co-located within assets of swine barns that have been emptied or with existing greenhouse technologies where water would be accessed from groundwater and then it would flow through the fish farm and be pushed straight back into the greenhouse. We need to start thinking about highly integrated systems where the waste of one process becomes the feedstock for another.

Stocking density in closed containment compared with open net cage systems

A participant asked:
I saw that you had a target of 50 kgm^{3-1} of fish in a closed containment system. I know that Marine Harvest tends to stock at between 25 - 30 kgm^{3-1}. Does the technology you are describing allow for increased density in production?

Andrew Wright:
The 50 kgm^{3-1} is a block of water that weighs 1,000 kg. To put that in perspective, 50 kg of that block are fish, the other 950 kg is water. In the open net farms in the ocean today, typical stocking densities are between 15 and 30 kgm^{3-1}. The reason the densities are so low is that there are often large pools of deoxygenated water flowing through the net, and fish have to have the space to respond and dive and escape from the poorer quality water. With closed containment technology, especially recirculation, you have the luxury of running at highly saturated oxygen levels. These fish are going to be the most cared for fish going because the water quality is much higher than the ocean water quality. In fact, 50 kgm^{3-1} is actually at the low end of the expected densities that could be supported in these systems. Another hidden cost factor in my design is that it is capable of going up to densities of 80 kgm^{3-1}.

Is it possible to farm salmon on land economically?

John Fraser:
There is a very interesting aspect to this. Several years ago a legislative committee appointed by the premier recommended closed containment aquaculture and even said that this should happen within a certain number of years. The Pacific Salmon Forum looked at this recommendation very closely and could not find a single place that had efficiently and competently actually run a closed containment salmon operation. Therefore, in the report we said that we could not find any evidence that it had been effectively put into effect, but that somebody should work at it and find out whether it can be done because it would solve a lot of problems, not just environmental, but also for public relations for the fish-farm industry. Can you comment on this?

Andrew Wright:
The Save our Salmon Conservation Foundation is a group of people who are very strong conservation advocates and are focused on finding solutions; closed containment is part of our suite of tools that we are offering. We have met extensively with both federal and provincial ministers

and deputy ministers arguing for the creation of an aquaculture innovation fund. That is now being hosted by Tides Canada with monies being raised from private citizens, private foundations and hopefully government funding. That funding will allow us to build one of these turnkey solutions and dedicate it to salmon. These types of facilities have been built around the world for a variety of both marine and freshwater species, but not yet for salmon species. The technology is used extensively for smolt production at densities of up to 100 kgm^{3-1}. We know it works. The question is all about the economics and the politics of bringing the production of fish out of the ocean and onto land.

Today the net-pen industry is afforded the luxury of using the environment to effectively clean up the sewage from their plants. They get free services from the ecosystem. The power budget in closed containment is what those services provide. But the benefit is the nitrate fertilizer stream off the backend that can be captured and used. When this is all put into the mix, it is my belief that if we had clear and accurate net-pen accounting available, transparent accounting to us, the economics for the two systems would be very close. The question then becomes one that is related to public policy- it is arguing for politicians to advocate for change. I draw the analogy with smokestacks in Britain and the acid rain issue. This issue was on the table for discussion all the way through the 1970s. The big petrol-chemical companies argued that they could not possibly afford to change and that jobs would go, invariably the same arguments that we hear today. The reality is that push came to shove, and enough people argued for change, just as we are advocating. Change occurred, those companies were forced to invest in technologies, and today they are more profitable than ever with technologies that they didn't expect to invent and receive benefits from.

The same situation exists here. If we take that step of trying to advocate change to a different plane of practice, that plane being closed containment on land, I believe the spin offs will be far beyond what we have actually spoken to today. There is a huge array of benefits to be spun off. We could be the equipment industry leaders, like the Norwegian company Akva, and export this technology to other jurisdictions in the world. There is a lot of good that could come by taking the courage to take a step forward. We are now in a position where we can, with the science and engineering knowledge, advocate for closed containment aquaculture on land.

What is the definition of strongholds?

David Anderson directed a question to Ken Beeson:
What is the definition of salmon strongholds? We have had the experience of instituting marine protected areas in Canada. Some years ago in my visit to the US I learned that there were 18 different marine protected areas and everyone had a different set of criteria as to what constituted a marine protected area. It was the same experience with respect to what constitutes a heritage river. Is there a definition of strongholds?

Ken Beeson:
There is no standard definition. This is still being developed. The notion of strongholds is still in the very early stage. If I compared it to marine protected areas, for example, the notion of marine protected areas was that it was virtually a national park, very isolated and nothing happens in it. The notion of strongholds is a less exclusive idea of what could be done in a particular area, and what would be allowed to be done. Beyond that it is still in an early stage of development and has only been in the formation stage for about five years.

SECTION VIII
What Tools Do We Have?

Presentations by:

Salmon Genomics

Willie Davidson, Professor, Molecular Biology and biochemistry, Simon Fraser University and co-Principal Investigator of the Consortium for Genomics Research on all Salmonids Project

The *Species at Risk Act*

Arne Mooers, Associate Professor, Biological Sciences, Simon Fraser University

Water Act Reform

Linda Nowlan, Environmental Lawyer and consultant with Watershed Watch Salmon Society

Integrated Salmon Dialogue Forum

Glenn Sigurdson, Facilitator, Integrated Salmon Dialogue Forum and Principal, CSE Group

Fisheries Monitoring and Compliance Initiatives

Craig Orr, Executive Director, Watershed Watch Salmon Society

Wild Salmon Policy

Terry Glavin, Writer/Researcher

SALMON GENOMICS

Willie Davidson, Professor, Molecular Biology and biochemistry, Simon Fraser University and co-Principal Investigator of the consortium for Genomic Research on all Salmonids Project

With funding from Genome Canada and Genome British Columbia, we have conducted several major projects on salmonid genomics. I say 'salmonid' because what we learn about one salmon species is readily transferable to another. Beginning in 2000 GRASP, the Genomics Research on Atlantic Salmon Project, came into being. At that time there were really no genomics tools available for Atlantic salmon or any of the other salmonid species. This project was followed up in 2006 by cGRASP, the Consortium for Genomics Research on All Salmonids Project, and this project was completed, March 31, 2010. There is currently no new federal funding available for large genomics projects to do with salmon so this collaborative research project will now cease.

cGRASP

In this project our research focused on the DNA of the fish and then the phenotype, and then we looked at the interaction between the fish and its environment. Our main focus was to produce genomic tools, in the form of physical maps or genetic maps, for example. These tools can then be integrated and applied to provide information about environmental risk, growth and development trends, disease susceptibility, and the overall health of fish. All of this information can be applied to conservation biology and wildlife management (Figure 1).

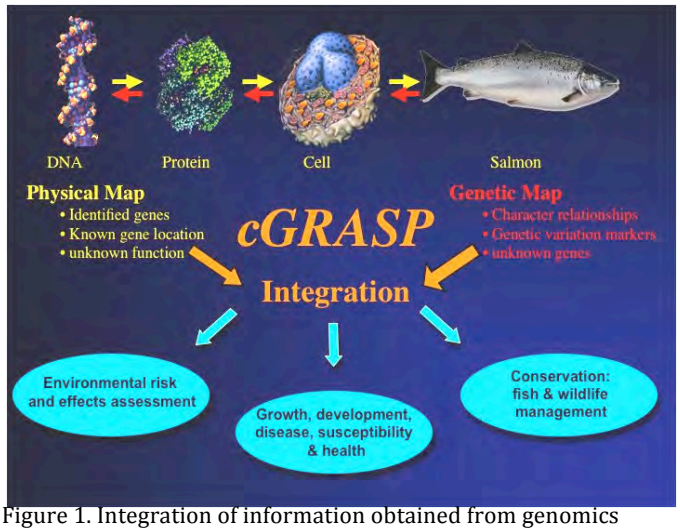


Figure 1. Integration of information obtained from genomics tools to build an understanding of the biology of the salmon and its interactions with the environment.

The genomics and genetics components of these large-scale projects can also provide DNA markers to identify traits of particular salmon runs and specify stock composition (Figure 2).

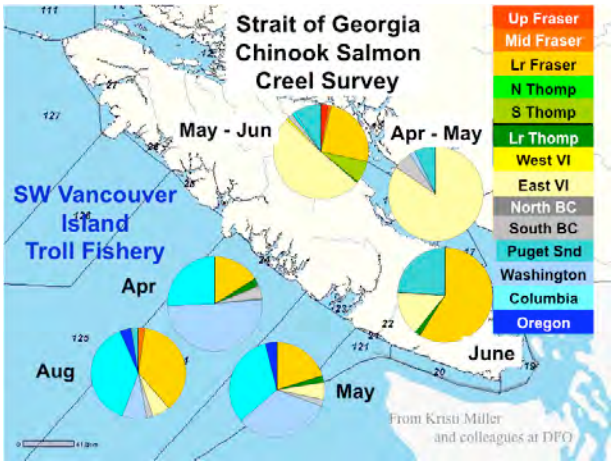
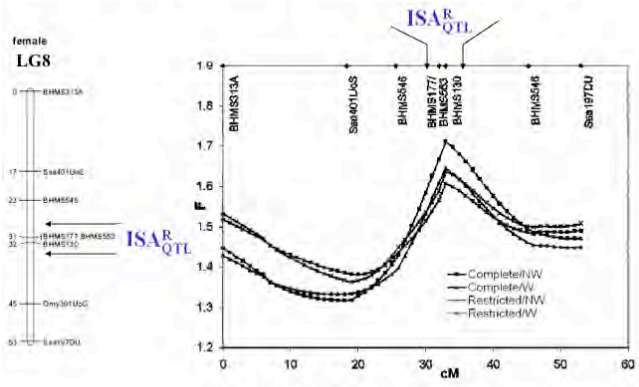


Figure 2. Use of genomics tools to identify stock composition of Strait of Georgia and SW Vancouver Island Chinook salmon.

In addition, we can actually look at regions of the genome that are associated with, in this case, disease resistance to ISA (Figure 3).



Moen et al. (2007) BMC Genetics 8:53

Figure 3. QLT Mapping of resistance to ISA.

Is this important for wild fish? It is important not only because we will be selecting for resistance for ISA and wild fish (Figure 4), but it also provides an entré into the immune system of salmonids in general. Now we can understand part of the basic biology of these fish. We can do comparative genomics and in the case of ISA, we have a very strong candidate gene so we can actually identify which fish will be resistant and which ones will not be resistant.

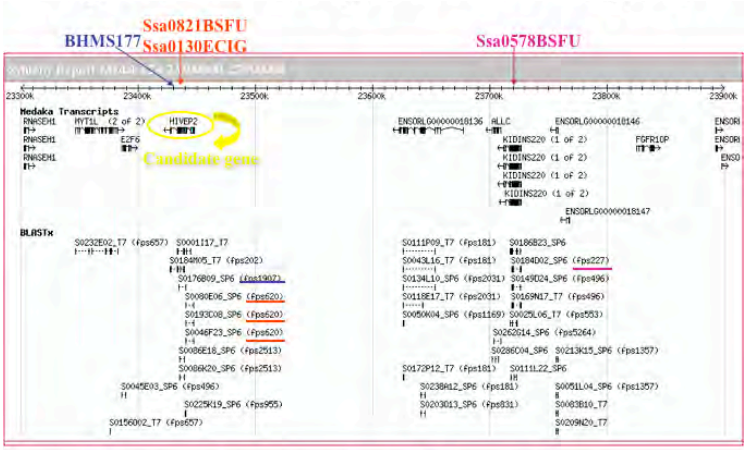


Figure 4. Identifying the candidate gene for ISA resistance.

Probably the biggest resources produced through the cGRASP research are gene chips or microarrays. These allow scientists, including biologists and physiologists, to ask questions about changes in gene expression as a function of environment, or a function of exposure to bacteria or toxins, for example (Figure 5). Again it gets us down to the nitty-gritty; that is, what is going at the molecular level and the fundamental biology of these species.

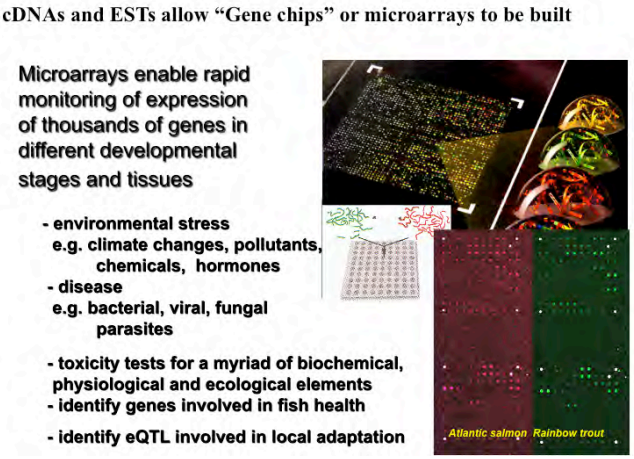


Figure 5. Microarrays used to monitor environmental conditions.

Genomics information used for environmental monitoring

Environment Canada has a simple test to assess the composition of municipal effluent; rainbow trout fingerlings are introduced to the effluent and LD 50 levels of contaminants are determined (Ken Ashley, p 124). We think we can do better than this. Many of the fish that are exposed to municipal effluent are not going to die but instead there will be sub-lethal consequences. By using gene chips we can look at the effect of 10 % effluent, or 60% effluent (Figure 6) and examine changes in gene expression and then ask: Is this disrupting certain pathways of development, pathways associated with sexual development or olfaction or the immune system?

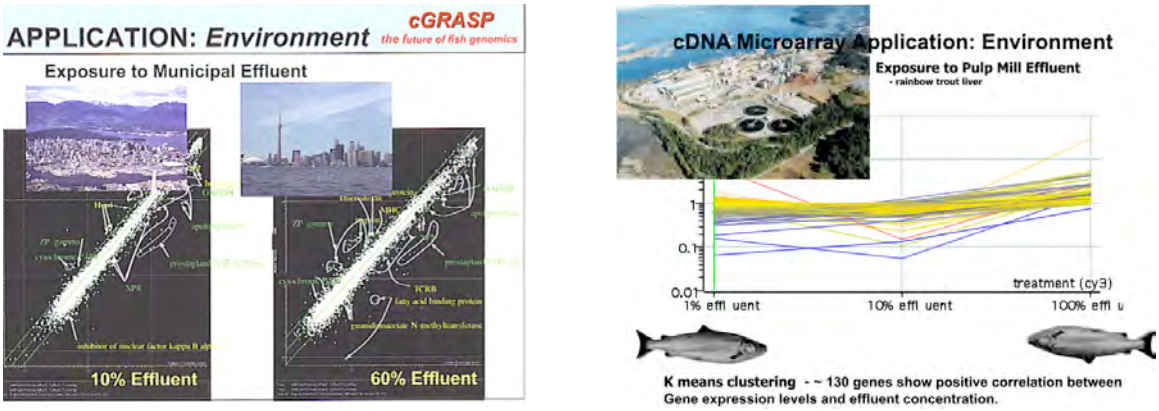


Figure 6. Examples of microarray application to environmental monitoring. A. Assessing effects of exposure to municipal effluent. B. Assessing exposure to pulp mill effluent.

These tools can be applied to more than just municipal effluent. (See Figure 7, for example). There are about 60 laboratories around the world that are using these chips for environmental monitoring, looking at the health of salmonids, and actually using salmonids as sentinel species. These fish are the 'canary' in the ocean.

Kristi Miller of DFO has been using these microarrays, and tracking the physiological shifts associated with the spawning migration of sockeye, predicting which ones are going to be successful spawners. In fact, this work has been so successful that Genome British Columbia is now funding the program, FishManOmics. This project is taking genomics to the generation of new fisheries models and providing genomics tools for fisheries management.

Future applications of genomics information

One of the things that we have all realized is that genomics is going to change our lives. For example, when you go into a doctor's office ten years from now they will have the sequence of your DNA or they will be doing personalized genomics. This is not a scary thing; it is an advance in helping the diagnosis process. We would like to have that for salmon.

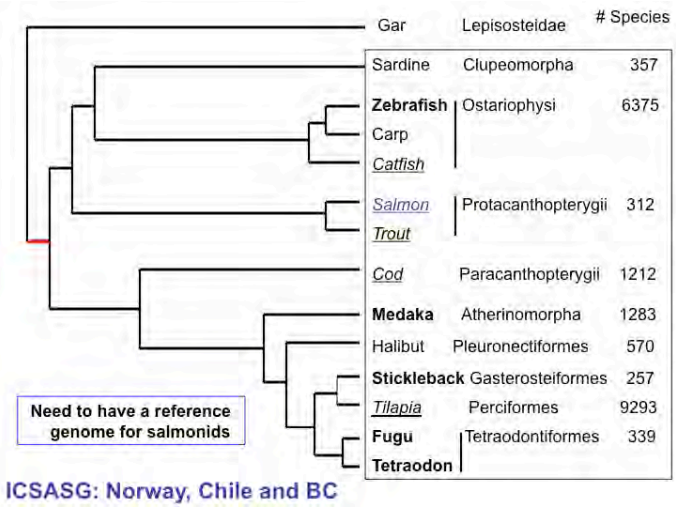


Figure 7. Phylogeny of fish species indicating availability of genomics sequencing information.

The species noted in bold in Figure 7 are the five species of fish whose genomes have been sequenced similar to the human genome: zebrafish, medaka, stickleback, fugu and tretraodon (the latter two are species of pufferfish).

To date, there is no fish species in the salmon and trout group whose genome has been sequenced. Fortunately, there is now an international collaboration, involving Norway, Chile and BC, to sequence the Atlantic salmon genome and this genome will be a reference genome for all salmonids. Once we have that sequence it will be very straightforward to get a sequence for sockeye, Chinook and other species. The sequence should be available in June 2011. Getting the sequence however is just the beginning. Then we will have to build an understanding of the sequence and how we can use it and carry on from there. This will require funding and that is becoming increasingly difficult to secure from the federal government.

GiLS

Another project, funded by Genome British Columbia, involves the application of genomics to study the relationship between salmon and sea lice - GiLS (Genomics in Lice and Salmon). The focus of this project is to look at the sea louse genome and the salmon genome, and use microarrays to determine what is happening on the battleground, the battleground being where the louse attacks the salmon and then the salmon tries to defend itself against the louse using its immune response and so on.

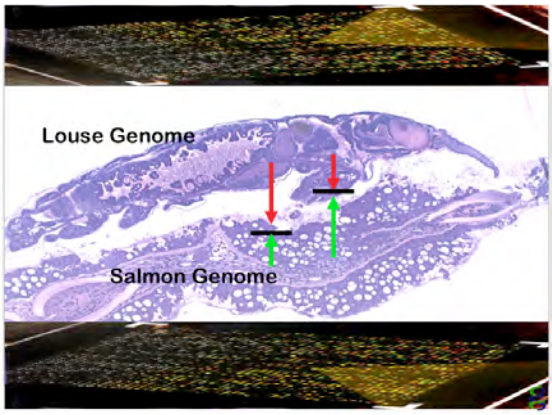


Figure 8. Interaction between louse genome and salmon genome.

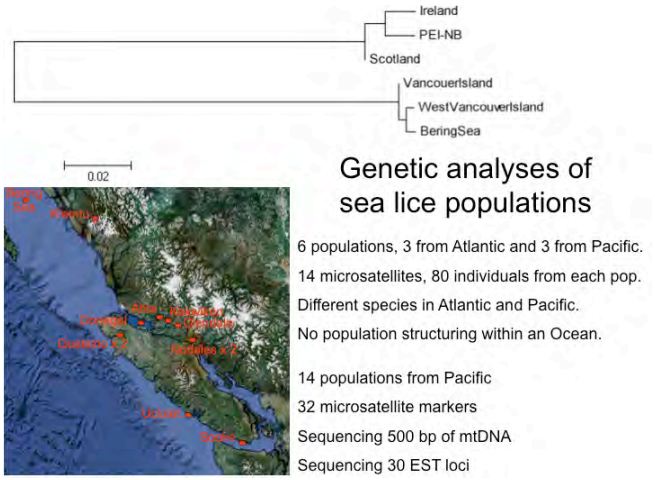


Figure 9. Genetic analyses of sea lice populations.

Figures 8 and 9 describe some of the results from the component involving the genetic analysis of sea lice. We took six populations, three from the Atlantic from Ireland, Scotland, PEI and New Brunswick, and three from the Pacific from Vancouver Island East, Vancouver Island West, and the Bering Sea. We examined them using a total of 14 micro satellites and 80 individuals per population.

What we have learned is that sea lice of the Atlantic and the Pacific, although they are given the same taxonomic designation, are different species. Knowing this information has an impact on how we deal with sea lice in the Pacific, where the lice have co-adapted and co-evolved with Pacific salmon and now are found on Atlantic salmon on the farms. We have also learned that there is no genetic structuring within the ocean. We have now looked at more samples including 14 populations from the Pacific and replicate samples from two fish farms, over two consecutive years. We have used 32 microsatellite markers and sequenced 500 base pairs of mitochondrial DNA and 30 EST loci. There appears to be no genetic structuring.

This has significant implications. There are no standing populations that we can see within a fish farm. This means that new lice go into the farm, their progeny get flushed out, and the cycle repeats. These findings are definitive.

Finally, we are also carrying out a comparative genomic analysis of upper temperature tolerance in salmonids, as described in Figure 10. Regions of the Arctic charr genome and the rainbow trout genome that are associated with upper temperature tolerance have been identified. These regions are syntenic, meaning that they contain the same genes. We are now identifying these genes using the equivalent regions of the Atlantic salmon genome.

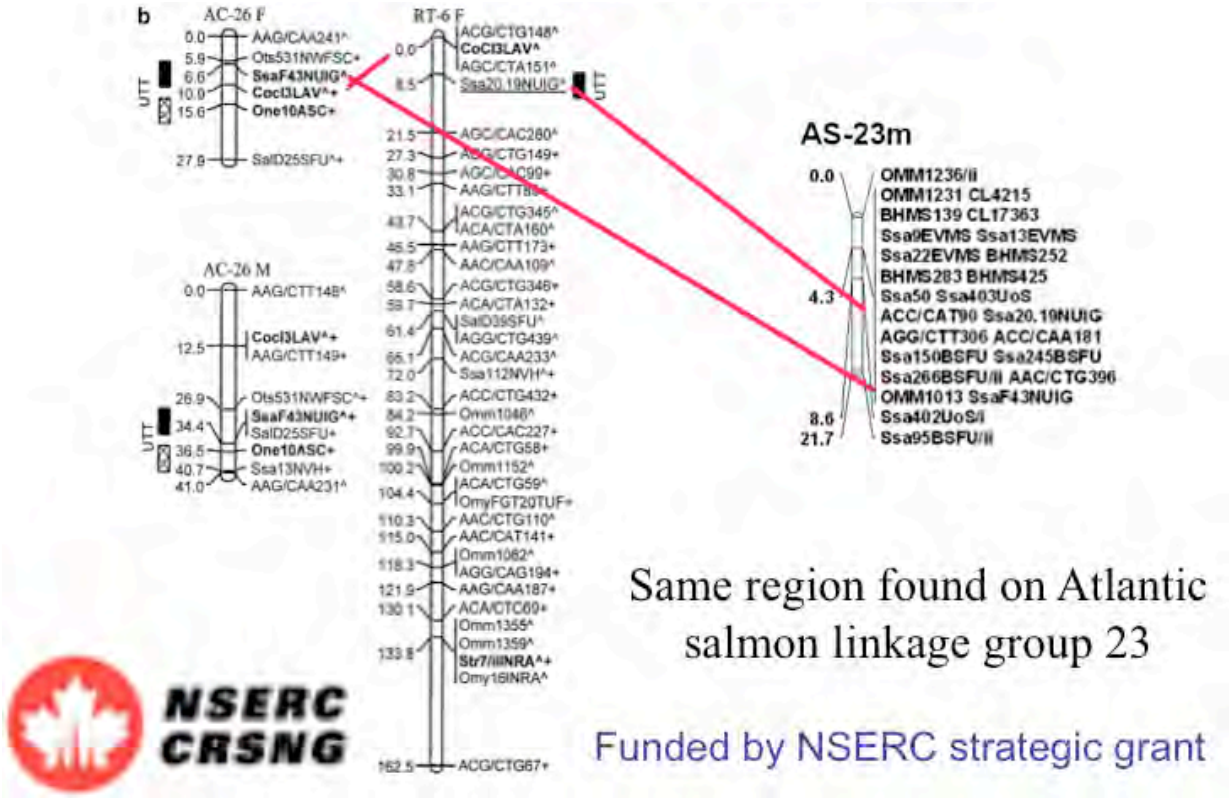


Figure 10. Identifying quantitative trait loci associated with Upper Thermal Tolerance in salmonids.

This is why I say that whatever we learn about Atlantic salmon will be readily transferable to any of the other salmonid species. We are now actively trying to identify the actual gene and the variation within that gene and this will allow us to determine and predict whether or not a fish will survive at high water temperatures or low water temperatures.

When we do find that gene, then the question is: What are the social implications of this information? For example, do we want to screen populations and decide that this one will survive but this other one is unlikely to and leave them to their fate? Or do we want to use the extensive hatchery system that we have here and actually do marker assisted selection and influence the genetic stock of fish that will now be capable of sustaining high temperatures in the Fraser and elsewhere? These are important societal and political questions.

THE *SPECIES AT RISK ACT*

Arne Mooers, Associate Professor, Biological Sciences, Simon Fraser University

When I started to prepare this presentation I was fairly convinced that SARA was not a good tool to deal with the Fraser River sockeye. I am less convinced of that now given my feeling that there are perhaps few other very good tools, but I would like to be disabused of that.

Background information on the Species at Risk Act

There are two issues here: one is to actually have Fraser River sockeye assessed by scientists and the second is to convince the government to award protection if that assessment suggests that protection is warranted. The Species at Risk Act, or SARA, is Canada's official response to the Rio Convention of 1992; Canada was the first industrialized country to ratify that international agreement. Because we ratified it we had to do something and one of the things we had to do was to enact federal legislation to protect our biodiversity. It became law finally, after many failed attempts, for the most part in 2003, with additional parts in 2004. Because it is a federal act, it deals directly with all aquatic species and with migratory birds as well as all the other bits of biodiversity that we care about, but only what is on federal land.

It is quite a special act in that sense. It does have responsibility for everything but there are many hoops that must be jumped through to do that. The other relevant point is that the Act is now undergoing official review for the first time.

Figure 1 is schematic of how the process works. The white boxes are science-based and the grey boxes are more policy and science mixes.

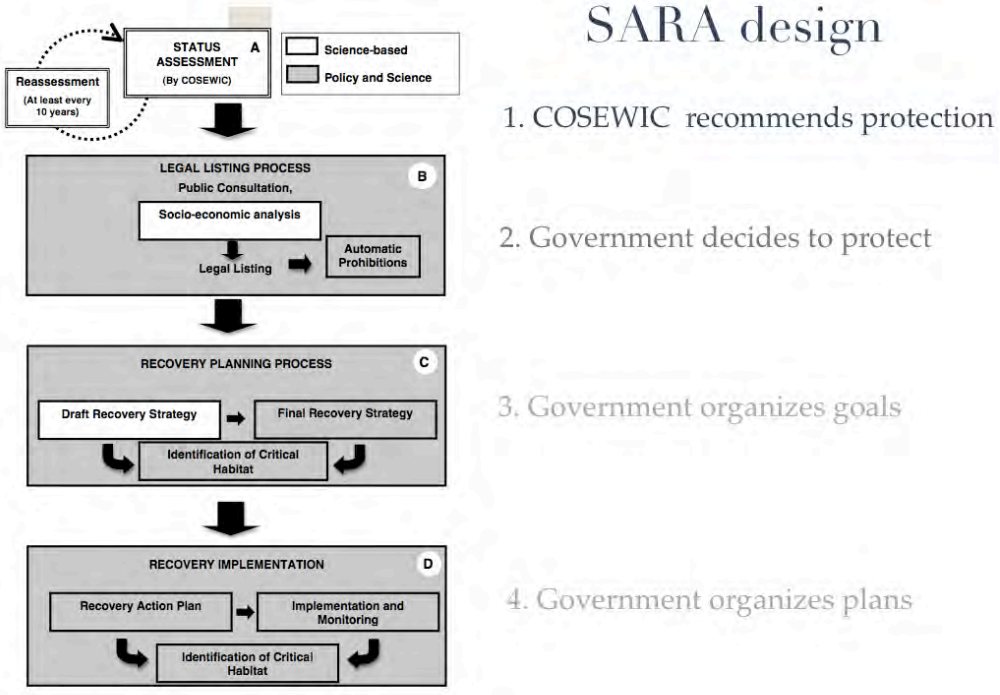


Figure 1. A schematic of the SARA Process.

The first thing that happens is that species have to be assessed. That work is conducted by a scientific committee, which is at arms length to the government, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). After the assessment, the government decides if the

species will be legally listed and then things flow from that. If the government decides to protect the species then recovery strategies and action plans are implemented.

The role of COSEWIC

What does COSEWIC do? First they prioritize which bits of biodiversity they should assess - this is no small task. Then they assess those components and assess the status, and finally they write reports. Those reports will contain recommendations, such as "please list, we believe this species is at risk," or not. The report then goes to the Ministry of Environment, for terrestrial species, or the Ministry of Fisheries and Oceans, for aquatic species. This distinction is critically important when it comes to salmon.

What they do not consider is how much it would cost to protect the species. Nor do they consider whether what they are looking at is a management unit. They simply assess the risks.

Figure 2 presents an example of some of the species that have been assessed to date using this process; for example, the Canadian lynx was assessed and found to be 'not at risk' while the mountain beaver was listed as 'of special concern'. 'Of special concern' ranking can be thought of as being at increasing risk of going extinct or, in fact, being extirpated; that is, going extinct in Canada. There is one salmon wildlife species that has been so designated.

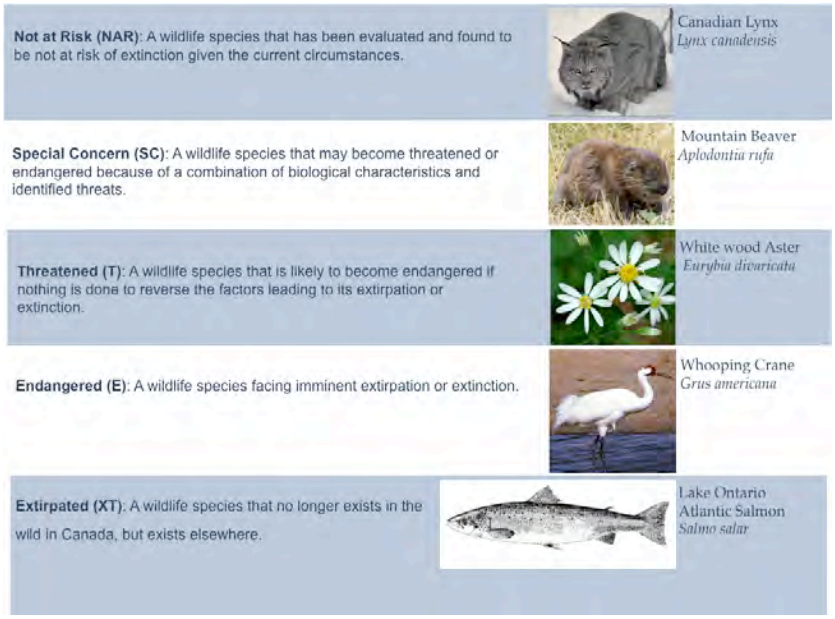


Figure 2. Some of the species assessed to date using the SARA process.

Five hundred and ninety-eight species have been assessed and found to have fallen into one of these categories, either extinct, extirpated, endangered, threatened or of special concern. Most of these species are plants or fishes. Therefore, the majority of species that are considered 'at risk' by COSEWIC, not under the law but under COSEWIC, are either fish or plants.

TAXON	EXTINCT	EXTIRPATED	ENDANGERED	THREATENED	SPECIAL CONCERN	TOTALS
Mammals	2	3	20	17	27	69
Birds	3	2	28	21	23	77
Reptiles	0	4	14	13	9	40
Amphibians	0	1	7	6	7	21
Fishes	6	4	38	29	42	119
Arthropods	0	3	22	6	5	36
Molluscs	1	2	18	3	5	29
Vascular Plants	0	3	92	50	35	180
Mosses	1	1	7	3	4	16
Lichens	0	0	4	2	5	11
Totals	13	23	250	150	162	598

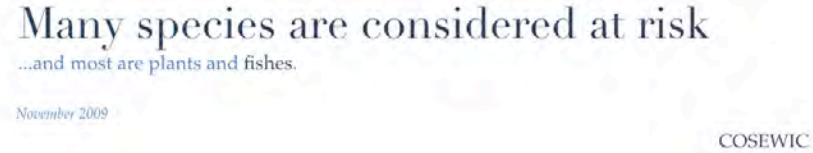


Figure 3. List of species that have been assessed by COSEWIC.

Figure 3 shows a list of those species that have been assessed by COSEWIC and note that after each I have indicated whether they have been actually legally listed, or not. Note that COSEWIC has assessed salmon.

The only salmon species that has been legally listed, however, is the Atlantic salmon, Bay of Fundy

population. It is interesting that it was listed and also received protection. I am not quite sure how Minister Anderson was able to do this but when the law came into force, 232 species that had been assessed by COSEWIC automatically received protection. Thus, half of the species that now have protection received this status immediately when the law came into force and this salmon population was one of those. Note what has happened to the other stocks and species of salmon that were listed: Interior Fraser coho, Cultus Lake sockeye, and Sakinaw Lake sockeye. These salmon were all assessed by COSEWIC as being imperiled but unlike the Atlantic salmon they were not actually given legal status.

Likelihood of Pacific salmon listings

Interestingly, if you visit the website for COSEWIC you can see what is going to be considered next for assessment (Figure 4). This is a ranked list of what COSEWIC will be assessing soon. Note that sockeye, the entire species, is on that list along with steelhead and chinook.

Figure 4. Ranked list of what COSEWIC will be assessing.

This is a critical issue. Under the law, a wildlife species is maybe not what you think of when you think of a species. It can be a species with a name, or it can be a sub-species or a variety, or a geographically or genetically distinct population. That is what the law means when it talks about 'species' because it is always prefaced and called a 'wildlife' species. However, when people talk about species at risk, they are talking about genetically distinct populations of anything that is not a virus or a bacterium, at risk.

Obviously, this is relevant when we are talking about salmon. A wildlife species under the law has been termed a designateable unit by COSEWIC. COSEWIC refers to designatable units (DUs), which are the bits of biodiversity, for want of a better term, below the traditional species level

The policy of COSEWIC is that DUs, designatable units, may be assessed separately when a single status designation is thought not to reflect the probability of extinction of the entire species. This is where the Fraser River sockeye falls. Therefore, the issue is that before you can decide whether or not a particular DU should be assessed, you need to know all of the DUs. And then you need to know whether the one you are interested in is likely to receive a different designation than the entire species.

That means that until now, and this is changing I am told, it has been difficult to put particular bits of biodiversity, especially for fish, below the species level on the priority list to be assessed, because all of the DUs that make up the species have not been studied. So you have to actually identify them. (I have just learned that the Conservation Unit (CU) designation from the Wild Salmon Policy will be considered a DU under COSEWIC. This is new.) And then you have to make an argument that there should be different status designations across DUs. Now normally COSEWIC identifies and assesses all DUs for a species before deciding on listing any particular DU. However, a precedent has been set for rainbow trout where they have made the case that even though all of the DUs have not been identified, they know that there is one that is in trouble, and therefore they want to actually assess that one. That is the Athabasca rainbow trout. Therefore, even though the rainbow trout DUs have not been identified across the entire range, they know that this one needs an assessment and so they are going to go ahead. However, this is rare.

Interestingly, in 2008 a bid went out from COSEWIC to have DUs identified for sockeye, but no one took on the task of doing this.

Now let us say that we have a designateable unit identified and it has been assessed and then it is recommended for protection by COSEWIC. The government then has to decide to protect it. This is the second issue. Remember that there were 232 species that were listed immediately when the law came into force. Since then, 252 species have been recommended by COSEWIC (up to November 2007), and of those, 61 have not been listed. That means that 24% of the species that COSEWIC has presented to the federal government, with a recommendation for listing, have not been listed by the federal government. It is up to you to decide whether 24% is a large number or a small number, but the fact is 61 of these wildlife species have been refused listing by the federal government after they were recommended for listing by COSEWIC.

And as you might expect, if you are harvested then your probability of being listed is significantly less than if you are not harvested (Figure 5). The three bars in this diagram represent three potential fates - ways to not list species. The other interesting thing, and why I said it was important to consider who the recommendation goes to, is that even if you control for whether the species is harvested or not, if the Fisheries and Oceans Department is the responsible department, then the species is significantly less likely to be listed. These are two patterns that bear keeping in mind when thinking about Fraser River sockeye.

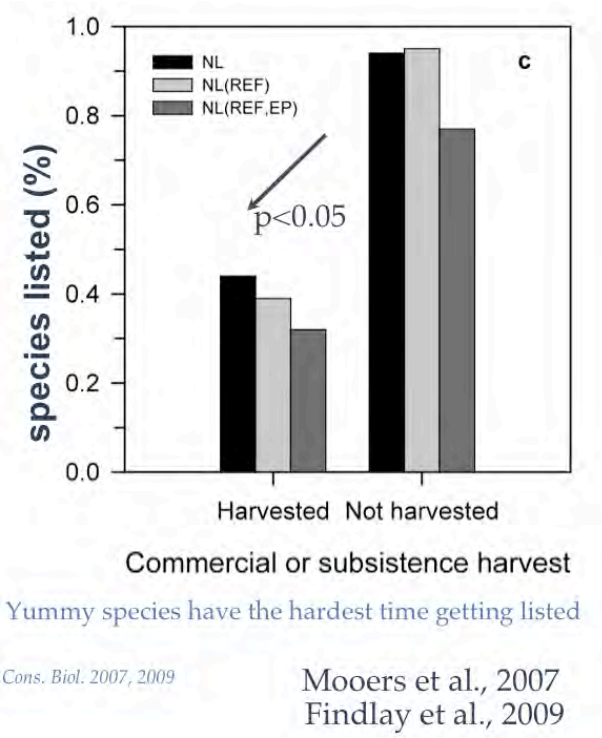


Figure 5. Ways to not list species. Relationship between numbers of species listed and whether the species is harvested or not harvested.

Conclusion

In conclusion, salmon, as you know, are most effectively managed at the DU level. If I read the literature correctly, there are about 30 such conservation units for Fraser River sockeye. That means, then, that just for the Fraser River there are around 30 of these DUs, which would have to be assessed one by one, and that does not include all the other DUs across the landscape for that particular species (*Oncorhychus nerka)*. There are many examples like this. They are harvested and they are under the jurisdiction of DFO. And, of course, they are harvested currently at a time when many of these DUs are mixed (mixed stocks). This is, of course, one of the provisions once listed; that is, you cannot kill a listed species without very special provisions. Therefore, it would be very hard to fish in the Fraser River.

As I said earlier, I did not expect SARA to be the appropriate tool because it is slow and these are weighty decisions, whether a species is listed or not. There are arguments, perhaps good arguments, for it being slow. It is certainly not designed for year-to-year events. And I think the last point speaks for itself.

WATER ACT REFORM

Linda Nowlan, Environmental Lawyer and Consultant with Watershed Watch Salmon Society

The BC Water Act is currently in the process of being modernized. Figure 1 shows the poor regulator standing in the water with his briefcase open, full of laws and he is trying to figure out what to do next. It is a difficult job to try to do this on your own.

Figure 1. Struggling to understand water law.

The main focus of this presentation is whether or not fish should have rights to water. Currently they do not. Whether fish should have rights is a live issue that is coming up for discussion around the Water Act modernization process. If you do think that fish should have rights to enough water to enable them to survive, then you need to make that message clear to your government.

Background to the BC Water Act modernization

Water is a very complex subject constitutionally. Each level of government, including aboriginal peoples and aboriginal governments, has very complex responsibilities related to water (see Figure 2). When you are talking about salmon in a body of water it gets even more complicated. Aboriginal water rights are particularly complicated and have been referred to as "the sleeping giant" in Canadian water law; there are currently a number of disputes in the courts about aboriginal water rights. They have not yet been fully defined by the courts, but these types of disputes will continue and the rights will continue to be explored and outlined.

Figure 2. Overlapping constitutional responsibilities for water law.

The Fisheries Act

The federal Fisheries Act prohibits harmfully altering, damaging or destroying fish habitat. It can be invoked in a number of situations: for example, if groundwater extraction causes this type of harm, and violates the prohibition in s. 35. It is difficult to prove that one particular water extraction has damaged fish habitat, however, and prosecuting someone for damaging habitat after the fact is a reactive way to proceed. It is much better, if possible, to take a proactive approach to protecting salmon and protecting fish. Giving water rights to fish under the BC Water Act would be more proactive.

This again highlights the complexity of water law. In Figure 3 the Water Act is at the centre of all the different provincial laws that relate to water with some of the federal laws outlined in yellow and the local government laws in the orange blocks.

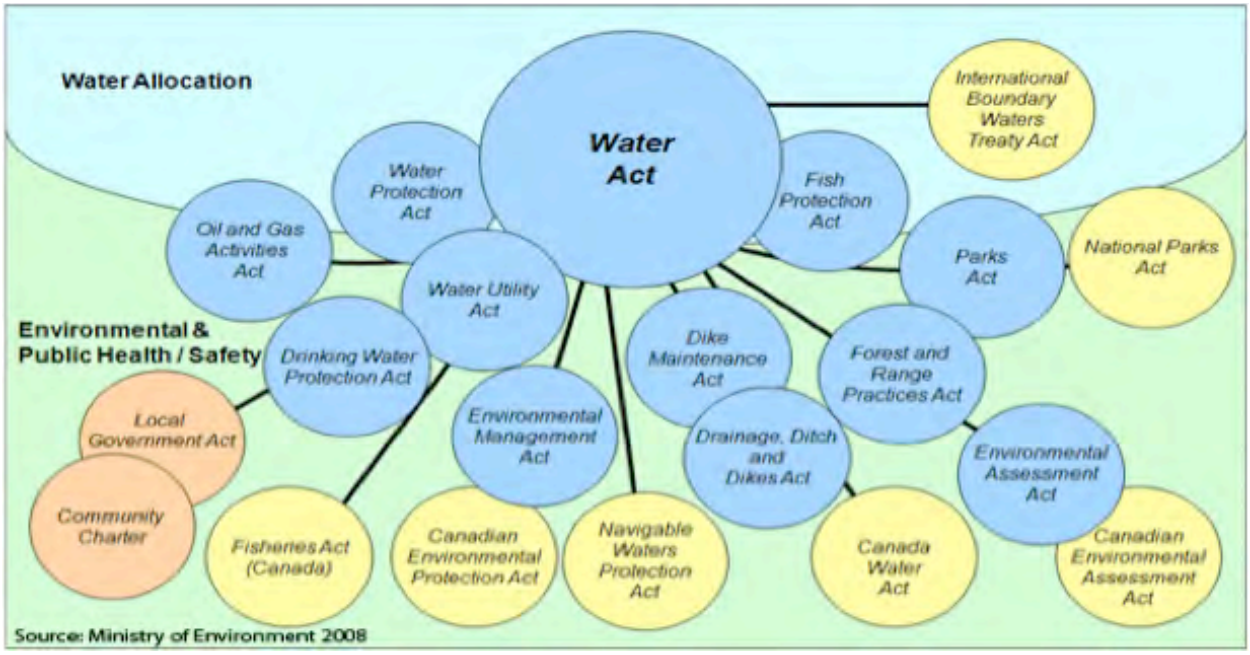


Figure 3. Complexity of water legislation in BC.

The Water Act is over 100 years old. The last comprehensive attempt to reform it was in 1993 when the NDP government issued a series of 10 discussion papers about what should be changed with the Water Act. Not many of those changes actually took effect, however. Most of the issues are still relevant today.

The BC Fish Protection Act

One of the issues that the province did go ahead with was trying to take a proactive approach to protecting fish and fish habitat. The BC Fish Protection Act was enacted in 1997 and it had a number of new tools that were useful for fish protection, particularly the prohibition against new dams on a number of listed rivers and streams.

There is also a provision for designating a stream or a river as a sensitive stream; that designation requires a special planning process to be followed for the stream and also put limits on licenses or additional considerations on water licenses that would be issued for those streams. Currently, there are 15 streams in BC that are listed as sensitive streams under the regulations.

There is also a provision that would have given some limited rights to fish for water, through community stream flow licenses, where a community group could have applied for a water license specifically to protect fish or other aquatic ecosystem features. But that part of the Fish Protection Act was never brought into force by the necessary regulations. Riparian protection was also part of the law.

Therefore, the province did make some reasonably good strides at trying to address fish protection but a lot of what they tried to do in this Act remains unimplemented.

Modernizing the BC Water Act

There are four goals to be achieved in the process of modernizing the BC Water Act:

1. Protect stream health and aquatic environments,
2. Improve water governance arrangements,
3. Introduce more flexibility and efficiency in allocation, and
4. Regulate groundwater use in priority areas and for large withdrawals.

The first goal in particular, and the whole set of related actions that will be changed under the Water Act, is key for sockeye salmon. Improving water governance and changing the water allocation system are also going to be very important for sockeye and the Fraser. BC is shamefully alone on the continent, and probably the developed world, in not regulating groundwater extraction unless it is a very large project subject to environmental assessment regulations. Changes here will also significantly benefit salmon.

NGO response to Water Act Modernization

A number of NGOs have come together to endorse a statement of expectations of what the Water Act reforms should include. Twenty-nine such organizations endorsed the statement, including all the major environmental groups in the province, some of whom are represented here at this meeting.

The first and most important expectation is associated with the first goal, protecting stream health and aquatic environments: the NGO response to this goal is:

"Protect water for the environment by legislating instream or environmental flows with priority over other licensed uses; and require a 'cap' on water withdrawals to protect key physical, biological and chemical processes in the aquatic system (ecosystem services)."

Legislating instream flow protection has been carried out in other jurisdictions, but not to date in Canada. There are guidelines in Canada, in BC in particular, that are used to evaluate Independent Power Producer projects but these are not legislated standards. This is a very important issue. As Craig Orr discussed above, the provincial government's Living Water Smart document does make an explicit promise that legislation will recognize water flow requirements for ecosystems and species.

The province has now issued a discussion paper giving more detail about what the Water Act changes for instream flow protection will look like and there are a few issues that need to be addressed.

The first is whether the protection should be in the form of guidelines or standards. Any people in fisheries, especially those who work in the field, will know about how well guidelines work, as opposed to standards. Legally binding standards are a much more efficient and effective way of providing protection.

The second issue is related to water flow requirements and whether this will be a factor for new water licenses. The discussion paper, however, does not talk about how instream flow protection is going to take place for existing licenses. This is an issue where input from scientists is clearly needed and I urge you to make your voices known about this.

Another expectation of the NGO document is related to the goal of improving water governance.

" Provide water for the future by requiring legally binding watershed plans, developed at the local level with public consultation in accordance with strong provincial standards, to address threats to water quality and quantity and ecosystem protection. The Act must require ongoing public engagement in monitoring, implementation and updating of watershed plans."

Water governance is basically about who gets to be at the table when decisions are made and how the decisions are made. And instead of that poor regulator standing by himself trying to figure it out, as

shown in Figure 1, improved governance means involving different levels of government working together and also working with those outside of government such as NGOs, and user groups such as the industrial sector. A considerable amount of work has been carried out looking at "shared water governance" which also goes by the name of "devolved", "delegated", or "collaborative" governance.

The description of the 'Heart of the Fraser' by Mark Angelo made me think that this might be the perfect place to have a shared governance body that could develop a watershed management plan to address the threats and identify tradeoffs and solutions for that area. The Fraser Basin Council is a shared water governance body, but its geographic area of responsibility is extremely large and it has not yet pursued the idea of preparing watershed management plans for any particular area.

This will also be a topic that a new modern BC Water Act will address. Governance reform is one of the government's four priorities. Table 1 describes the many different types of water bodies currently in existence in this province. They need a common framework.

Table 1. Range of water governance bodies in BC.

- Water Council
- Watershed Council
- Watershed Agency
- Basin Organization
- Source Protection Committee
- Watershed Stewardship Group
- Streamkeeper Group
- Water Management Planning Committee
- Water Board
- Water Trust
- Watershed Restoration Committee
- Watershed Planning and Advisory Council
- River Roundtable

One of the main reasons to involve a greater number of people and get governments working together when reforming governance is that the evidence shows that when people take part in making a decision they have more of a stake in ensuring that the results of that decision get implemented. Conflict over water can be prevented in this way; this is something that we are going to see more of as water scarcity grows, especially in the more arid parts of the province.

The third area for reform of the Water Act included in the NGO response statement is allocation.

"Embed requirements for conservation, efficiency, and quantity monitoring"

and

"Develop a progressive allocation system that recognizes rivers, lakes, wetlands and groundwater as 'legitimate priority users' and moves beyond a prior allocation ('first in time, first in right', FITFIR) system and codifies a system based on the principle of equitable sharing of an available consumptive pool among all identified water users."

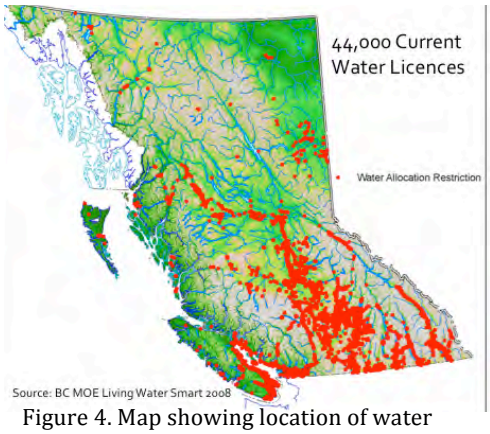


Figure 4. Map showing location of water licences in BC, 2008.

When talking about how the Water Act should be changed, one significant key issue is what to do about all the existing licenses. There are 44,000 water licenses right now in the province (see Figure 4).

Should some of them be cancelled? If so, should compensation be paid to the people who hold these water licenses? How is this going to impact Fraser River sockeye? What water licenses now exist on the Fraser River?

The Okanagan Basin represents a good case study for us to consider. Figure 5a shows the number of water licences the Okanagan Basin, present in 1959. The red dots represent restrictions on issuing new licenses, blue dots are water works licenses, and green dots are irrigation licenses. Figure 5b shows the situation in 2003.

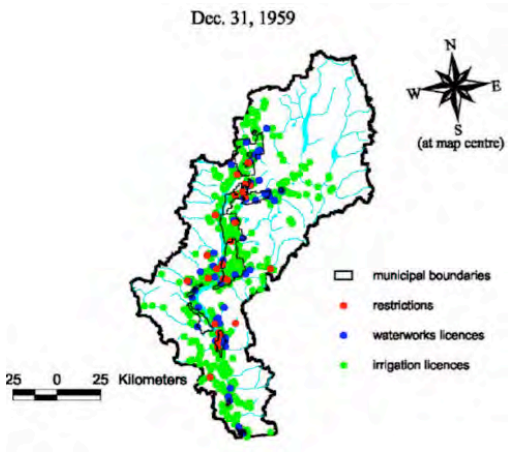


Figure 5a. Map of Okanagan Basin showing water licences, and restrictions 1959.

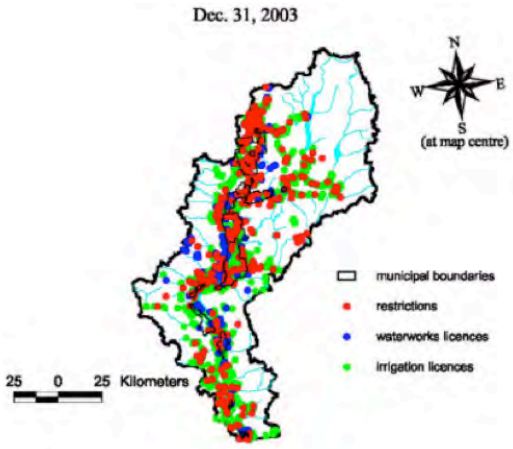


Figure 5b. Map of Okanagan Basin showing water licences and restrictions, 2003.

The number of restrictions, in particular, have mushroomed. It would be interesting to see a similar mapping for the Fraser River. The fourth issue that the NGO statement addressed has to do with groundwater in BC; this is a very important part of the Water Act that does need to be changed as soon as possible. The Water Act actually provides the legal authority currently to license groundwater extraction but, again, the regulations that would bring that part of the law 'into force" or make that have legal effect have never been drafted. Moreover, surface/groundwater interactions are given little attention by regulators. And, if there are no staff present with the ability to regulate and enforce, then even the best regulations won't make a difference.

There are a number of significant threats to groundwater in BC including those affecting quantity, such as increasing demand and lack of controls, and those affecting quality such as agriculture runoff, urbanization and non-point source pollution. Groundwater quantity is particularly relevant to sockeye because of their reliance on the cold water from the groundwater influent areas (see Craig Orr, page 114). There is a groundwater protection regulation in BC, but it deals mainly with the conditions for construction of wells and not with the effect of groundwater extraction on stream productivity or habitat. Table 2 shows the three phases involved in groundwater protection regulation in BC beginning in 2005 with Phase 1. Phase 2 has been drafted and is ready to go – there is no reason why the government hasn't actually brought it out yet. It will provide additional standards for well construction. Phase 3 may deal with groundwater-surface water interactions.

Table 2. Phases in development of groundwater protection regulation in BC.

- Phase 1 came into force in 2005. Focus is on well drilling/construction/closures, not effect of extractions on stream productivity, habitat.
- Phase 2 under development with Groundwater Advisory Board:
  - Additional standards for well construction
- Phase 3:
  - May consider drilling authorizations

The BC Water Act modernization process now underway is striving to meet the goals in the four areas

laid out above. The simple message is "Act Now": address the issue of water rights for fish; require that watershed and water management plans be put in place; address the issue of over-allocation; and, encourage government to pass groundwater regulations. This type of input would be very useful for the provincial government to hear, particularly from the scientists participating here. I also urge you to address the idea of requiring multi-sectoral, multi-government bodies to have the responsibility and the duty to prepare watershed management plans.

INTEGRATED SALMON DIALOGUE FORUM

Glenn Sigurdson, Facilitator, Integrated Salmon Dialogue Forum and Principal, CSE Group

Yesterday I was struck by the insight and concern expressed by a young fisherman. And it reminded me that while the scientific knowledge we have been immersed in here is impressive, there is a people side to this equation of which we must never lose sight. Today it is the people side I want to focus on. And that young fisherman reminded me of my own life and my own family.

Like many of you in this room my grandfather was a man who had great passion for fish. He fished Lake Winnipeg for 62 years. My father was the fourth generation to be fishing on that lake, and my brother and I, as young boys, were the fifth. When my grandfather spoke, his passions were roused first around protecting the fish. He was convinced beyond a shadow of a doubt that chemicals would ultimately get us all, the fish and us, and he articulated that view from the 1930s through to the 1970s. So when mercury shut down Lake Winnipeg, having traveled some 800 miles from a Dryden, Ontario pulp and paper plant, it seemed to him that every one of his predictions had proven to be true. I speak of him because he was a great favourite of the young biologists. When he took his boat out on Lake Winnipeg he was the epitome of the old man of the sea. The fact is that he taught these young men an enormous amount; and they taught him a lot.

He had a deep appreciation for intellectual knowledge and intellect. But he loved to debate and argue and he epitomized in a profound way the need to talk things out; that we are better if we combine many truths and if we understand the truths that come from people that live and work on the water. In aboriginal communities it is called traditional knowledge. (see box ….)

I speculate and invite you to think about a session where we had a room of aboriginal fishermen for whom the bounties of the sea have been integral to their lives, passionate sports fishermen who had fished from the banks of the rivers, and the commercial fishermen who had moved across these coastal waters for a lifetime. All of these people with passionate about fish in one way or another are doing all the presenting, with an audience of scientists listening and asking questions. What kind of a dialogue would we have? Would it mature the conversation in some kind of a way that we are not used to? Which leads me to the Integrated Salmon Dialogue Forum.

A fancy name for a simple thing "The need to talk things out"

In addition to learning about the DNA of fish and genomics tools, we are also going to have to talk about how we talk with each other, because the fact is that if we don't figure out how to talk to each other, we are not going to have any fish to talk about. That is what the Integrated Salmon Dialogue Forum is all about.

Speaking for the Salmon

First, I invite you to join with me and image we are listening to the salmon speaking. This is what

I am hearing: (Table 1) "Recognize some facts, folks. We don't understand forecasts. We don't like hot water and we don't work with stopwatches. Accept us for what we are, unpredictable, quirky, delectable, mischievous but loveable. That's who we are. Work with us by working together. Live with the uncertainty and get your act together and your numbers synchronized when we're swimming by your doorstep. Do what you can do at home because that is where the greatest risk of managing the uncertainty lies. Protect us in your backyard. We are on our own out in the deep reaches of the ocean where mysterious forces are at work together with multiple other factors that you can't control but other people in other parts of the world could be affecting. Do your best to help us there but get your act together back home first if you really want to help us. And finally, conflict feeds on us and kills you. You've got to talk things out."

Table 1. Speaking for the Salmon.

Speaking for the Salmon

- recognize some facts
  - we don't understand forecasts
  - we don't like hot water
  - we don't work with stopwatches
- accept us for what we are
  - unpredictable
  - delectable
  - quirky
  - mischievous but loveable
- work with us
  - by working together
  - live with the uncertainty
  - get your act together and your numbers in synch when we are swimming by your doorstep
- Conflict feeds on us, and kills you. You have to talk things out.

What is the Integrated Salmon Dialogue Forum (ISDF)?

The ISDF was inspired by a simple concept, talking things out, and doing this by providing a different way of talking about things across all sectors; a way in which we are not representing anything but a point of view. We are creating a space where we can actually have a conversation about whether or not we can break through to some different places without negotiating a change in the constitution, the law, in policy - these are givens we accept. Instead we explore and test whether there are good, solid ideas that we can grow together that can help move out and populate decisions and thinking in other places where decisions are made. It is about creating a special space.

We are creating a space for cross-sectoral conversations and for relationship building; a space that has been grown by the participants. We were not mandated. And we agreed that this would not go anywhere unless there was a commitment amongst a group of committed people that this was a space worth creating. That was about three years ago.

Goals of the ISDF

What are we trying to do? We are exploring and incubating ideas about approaches, tools and structures, to help facilitate, promote, and support their implementation where there is broad-based support. Who has participated? We have been elastic and inclusive and have provided the opportunity for anybody who wanted to, to participate. Inevitably people who really believe that you can make a difference and that you should put time and energy into this, migrate there. They are prepared to make the commitment of time, as they believe that this is an important tool in exercising leadership responsive to the reality that 'change is here'.

Change is here

How do we fit in with change, not fight it and risk not fitting in at all. ? How do we make it work for us and not against us? That is the question. This is the topic that we chose for the annual

"Widening of the Circle" conference held this January, where we share and test our ideas with a much bigger group.

Monitoring and Compliance Panel

We ultimately came to drill in on our own backyard and said that we have to get the numbers right. It is not that we don't have lots of good numbers. The problem is that people don't believe each other's numbers. And if everybody thinks everybody else's numbers are wrong, implicitly they are making the assumption, "Somebody's stealing from me." As long as you think that and you don't have solid numbers, you cannot ever start building relationships and trust with any integrity.

What will the public at large think if you don't even know your numbers in your own backyard? You are worried about what is going on out in the deep sea and forecasts when we cannot even agree on what the story is here. How are we going to sell that to anybody? Addressing this problem was identified as a priority and we have created a Monitoring and Compliance Panel (see Craig Orr, page 154). The panel is based on the principle that better and more timely information leads to better decisions, which create more economically sound fisheries and thereby protect the environment, communities and fish.

Integrated Governance Tools Panel

We have also started to drill down on what it is going to take to improve decision-making processes so that they are responsive to people and fish and where there is shared ownership, clarity, accountability and transparency. We need to have clear expectations about how we are going to do business together and what business we are going to do where, and at what scale and at what layer.

This is a very complicated problem. Ultimately it starts with people of good will and good faith saying that they are going to keep working on this until they get something that is going to make some sense. We can have all the fancy stratosphere tools of policies, legislation, collaborative governance - the rhetoric is everywhere. On Ground Zero however, we have to figure out how we are going to talk to each other, where people will stay and keep talking no matter how difficult the conversation, because they feel safe and respected. If we don't keep that conversation alive, then we have no chance of going anywhere. Nobody can get out of this conversation – the scientists, the sectors, and the governments - because this problem is "not for fixing if everybody is not into the fix". We don't have enough fish cops to track people. If we cannot start relying on people to be part of the solution, then we are hooped. So we must have a shared commitment and that is going to breed other shared commitments.

Widening of the Circle

Finally, we have agreed that we are going to continue to be accountable and share the kind of focused work we are doing within these discipline groups at an annual 'Widening of the Circle' meeting. This event will broaden the base of awareness, involvement, and input and will review ongoing work and emerging work products. We will be looking for new ideas, and for ways to move these forward.

Passion for fish is good, but we have to start caring for each other as much as we care for the fish. Everybody sees the world from where they stand and there are many truths. Our job is to reconcile many truths into a truth that we can all accept and live with, not one universal truth.

The story of Harry from Norway House, Manitoba

In 1974, I had a remarkable conversation with a man named Harry, a Cree person from Norway House, Manitoba, where I was acting as a lawyer for 12,000 people in six communities affected by Hydro. Harry was worrying that his life was coming to an end. He worried that the dams were going to break and the waters would drown the land and the people. And he said to me, "What happens if we can't stop this project?"

I replied, "Harry, that is a very good question because I don't think we're going to stop it."

The fact is that Harry had asked me a question that drove right into the heart of what I was trained to do as a lawyer. He asked me a series of questions:

"What happens, Glenn?"

"Well," I said, "we've got to prove damages."

He said, "Damages? Everything is damaged here. What kind of damages do we need to prove? It is all going to heck. They are raising the water, destroying everything."

I said, "Yes, but damages is a legal term. We have to be able to express it in money."

"Money? What about my land? I want land for the land they're taking from me. The shoreline is the most important land."

And I said, "The courts can't do that."

He said, "What are you going to do?"

I said, "We're going to get an appraiser from Winnipeg." "What about the fish?", he asked.

I said, "We're going to have to get some experts."

He said, "Well, they don't need experts. The nets are all full of moss and they put in this canal that's coming in from the top end of Lake Winnipeg. It's changing everything up here. What kind of experts?"

I said, "We're going to need to get a guy that can go and give evidence in court."

Harry said, "I'll tell them what's going on."

I said, "But we have got to be able to turn it into money. So we're going to need an economist."

Harry replied, "They've got economist people down in Winnipeg that know about my fishing up here?"

"Glenn, there's no hope if we go down to Winnipeg. You got to get those guys up here to talk with us. We've got to talk this thing out."

I said, "No, they don't really so we're going to have to teach them."

He said, "It sounds like I'm going to do all the teaching here and there's nobody going to be helping me. I can't go down there to Winnipeg. You can't take this down to that place. You better figure out how to get those people up here to talk to us."

Fisheries Monitoring and Compliance Initiatives

Craig Orr, Executive Director, Watershed Watch Salmon Society

The photograph in Figure 1 is a rare placid scene under the Port Mann Bridge in the Fraser River where the commercial gillnetters are having a chum salmon opening. But this is a bit deceptive. First, that bridge will soon be replaced by a huge 10-lane bridge, despite all the evidence that shows that this is not the way to relieve traffic congestion. The other reason it is deceptive is in the fact that these fisheries are no longer so common due to a number of concerns, including those about by-catch and the numbers of fish.

Figure 1. Fraser River fall chum gillnet fishery near the Port Mann Bridge.

About trusting the numbers

Whenever fisheries openings would happen in the past, my email would start to get clogged by people saying, "Whoa, how many steelhead are these guys catching? and, We don't believe the numbers." Then it would start going the other way and we would hear from people that did not believe the sport fishing numbers. "How many fish are they catching? We don't believe those creel censuses and we don't believe the numbers that are being reported." And then we would hear about the First Nations fisheries, and they would complain about the sport fisheries or the commercial fisheries or vice versa. And that was the way that things were done and are still done, unfortunately, to a large degree.

To give credit to a number of people involved in the commercial fisheries, they have recognized that the public does not have a lot of confidence in their numbers, let alone the numbers for all the sectors, and they have stepped forward to try to rectify this. They are saying: "If we do not have good numbers then we cannot really prosecute these fisheries. You have to have good catch statistics; otherwise, you really do not know how many fish you should be catching or whether you should be opening fisheries or closing fisheries or even be fishing whatsoever".

The Integrated Salmon Dialogue Forum

The Integrated Salmon Dialogue Forum (see Glenn Sigurdson, page 150) was an experiment where all the sectors including First Nations and the conservation sector, met together and shared perspectives and engaged in dialogue for 18 months or more about salmon in BC. According to many experts, this is about the length of time that you need to build trust and develop dialogue to move forward on difficult issues such as these. Out of this dialogue, we were able to form the Monitoring and Compliance Panel. This is one of the more interesting co-management experiments I have seen in about 20 years of working on these issues. It is based on the fact that we have to get the numbers right and we have to rebuild public confidence in the numbers.

The Monitoring and Compliance Panel

This presentation focuses primarily on the catch monitoring part of the Monitoring and Compliance Panel. However, the progress on the compliance side has also been significant and very innovative with former Justice Barry Stuart helping us out on restorative justice issues.

The numbers

Those who viewed *End of the Line* will note that it referred to a remarkable statistic; that is, 50% of the fish caught globally are caught illegally. That means that one in every two fish that are showing up on your dinner plate was caught illegally. I am not saying that this is happening in BC fisheries. However, we do know that there is an unreported catch and there is grave public concern about what is happening out there in the fisheries and whether we can get the numbers right.

The Monitoring and Compliance Panel works with, but independently of, Fisheries and Oceans Canada who know that they have to improve their catch monitoring program. DFO and the Panel are moving forward together in a parallel process and co-funding projects to improve catch monitoring.

In one project both groups jointly hired a consultant to look at catch monitoring for all fisheries in British Columbia and all sectors. The result was a report which was the very first to examine the level of monitoring in these fisheries. This report has proven to be very useful. The Panel has also recognized the significant value of going out and visiting ongoing fisheries together as a Panel. So far we have gone together as a Panel to observe the Chehalis Beach seine fishery (see photo on front cover). We have plans to do this with other fisheries. The ultimate goal, when you listen to the Sto:lo Nation representatives on the panel and the representatives from the Commercial Salmon Advisory Board and the Sports Fishery Advisory Board, is for each sector to be able to verify the numbers of the other sectors and agree that those numbers are accurate.

Catch Monitoring Roadmap Strategy

Unfortunately, DFO was unable to join us at this workshop. What follows is information from a presentation on this subject at other workshops, prepared by a DFO representative on the Monitoring and Compliance Panel. A DFO Catch Monitoring Roadmap Strategy has been put in place to address the question: Why do we need better catch monitoring? The objectives of this strategy are to set and communicate common objectives to all users. Fairness is one principle that the strategy embraces in that DFO and the Panel believes that we must assure users that standards are based on a common set of principles and the needs of their specific fisheries. The strategy also acknowledges the need to measure progress to ensure that we are actually moving towards the goals that we set out. In addition, it recognizes that there needs to be buy-in to encourage participation and compliance. You cannot just throw people in jail or fine them all the time when they don't follow the rules; there have to be other ways of dealing with this problem. One of the innovative solutions is to try and use a conservation trust foundation model where court fines are actually put back into the resource. The strategy also requires management to put the tools in place and set priorities. Finally, there must be clarity. A roadmap needs to be established for this complex initiative and bring the parts together.

The vision for the roadmap strategy is to have improved confidence in fisheries monitoring and catch reporting in all Pacific fisheries. The overall goal is to have "accessible, accurate, and timely fisheries information, such that there is required information and public confidence for fisheries to be managed sustainably and to meet other reporting obligations and objectives." The strategy is based on four principles:

1. Information necessary to sustain and conserve fisheries resources is the first priority.
2. Use consistent monitoring standards.
3. Data must be accessible, accurate and timely.
4. Harvesters are individually and collectively responsible for providing fisheries monitoring and catch reporting information.

The Wild Salmon Policy

Figure 2 provides a summary of the Wild Salmon Policy. Note that it starts with a vision, followed by the objectives, the strategies and then it describes the principles listed above. This roadmap strategy parallels the Wild Salmon Policy visual portrayal.

The roadmap strategy will provide a high-level overview of the current monitoring programs and highlight areas for improvements by species grouping, harvest sector and by commercial fisheries. It will also portray bycatch, such as steelhead and sturgeon and there has also been discussion about including bycatch of birds. In addition, a consultant went around and talked to all the managers to verify whether the fisheries currently in place have no monitoring, basic monitoring or enhanced monitoring, and based on this input he assembled a very comprehensive spreadsheet that will be used to enter this type of information. Enhanced monitoring includes monitoring at a level that deals with species or stocks 'of concern' in those fisheries.

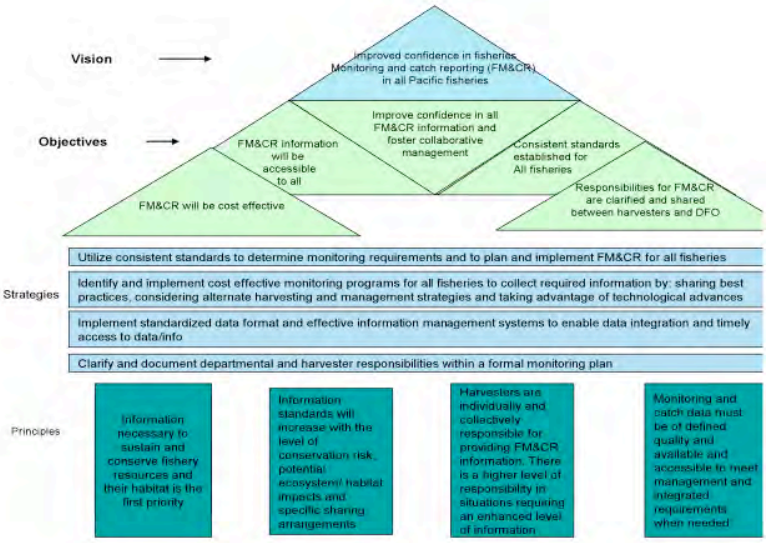


Figure 2. Fisheries monitoring and catch-reporting framework, Fisheries and Oceans Canada.

It is probably no surprise to people who follow the fisheries that the groundfishery is one of the better monitored group of fisheries. A lot of these vessels are required to have cameras on board, although we are not suggesting that requirement for every vessel that is out there. The graph in Figure 4 describes what the desired levels of monitoring are for these fisheries; enhanced monitoring is represented by the bright green bar, basic monitoring by the yellow bar.

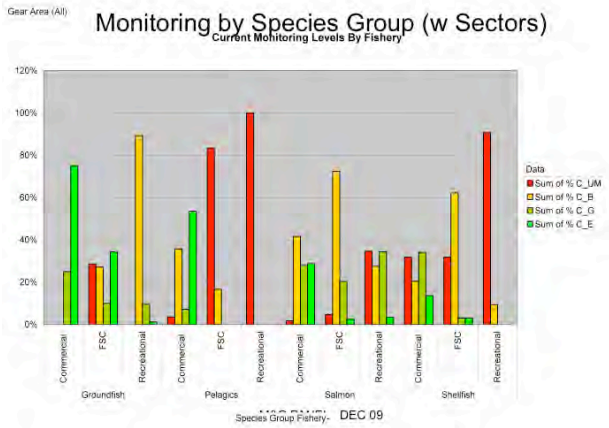


Figure 3. Snapshot (draft) of current monitoring levels of BC species group, by sector, DFO.

A lot of the monitoring that is needed is for the stocks 'of concern' that are intercepted in the fisheries whether they are Upper Fraser coho, Kitwanga sockeye, or some other stock.

We can take it further now and look at various gear types, in terms of monitoring through gillnet, seine and troll fisheries (for example, Figure 5).

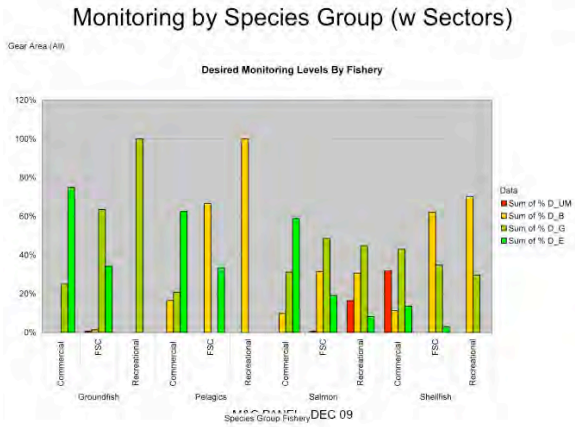


Figure 4. Snapshot (draft) of desired levels of monitoring for various fisheries; enhanced monitoring is represented by the bright green bar, basic monitoring by the yellow bar, DFO.

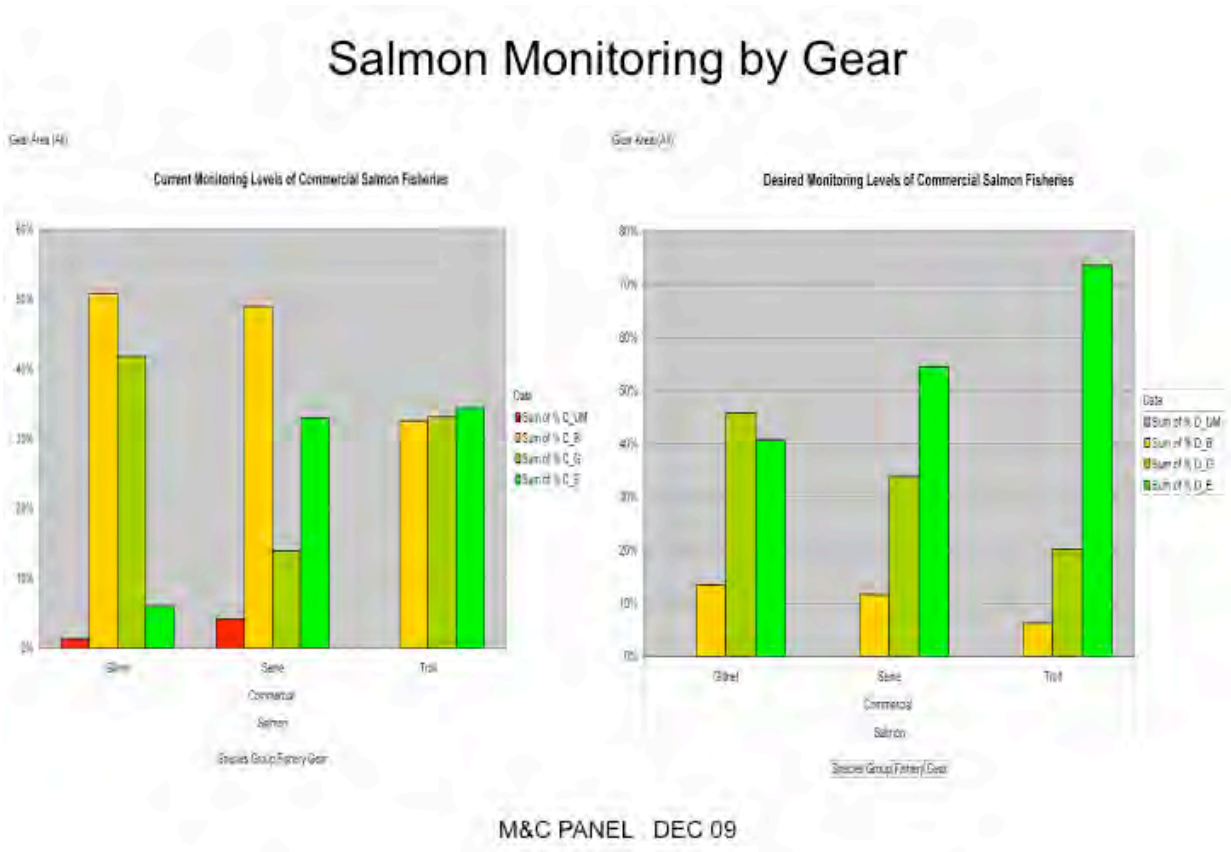


Figure 5. Snapshot (draft) of current and desired levels of monitoring by gear type, Fisheries and Oceans Canada.

Where we are, where we would like to get to

We have a roadmap of where we would like to get to and where we are at this time. This is a good start, and we are further ahead than we have been before in fisheries management.

We will be able to look at geographic areas along the coast and at in-river fisheries and obtain the same kinds of information. We are very grateful to have a budget from the Fraser Salmon Watershed Program and from the Pacific Integrated Commercial Fishing Initiative to move this initiative forward. We would also like to have a budget to be able to do the same kind of work on the Skeena where we have been invited to assess the food, social and ceremonial fisheries. It is particularly interesting to note that we now have a First Nations fisherman chairing a panel whose members include sport fishermen, commercial fishermen and conservationists. That is a real sign that we are actually making some progress.

WILD SALMON POLICY

Terry Glavin, Writer/Researcher

I'm supposed to be talking about the Wild Salmon Policy, but rather than dissect the policy and evaluate the various components of it, its objectives and the various strategies within in and so on, I'll try to place it in a broader cultural, political, social, anthropological context. And to talk a little bit about where it came from.

In May 2005 the fisheries minister at the time, Robert Thibault, said that we have something called the Wild Salmon Policy. And it was a very bold attempt to articulate an answer to the question, What is it we're trying to do here? What are we trying to conserve when we talk about conservation?

In its own small way, at least in its language, it brought a 19th century fisheries management regime into the 20th century, five years into the 21st century. And there are people in this room who are far more competent than I to actually evaluate its effectiveness. To my friend, Dave, I think, just the word "slow" is probably sufficient in kind of an overview assessment of how successful it's been.

If you look at the origin of the actual Wild Salmon Policy itself as a federal policy, you have to go further back than five years. You actually have to go back quite some distance, but I think I'll go only back a decade, five years before the Wild Salmon Policy was unveiled. There is a little funny story that people tell about a regional director general, Donna Petrachenko, who walked down the hall one day to talk to Paul Macgillivray, who was at the time the director of policy for the Department of Fisheries and Oceans, and said, "Paul, what's our policy on wild salmon?" And Paul said, "Well, we don't really have one." And she said, "Well, we're the Department of Fisheries and Oceans. Don't you think we should have one?" He said, "Yes, that's probably a good idea."

This began a conversation, or it allowed policymakers and fisheries managers to engage more fully in a conversation, that had engaged fisheries biologists, conservation biologists, and ecologists for some time. The point was to grapple with this idea of whether or not we're managing salmon to abundance, commercial value, or -- whether in proper recognition of the resilience of biological diversity -- the architecture of salmon, the genetic architecture of salmon; that maybe that's what we should be paying attention to. So really we have to start back a decade ago and I'm going to draw from an idea. I think it was best articulated in a paper written by Gordon Hartman, Cornelius Groot and Thomas Northcote in 2000. I'll take a little bit of a liberty with it and sum it up: Sorry to inform you, but fisheries managers, geneticists, biologists and ecologists, specialists of the kind that are sitting around this room, have no influence at all in determining the future of wild salmon anywhere in North America's northwestern corner. None of you do. None of us do. Forget it.

The idea was that the future of wild salmon lies with much broader social, cultural and economic forces of the very kind that informed and shaped the North American landscape in the five centuries since European settlement. And which have so utterly obliterated so many of the wild landscapes and the wild rivers that supported salmon in such great abundance here for time out of mind. The way Groot and Hartman and Northcote put it was, if there is to be a reprieve for Pacific Northwest salmon, it will come in the form of initiatives that reach into areas of society beyond fisheries science and management.

At the time we were blessed with some very interesting forces and voices, not least that of the Honourable John Fraser, not least the Honourable David Anderson. It was a very interesting and sort of counterintuitive thing to observe that at that very time -- at the very moment when wild

salmon as a resource, a natural resource that fueled a resource economy -- salmon had dwindled into absolute irrelevance. And it is, I think, much worse now in British Columbia, at least. The actual contribution of salmon to the gross provincial product was one half of one percent.

And yet at the same time a very interesting thing had happened and the way I like to succinctly explain it, although it's a very complicated process, is that this complex that had swum at the vortex of aboriginal cosmologies in this part of the world for so long had also begun to swim at the vortex of settler consciousness in the northwest corner of North America. That it had come to mean something to us that was actually very difficult to articulate in conventional terms with empirical evidence by resort to the disciplines of economics and so on. But that it was very much about desire. It was very much about human desire. It was very much about who we understood we were as people, and it was very much about how we understood the place in which we had come to live.

This isn't an easy thing to articulate by way of federal policy. And it was a very difficult thing to imagine that we could put this into a document that would inform fisheries management decisions, habitat protection decisions and so on. But it's nonetheless, I think, a very important thing to get your head around -- what we might call the "non-extractive" value of salmon and the role that they perform as a keystone species in terrestrial ecosystems had suddenly assumed this irreplaceable value and this irreplaceable role in British Columbian identity, our sense of place, notions of our heritage and our moral responsibilities to those that came after us and so on.

How far have we come? How have we done? How has the Wild Salmon Policy done? If we look at what Canadian and British Columbian values we were trying to capture here, they were that salmon runs should be protected and salmon habitat should be conserved even if it meant a slowdown in the rate of economic development or paying higher taxes. All the polls showed this to be true. Support for conserving salmon habitat was there, even if it came at the expense of economic development. It was the same pretty well everywhere in the province. Support for the idea of paying higher taxes to provide fish and wildlife habitat was very, very high and it was not just in Kitsilano, by the way. It was in Prince George and it was in the Southern Interior and so on.

So to what extent does the public interest in the conservation of salmon and the public will to conserve salmon influence public policy and restrain those forces that weigh against the diversity and abundance of salmon? I have to conclude, reluctantly -- not much. And I think that you have to get into the metaphysics of this, there are actually some fairly simple explanations. Not least is the way we tend to become victims of our own success. You wage a public struggle to force politicians and force industry leaders to conform to what the public values might be. You win. You're invited into the rooms. You sit around these tables. Everybody rolls up his sleeves. Grand. We're going to co-author fisheries management plans and so on. You do hard work. But the forces that have been roiling around you all these years continue to do so.

And the next thing you know, you don't have that constituency anymore and the sense of urgency isn't there any longer. There's a lot of really broad and very difficult to articulate phenomena that have made the gulf between public policy, government policy and the public will in many cases actually seem much wider than they were 10 years ago. That's a whole interesting conversation that I've tried to get my head around and it involves everything from changes in technology to the collapse of the business model of mass media, to the atomization of communities and so on.

But we are stuck with this situation again, I think, where government policy tends to be quite out of step with the cultural changes under way in human communities throughout the range of salmon. I don't want to sound too dreary about this, by the way, because I think you will find that all of the evidence still remains -- the evidence for the human desire, for kind of co-existence

between ourselves and various species - it's still very much there and it expresses itself in different ways. And I really do believe that that is something that we have to get back to. Part of it is the language that we use. This is an observation that I commonly make. And we're all guilty of this, by the way. You know, if DFO didn't exist we'd have to invent it and do the villagers with torches thing and string it up and all that fun stuff that we always do when we talk about the Department of Fisheries and Oceans.

We're all guilty - every last one of us in this room. We all share blame. We all share credit as well for what accomplishments we have made. But as conservationists, as environmentalists, it's also the language that we speak. It's the jargon. It's the performance, the role, the identity politics that we engage in, that tends to put a lot of people off. And we have to be mindful of that. We have to think about this as a relationship between Canadians and salmon, between British Columbians and salmon, Vancouverites and salmon. And we have to be very careful not to retreat into our own little identities and jargons and so on. We have to make this, again, part of the public conversation.

So how did we approach this when we set out to change federal policy? We started with what you could call three very simple principles. Not one fish should be taken from Canada's Pacific waters unless it comes from an identifiable, harvestable surplus of a stock of known abundance, distribution and productivity. Not one fish should be caught that is not accounted for by scientifically defensible catch monitoring methods. No fishery whatsoever should be permitted in Canada's Pacific waters unless its consequences, both for the fish species and for the ecosystems they inhabit, are fully anticipated and accommodated. I would put this to you and this is my claim: That the general public is actually far more vigilant about protecting principles like that than environmentalists are. The general public is actually far more enthusiastic than environmentalists are. Any woman or man on the street is, and would be, far more full throated about the protection of wild salmon in their diversity and abundance, than any environmentalist in this room. There are interesting reasons why that should be so.

I have to dissent a wee bit from the discussion of "wild salmon strongholds." The idea has been presented as a new idea. I'll suggest to you that it's an old idea. It's been described as sort of an advanced and progressive idea. I'll suggest to you that it's actually a reactionary idea, in this way (and I do respect what Ken Beeson said, that it's not intended as an either/or situation or we should forget about all salmon populations). But this is actually a very old idea and it's an American idea. And it has its roots in manifest destiny. It has its origins in the notion that one must preserve monuments to North America as we might have imagined it to be before settlers arrived. That some "last best place" had to be preserved and protected.

My claim is that the greatest and most effective salmon stronghold is the people.

My claim is that the public, the general public -- people who live in the suburbs, people who don't know much about salmon, people we tend to look down our noses at -- are the greatest resource that we have.

There's a little story I like to tell about the Great Bear Rainforest. Two years ago what was seen in the Great Bear Rainforest was very little in the way of salmon. What was heard in the Great Bear Rainforest wasn't the splashing of wolves as they went after spawning salmon. It was quiet. There weren't very many birds in the trees. All of that effort, all of that effort to protect the Great Bear Rainforest and the rivers and the creeks of the Great Bear Rainforest were practically barren of fish. And now I'd like to remind you about a very small and robust sockeye population that produced one of the greatest returns that same year. Nobody had seen anything like it in 60 years -- 130,000 spawners in a stretch of river less than five kilometres in length, most of it within the confines of the Okanagan Indian reserve. Okanagan sockeye traversed nine mainstream dams on

the Columbia River and came back and they kept coming and coming and coming and spawned in all that abundance. Nine mainstream dams on the Columbia.

Now, one withdraws in some humility to observe this, this great and spectacular creature that can do this. But I think there is a bit of a lesson in this. And it goes to what John Fraser was saying this morning. That we can no longer-- and we have to always remind ourselves of this -- have these conversations by ourselves. I was happy as well, that David reminded us that the title to salmon is actually Crown titled but is vested with the customs and traditions and practices of aboriginal peoples who have lived here from time out of mind, that this is about enforceable, constitutionally-protected customary law, that it's about all of us. It's about who we are, and we actually have to start mixing it up again. And we have to go back out to our betters in the streets, on the buses, and we have to engage them in conversations about salmon, in language that they will understand.

DIALOGUE

Having an Act in place is one thing; implementing it is another

A participant commented:
It is not really an either/or choice. There is one choice we have which is to reform the Water Act. But we also have to implement the Acts that are already in place; for example, the Fisheries Act.

Fisheries Act

There was a time, starting in 1998 when some brave decisions were made for conservation with full coho closures on the entire coast. I do some work for the Takla Lake First Nation at the top of the watershed and today was the deadline for the DFO to report to First Nations from around the province with a decision about Chinook. The early spring Chinook are in deep trouble. They should be at the top of the SARA list. To give you perspective, last year 26 Chinook returned to the Coldwater River in the Thompson River watershed, 138 returned to Spius Creek, and 461 to the Nicola spawning grounds. It is estimated that that the Coldwater requires 2,000, Spius Creek, 2,000 and the Nicola, 6,000 for the populations to sustain themselves. There have been voluntary closures up and down the watershed on these spring Chinook on the First Nation front. The Fisheries Act is very clear – the first priority is conservation, and then it is First Nation food, social and ceremonial fisheries followed by commercial and sport fisheries. However, right now, coast-wide there is an open sport fishery on Chinook salmon. These fish are migrating right now and there is open sport season, two a day, from the mouth of the Fraser River to the north end of Haida Gwaii.

This means that food, social and ceremonial obligations are not being met, which also means that conservation requirements are not being met. It goes back to what Mr. Fraser said very clearly, that there needs to be the political will to implement what is already there in place, as well as to bring in reforms.

There is a section within the Fisheries Act that allows mining companies to turn lakes into tailings facilities. Right now the Tsilhgot'in and the Xeni Gwet'in nations are fighting against a mining company, Taseko Mines, that wants to turn Fish Lake into a depository for waste rock and tailings. Fish Lake is at the top end of the Fraser River on the Chilcotin Plateau and these nations have fished there for thousands of years. Spring Chinook spawn just downstream from this proposed tailings facility in Taseko River. This has happened in Nunavut. It was proposed in the Kenmess North project on the Arctic drainage, which I was involved in with the Tsay *Keh* Dene First Nation and the Tsay Keh Nah. The decision was to not allow a proposal to turn an 8 km lake, Amazay

Lake, which is considered sacred, into a tailings facility. In this case, the First Nations were successful in getting this overturned. This was the first joint environmental assessment that was ever overturned.

Finally, within the Fisheries Act, fish do have a certain amount of rights to water. It is also within aboriginal rights and title, which is an interesting point that has not been brought up in here.

Fish Lake (Tetzan Biny)

A participant commented:
With reference to the poisoning of Fish Lake, I want to reemphasize what was just said; Tsilhgot'in and the Xeni Gwet'in are fighting the poisoning of the lake right now under the federal Environmental Assessment legislation in Williams Lake. Visualize a lake, Fish Lake, and Little Fish Lake and Fish Creek. They are given these names because there are fish there; there are estimated to be around 85,000 rainbow trout in Fish Lake. The plan, which has been passed by Environmental Assessment BC, is to turn this lake into a toxic waste dump for a mine. And they will build another lake and everything will be fine. This lake flows into the Taseko River and into the Chilko River and into the Fraser so this will obviously impact sockeye and other fish that swim in that direction. If we are talking about political action, this is something that we in this room cannot support. It is not okay.

Another participant commented:
I work for the Xeni Gwet'in people as a special projects biologist and am dealing with the Fish Lake proposal. In one of the earlier sessions it stated "what actions can be taken over the short term". I would encourage all of you to go to the Canadian Environmental Assessment website and voice your opinion through that medium. Those who are opposing the proposal need your help in a big way.

About SARA listings

A participant commented:

With respect to SARA, DFO never allowed endangered species legislation on any fish that might be harvested and we know that from Cultus and Sakinaw sockeye. North Atlantic cod was on the COSEWIC list at one point, too. It is 99.9 % depleted and it still it is not classified as an endangered species. Clearly SARA has not shown itself to be very useful.

Groundwater legislation is needed

A participant commented:
From the water point of view, up in the northeast of BC, another tragedy that is occurring is the whole shale gas industry that we are not hearing much about. From my information there aren't even water licenses being granted - they are just pulling water out of the rivers, wherever. To get at the gas they have to put water under pressure underground to pull the gas out through a process called fracting. That is impacting the groundwater in the surrounding area and already some of the farmers and ranchers there are losing their water. This is another reason why we need groundwater legislation and why we need to update the Water Act.

John Fraser:
Regarding the groundwater protection, we need to make certain that all groundwater withdrawals are checked out and verified. Usually there is a six-month lag time from the temperatures in the river so that the coldest water comes out in the middle of the summer and the warmest water comes in the middle of the winter. That is how the groundwater flows. You cannot limit item number four to just large groundwater volumes. It has to be all groundwater volumes because it is so important for our fish. Many times we have been walking in BC's beautiful fish creeks, and there is no water because the water license has taken it all away. We need to have legislation that will reestablish minimum water flows in those rivers. It is critical to make certain that we have water for the fish.

A participant commented:
When we talk about groundwater we should also talk about the discharges into the Fraser River, the point and non-point sources. There are 54 of them in the North Arm, right in the estuary. The middle arm has another 18. We should also know about what is going into the river and in the estuary as well as groundwater in the Interior. We have to get an overall view of all of this – it is not just groundwater. When you send fish down from the Interior, they have to go through our estuary and our estuary has to be working well.

We need to protect the out-migrating juveniles in the short term

A participant commented:
I am a commercial fisherman and I have fished sockeye for 39 years. Time is running out for the sockeye that are going to migrate out into the ocean this year. We need to consider what we can do in the short term. The precautionary approach was taken and commercial fisheries were closed. Now we need to provide a corridor for the outgoing migration of the sockeye. This is the smallest population ever leaving and we have no protection for those fish on their way out to the Pacific. People say there is no smoking gun. I do not agree. I have seen the photographs of the effluent from fish farms and fish plants that is full of sea lice and also photographs of juvenile sockeye that are totally unprotected from lice infestations. There is no way that this cannot be damaging the fish. We know that there is a greater rate of mortality for juvenile sockeye that pass farms on their migration. We have to protect the outgoing juveniles in this next generation heading out to sea. We could, for example, fallow a route for the outward migration as Alexandra Morton has suggested. We need to act on this because we do not have a lot of time and we can't run the risk of putting a small population at risk again. Until we actually have the science and until there is proof that the farms are not interfering with the juveniles by running large feedlot operations along the migratory routes, then I believe it is necessary for us to take action. As we have discussed, people should stand up forcibly and tell the governments to protect our wild fish.

A participant asked:
What tools are there to shut down the farms for three months?

Another participant commented:
Someone would need to go to the DFO office and ask who is in charge and who can order the three farms in the narrows to be taken out of the wild salmon migration route before the middle of May. That is something that can be done right now.

A participant commented:
I am from Lillooet and am part of a group called Salmon Talks. We have been meeting since last fall. We have a lot of concerns but we have narrowed them down to things that we can actually do something about. One of those includes fish farms. We have narrowed that down even further and decided that we need to focus our attention on the three key farms that are right near Quadra Island: Venture Point, Cyrus Rocks and Sonora. They are full of adult fish at this moment and they are in what is called by different activists, the Wild Salmon Narrows. Next week we are going to go to the DFO office in Lillooet and we are going to ask them to explain to us who it is that has the power and authority to order the emergency harvest of those three farms, because they all have adult fish. There are two others that have juveniles, which are not as much of a threat to the migrating smolts. We want those fish out of the water before mid-May. And we have invited other people to either call up their local DFO or show up next week and make the same request.

Strongholds need both habitats protected

A participant commented:
I support the idea of salmon strongholds and the notion of their protected watersheds. But that is only half the equation. If we are really going to protect these fish then we have got to start protecting their migratory corridors

on the outgoing migration and also on the return. That means taking whole runs that will not have any exploitation by fisheries and allowing them to come back and spawn in these strongholds in the watersheds. Moving in that direction will build the resiliency against climate change and it will help to rebuild their abundance. When we talk about strongholds we really have to broaden the concept to include the marine as well as the freshwater stages.

SECTION IX

How Do We Move Forward and Who Pays for This?

This session followed a roundtable dialogue format. The moderator and panelists included:
Iona Campagnolo, Member, Collaborative Watershed Governance Initiative and session moderator
Chief Allan Claxton, Tsawout First Nation and co-Chair, BC First Nations Fisheries Council
John Fraser, Member, Pacific Fisheries Resource Conservation Council
Rick Routledge, Professor, Statistics and Actuarial Sciences, Simon Fraser University
David Anderson, Former MP and Minister of Environment, and Fisheries and Oceans
John Nightingale, President, Vancouver Aquarium Marine Science Centre

IONA CAMPAGNOLO, MEMBER, COLLABORATIVE WATERSHED GOVERNANCE INITIATIVE AND SESSION MODERATOR

The question we have to answer as we wind up this meeting is how do we move forward and who pays the cost. We also have to answer the question: Is this province and is this country prepared to protect the salmon stocks of the Fraser? It rather reminds me of that old allegory of the blind people and the elephant. We have all got a piece of the answer but we haven't yet brought the answers all together into an integrated whole so that we can take action on those things that we agree are now actionable.

Issues that were raised

There have been a vast number of issues raised here and I am in awe of the scientific expertise and the research that has gone into the presentations that all of us have been able to access these past two days together. I'll just a list a few:

- Predators. Reminds us of the balance of nature
- Chemicals and pollutants. Most depressing statistics of all on wastewater management.
- The sea lice. The gauntlet of the fish farms. The degree of threat as was enunciated by Alexandra Morton.
- Cause and effect regarding global salmon enhancement.

Innovative Aquaculture

But then there is the more positive idea for a potential aquaculture innovation. And if there could be at least one example of the proposed land-based closed containment facility actually working and making money for the people who made the investment, then I think the issue of fish farms would be resolved in a very fast way. Thirty years ago I saw contained fish farms in Israel where they cleaned out the waste every morning and used it for the grape arbours up on the hills. Surely, we can move on that one.

Habitat loss and urbanization

The issue of habitat loss, development, and urbanization was also raised. The Agricultural Land Reserve has saved the Fraser River immense difficulties because when the Fraser floods, and it will, all the land in the reserve will not have huge emplacements built on it and therefore we will not be paying out of our taxes for massive rebuilding. However, in those places where the Agriculture Land Reserve has been sold there will be major costs coming back to us.

Climate change

I was so struck by the presentation showing the declines in many Fraser River sockeye stocks, and yet the Harrison sockeye are doing well. What is the difference with the Harrison? One thing is that they have a deep lake with cool water at the bottom whereas when the fish get up to Lytton, the much higher river water temperatures are beyond their ability to survive.

There have been many attacks on the Fraser River in the last 150 years but we have managed to overcome some of the more difficult ones and we have proven that we are capable of fixing what is wrong. For example, people were able to stop the dams being built on this river. I always think that we owe the Columbia a great debt of thanks because if it wasn't so heavily dammed, then the Fraser and the Skeena would be. There are many things to look back on that seemed intractable at the time but that proved not difficult in the end because people chose to work together across disciplinary lines to do the job that had to be done.

In *End of the Line*, one conclusion was that no more new knowledge is required – we know enough to take action. That is what we want to address in this panel. We have a lot of knowledge and science will continue and all the new knowledge will be part of the future. But it also means that we may have heard enough in this room and over these past 15 years of Speaking for the Salmon workshops to take action together. The diversity of this group, coming from all sectors as you do, is a remarkable testament to the future. As well, I am happy to see so many young faces. Many of us have grown old in this business and it is time for you to take over. But on top of that, as we look forward to what we have to do, it is important that the universities and the NGOs doing the scientific research bring in the whole community. The entire community has to be involved and that is the breakthrough that these workshops have made possible over many years.

Chief Allan Claxton, Tsawout First Nation and co-Chair, BC First Nations Fisheries Council

Some of my earliest memories of fishing are from my father and the stories that he and my grandmother told me. Unfortunately, I wasn't able to enjoy the lifestyle of fishing that my father had as a boy when he went out in a canoe into our traditional territory, which is the Southern Gulf Islands, and he talked of being able to walk on the backs of the fish. But my father brought me out into the territory and he not only showed me how to catch the fish but he also told me stories about respecting the salmon and the territory. Unfortunately, I wasn't a good listener all the time and I look back and wish that I could have listened better to my father and the other elders that passed on the teachings.

Within my lifetime we have seen these resources decline. Not only the Fraser sockeye but also other stocks of other species of salmon. I have seen the coho disappear from Samson Narrows. Rockfish, halibut, cod and some shellfish have also declined in our

territory.

My nation is part of the Douglas Treaty that states that we can hunt and fish as we did formerly and our village sites will be protected forever. I always focus on that last phrase, "Be protected forever", because that has not been the case. We have seen development all over our territory that has affected the creeks and the streams. In the 1980s a marina was planned for the mouth of the river of our community and this was approved by all levels of government at that time. We filed an injunction to stop that development; it would have been located where our crab fishery took place. This took a lot of money and time but we won that injunction. But at what cost? Our Band office was shut down for approximately three years with only two people to run it until we were able to deal with the deficit that was caused by the court costs.

First Nations have been fighting governments for years, to hold them accountable for the health of the fisheries resources. There have been numerous court cases that have acknowledged our rights to the fish we depend on. We have won hard-fought cases and won recognition in the Canadian Constitution, which states that we have priority rights to access food for culture, ceremonial and economic purposes. Yet these victories mean nothing if there are no fish. We look at our environment as an extension of ourselves. We are protectors of the territory in the custom and traditions of our teachings.

Today, First Nations are coming together to discuss how our many diverse nations can work together to protect our fisheries resources. We are speaking about co-management, and the need to act in a precautionary manner, and about the responsibility to give back. The way we have been managing is not working. We believe that part of the solution is to implement a co-management system for fisheries including Fraser salmon. This would include decision-making roles for First Nations and management and a link to local areas.

The authority and accountability needs to be put into the hands of First Nations and the local people who have a direct connection to those resources. We have lost the ability to integrate local knowledge into decision-making and we have taken away the sense of personal responsibility that people need in order to have their own local resources. I speak to my people all the time about the rights that they have under the Douglas Treaty to hunt and fish as formerly, but on the other hand I also tell them they have responsibilities to protect those resources. We need to ensure that the people who are going to impact the population of fish pay the costs associated with maintaining the health of those stocks.

When we go to the bank and continue to take money out of our account time and time again, without putting money back into that account, then it gradually disappears. I think about the resources in the same manner and I see those resources as being more valuable than money.

We have also established a First Nations Fisheries Council and it is focused on finding solutions. The council has 14 representatives from different geographical regions in BC. We are working collaboratively to define our position as First Nations and we are working with government to try to influence positive changes in management and decision-making.

When we talk about the cost, I ask: Who is going to pay when the coho and the sockeye disappear? The answer is, it costs us all. We have seen different stocks disappear in our territories and some of them will never be back again. What I have heard today is very positive and proactive. I do not want to be that generation that when our future generations pass them they look back and say this was the generation when the fish disappeared. If there were no more sockeye we would all have to answer to them. It is not too late. We have a good working group here and if we move ahead and work together hand-in-hand to protect our resources and our environment we can be successful in saving the salmon for future generations.

Iona Campagnolo: With two of the speakers on this panel being former Ministers I hope you will all put your ministers' hats on your heads and think about what you would do if you were in the position to make the decisions that would change society in the

direction in which we have been led with the information we have been provided with here.

JOHN FRASER, MEMBER, PACIFIC FISHERIES RESOURCE CONSERVATION COUNCIL

I can remember my wife coming back from watching Question Period one day in the House of Commons and she said, "I was looking carefully at both sides of the House, both the government side and the opposition side. I counted about 25 people from both sides and if you could get them together you would have a terrific government; a lot better than what is there now." This fits into what not only Glenn Sigurdson was saying but also what I said earlier. We have to elevate these issues to a political level. It is very important that we are talking here, but somebody at the political level from Members of Parliament and Members of the Legislative Assembly and the members in both the opposition and government sides have got to hear what we are talking about. Unless we get it to them we are not going to achieve what everyone around here knows we have to achieve. But first we have to do some more homework.

Recently, and twice in the last number of months, I participated in meeitngs put on by the Bulkley Valley Research Centre in Smithers. One of them was a very big conference that went on for two days and the second, some months later, was a smaller get-together to identify what we could take forward out of all that we heard. The whole thrust of the conference was how to save the Skeena River Watershed, which includes the Bulkley and the Maurice Rivers and others. It is a very large natural watershed and it is threatened by a proposal for a coal bed methane operation and other activities in the Sacred Headwaters. There were people there from DFO and the provincial government and many others. After listening for some time I addressed the group and I told them, "Put yourself in the shoes of the minister. If you have some very good ideas about what you must do to save the Skeena River Watershed and everything in it then you have got to be prepared." A good minister is going to come along and say, "What exactly do you want me to do?" And a good minister is not going to be able to sit day after day and hear all of the discussion and the argument that goes into coming up with what it is the minister ought to do. To move forward, I suggested that they make a list of the ten most important things that need to be done right now. If I was the minister, that is what I would want to know about.

Now it seems to me that the same thing applies to what we are doing here when we get to the very difficult issue of how we move forward and who pays for this. The first thing a good minister is going to ask is, What do you want me to do? and then he or she is going to say, What do you think it will cost? and then, What will it cost if we don't do it?

Iona Campagnolo said that maybe we could be thankful for the Columbia because if the Columbia hadn't been dammed the Fraser River would have been dammed. I remember vividly those days and I can remember going to see the two co-chairmen of BC Hydro at the time. I told them that the whole idea of damming the Fraser was madness and they told me that they thought they would be able to get the fish over the dam. I asked them what would happen to the fish when they came over the dam going downstream and noted that the loss of oxygen and the fall would kill them all. I then realized that these were decent people with great brains and yet they had not even thought about how to get the smolts downstream. That is why I say that we have got to get the facts up to the political level.

The question is: How do we do that? One of the things everybody can do is to phone their local MLA or local MP and say, "This is what we've discussed, these are some of the items. We want you to come back in a few weeks and tell us who you have talked to about it and what you have done." That is something you all can do now. But we also have to take some coordinated approaches on this and that is something that a smaller group of people might be able to sit down and do. They would have to figure out how to get the message not just to the present Minister of Fisheries and Oceans but also to other members of the federal government and the Fisheries Standing Committee. We have to go to these people with

something fairly exact and we have got to be able to say these are the ten things that we have to do - there may be twenty other things but these are ten of the most important.

There is another thing that I mentioned yesterday and many times over the years. That is, when you ask who is in charge and nobody knows, then you know what the problem is. That applies to many different organizations, but it especially applies to DFO right now. I can say this because as some of you know I have been a fierce defender of the constitutional authority and position of the Department of Fisheries and Oceans for all of my adult life. I have never agreed with those who thought that all the authority of DFO should be moved over to the provincial governments. However, at the moment, I am a critic of DFO, at least a patriotic critic. There is a very fundamental question here and that is: Who really is in charge? If we want to go and talk to DFO we may or may not get to the minister but we should be able to talk to the deputy minister. We should be able to talk to somebody else who has some authority. I don't think anybody really has overall authority and this is one of the issues that we have to pursue.

Some years ago the BC government asked us to set up a forum to try to resolve fish farm and wild fish issues and to advise them on what they should do to save salmon and habitat. The Pacific Salmon Forum, chaired by me, worked on these issues for four years and a report containing a number of recommendations was published in February 2009. What has happened to this report? It has disappeared, because a week after it was published the Supreme Court of British Columbia said the transfer of authority to the province from the federal government is unconstitutional. Some of what was discussed in this workshop is contained in the report, including the need for a systematic approach, the need for monitoring and continued scientific research. As well, there need to be specific rules applicable to the fish farms and there has to be fallowing. There also has to be a background of no more than the lice infestation that would be there in a natural background where there are no fish farms and the precautionary principle must be applied. Furthermore, all fish farms should have to reveal their basic data because they are operating in a public domain. This report not only said what the fish farms have to do but it also said what the provincial and federal governments should do.

Now this was before the decision to transfer the responsibility for farms to the federal government. And this is my final point. We cannot do this just through the federal government. The provincial government has a tremendous interest in salmon as part of our culture, as do First Nations, but it also has very real economic interest in the fishery.

We have a lot of work to do and a lot of people to persuade but I do not for one minute take the view that there is nothing we can do. There are some very complicated things that need to be done, but we cannot afford to do nothing. We have to make sure that we elevate this to the political level.

RICK ROUTLEDGE, PROFESSOR, STATISTICS AND ACTUARIAL SCIENCES, SIMON FRASER UNIVERSITY

I would like to pick up on a challenge that John Fraser put to us; that is, if I was talking to the Minister what would I say and what would I want him or her to do.

First, I have a sense that we all have a common vision – that we would like to see salmon consistently returning in abundance as they did in the past, not just sockeye to the Fraser River, but salmon to the coast in its entirety. In addition, I am very worried about the future so I have to add a caveat to that, and that is if that goal is not possible in the relatively near future, and I don't think we can count on it, then I would hope that we can all commit to preserving what we have left, both salmon populations and their habitat, in order to maintain the opportunity for future generations of salmon to thrive once again. I have a feeling that this may be a very long-term struggle, and we will be counting on the young people here to carry this forward as Iona Campagnolo suggested. Though we may differ in some details, that is my understanding of our common goal.

How do we achieve that goal? We have heard

many constructive suggestions from the floor here. I have been amazed at how eloquently people can speak off-the-cuff with remarkably thoughtful, constructive suggestions. In addition, I was particularly impressed by the proposal put forward by Andrew Wright of the Save our Salmon Foundation for a potentially economically viable closed containment system for salmon aquaculture. That would be a tremendous step forward as Iona mentioned earlier. I have also been very pleased to hear constructive ideas for fallowing parts of the salmon migration route this summer with careful thought as to where it might be most feasible in terms of the fish being almost ready to be harvested.

In addition, I am a scientist, and want to talk about the contributions that scientists could make. I am not looking forward myself to any more work than I have already, and hence this is not a self-interest topic for me be addressing. First, I would like to list the three main areas of concern that seem to have come up over and over again in not only this workshop but in the Scientists' Think Tank in December. In addition to the obvious climate impacts that Scott Hinch summarized so effectively in terms of the migration up the Fraser, the issue of the more complex implications of climate change on coastal and open ocean food chains is critical. The topic of interactions between fish farms, sea lice, and disease in wild salmon has also come up repeatedly. Finally, it was good to see the emphasis emerge from this meeting (that did not come out quite so clearly in the scientists meeting) about the impacts of pollutants in the Fraser River and Salish Sea.

I would argue that it is very important that we learn as much as we can about these critically important concerns now. I am reminded of the situation in 1951 when a special issue of The Journal of Wildlife Management focused on the impacts of DDT on wildlife. This had just emerged as a concern, and a special issue had been put together to address it. I believe it was the editor who commented that when the elm trees on a campus of the University of Illinois had been sprayed for Dutch Elm disease from the early spring through to the late spring and robins suddenly died in the late spring, maybe the robins would not die if they sprayed only in the early spring. In retrospect, it was a fruitless suggestion but it made sense at the time. In fact, it continued to make sense for another seven years when the phenomenon of bioaccumulation was finally discovered and reported, in another article in that same journal. Without that fundamental knowledge, regulatory agencies were severely handicapped.

In many ways, I think we are in the same situation with respect to Fraser sockeye. We need to address our profound uncertainties, and we need to do it quickly. Until we do develop more insight we have to give people like Mike Lapointe and others who have to make management decisions much credit for taking tough decisions under uncertainty. And we need to support them when they choose to promote a precautionary approach.

In addition, I believe that we should carry out an aggressive program of scientific research. Some insight might come quickly, but some might take a very long time. I have been working in Rivers Inlet for eight years now. We have some insight which I find to be very promising, but oftentimes I sense that I am just beginning to understand some key aspects of this ecosystem, and it warrants much more time and attention. Maybe other scientists could make faster progress, but I believe that ecosystem research simply takes time. At best, you get little snippets of information in any given year, and it takes many such years to generate firm insight.

I would like to comment about Chief Allan Claxton's remarks about local knowledge. In the Rivers Inlet project, and any project I have ever worked on, the knowledge of local people has been incredibly valuable. I agree with Chief Claxton that this vital source of insight must be cherished, recorded, and incorporated into any scientific investigation. It is a challenge to meld together the perceptions of people with such divergent approaches to knowledge generation, but the opportunity must be seized.

I have another difficult point that I feel I have to raise. That is, I am very concerned with the Cohen Enquiry about to start up that they will be looking for some recommendations to the minister, much as John Fraser was referring to

earlier, that can be readily implemented. My concern is over who they should recommend to do the implementation. I urge them to consider my perception that science within the Fisheries and Oceans Canada is in a state of malaise. This is despite the fact that there are some very good scientists who still work there and ones who used to work there like David Welch. My concern is not so much with the scientists, as it is over the constraints that they are under.

In my assessment, these constraints have become particularly debilitating with respect to the fish farming issue. This is not the forum to go into that in detail, but until those restrictions are lifted, we are going to have to do something else other than just turn over the problem to DFO science to sort out. I agree with John Fraser that those kinds of major policy changes have to come from the very top – from the minister. In addition, any new policy of openness and objectivity will need to be enforced forcefully and tenaciously. I sincerely hope that the Cohen Inquiry will take this overriding issue very seriously indeed – that they will recommend such sweeping changes to the ground rules for conducting research and management within DFO, and that until such changes are thoroughly established, research on such contentious issues as fish farming impacts be coordinated through a panel of thoroughly independent scientists.

I would like to finish with a plea to the young people here. I sincerely hope that I am wrong, but I am greatly concerned that we are entering into a protracted period of difficulties for not only Fraser sockeye but for salmon in general. If so, there will be much that you will need to do. You will have to be persistent, tenacious, and wise. And if need be, I hope that you will take the opportunity as you get older to educate your children, and maybe even your grandchildren, about the tremendous value of this once teaming resource that is now in decline. It may take several human generations for this problem to be turned around. It will be up to you to preserve the common vision for the future that I believe we all share, my cherished friend, Ron MacLeod, who inspired me to take up the cause of Rivers Inlet sockeye, taught me the power of the salmon spirit. I hope that you will not only let the salmon spirit invade your soul, but that you will also open the minds of your children and grandchildren to its powerful influence.

Iona Campagnolo:

I might add one thing to those wise words. Don't be afraid to be disliked. Don't be afraid to be opposed. We are all taught to be nice and to be pleasant and these meetings 15 years ago were much more contentious than they are now; they were not always as polite as this one is, we have grown into this.

I just wanted to follow up on one point. After fighting against a proposal for a pipeline through Kitimat in the 1970s together with the Environment Minister, Len Marchand and others we managed to stop it. But now there is the proposal for the Enbridge Northern Gateway Pipeline that will pass through the Upper Fraser, the Nechako, and the Skeena to Kitimat where the international oil tankers will transport the crude oil through Douglas Channel, the Inside Passage, passing either north of or south of Haida Gwaii, going directly by Hartley Bay where the Queen of the North sank, and if it goes to the north, the Skeena estuary. And I bring that to your attention. I lost the next election in part because I opposed the Kitimat pipeline. But you have to remember: Don't be afraid to say what you think is right, even if people don't like you when you do it.

David Anderson, Former MP and Minister of Environment

I am very pleased to be here but somewhat saddened in a way, as we are all coming back and back again over the years on this same issue.

In terms of moving forward, let me pick up on a few points. One, we have talked a fair bit about the iconic symbol that the salmon is, or as I like to call it, totemic, because West Coast totems are more appropriate for us. I think it is very important that we build on this concept although I would warn you very strongly not to count on it too strongly at the political level.

When I was young we were closer to the

resource and it was a very important part of the economy of British Columbia. It wasn't the 0.5% of the economy, which Terry Glavin correctly pointed out, it is today. We had fewer opportunities for recreation in those days and we didn't have the types of facilities that would entertain us as there are today, so we used to fish or we used to do other things that involved the outdoors. Furthermore, there was a closer connection with First Nations. People might disagree and say that the respect for First Nations has increased over the last 50 years, but I would argue that it was not inconsiderable 50, 60 or 70 years ago. In fact, John Ralston Saul has just written an extremely interesting book on the impact of First Nations people on Canada.

I would suggest that the totemic impact of salmon should not be relied on. We are going to have to keep reinforcing the point that Pacific salmon are tremendously important to all of us as a people living in this area. This is not something that you can pick up and drop. There have been some interesting studies about species of animals that have disappeared that show how quickly these species are forgotten by the populations that used to use them or perhaps at least used to live in the same area as them. Fish, in particular, were some of the species studied, and here they noted that the young fisherman simply did not know that there had previously been a species of fish that had been fished out, although the old fishermen remembered it.

We are in the situation here where you cannot rely on the fact that when it really comes down to a crunch situation people will side on the side of the fish. Instead, they may well side with whatever happens to be explained to them, such as the loss of jobs or some other economic activity. Therefore, it is very important to strengthen the role of salmon as that totemic issue.

How do we do that? The first thing is to link it with other important issues. For example, you can say to somebody on the street who is a newcomer to Canada and unaware of the history of British Columbia or relationships of First Nations to fish or indeed other people to the fish, that this is tremendously important for reasons that are not economic. They will, generally speaking, be a little surprised. They may tend to think of the value of fish in terms of what is on the plate or in terms of economic value, and that is not just people from other countries, it is a lot of Canadian-born people as well.

So let's see how we can tie that in with some other important aspects and today I thought we heard one. It really was a shocking to hear that in the City of Vancouver there is this problem with contaminants in the wastewater going into the freshwater systems. If these contaminants are potentially harmful to fish then you would think there would be an uproar. Yet, there isn't. To me this proves the point that people are not as concerned about fish as we would like to believe. There should be an uproar. This should be the first item on the public expenditure agenda. It should have been done prior to the Olympics, for example, or it should have been tied in with that. But it wasn't. Why not? Because people did not put fish forward as the number-one thing of concern. People can understand clean water. They can understand fish as a symbol of clean water. So that is an issue that we have which I think we should be linking with at every possible opportunity.

Where do we go beyond that? Yes, we want to make sure that people understand that fish are important but maybe we won't persuade enough people to really have the political clout that John Fraser is talking about. Then we have to explain to them that it is something beyond the economic value or the connection with freshwater. I think we have to start putting this is in moral terms; that is, the moral importance of protecting species is a responsibility that we just cannot get away from. You have a responsibility to leave behind, at least in general terms, what you found. I don't know why it should be considered possible or at least without censure that we could live in British Columbia for a lifetime and then say, "Well, of course, this, that and the other species disappeared." If there is a reason for a species disappearing then we need to know why.

We don't know enough about interactions as

has been said time after time today and this is very important. So that would be a factor that we have to start putting forth as a moral issue. And we have to ally ourselves with some other people. Think of the success of the fundamentalist Christian right in the United States politics. They decided to be influential and they were and still are enormously influential. Another example is the recently formed American-Israel Committee on Public Affairs; they are an enormously influential organization that decided, despite small numbers, to be influential. We must do the same.

Now how do you do that in our system? John Fraser made it perfectly clear that our political system is wide open. Cut the nonsense of trying to figure out a new political system for Canada with proportional representation of this or the other thing. We are probably never going to get it because there are far too many people that have to agree before this change can happen. Instead, work with the existing system that is *open*. The influence that people can have on politicians is enormous because less than one percent of the population takes part in all political parties, let alone just one party. So, there is a leverage there. And furthermore, people get elected with relatively few people being willing to assist them. So if you do want to take part in the political process to assist someone in getting elected, or get elected yourself, the system is wide open. This is one worry that I have. People tend to think that because people aren't voting, the system is hopeless and we have to change the system. This is not true. If we want to achieve things through the political process and have something more than the influence than perhaps numbers or economic values might suggest, do what others have done. Work in the political process and turn it to our advantage. I think we could do more and be more effective and more successful in getting the things we want from the government than we have.

JOHN NIGHTINGALE, PRESIDENT, VANCOUVER AQUARIUM MARINE SCIENCE CENTRE

I am going to start by backing up a step. It is not that I don't think that this meeting wasn't specifically called to think about sockeye, but rather I think we need to think more broadly about all species of salmon. Because on our coast the issues that we are talking about around sockeye are going to be seen over and over again with other species with the potential impacts of climate change and all the other issues. I am also a going to differ with whoever said, "We know enough." I don't think we know enough. And I don't mean that that should stop action or many actions. We still have huge gaps in our knowledge of basic biology and natural history. You may say "sockeye" is a species, but how many different stocks are there on the Fraser and they are all different in some ways. One of the reasons that I think we don't know enough is that we have a terrible time ferreting out trends and we cannot ascribe cause and effect.

Clearly, that is one thing that a minister would care about. Can you go to the minister and say, if you do this, this is going to happen or if you don't do this, this is going to happen? We can't do that with any certainty. Therefore, there is an issue of more research being needed, but also there is probably an issue with the way research is being done and the results being shared or not shared. I am not so sure that a good part of the problem is not the organizational and government structures that hamper, direct, restrict, or constrict research or prevent collaboration with raw data and results.

I also think that we do not have a regulatory management and research structure that is conducive to a collaborative approach. We see that by the absence of the federal government, and for the most part, the provincial government from this important meeting. There is no one organization in charge and there is no one person in charge. Who do you go to, to lay out a simple proposal at the concept level? Who can judge the positive benefits versus the risks? I agree with David Anderson. I have given up trying to change the structure; instead, let's just work with it and mine it for all it is worth. The current situation is worse because my sense is that in Ottawa everybody is trying to avoid making mistakes, instead of trying to get something done. That is usually the first question. Any time you talk

to somebody it is, "What's the downside? What are the risks?" not "What are the benefits?" They may get to that part of the discussion if they judge the risks.

I also think that the people working in salmon have great public sympathy but not a lot of public support and I think we are on the verge of salmon fatigue. One of the big problems that we have is a fundamental communications problem. It starts with scientists. Scientists tend to confuse ordinary people. People want clear answers. "Well, what's the problem? What should be done?" And you never get a straight answer from a scientist because that is the nature of science and the training that scientists have. So there are conflicting stories and there is also competition between agencies and competition between NGOs who have different strategies. We do not present any kind of a clear picture and I think that is a real problem. There is a great reservoir of public sympathy to be mobilized and I think David Anderson put his finger on that, but I don't think we are doing a very good of tapping into that at all.

To my way of thinking the big question is: How do you find or develop an effective organizational approach? And the answer is, there probably isn't just one, there are going to have to be several. One of those clearly involves some kind of a better-organized effort at public communication to raise awareness and give the public a sense of what the problem is and what needs to be done.

So I come back to John Fraser's suggestion of the ten things. I think he is spot-on. One outcome of this meeting could be to identify ten or even five of the things we need to do. We could say: Here are some very short-term things that need to be done in the next 60 days. Then there are some things that have a half-year long timeframe or a year long timeframe and then there are some things that are a little further out. If we can't be that clear and that prescriptive and that exact, then who is going to do anything? There is always so much wiggle room that we let them off the hook, so to speak.

I also think that we could name four or five areas of research that would greatly help to inform some of the missing gaps in knowledge. We could alsoput our finger on four or five immediate actions around research problems: fish farms have been mentioned and there are probably two or three other topics. Putting a plug in the sewage treatment plants is probably a bit of a problem. That may be one of those longer term, bigger cost issues. And you can guess what a minister would say: "Where is the correlation between those toxins and the decline in the fish?" And your response: " Well, gosh, you know if you just used activated sludge it would take out 95% of that stuff. That stuff can't be good for the environment." And the minister would say, " Well, can you prove that?" That is the kind of question you get when you go and appear in front of a committee.

I think this is time for a top ten action list that we can all get out and support. The communication isn't all just about getting on TV and having articles in the newspaper – there needs to be a lot of one-on-one communication. If everyone in this room knows 30 people and will meet 50 other people in the next two weeks, out shopping or at the grocery store, this would help to get the message out. You risk getting a certain kind of reputation if you buttonhole everybody you walk up to, but there is probably a happy medium. Every time I get a chance to talk to people at the aquarium and explain to them some of the things that are going on, their first question is usually, Who should do something? What should they do? and How do they make it happen? Then, often they say that they will become involved too and there are some steps that they should take. There is a reservoir of interest and sympathy that we have not mobilized yet.

DIALOGUE

A Marshall Plan for the Fraser River and the role of juvenile enhancement

A participant commented:
The situation reminded here reminded me of another one which happened in Europe after World War II and the Marshall Recovery Plan was put in place. It was very successful and

helped entire European nations recover. My idea is that we have to find around us somebody who can lead this and make some kind of a BC Marshall Plan for the Fraser River and apply the same principles. That is, get a fresh start and support it with technology, ideas, and science. First, I would completely support the proposal for a land-based closed containment fish farm. This needs to happen as soon as possible.

Also, there is an unquestionable situation with salmon recruitment. My suggestion is to put out a large number of juveniles every year and at least this could give us a little bit of time and maybe the science will be more sophisticated and more clear. I would like to propose an idea to use equipment for in-stream incubation which has been working well for about two years – there is a 95% survival rate from egg to fry and it is suitable for any salmon species, including steelhead and cutthroat.

Rick Routledge responded:
Although I agree with much of what you said, I do have some concerns about juvenile enhancement. I would agree that if a local population was threatened with extinction or extirpation then the record has generally shown that that approach can work and it can save some irreplaceable genetic information that might be lost for a hundred years. I am thinking about the work that I have been doing in Rivers Inlet with the sockeye salmon population that virtually collapsed there about ten years ago. We have reason to believe that the problem is related to a bottleneck in the inlet itself and if we were to encourage more young salmon to come down into the inlet to face that bottleneck I'm not sure it would do any good. Other instances could be different. I would approach this on a case-by-case basis, consider each case separately, and put the priority on situations where if nothing was done the population might go extinct.

John Fraser:
I am fascinated with the proposal and especially the historic parallel with the Marshall Plan in Europe. When it comes to what specifically we can do about streams where the native population has so diminished that it is about to go extinct or has gone extinct completely this suggestion is something we should consider. In cases such as this we should do something about rebuilding the run by using smolts from some other place, as closely related as possible, obviously. Some years ago the Pacific Fisheries Resource Conservation Council delivered a paper on hatcheries where we said that the blind use of massive hatchery production was not necessarily going to help very much and, in fact, there was some historical evidence that it did not work. It seemed to work at first and then subsequent runs diminished.

However, one of the streamkeepers told me that there are a number of streams that they have monitored going into the Fraser River where the native stocks were completely gone and they brought those streams back by getting fry or smolts from similar areas and putting them back in. The greater question is if you have done this by getting the eggs and sperm and raising the alevins to fry and then releasing them in the stream, then have you abandoned the concept of wild fish? That is what some of this debate is about. After three or four return runs that have been built upon the smolts you put in, then you have got a form of a wild fish. It may not be exactly the same genetically but there are now fish in those streams and they wouldn't be there otherwise. Therefore, this suggestion has to be considered carefully and acted on cautiously. The fact is that we have already brought streams back from where fish ceased to exist to runs that are now viable.

What goes on the list?

Willie Davidson:
One of the lasting images that I will have of these two days of discussions is the slide presented by Alexandra Morton showing the outflow from the fish plant. To follow up on John Fraser's question "Who's in charge?" who actually has jurisdiction over fish plants? Who actually monitors and controls and regulates the effluent that comes out of them? Who knows?

A participant commented:
Picking up on the idea of the ten issues and looking at the expertise at this table and recognizing the public responsibility to protect

salmon and that we must work in the political system, I would ask both the former fisheries ministers here, David Anderson and John Fraser, to immediately set up a meeting with Stephen Harper and also with Minister Gail Shea and the deputy minister. We could work together in this room and decide on what major issues should be brought up and supplement the information they already have. One very important issue to my mind is to make sure that scientists are allowed to speak out again within Fisheries and Oceans? This is a real problem for government scientists right now. In Environment Canada, the climate change scientists are not allowed to say anything to the media or the public about all the recent reports and research on climate change impacts. Obviously, there is something very broken there and that has to be fixed.

I would say to John Nightingale, you were very clear about communications. You have the aquarium; you could work with many of us on a communication strategy on how we reach the public. We all have a role to play in raising public awareness.

There are issues that we could add to this list right now: obviously the issue of Vancouver sewage and wastewater disposal would be near the top. I would also add the need to immediately fallow the fish farms along the sockeye migration route - that is the very least we can do if we care about the future of Fraser River sockeye or any salmon in the ocean and the Strait of Georgia and Johnstone Strait where there are critical migratory routes. I would also move right along with Andrew Wright's proposal for land-based closed containment fish farms and move ahead with getting a fundraising proposal together. We have politicians here or former politicians who could work with the provincial and federal governments in getting funding in place to make that happen. Reforming the Water Act to ensure that fish have a right to water has also got to be high up on the list.

The Fraser River Sockeye Spawning Initiative

A participant commented:
The Fraser River Sockeye Spawning Initiative is broken. I suggest we get rid of it. We cannot rely on the past to predict the future. Let's move on a new course and put the whole issue of a precautionary principle first and have a Ministry of Fish and not a Ministry of Fishing. Let's put salmon first, if we are taking responsibility for salmon.

Change happens at the individual level as well as the political level

A participant commented:
I want to applaud Glenn's point, and Iona made the point as well –sometimes people need to stir the pot a little bit and I think I would like to do it again.

There is a lot of doom and gloom in here and it is something I hate subscribing to. Salmon have been around for millions and millions of years and they will be around for millions and millions more. It is us that I worry about. Salmon naturally have strongholds. There was a time not that long ago when this province was covered in ice, and salmon lived in Beringia in the Yukon and Alaska, and they lived south of the Columbia and waited out the ice. Salmon will figure it out. For example, I was involved in streamkeepers projects on Haida Gwaii where there were populations of chum and coho salmon that were nearly extinct. The streamkeepers groups there have, however, brought these populations back using hatcheries in a very limited format, over two lifecycles.

The problem with going political is that politicians, political parties, or the governments in power have lifespans that are shorter than salmon, three to four years right now. I agree that there is a place for the political approach and I look to the politicians and the former politicians to help us get that voice. I have gone that route and for me it did not work out so well. That is why I fully believe in the individual choices. The bottom line is that we all have an impact and it is about making choices. It is about personal responsibility, exactly as Chief Claxton said. There's an old saying: We don't own the resources; we borrow them from the future. That's what we are doing. We are borrowing them from future generations. This panel addressed the question: Who is to pay? Well, we are to pay and we are to pay in hard

choices, in hard decisions and hard discussions as Glenn said, which happen at the individual level and happen at the political level. It happens at kitchen tables and it happens door-to-door. That's where the change happens.

One of the things that I do, for example, is to keep a website: salmonguy.org. I try and post to it daily – I have posted about this think tank and meeting. The media has changed. Going to people individually is where it is going to happen.

About communicating the message

A participant commented:
There is something that you all can do. I have been working on a scroll, and it will be going to schools and different lectures, and to regular people that don't really know very much about salmon. If there is any information that you would like to include on this scroll let me know by either emailing at lulu@streamofdreams.org or you can just write it on one of the papers and I will put it on.

I wanted to mention to David Anderson that ten years ago Byrne Creek suffered a terrible fish kill where there were 5,000 fish that perished, that's what inspired Stream of Dreams. As some of you may know, it has happened once again, this time it was only 2,000. This tells us once again about the importance of clean water.

The Barkley Somass system as an example of a successful partnership

A participant fisherman commented:
I want to encourage everyone - the sockeye picture is not all doom and gloom and despair. There have been a number of what I would call success stories in recent times. One of them that we could learn from is in Barkley Sound with the Somass sockeye. I have been involved with the watershed and harvest groups there, and we have seen returns that are exceeding expectations. One of the reasons why that system seems to work, and that there is a lot less animosity and despair in the community, is because we meet together, the Tseshaht and the sports fishermen and the commercial fishermen, and we plan harvests cooperatively. It is not that we all agree or that everything is rosy but because we have our disagreements together and we are all there when the decisions are made, we all can buy into the process. Maybe we can learn from other systems that are working better.

How to get the message to the Minister

A representative from DFO Ottawa commented:

I am a senior bureaucrat and I work for Gail Shea. It has been a very interesting couple of days. I suspect that a list of ten concise points would be welcome. It comes back to some of the discussions that I have heard here and some of the daily life as a political staffer for a minister. Recently I attended a meeting where I heard one of the most undiplomatic debates I have ever heard in my life and it was around African elephants. As iconic as the sockeye salmon is it doesn't touch African elephants, globally. One thing that struck me there is that there was a whole host of African nations and Western nations who were all fighting for elephants, and most of them believed in exactly the same things, but they could not agree on how to get there. They fought with each other and as a result, there was no clear decision that came out of the meeting and it gave everybody an opportunity to pretty much dismiss everything that could have been accomplished.

I could walk away from here today and probably get ten letters, and although you may all agree on what has to be done, I am not sure that I heard that everybody agreed on what action has to be taken. When letters come in to the minister there is often so much polarization on what has to be done and how it has to be done that the message is diluted. Therefore, if something is coming out of here the more buy-in you have as a group like this the better chance you have, because if the first thing the minister has to do is mediate right away then you have a problem. I would leave you with that one message: Don't let the intersectoral fighting on the "how" undermine the "what".

Iona Campagnolo:
The message from this conference has to be that we integrate those decisions that we are going to make and I trust there will be forthcoming action on a number of fronts.

Final comments from the panel:

John Nightingale:
I am mindful of what we just heard and mindful of picking a method that can clearly communicate what we think. I do think that if a smaller number of people put their heads together they could come up with a list of five items that need to be done in the next 60-90 days and five items that might stretch out over the next couple of years. Some of those will cost money and some will just take people working together in different ways or will take some government action. But if we are not that clear and that simple then we will not be heard by anybody. If we want to get something done then we have got to think about effective communication.

Allan Claxton:
I will just leave you with this thought. We all have to work together to protect what we have out there - individually we can't do it but collectively we can. I believe in our First Nations, but also believe in everybody in this room and I think we need to move forward.

David Anderson:
I would agree with the representative from DFO about the need for an end to the fighting amongst ourselves. The various sectors in the fishing industry have been notorious for fights of every type and it has certainly weakened the voice. Anything we can do to cooperate or to have an umbrella organization would be effective. For example, I personally believe there are too many environmental organizations in this area. We should have fewer with a stronger voice - maybe umbrella organizations are what we need.

Rick Routledge:
I did not mean to sound as negative as I did, but I do think we need to hope for the best and at the same time we need to think about and plan for the worst.

John Fraser:
In terms of aquaculture policy in BC right now, because of the Supreme Court of British Columbia decision, the system is operating in limbo and the federal government is figuring out how to take over the responsibilities. Therefore, it is very hard to get anybody to do anything and I don't think you're going to get clear answers on these issues at the moment.

In response to the suggestions of the Ottawa bureaucrat, I think we should thank the minister for allowing this person to attend this workshop. I agree that there is no use just writing individual rambling letters; we have got to put together a case. But I do want you to say this to the minister, because I certainly will, and that is: Within the department there is a problem. Nobody seems to know who is in charge.

APPENDIX 1
Dialogue after viewing of *End of the Line*

At the end of the first day participants were invited to view *The End of the Line*, a film based on the 2004 book, which follows the investigative reporter Charles Clover as he confronts politicians and celebrity restaurateurs, who exhibit little regard for the damage they are doing to the oceans.

After the viewing, a panel of respondents offered their perspectives and engaged in dialogue with the audience. Panelists included:

Ken Wilson, Member Canadian Caucus, Fraser Panel (Moderator)

Daniel Pauly, Member, Fisheries Centre, University of British Columbia

John Nightingale, President, Vancouver Aquarium Marine Science Centre.

INTRODUCTION TO THE VIEWING OF *END OF THE LINE*

Ken Wilson, Member Canadian Caucus, Fraser Panel (Moderator)

This film explores the relationship between fishers, fish and their fisheries and the changing ocean. It explores our relationship to fish and the way that relationship is going to have to change if we are going to maintain our fisheries and support the communities that depend on these fish.

Although we are not making the argument that the issues raised here directly apply to Fraser River sockeye, you will find that a number of the issues raised do have a direct bearing on some of the problems facing Fraser sockeye.

The timing of the message

Daniel Pauly:
For many years Charles Clover was not able to find a publisher for the book on which this film is based because at the time in the early 1990s there was no perception of the crisis of fisheries being more than just a series of isolated incidents. The story was different in the late 1990s however, because people began to understand that this was not the case and also there were a number of research articles that showed very clearly that the crisis of fisheries was not just a series of isolated incidents but rather it was a systemic problem.

Public awareness of coastal and oceans sustainability issues is increasing

John Nightingale:
Some recent polling was carried out through The Ocean Project, a loose amalgamation of about 900 aquariums, university departments, government labs, private foundations, and others, all across North America. The survey took place mainly in the USA but it did include Vancouver and Toronto in Canada, with samples of about 5,000 split between the two cities. Since the last poll was done 10 years ago, the percentage of people who acknowledged that there are serious environmental problems that require action, is up about 15 points. To a person, these people responded to the poll saying something should be done and Canadians, much more than Americans, said that government is responsible for taking action. However, less than 40% of those polled felt that they were personally

connected.

The poll was not just about ocean and fisheries issues – there were also some broader ocean issues as well as issues of coastal development, pollution, and a number of other coastal issues. These are actual data then that say that people now care more. Better evidence comes from the response to programs such as the Ocean Wise or Sea Choice programs or the Monterey Bay Seafood Watch. The corporate response to sustainable seafood programs has increased very significantly, mostly in the last 18 months, with almost every chain store now signing on to one program or another. You might say that they are just competing with others to greenwash. There is certainly a fair degree of that because they know their consumers are beginning to pay attention so they want to be part of the solution, not part of the problem.

Clearly, something is going on to broaden the public's interest. However, this alone cannot deal with the problem. Marine protected areas alone can't deal with the problem nor can regulations, and reductions in the fleet seem unlikely to be able to deal with the problem in any kind of a responsible way; for example, the bluefin tuna story at the recent CITES meeting took a gigantic step backwards. It was demoralizing. Our own cod story in Canada was the same. Scientists knew ten years earlier that we were driving off the edge of a cliff and yet there wasn't the political will to do something about it because of the social dislocation and the political ramifications of fisheries closures. However, when it truly did go off the edge of the cliff, the long-term economic impact to the country and the social impact to those people was far worse than if there had been some kind of a painful but more orderly transition.

It makes you wonder about the whole question of sockeye. As salmon face climate change and they face our lack of knowledge to truly understand cause and effect, should we not be a bit more proactive as opposed to just reacting?

Is the Marine Stewardship Council (MSC) certification process effective?

A participant posed the question:
Is there any evidence that certification is making a difference?

Daniel Pauly:
Up until now people have supported the MSC almost in the manner of a reflex reaction. I was involved at the very beginning with the design and criteria and with the launching of the MSC. Many scientists have participated with great hope for this tool. Since then, the MSC has grown and has certified a lot of fisheries. But now it is beginning to certify fisheries that are very questionable. The conservation community is hesitant to criticize the MSC, both with regard to the certification of certain doubtful fisheries, for example, the Fraser River sockeye, and with regard to whether it is really effective, on the ground. We have recently published a series of papers focused on these questions and this has triggered lots of reactions. Some are outraged: How do we dare to even ask? However, others are suggesting a reevaluation of the certification process, because there is a real danger of greenwashing. The MSC can evolve toward a greenwashing machine or it can revert back to certifying fisheries that are ecologically sound. It is very much at a decision point.

John Nightingale:
If you look at the MSC, one of the issues is that the process of certification of a specific fishery is quite expensive. For instance, the BC government has put up about $600,000 over the last couple of years to get a number of fisheries certified. That tends to mean that they get lumped together; for example, all the coho fisheries from the Strait of Georgia. The problem is that we need to head back toward more localized fisheries, and this does seem to be happening in some places. A hundred years ago in the BC salmon fishery, every community had their fishing fleet and cannery and they fished locally,

because there wasn't a lot of ice and fresh food and good transportation and the fish had to be canned. This is true all over the world. In the film, we saw the fishing fleet from Africa where local fishermen were being displaced by the international industrial fleet. Therefore, if we are going to head back that way then we have to have certification programs that can respond much more quickly and much more locally and do not cost a fortune to go through the process. For example, there is one restaurant in Vancouver that buys the catch from one single Skeena River boat that fishes the way they want them to. That is never going to be put through a formal certification process. There is just not enough money in the system to make it work. But we can work on other things here in BC. In some other parts of the world the industrial fleets are scary and demoralizing and one tends to feel helpless and, in some cases, hopeless about it.

Another participant commented:
The part that I struggle with, and that presents an interesting paradox, is the certification scheme. When I saw that the Marine Stewardship Council plans to certify sockeye, I had to shake my head a bit. In January there was an announcement by the U.S. about the commercial fishing disaster on the Chinook stocks on the Yukon River. This has never been a big fishery, less than 100,000 Chinook, but certainly it supports a lot of communities. Those fish have travelled all the way up the Yukon River, 3,300 km, and 92 different Nations depend on them. The curious thing is that this fishery is certified by the Marine Stewardship Council as being sustainable. And even more curious, if you follow it a little bit further, the Alaskan pollock fishery is also certified, yet this fishery catches a very large number of Chinook salmon as bycatch. So there is a disaster happening on a certified fishery, caused in part by another fishery certified by the same body, the MSC, that has a rather strong relationship with Walmart. The Prince William Sound fishery is also certified as sustainable, yet 95% of the catch in Prince William Sound comes from salmon ranching. I would be curious to learn about how much fishmeal has to go into a fish ranching operation. This brings me to the Marine Stewardship Council proposal to certify BC sockeye. The fishermen here haven't fished on the Fraser in three years, and the last seven years have been brutal. On the Skeena River it is 90% enhanced from the Babine and the rest of the sockeye stocks barely exist. This does present some interesting paradoxes.

Daniel Pauly:
The Marine Stewardship Council has challenged its friends and supporters with what is said in French "one more toad to swallow after the other." And they continue to get bigger. For me, the tipping point was the Fraser River sockeye salmon. I remember 10 years ago when the MSC was founded, one criterion was that no fishery would be certified or accepted in the process if it was under a cloud at the national level, especially if there was a lawsuit involved in that fishery or a legal problem of any kind. If there is any fishery in Canada that is now under a cloud, it is certainly the sockeye in the Fraser River. In fact, there is a parliamentary commission in place and a number of stocks have been identified by the IUCN as endangered. Yet recently when I was able to talk with some high level representatives of the MSC in Paris they told me that it is not demonstrated that the fishery is the cause of the trouble with the stocks. It is true that this has not been demonstrated, but it has also not been demonstrated that the fishery is doing the right thing. We don't know. For the MSC to intervene in this case and in a sense ajudicate on something that is open for Canadians to decide on, was, I thought, a bit steep. That was the point at which I could no longer accept this certification, in addition to the fact that they are certifying the anchovies and other fishmeal fisheries. Fishmeal fisheries are never fishmeal. When is the last time you saw fishmeal in the supermarket?

This is not offered for sale, so that people can choose between different kinds of fishmeal. This means that there will be certification of salmon farming through the back door. And it is explicitly against the policy of the MSC to be involved in aquaculture. These two things, for me, were the big tipping point. This film is two years old and in the meantime, these horrors have all happened.

John Nightingale:
The way that the MSC is structured now means that it cannot deal with localized fisheries on a smaller scale. It is too expensive. The reason BC went in that direction was that they wanted to sell fish in Europe where the consumer and the corporate bases have moved to the point where the product needs to have a certification label. Recognizing this, the BC government acknowledges that if they want to continue to export fish products, they will need certification. Economic activity was the driver for this, but we might accidentally get the wrong kind of result.

Changes to the harvest and the fishing fleet

A participant commented:
Some of the points that were raised in the film about fleet reduction have already been implemented in BC. In 1996, there was a major reduction in the salmon fleet through the Mifflin Plan. It sounded like a 50% reduction but, in fact, when they added area licensing to the fishery, it actually was reduced to about 15 – 20% in a lot of areas. In the past on the Fraser River, for instance, the gillnet sockeye fleet in a year like the one coming up, would have 2,000 boats fishing on the Adams River run. They would not just fish it for one or two days or 12 hours - they would fish, in some cases, for 30 straight days. The fishery in those times, even with that kind of fishing pressure, managed to sustain itself. Now the fleet has 320 boats, with usually only about 300 showing up to actively fish in the fishery. I don't think it can actually go any lower without actually saying there is no more fishing.

Three of us that are here today have not caught a sockeye in the Fraser River in three years, and realistically we have probably only had three 12-hour fisheries in the last seven years. Every weekend you will probably see boats fishing on the Fraser but these are mostly Native boats conducting a food and ceremonial fishery. That is not a fishery that is designed to over-fish. And if you followed the graphs we saw earlier today, you will note that the escapements have been bigger in the past 10 years than they were in the previous 30 or 40 years.

In some parts of the film, there was talk of a 10% exploitation rate on salmon in Alaska. However, anyone who has followed sockeye knows they are catching 25 - 30 million sockeye in Bristol Bay and escaping 6 to 8 million and that it is a sustainable harvest with something like a 60 – 70% harvest rate. How will the public be able to judge how much of what is reported is really true if a documentary like this reports the figures untruthfully?

Daniel Pauly:
You have to watch how they reported this, very carefully. It didn't say they have a 10% exploitation rate on "everything". It said that this was 'on average' and in Alaska, the average is always determined by pollock. In other words, if they have 10% for pollock and 90%, for example, for everything else, the final number will be closer to the average for pollock because that fishery is so enormous. There was in some cases contradictory reporting in the film; for example, Hilborn did not agree with Worm.

On the second point, about the fleet declining, that is true, and in fact in most of the world, the number of boats have declined. However, across all fleets, the technical capacity of the boat is increasing by about 3% per year. That means that in about 20 years with 100 vessels in the port, it would be as if you had 200. That augmentation of catching power is very subtle. It happens because of GPS, more experience, and modification in the rigging

and gear. Fisheries scientists can calculate this effect – it is called technical creep. You may have the impression when you go out fishing as an individual, that you are the same fisherman now that you were 20 years ago. In fact, you are much more efficient than you were 20 years ago. And that fully compensates for the programs of fleet reduction that happened in most countries whose level of fishing effort may remain more or less constant but whose effective fishing power is increasing. Further, if the stock declines are simultaneous then there is really a massive increase of effective effort, in the face of dwindling resources.

The participant commented:
With regard to the Fraser River sockeye we, in fact, are not gaining 3% technical expertise. I am still using the net I was using 10 years ago to catch sockeye salmon. I can't afford to buy a new net because we are not getting the fisheries opportunities in order to advance ourselves with technology. We spend our time coming to these kinds of meetings to find ways to make our fishery sustainable and to work with other stakeholders to harvest the fish responsibly. I think this is a responsible approach and it should be reflected better by the media and in films such as this one.

Another participant commented:
In watching this film, I got the impression that most of the fisheries we were looking at there were open fisheries. On this coast our fisheries are all integrated fisheries. It doesn't matter what kind of fish we catch, we have to account for every one of them – we have either a camera or an observer on board. We probably have the most modern and efficient fisheries in the world as far as sustainability goes because of the fact that we are integrated. Almost all the other places in the world are open fisheries.

When you talk about the technology being more modern this does not affect our overall catch, because we are on a quota and can only catch the amount of fish that our quota allows. So whether you get in one day or ten days of fishing time, it doesn't make a difference – you still can only catch that amount.

Daniel Pauly:
Many fisheries would benefit from being managed as well as the fisheries in British Columbia are. Moreover, in most conservation-oriented films such as this, the motivation of the people who make the statement is usually that fisheries should continue. The point being made in this film however is that if over-fishing is allowed to happen fisheries will collapse and they will not exist. So the basic motivation of the people who made this film was to ensure that enough fish exist in the future in order to fish them and in order for people to eat them. That is important.

Potential impact of climate change

Coming back to fisheries in BC, we could assume that the fisheries are very well run for the existing stocks. However, Scott Hinch has shown us what can happen if it gets too hot in the Fraser River - the stocks that survive will be the ones that are a little bit better adapted to warm temperature water. What scientists would tell you in that case is as many of the fish as possible should be allowed to survive in order for the ones that are pre-adapted to warm water to make it. The subsequent generations of fish will be the descendents of those ones and the ones that cannot tolerate the warm temperatures will die and not have descendents. In this case, when there is a huge challenge from the environment, such as there is with global warming, the response must be to leave the fish in the water, and not fish them at all. This is because you want the biomass to be as big as possible in order to have variance - to have fish that are different to make it and to essentially breed themselves to the ability to withstand the heat. If then you have a fishery, at the moment when you need lots of fish in the water, you might fish the one fish that can handle the high temperatures, and that could be the father or mother of subsequent generations. So even when you

have a good management system, as you say you have here, you have to foresee the damage or the effect of global warming. And that can involve reducing fishing sharply.

Ecological impact of fisheries

John Nightingale:
Situations are different in different parts of the world and different fisheries. In terms of ecological impact, I haven't yet found an ecologist who would have predicted that one of the outcomes of the crash of the Northern cod would be the jellyfish moving into that whole part of the ecosystem to the degree that they have. We are now seeing with shark finning around the world that it is having dramatic impacts on the natural history of the species involved. Removing the predators is allowing other things to take over. This is happening in other parts of the world with potentially more serious consequences. That is one of the issues that I focus on; that is, as we take too many of something out of the ocean, there seems to be, from the little evidence we have, that there are more defined tipping points where nature bounces but not necessarily back the way it was. It bounces in a bit of a different direction. And I don't think we are going to like some of those bounces – we haven't even scratched the surface in understanding them.

Why are the Northern cod not recovering in Atlantic Canada?

A participant directed a question to Daniel Pauly:
With regard to the East Coast cod, they have had quite a bit of time to recover, yet they have not recovered. Is this the fate that other species are looking at in the future? Has it gone beyond the tipping point?

Daniel Pauly:
The answer is at two levels. First, there is a fishery going on at present, although DFO doesn't call it a cod fishery. It is a fishery for shrimp. This has a bycatch of fish of which small cod are an example. There are thousands of small cod thrown overboard by the shrimp fishery and the bycatch is not monitored. This has been going on throughout the moratorium. There was a sport fishery for about five years and there was tolerance of fishing for local consumption. Given the enormous reduction of the stock, the continued fishery that was not really monitored for sport and for home fish consumption was actually quite significant. So they are, in fact, continuing to fish this stock, but not with targeted fisheries that are monitored.

The second point is that any animal that is very abundant in the sea is going to modify the structure of the food web through the things that it eats. Adult cod not only eat small cod, but they also eat the competitors and the predators of small cod. If the big cod are removed, then the competitors and predators of small cod take over; for example, sculpins and other fish with no commercial value. DFO on the other hand goes after the seals because the seals are spectacular consumers of fish, but probably the bigger consumers of cod are things like sculpins and other fish that aren't fished commercially.

John Nightingale:
The role of jellyfish is also quite interesting because it was the baby cod that ate all the plankton. The jellyfish are not voracious hunters; they just drift around and passively hoover up a lot of plankton. They have multiplied into that niche so much that they are now eating all the food that baby cod ate and the cod eggs and baby cod are getting hoovered up as well. When a scientist from Dalhousie University was asked at a conference: "When are the cod coming back? ", his answer was, "Not in a thousand years and not in the way that we knew them for centuries." Yes, we did go over a tipping point. And nature did bounce and is still bouncing back but not to the way that it was. That is a scary thing to confront when you look at BC in terms of climate change. Salmon are amazingly resilient and I am sure that there will be salmon around. But they may very well move around, populations of them, different species and stocks, and

different numbers in different places. That is what the dialogue of this workshop is focused on – everyone is trying to understand cause and effect and trends - what has an impact on what else - so that you can make some predictions. But as someone noted, predictions are dangerous, especially about the future.

Is this film overselling the issues?

David Anderson:
The discussion about certification really is very similar to the first comment made by the fisherman. That is, we really do need some rigorous scientific research. The comments on certification were similar to the original comments on the film and the criticism of the film, which are both important. That is, credibility depends on rigorous scientific objectivity. I was a little concerned when Professor Pauly suggested that we have to consider the motivation of those making the film. For a film like this to have the credibility that it needs with professionals in the field, it must be at a very high level of objectivity, particularly when it quotes so many scientists directly. That said, I agree that in general terms, films like this are absolutely necessary and important and I am glad the film was made. But I think that we have to recognize the difficulties we get into when people take broad brushstrokes and shortcuts. And the same is true with the Marine Stewardship Council as it is with the film. The film is on a critical issue. I wouldn't want to spend my time arguing about the validity of the film and the motivation of those who made it, except to say that this is an issue we have to face. The substance, rather than who made it and their motivation, is what should come out of this. In fact, I do not see this as a film that criticizes fishermen who fish for a living.

Daniel Pauly:
I would say that I spoke about the motivation that people have who are generally in the conservation movement because in their discussions with fishers, the issue often comes up that the fishermen perceive that the conservationists want to destroy the industry. Over the years, I have never met anybody in this sector who was explicitly against fisheries and wanted to close them, although I have met many people who criticize practices which will cause fisheries to be closed, because there will be no fish. It is important to talk about the motivation in this context because it is assumed that the people that made the film have a bad faith with regard to fishers. Actually, however, I think one can say they have good faith.

John Nightingale:
To pick up on David Anderson's point, one of the issues here is overselling or not overselling to the public. I invited some friends and neighbours who have no professional connection with the ocean whatsoever to watch the movie. One of the friends who is involved in the filmmaking community thought that from a film craft point it was a terrible film and it could have been shortened by 30 minutes at least. But another friend who is a young mother with three children said, "I know there are issues. What I want to know is what I should do. What can I do to help? I don't need to be beaten completely over the head about all the problems around the world. What I want to know is what can I do to help?" We find there are a lot of people with that kind of an attitude. The polls showed it and our experience at the aquarium shows it and so does the growth in the sustainable seafood programs. My sense of the film was there was a 50% oversell for the general public. I think we do have to be careful not to over-dramatize the facts. If the situation is clear and speaks for itself, then it needs to be conveyed simply and directly.

Is it a conservation issue or is it a political allocation issue?

A participant commented:
From a fisherman's point of view, I think we get it. As a gillnet fisherman on the West Coast of British Columbia and in the Fraser River, I have seen our catches drop by a rolling four-year average of approximately

10% of what we would have caught in the past. For us it is difficult to believe that we are at crisis proportions because we see that the cuts come first to the commercial fleet. In the film it also only deals with the commercial catch and that is because in the fisheries that they are talking about, there is really no other large shareholder. However, what we have seen happen in British Columbia is as the commercial catches have dropped, other user groups have moved in and have, in some fisheries, taken up the entire reduction, with allocation going to recreational or different uses. From the commercial fisherman's point of view, if there truly was a crisis, we would see reductions across the board and we would not see the increases in recreational fisheries or the transfer of fish to other user groups. For us, it becomes more of a perception that it is actually a political allocation issue and not a true conservation issue. I think you would find that the fishermen would be even more willing to do more and to cut back even more if you could convince them that it truly was a conservation issue and not just a political allocation issue.

John Nightingale responded:
This is a good way to close this discussion and bridge to tomorrow because I think that is probably where a lot of the discussion will go in terms of whether or not we are at a crisis point, and what tools we have available to use, and what we can do to change this, whether it is with more information or better management. Although you can't help but watch this film and not think about BC, one of the great things about the film is that it raises awareness about a worldwide problem that exists in almost every fishery, and it is exacerbated by climate change, social dependencies and national and international politics. It is not an easy task to ferret out solutions.

APPENDIX 2

Adapting to Change:

Managing Fraser sockeye in the face of declining productivity and increasing uncertainty

STATEMENT FROM THINK TANK OF SCIENTISTS

The total return of Fraser River sockeye in 2009 was the lowest in over 50 years. This was only a small fraction of the number expected. The productivity of Fraser River sockeye salmon, which is the number of adults produced per spawner, has been declining since the mid-1990s to the point where Fraser River sockeye are almost unable to replace themselves.

We believe that expectations in 2009 for Fraser sockeye were overly optimistic because forecasts did not adequately account for this decreased productivity. This trend is not due to fishing. In 2009 management responded appropriately by greatly restricting fishing to maximize the number of fish available for spawning. The weight of evidence suggests that the problem of reduced productivity occurred after the juvenile fish began their migration toward the sea.

There is a need to increase Canadian research and action on the marine coastal environment and on climate impacts. Specifically, the following four research activities are vital to address critical knowledge gaps regarding the declining productivity problem.

First, there is a need to assemble and analyze all existing data on Fraser River sockeye health and condition and to estimate survival throughout their life cycle. The gaps revealed in this review merit immediate attention to explain changes in the survival of Fraser sockeye by life stages.

Second, we need to compile historical data on the abundance and health of farmed salmon along the sockeye migration route in order to better understand the potential for transmission of disease and parasites to wild salmon.

Third, programs to assess timing and survival of migrating juvenile salmon should be expanded at various locations in the Fraser and in the coastal marine environment.

Finally, we need to understand why some populations and species are doing better than others, including links to climate change. We should therefore compare trends in abundance and survival of various stocks and species to determine whether there are shared stressors linked to changes in productivity. These comparisons may help us identify locations and times where problems arise such as lack of food, predation, disease, and parasites.

The low numbers of Fraser River sockeye in 2009 highlight our large uncertainty in forecasting salmon returns. We need to be more realistic in our expectations for the accuracy of forecasts. We should also do a better job of communicating and responding to the large uncertainties and resulting risks. Everyone needs to plan and act accordingly. Forecasting methods for Fraser sockeye must take into account the time trend of decreasing survival

rates. In the absence of reliable forecasts, in-season abundance data, which are gathered while the adult fish are returning, are critical and need to be enhanced.

Over the last 15 years, survival rates of Fraser River sockeye have not been as high as in the past and it is not clear why. This underscores the need for the research initiatives we have identified. In the short term, even before the federal judicial inquiry is completed, we must be prepared for the need for continued fishery closures and additional precautionary measures such as experimentally removing farmed salmon from sockeye migration routes.

Climate change poses a major threat to the future of Fraser River salmon, not only through direct effects of temperature on the fish, but also through impacts on food webs and habitats. Management agencies must take this information into account in order to meet the objectives of Canada's Wild Salmon Policy, which include maintaining biodiversity as well as monitoring and protecting habitat.

These are clearly challenging times for Fraser River sockeye salmon. The scientists in the Think Tank are confident that taking the appropriate research initiatives and management actions immediately will improve the prospects for these fish and their ecosystems, to the benefit of the many people who depend upon them.

For more visit or website: http://www.sfu.ca/cstudies/science/adaptingtochange.htm

Contact:
John Reynolds, Tom Buell Leadership Chair in Salmon Conservation, SFU, 778.782.5636
Laurie Wood, Coordinator, Centre for Coastal Studies, SFU, 778.782.5466

APPENDIX 3

On-site Program

Summit on Fraser River Sockeye Salmon

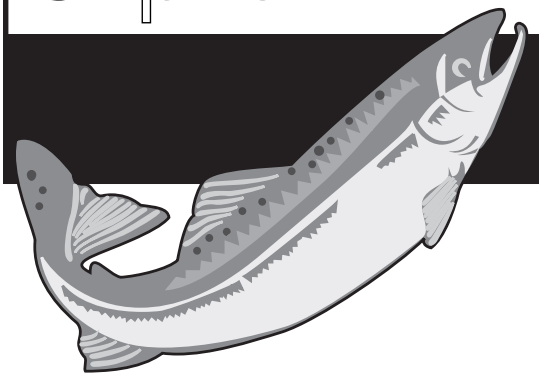
Understanding Stock Declines and Prospects for the Future

March 30-31, 2010

Morris J. Wosk Centre for Dialogue

Simon Fraser University

Speaking for the Salmon



Objective

A scientists' think tank met on December 7–8, 2009, to consider the causes of the unusual and unexpectedly low returns for Fraser River sockeye salmon in 2009. They examined these questions:

- Is marine/ocean survival the problem?
- What other factors must be considered to develop a better understanding of marine and freshwater survival?
- Do forecasts provide useful information to fisheries managers?
- How can we improve monitoring and management in a changing world?
- Where should research be focused?

Their findings were published in a statement which is available at:
www.sfu.ca/cstudies/science/adaptingtochange.htm

This website also includes information about the scientists and some of the resource materials considered in their review.

The Summit on Fraser River sockeye will review the findings of the think tank in relation to the questions that were posed and seek solutions from a broader audience to ensure survival of Fraser River sockeye for future generations.

Taking a life cycle stage approach, we will follow sockeye from their emergence from the gravel to the time they return as adults, to gain a detailed understanding of the challenges they face, and what can and should be done to ensure their survival for generations to come.

Context for Dialogue

All proceedings will be recorded to support the post-workshop report. Photographs may also be included. The report will include a synthesis of perspectives and will be available electronically after the Dialogue.

Guidelines for Dialogue

These guidelines are designed to create opportunities to maximize participation, foster a safe place for dialogue, enable vigorous differences to surface without disrespecting anyone, promote an open and full exchange of information/ideas and generate an environment of shared learning.

- Presenters/responders respect time by keeping to their allotted timeframe.
- Participants respect time through concise comments and questions.
- Participants identify themselves when speaking.
- Participants listen and speak with respect.
- Participants try to find a good way to say difficult things.
- Let there be humour, when we explore tough issues, with a spirit of learning, creating a healthy and constructive learning environment.
- If there are any questions or concerns please bring them to the session Chair.

Tuesday, March 30, 2010

Day 1: Challenges to Sockeye

Asia Pacific Hall—Room 100

8:00 am

Registration and light refreshment

8:30 am

Welcome

John Pierce, Dean, Faculty of Environment, Simon Fraser University

8:45–9:30 am

Report from the December Think Tank of Scientists

10-minute presentations followed by discussion.

Chair: John Pierce, Dean of Faculty of Environment, Simon Fraser University

Mike Lapointe, Chief Biologist, Pacific Salmon Commission

Mark Angelo, Chair, Pacific Fisheries Resource Conservation Council

John Reynolds, Tom Buell Leadership Chair in Salmon Conservation, Simon Fraser University

John Henderson, Councillor, Weiwaikum Band and Member, First Nations Fisheries Council

9:30–10:30 am

Panel I: Fry emergence and migration to sea

10-minute presentations followed by discussion.

Chair: *Craig Orr, Executive Director, Watershed Watch Salmon Society*

Mike Lapointe, Chief Biologist, Pacific Salmon Commission

David Welch, Kintama Research Corporation

- What is the "typical" life history of sockeye and what can we learn by comparing typical lake rearing populations (Chilko) with atypical, non-lake rearing populations (Harrison Rapids)?
- How do we know how many fish go to sea?
- What is the variation in freshwater productivity; is diversity important?
- What do we know about mortality during downstream migration?
- What are the general trends and issues related to freshwater sockeye stewardship?

10:30 am

Break

10:45 am–12 noon

Panel II: Smolts enter nearshore marine environments

10-minute presentations followed by discussion.

Chair: *John Reynolds, Tom Buell Leadership Chair in Salmon Conservation, Simon Fraser University*

Andrew Trites, Professor, Marine Mammal Research Unit, Fisheries Centre, University of British Columbia

Michael Price, M.Sc. Candidate, Biology, University of Victoria

Alexandra Morton, Director, Salmon Coast Field Station

- What stressors may be encountered?

12 noon

Lunch, ICBC Concourse (downstairs)

1:00–1:45 pm

Panel III: High Seas

10-minute presentations followed by discussion.

Chair: *Craig Orr, Executive Director, Watershed Watch Salmon Society*

Sonia Batten, Sir Alister Hardy Foundation for Ocean Sciences, presented by David Welch, Kintama Research Corporation

Skip McKinnell, Deputy Executive Secretary, North Pacific Marine Science Organization

- Where and when do sockeye feed in the high seas?
- What are the recent survival and climate trends?

1:45–4:00 pm

Panel IV: The return migration

- What stressors may be encountered on the long trek back to natal streams and what data are available with respect to survival bottlenecks for sockeye?
- What is the quality of pre-season forecasts of adult abundance?
- What is the fishing mortality by gear, area, and historical trends?
- What is the potential impact of climate change in terms of thermal stress in marine and freshwater environments?
- What are the trends in productivity (recent escapements, mortality events)?

10-minute presentations followed by discussion.

Chair: *Mark Angelo, Chair, Pacific Fisheries Resource Conservation Council*

Randall Peterman, Professor, Resource and Environmental Management, Simon Fraser University

Mike Lapointe, Chief Biologist, Pacific Salmon Commission

Break (15 minutes)

The return migration *(continued)*

Karl English, Past President, LGL Ltd.

Scott Hinch, Professor, Institute for Resources, Environment and Sustainability and Department of Forest Science, University of British Columbia—Adult Sockeye Salmon: Challenges to Complete the Journey and Spawn

4:00 pm

End of Day One

4:15 pm

Special Viewing—*End of the Line*

Introduction by Ken Wilson, Member, Canadian Caucus, Fraser Panel on diversity

Viewing followed by panel of respondents:

Daniel Pauly, Member, Fisheries Centre, University of British Columbia

John Nightingale, President, Vancouver Aquarium Marine Science Centre

Based on the 2004 book, *The End of the Line*, this film follows the investigative reporter Charles Clover as he confronts politicians and celebrity restaurateurs, who exhibit little regard for the damage they are doing to the oceans.

"*The End of the Line* is not against fishing. It is not against eating fish. But it is for a responsible attitude towards the oceans."

"We are given glimpses of hope and … this shines from the eyes of … eminent marine biologists. Each speaks with an insistent optimism, and as the story unfolds it is obvious why. This is not an insoluble problem. The answers are already known — all that is required is to get them into the minds of those making the decisions. … After decades in the wilderness, warning about the coming crisis, people are starting to sit up and pay attention. No new knowledge is required — just action."

Wednesday, March 31, 2010

Day 2: What Can We Do?

Asia Pacific Hall – Room 100

8:00 am

Light Refreshment

8:30–9:15 am

Panel V: Review of Day One including results from the December Scientists' Think Tank and Recommendations for Action

10-minute presentations followed by discussion.

Mark Angelo, Chair, Pacific Fisheries Resource Conservation Council

John Reynolds, Tom Buell Leadership Chair in Salmon Conservation, Simon Fraser University

- Is marine/ocean survival the problem?
- What other factors must be considered to develop a better understanding of marine and freshwater survival?
- How can we improve monitoring, pre-season and in-season management in a changing world?
- Where should research be focused?

9:15–10:45 am

Panel VI: Putting a value on salmon—social, economic, ecological and cultural considerations

Chair: *Craig Orr, Executive Director, Watershed Watch Salmon Society*

15-minute presentation followed by discussion

Kai Chan, Canada Research Chair and Assistant Professor, Institute for Resources, Environment and Sustainability, University of British Columbia

10-minute presentations followed by discussion.

Kelsey Charlie, Councillor, Culture Portfolio, Chehalis Band

Ken Wilson, Member, Canadian Caucus, Fraser Panel

What does Fraser River sockeye mean to society in broad social, cultural and economic terms?

- Food, social and ceremonial fisheries
- Commercial net fisheries and Recreational fisheries
- Other social/cultural/economic/ecosystem services concerns

10:45 am
Break

11:00 am–12:15 pm
Panel VII: What actions can be taken over the short and long terms?

10-minute presentations followed by discussion.
Chair: *Mark Angelo, Chair, Pacific Fisheries Resource Conservation Council*
What stewardship and stock recovery initiatives are underway or needed? Case Studies:

- Salmon Stronghold
  Ken Beeson, Pacific Fisheries Resource Conservation Council
- Water conservation
  Craig Orr, Executive Director, Watershed Watch Salmon Society
- Contaminants and sewage
  Ken Ashley, Instructor, School of Construction and Environment, BC Institute of Technology
- Change to land-based, closed-containment aquaculture
  Andy Wright, Member, Save Our Salmon Foundation

12:15 pm
Lunch, ICBC Concourse (downstairs)

1:00–3:00 pm
Panel VIII: What tools do we have?

10-minute presentations followed by discussion.
Chair: *Patricia Gallaugher, Director, Centre for Coastal Studies, Simon Fraser University*

- Salmon Genomics
  Willie Davidson, Professor, Molecular Biology and Biochemistry, Simon Fraser University and co-Principal Investigator of the Consortium for Genomic Research on all Salmonids Project
- The Species at Risk Act
  Arne Mooers, Associate Professor, Biological Sciences, Simon Fraser University
- Water Act Reform
  Linda Nowlan, Environmental Lawyer and Consultant with Watershed Watch Salmon Society
- Integrated Salmon Dialogue Forum
  Glenn Sigurdson, Facilitator, Integrated Salmon Dialogue Forum and Principal, CSE Group
- Fisheries Monitoring and Compliance Initiatives
  Craig Orr, Executive Director, Watershed Watch Salmon Society
- Wild Salmon Policy
  Terry Glavin, Writer/Researcher

3:00–3:15 pm
Break

3:15–5:00 pm
Panel IX: How do we move forward and who pays for this?

10-minute presentations followed by discussion.
Chair: *Iona Campagnolo, Member, Collaborative Watershed Governance Initiative*
Chief Allan Claxton, Tsawout First Nation and Co-Chair, BC First Nations Fisheries Council
John Fraser, Member, Pacific Fisheries Resource Conservation Council
Rick Routledge, Professor, Statistics and Actuarial Sciences, Simon Fraser University
David Anderson, Former MP and Minister of Environment
John Nightingale, President, Vancouver Aquarium Marine Science Centre

Closing Remarks: *Iona Campagnolo*

For information about Speaking for the Salmon initiatives, visit our website at www.sfu.ca/cstudies/science/salmon.htm

Contact us
Continuing Studies in Science
Simon Fraser University
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Participant Biographies

The Honourable David Anderson was born in Victoria seventy-three years ago. He has been an active conservationist, particularly in the area of protecting our coastline from oil tanker traffic and offshore drilling. He served both as an MLA and an MP and served in the cabinet of Prime Minster Chretien as both Fisheries Minister (1997–99) and as Environment Minister (1999–2004).

Mark Angelo, Chair of the Pacific Fisheries Resource Conservation Council, is a noted river conservationist, outdoor leader, teacher and writer. He is the Chair of the Rivers Institute as well as Program Head of the Fish, Wildlife and Recreation Department at the British Columbia Institute of Technology. He is the founder and chair of BC Rivers Day, and also chairs World Rivers Day. Mark is a recipient of the Order of Canada and also holds the Order of British Columbia, in recognition of outstanding achievement in preserving Canada's waterways. He was the first recipient of the National River Conservation Award as Canada's most outstanding river conservationist in the past decade and he received the inaugural United Nations Stewardship Award. His involvement with conservation issues in British Columbia spans four decades and he has published close to 300 articles and editorials. In June 2009, Dr. Angelo received an honourary doctorate in science from Simon Fraser University.

Ken Ashley earned his BSc and MSc in Zoology, and MASc and PhD in Civil/Environmental Engineering from UBC. He worked for the Fisheries Research and Development Section of the BC Ministry of Environment for 25 years where he developed a variety of innovative lake aeration, lake and stream fertilization and habitat restoration solutions. From 2005–2007, Ken worked at the Greater Vancouver Regional District as Senior Engineer in the Utility Analysis and Environmental Management Division to learn about the deleterious effects of municipal wastewater discharges and drinking water withdrawals on aquatic ecosystems. He returned to the Ministry of Environment in 2008 where he was the provincial contact for the Living Rivers Program and other habitat restoration /compensation programs. A member of the Salmon 2100 project team, Ken is currently an instructor at the BC Institute of Technology in the new undergraduate degree program in Ecological Restoration, and an Adjunct Professor of Civil Engineering at UBC, in addition to operating his own ecological engineering consulting company.

Sonia Batten completed her PhD at Southampton University in the UK and then began a post-doc with the Sir Alister Hardy Foundation for Ocean Science working on the north Atlantic Continuous Plankton Recorder survey. In 2000 she moved to Nanaimo, BC and coordinated the setting up of the north Pacific CPR survey, now in its 11th consecutive year and supported by a consortium of funding agencies including DFO. Sonia's experience is in biological oceanography, particularly the large scale dynamics of zooplankton and their role in the oceanic ecosystem.

Ken Beeson is the Managing Director of the Vancouver-based Public Policy Management consulting firm specializing in environmental and health fields. He has been a senior executive in the private sector and has led national not-for-profit organizations, including serving as interim President and Chief Executive Officer of the International Centre for Infectious Diseases. He has worked for more than eleven years as a policy advisor to the Pacific Fisheries Resource Conservation Council and has authored several reports on salmon issues.

The Honourable Iona Campagnolo has had a long career in representing the interests of British Columbians, serving both in public office and in her private capacity. Ms. Campagnolo has assisted in Speaking for the Salmon series and other SFU Continuing Studies in Science initiatives since 1995. The founding Chancellor of The University of Northern British Columbia, Ms. Campagnolo was also the founding Chair of the Fraser Basin Council and is an honourary SFU Alumna. She is an Officer in the Order of Canada and a Member of the Order of British Columbia and served as the first woman and 27th Lieutenant Governor of our Province from 2001 to 2007.

Kai Chan is an assistant professor and Canada Research Chair (tier 2) at the Institute for Resources, Environment and Sustainability at the University of British Columbia. Kai is a Canadian who received his PhD from Princeton University and a postdoctoral fellowship from Stanford University. His research is interdisciplinary and policy-relevant, in three primary areas: (1) biodiversity and ecosystem services (the processes by which ecosystems benefit people, directly and indirectly); (2) biological infestations and invasions; and (3) applied environmental ethics. In all, he strives to understand the workings of and values associated with social-ecological systems, in order to facilitate decision-making that promotes human well-being and social and ecological justice. Kai leads the Conservation Collaboration in Interdisciplinary Study of Ecosystems (www.conciseresearch.net); he is a director on the board of the BC chapter of the Canadian Parks and Wilderness Society (CPAWS), a columnist at the Vancouver Metro, and a senior fellow of the Environmental Leadership Program.

Participant Biographies

Kelsey Charlie is a Councillor with the Chehalis First Nation. He holds the Culture portfolio among many other responsibilities.

Chief Allan Claxton (Sxed Qel A'new) has been the Chief of the Tsawout First Nation for the past sixteen years. During his tenure, Tsawout has taken charge of their sewage treatment plant, implemented a lands management program and introduced taxation. Chief Claxton's goal is to move his community into self-sufficiency through self-government, with the ultimate goal being a healthy community in control of its own destiny. Chief Claxton currently serves as a co-chair of the BC First Nations Fisheries Council, and as a BC representative for the Assembly of First Nations National Fisheries Committee. He is also a board member for the Centre for Indigenous Environmental Resources, a member of the Regional Chiefs' Health Committee, a member of the Chiefs' Committee on Health, and a BC Assembly of First Nations representative for the Leadership Council of Health. He has also served as the national representative for Health Technicians. He loves spending time with his wife, their five children, and their grandchildren. He enjoys golfing and the outdoors.

Willie Davidson is a Professor in the Department of Molecular Biology and Biochemistry at Simon Fraser University. His research interests are broad, but are all in the general field of molecular evolution. He has investigated population structuring in Atlantic salmon and Arctic char as well as the interactions between, and the hybridization of, brown trout and Atlantic salmon. For the past ten years he has been involved in salmonid genomic research, and was a co-PI of the Genome Canada/Genome BC funded Consortium for Genomic Research on All Salmonids Project (cGRASP). He is currently involved with sequencing the Atlantic salmon genome, applying genomic techniques to salmonid broodstock development and examining the population genetics of sea lice.

Karl English is a fisheries scientist with 29 years of professional experience working with LGL Limited on Pacific salmon fisheries. Karl has spent most of his career designing and implementing studies to improve the quality and quantity of information available for the management and assessment of Pacific salmon and steelhead stocks. Karl has conducted projects throughout BC, and in Washington State, Alaska and the Yukon. He has designed catch monitoring programs for commercial, sport and First Nation fisheries; directed multi-year studies to assess fish distribution, abundance and migration behaviour in coastal waters and large river systems; and provided expert advice to First Nations, industry, NGOs, university researchers and all levels of government.

A sample of the salmon and steelhead projects directed by Mr. English include: the 1982–85 International Salmon Tagging Studies conducted in northern BC and southeast Alaska; the Nisga'a Fisheries Program; the 1986–99 Georgia Strait Creel Survey; the 1996–2002 Yukon River Basin Salmon Harvest Study; and radio telemetry studies to assess migration behaviour and abundance on the Nass, Skeena, Fraser, Bella Coola and Columbia rivers (1992-present). Mr. English has also directed research on other fish species including: white sturgeon, arctic cisco, broad whitefish, and reviewed research and stock assessment programs associated with the fisheries in the Canadian Great Lakes. In additional to his research and project management responsibilities, Karl has extensive experience in Treaty negotiations process through his role as fisheries advisor during the negotiation of the Nisga'a Treaty and Tsawwassen Treaty.

The Honourable John Fraser graduated from the University of British Columbia and practised law until his election to the House of Commons. During his years in Parliament, he served in key positions, including Minister for the Environment and Minister of Fisheries. He was the first person to have been elected Speaker of the House of Commons by his peers, a practice instituted in 1986. In 1994, John Fraser was selected to head the Fraser River Sockeye Public Review Board investigating the salmon fishery. In September 1998, John Fraser was appointed Chair of the Pacific Fisheries Resource Conservation Council and remained as Chair until April 2005 and he currently remains a Council member. In December 2004, Mr. Fraser was appointed chair of British Columbia's Pacific Salmon Forum.

Patricia Gallaugher is Director of Continuing Studies in Science, Director of the Centre for Coastal Studies, and Adjunct Professor in Biosciences at Simon Fraser University. Dr. Gallaugher's research on salmon physiology and selective fishing conducted in partnership with members of the BC commercial salmon fishing fleet, coastal communities and First Nations, the Province of BC and Fisheries and Oceans Canada was recognized in 2002 with the Vancouver Aquarium Murray A. Newman Award for Excellence in Aquatic and Marine Conservation Research which she received with Dr. Rick Routledge and Dr. Tony Farrell. Patricia has helped to develop a number of programs dealing with coastal and ocean resource sustainability issues in BC and Atlantic Canada. In 1998 she initiated the Speaking for the Salmon series of workshops, scientists' roundtables and think tanks focusing on linking science to policy for the future sustainability of Pacific wild salmon.

Dr. Gallaugher is a member of the Science Advisory Committee for the Canadian Healthy Oceans Network (CHONe), Board Member of Coastal Zone Canada, a co-

founder and member of the steering committee of the Canada Ocean Lecture and a co-investigator on the Consortium for Genomic Research on All Salmonids (cGRASP) Genome Canada/BC funded research project based at Simon Fraser University and the University of Victoria.

Terry Glavin is a journalist, the author of eight non-fiction books, and an adjunct professor in the Creative Writing department at the University of British Columbia. His most recent book, *Waiting for the Macaws*, is published under separate titles in Canada, the United States, the UK and Germany. For this book, he traveled around the world to report on the impacts of globalization, biodiversity loss, and the vanishing of cultural and linguistic diversity. His book, *The Last Great Sea: A Voyage Through the Human and Natural History of the North Pacific Ocean*, was nominated for the Bill Duthie Prize and the Roderick Haig-Brown Non-Fiction Prize, and was the winner of The Hubert Evans Non-Fiction Prize. As a journalist and columnist for *The Vancouver Sun, The Globe and Mail, the Georgia Straight* and the *Tyee*, and a frequent contributor to such newspapers and magazines as *Lettre International* (Berlin), *Canadian Geographic*, the *Vancouver Review* and the *Ottawa Citizen*, Terry specializes in relating natural history to anthropology and contemporary cultural phenomena. He has won multiple awards for feature length essays, including several science-writing prizes, Western Magazine Awards and National Magazine Awards. Terry was the recipient of the 2009 Lieutenant-Governor's Award for Literary Excellence. His new book, *Come From The Shadows*, to be published by Douglas and McIntyre, is set mainly in Afghanistan, where Terry is hoping to learn how to properly flyfish the Panjshir River.

John Henderson is one of 17 children of the late master carver Samuel Henderson and May Henderson. John was given his name Tl'Wakgila (Holder of the Copper) in a memorial potlatch in the 70s that his father had for his mother. John was initiated into the Hamatsa society, which is a sacred dance given by Chiefs. John has worked with the Campbell River (Weiwaikum) Band for many years as a councilor, and also served as the Chief and is currently a band councilor. He has been working with the Kwakiutl District Council for the last 16 years, and is currently the vice chair. He has also been the chairman of the Hamtla Treaty for 8 years. John spent many years fishing with his parents, and then later fished on his uncle's salmon seine boats. He became a skipper on a seine boat in 1982, and has worked in this business ever since. John always thanks his uncles for all the knowledge they gave him in the fishing industry, and credits them for his success.

Scott Hinch is a fisheries scientist in the Department of Forest Sciences and Centre for Applied Conservation Research at the University of British Columbia. Since joining UBC in 1994, he has developed two broad research programs: the study of salmon migration energetics, physiology, behaviour and survival; and, the study of land-use impacts on salmonids and their habitat. He collaborates extensively with colleagues studying physiology, biochemistry and genomics and uses an interdisciplinary approach to tackle pressing issues in the conservation and management of Pacific salmonids. Dr. Hinch has been studying Fraser River sockeye salmon ocean and freshwater migrations for the past 16 years and has participated in several past inquiries into "missing salmon." He continues to lead an interdisciplinary research team investigating the early migration and high mortality phenomenon in late run Fraser sockeye, and the effects of climate change on Fraser sockeye.

Mike Lapointe has a Bachelor of Science degree in Wildlife Management from the University of Maine and a Master of Science degree in Zoology (Fisheries) from the University of British Columbia. Mr. Lapointe has over 20 years experience in Salmon Assessment and Management. For the past 17 years, he has been a member of the Pacific Salmon Commission (PSC) staff, becoming its Chief of the Fisheries Management Division in 2002. As Chief, Mike leads a technical team of about 15 individuals that provide in-season assessments of return timing and abundance of Fraser River sockeye and pink salmon used by the bilateral Fraser River Panel to regulate harvests under the terms of the Pacific Salmon Treaty between Canada and the United States. In addition to in-season duties, Mr. Lapointe and his staff assist the Panel in developing pre-season plans and liaise with agency staff from both countries in areas related to salmon assessment and management.

Skip McKinnell received a PhD in Fish Biology from Sveriges Lantbruksuniversitet (Swedish University of Agricultural Sciences) for research on the interaction of Atlantic salmon biology and the fishery. He was the first Lead Author of DFO's Wild Salmon Policy and is a former chairman of their salmon assessment review sub-committee. He was Canada's principal scientific investigator of the effects on large-scale driftnet fishing. Since 1999, he has been Deputy Executive Secretary of the international, intergovernmental North Pacific Marine Science Organization (PICES) where he is currently editor-in-chief of a new PICES book on the status and trends in North Pacific marine ecosystems. His hobbies include the making of forecasts of Chilko Lake sockeye salmon returns at the annual salmon forecasting forum.

Participant Biographies

Arne Mooers is an Associate Professor of Biodiversity at Simon Fraser University. Dr. Mooers received his training from McGill and Oxford Universities and previously held research positions at the Zoological Museum of Amsterdam, the University of British Columbia, and is a past fellow of the Institute for Advanced Study in Berlin. He is the incoming Chair of the Biodiversity and Conservation Committee, and a member of the Executive Committee, of the Canadian Society for Ecology and Evolution, and he is lead author of a review of the Species at Risk Act for the Federal Parliament. Arne's expertise is in phylogenetics, comparative evolutionary biology and ways to quantify biodiversity for conservation. (www.sfu.ca/~amooers)

Alexandra Morton is the director of the Salmon Coast Field Station in the Broughton Archipelago where she has lived and conducted research for 26 years. In addition to her well-known research on orca whales, Alexandra has authored or co-authored seventeen peer-reviewed scientific papers on impacts of salmon farms. The author of a number of books and a Registered Professional Biologist, Alexandra is the recipient of the Roderick Haig-Brown Conservation Award (2005), the Vancouver Aquarium's Murray A. Newman Award for Excellence in Aquatic Conservation (2006), and the Roland Michener Conservation Award (2008) among others. Ms. Morton was part of a research team that was the last to see the 2009 sockeye as they migrated out of the Strait of Georgia.

John Nightingale has a broad professional background in aquatic sciences, specializing in using them to enhance public awareness, education and promote conservation. A professional biologist and public educator, Dr. Nightingale has been responsible for the development and operation of some of the world's best aquariums. His background and lifelong work in public communications, and both formal and informal public education, make him a leader in the current rapid development of new conservation efforts in aquariums, zoos and museums. During his seventeen years at the Vancouver Aquarium, he has guided the expansion of the Aquarium's leadership in conservation and research while focusing operations on sustainability and solid fiscal performance. As a result, the Vancouver Aquarium is not only one of the "greenest" cultural institutions in Canada, it is the only one that is financially self-sufficient, operating without an annual subsidy from Government.

Linda Nowlan is a public interest environmental lawyer and independent consultant in Vancouver. Previously, she worked at West Coast Environmental Law, a public interest law organization, for ten years, after practicing civil litigation for five years. She has also worked for the Program on Water Governance at the University of British Columbia and the UK Foreign Office. Her water law publications cover topics such as groundwater regulation (Walter and Duncan Gordon Foundation), collaborative water governance (UBC Program on Water Governance commissioned by the province of BC), customary water law and aboriginal rights (UN Food and Agriculture Organization), water markets (Conference Board of Canada), and the human right to water (World Water Institute). Other environmental law publications include a guide to the Arctic environmental legal regime (IUCN), and a guide to international environmental treaties (WCELRF). She sits on the Greenest City Action Team for the City of Vancouver, the Board of the Sierra Club of Canada Foundation, and the Canadian Council of Academies' Expert Panel on Groundwater. Ms. Nowlan is a member of the Law Society of BC, the IUCN Commission on Environmental Law, the ELAW Alliance, and is a Fellow of LEAD International.

Craig Orr is a behavioural ecologist and the Executive Director of the Watershed Watch Salmon Society, where he promotes salmon conservation and public outreach. Dr. Orr has served as Associate Director of Simon Fraser University's Centre for Coastal Studies, Chair of BC Hydro's Bridge Coastal Restoration Program, Vice-Chair of the Habitat Conservation Trust Fund, and technical reviewer for the Pacific Salmon Endowment Fund, Pacific Salmon Commission, National Marine Fisheries Service, Fisheries and Oceans Canada, Vancouver Foundation, Friends of the Environment Foundation, and others. He also currently chairs the Pacific Marine Conservation Caucus, and the Monitoring and Compliance Panel of the Integrated Salmon Dialogue Forum. With Watershed Watch Craig has focused on a broad array of habitat and harvest issues, participating in numerous water use planning activities (Coquitlam Water Use Plan Consultative Committee, BC Hydro Fisheries Advisory Team, First Nations Water Use Planning Committee, Kwikwetlem Salmon Restoration Program), harvest planning committees (Integrated Harvest Planning Committee, Williams' 2004 Sockeye Review Panel, Fraser Salmon Table, BC Aboriginal Fisheries Commission (selective fisheries coordinator), and other initiatives. Dr. Orr has worked extensively on the issue of aquaculture impacts for nearly a decade, authoring numerous technical reports and peer-reviewed studies, researching lice infestations on juvenile sockeye, and serving as science coordinator for the Coastal Alliance for Aquaculture Reform, where he oversees collaborative research and louse monitoring programs with Marine Harvest Canada.

Participant Biographies

Daniel Pauly is a French citizen who completed his high school and university studies in Germany; his doctorate (1979) and habilitation (1985) are in Fisheries Biology, from the University of Kiel. After many years at the International Center for Living Aquatic Resources Management (ICLARM), in Manila, Philippines, Daniel Pauly became in 1994 Professor at the Fisheries Centre of the University of British Columbia, of which he was the Director for 5 years (Nov. '03-Oct. '08). Since 1999, he is also Principal Investigator of the Sea Around Us Project (see www.seaaroundus.org), funded by the Pew Charitable Trusts, and devoted to studying, documenting and promoting policies to mitigate the impact of fisheries on the world's marine ecosystems.

Randall Peterman is a Professor in the School of Resource and Environmental Management at Simon Fraser University. He holds a Canada Research Chair in Fisheries Risk Assessment and Management. Dr. Peterman's research focuses on quantitative methods to improve the understanding and management of fish populations, particularly in the presence of uncertainties and conservation risks. His research group specializes in developing and applying quantitative methods to improve fisheries management, mostly related to Pacific salmon, through using large data sets, simulation models, Bayesian and other statistical methods, and formal decision analysis. Most relevant to this workshop is his group's past research on developing and comparing the methods for pre-season forecasting of abundances that are used by salmon management agencies on the west coast of North America. Randall's group has received several international awards for the quality of its research. Randall has served on various policy advisory groups and helped to write the 1995 United Nations Food and Agriculture Organization's Precautionary Approach to Capture Fisheries and he is a member of the Royal Society of Canada (RSC) Expert Panel on Ocean Climate Change and Marine Biodiversity.

John Pierce has for the past 33 years served many diverse roles within Simon Fraser University as a researcher, teacher, administrator and community advisor. He has taught and published widely on topics relating to sustainable community development; food security, resource and environmental management/modelling; and public policy. As an administrator he served as Chair of the Department of Geography, Director of the Centre for Community Economic Development, Dean of the Faculty of Arts and Social Sciences; and most recently he serves as the inaugural Dean to the newly created Faculty of Environment at SFU. John received his PhD from the London School Of Economics.

Michael Price is a MSc candidate with the University of Victoria, and conservation biologist with Raincoast Conservation Foundation, where he is the project manager of their Juvenile Salmon Ecology Program. He is also a science advisor on wild salmon ecology with the Heiltsuk Nation. Michael has extensive field research experience, spanning multiple projects, and involving keystone and endangered species of terrestrial and marine systems. Michael's most recent focus is on anthropogenic influences on the early marine survival of Fraser River sockeye.

John Reynolds is a professor at Simon Fraser University, where he holds the Tom Buell BC Leadership Chair in Salmon Conservation and Management. His research focuses on understanding connections between salmon and their ecosystems, emphasizing implications for conservation and sustainability. This includes research on numerous streams in both the Fraser Basin and in the Great Bear Rainforest. Dr. Reynolds has held a wide range of scientific advisory positions, including the BC Pacific Salmon Forum and the Skeena Independent Science Review Panel. He has written five books and over 150 scientific articles on ecology and conservation. In 2000, he was awarded the FSBI Medal by the Fisheries Society of the British Isles, and in 2003 he received the J.C. Stevenson Award from the Canadian Conference for Fisheries Research. http://www.sfu.ca/reynolds

Rick Routledge develops and applies statistical methodology in population biology and renewable resource management. Current projects include (i) coordination of and participation in ecosystem research on the British Columbia Central Coast, and (ii) collaborative research on interactions between fish farms, sea lice, and wild Pacific salmon. Dr. Routledge has also worked with the Pacific Salmon Commission on alterations to their hydroacoustic estimation of fish passage in the Fraser River, and has developed models for generating theoretical insight on mixed-stock fisheries, extinction risks, and incorporating uncertainty into forest management decisions. He served on the Fraser River Sockeye Public Review Board in 1994–1995, and was a founding member of the Pacific Fisheries Resource Conservation Council. Rick was a co-recipient of the Vancouver Aquarium Murray A. Newman Award for Excellence in Aquatic and Marine Conservation and Research in 2002.

Participant Biographies

Glenn Sigurdson is the lead Facilitator for the Integrated Salmon Dialogue Forum and Principal, CSE Group. His background includes experience as a mediator, facilitator, and negotiator; he also brings with him an extensive adjudicative background as an arbitrator in workplace, commercial, and healthcare disputes, and as the Senior Vice Chair of the Manitoba Labour Relations Board (1980–1989, part time). Glenn is associated with Simon Fraser University, where he is an adjunct Professor in the Learning Strategies Group in the Faculty of Business. He is also associated with the LL.M. Graduate Program in Dispute Resolution, Osgoode Hall Law School of York University in Toronto (2002–2003).
He is a former President (1996) of the Society of Professionals in Dispute Resolution (SPIDR), now known as the Association for Conflict Resolution, the pre-eminent international organization in the ADR field, headquartered in Washington, D.C. He has recently been appointed to the NAFTA Advisory Group, established under Article 2022 of the NAFTA Agreement to deal with international private commercial disputes as one of the Canadian non-government members.

Andrew Trites is Director of the Marine Mammal Unit at the UBC Fisheries Centre and Research Director of the North Pacific Universities Marine Mammal Research Consortium. He is also a member of the Marine Mammal Specialist Group for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and a member of the PICES Advisory Panel on Marine Birds and Mammals. Dr. Trites has been studying marine mammals in the North Pacific for over 30 years. His current research is primarily focused on pinnipeds (Steller sea lions, northern fur seals and harbor seals), and involves captive studies, field studies and simulation modeling. Some of his work includes modeling the Bering Sea ecosystem, estimating the extent of competition between marine mammals and fisheries, and evaluating the junk-food hypothesis thought by many to explain the decline of Steller sea lions in Alaska. He trains students and collaborates with researchers specializing in other disciplines (such as nutrition, ecology, physiology and oceanography). His graduate students have worked on a variety of subjects including harbour seal genetics, killer whale / vessel interactions, Steller sea lion behavior, pinniped energetics, GIS mapping of marine mammal critical habitat, and predation on salmonids.

David Welch is the president and founder of Kintama Research Corporation. David has a BSc in Biology and Economics from the University of Toronto and a PhD in Oceanography from Dalhousie University. For the first 20 years of his career David worked for DFO's Pacific Biological Station in Nanaimo. David developed the original concept of building continental-scale marine tracking arrays to resolve critical issues in salmon management. David founded Kintama to begin evaluating sensor technology for this purpose, and to develop the required technology for building large-scale & highly efficient telemetry arrays.

Ken Wilson is a representative of the Marine Conservation Caucus, serving on the Integrated Harvest Planning Committee, and the Canadian caucus of the Pacific Salmon Commission's Fraser Panel. After completing his post-graduate work at the University of BC in 1980, Ken began his career with DFO, Fraser River Division, as a fisheries manager and stock assessment biologist, leaving in 1997 to assume responsibilities as the Stock Management coordinator for the Fraser River Aboriginal Fisheries Secretariat. In this capacity, Mr. Wilson chaired the Fraser Watershed Stock Management Committee and served on the Marine Fish Species Specialist Group of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Andrew Wright graduated from the University of Hull, England with a first class honors Bachelor of Science, a Diploma of Engineering and a Doctorate in Microwave Engineering. He has published numerous IEEE peer-reviewed research papers and has been awarded over 50 patents. After emigrating to Canada, Dr. Wright co-founded and was CTO of Datum Telegraphic Inc. Datum was subsequently acquired by PMC-Sierra. He is currently a Director of Actenum, Zymeworks, and Pharos Capital and a co-founder of Aegis Mobility. Dr. Wright is a proponent of environmental stewardship initiatives. He is a lead donor for the Tides Canada Great Bear Rainforest initiative, which promises to be a model for world conservancy. Upon visiting the Broughton Archipelago and witnessing the impact of open net-cage salmon farming, he has become an advocate for improving salmon aquaculture practices on the West Coast.

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Pacific Fisheries Resource Conservation Council

Steering Committee

Mark Angelo, Chair, Pacific Fisheries Resource Conservation Council and Chair, Rivers Institute, BC Institute of Technology

Patricia Gallaugher, Director, Centre for Coastal Studies and Continuing Studies in Science, Simon Fraser University

Craig Orr, Executive Director, Watershed Watch Salmon Society

John Reynolds, Tom Buell Leadership Chair in Salmon Conservation, and Professor, Biological Sciences, Simon Fraser University

Brian Riddell, CEO, Pacific Salmon Foundation

Ernie Victor, Manager, Aboriginal Community Liaison, Fraser Basin Council