STRAIT OF GEORGIA CHINOOK AND COHO PROPOSAL

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Prepared by the:
Pacific Salmon Foundation
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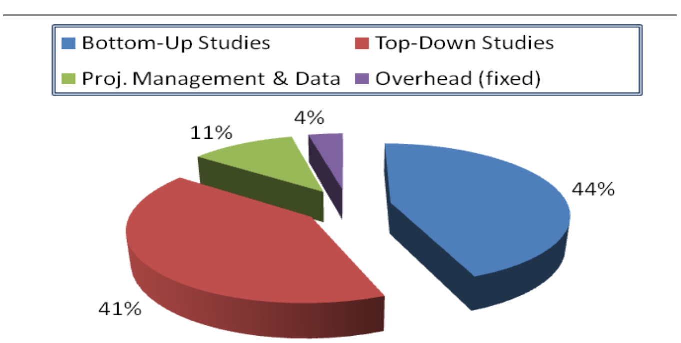
EXECUTIVE SUMMARY

Coho and Chinook salmon populations in the Strait of Georgia are presently less than one tenth of past peak levels, resulting in a ban on retention of wild coho salmon and historically low Chinook catches. Surprisingly, the causes of these declines in salmon abundance remain poorly investigated. This proposal investigates how to restore Chinook and coho production, fishing opportunities, and natural ecosystems in the Strait of Georgia by significantly improving our understanding of what currently limits the production of these salmon.

Given the limited past work, the authors recommend that to *design an effective restoration plan for these species it is essential to identify the primary mechanisms controlling production.* Therefore, the proposed activities will simultaneously investigate two extremes: (i) "Bottom-up" control: productivity of the marine food chain and how it is affected by changes in climate, and (ii) "Top-down" control: competition, predation, and disease acting directly on juvenile salmon. It is also recommended that restoration be conducted as an adaptive management plan implemented within this proposal period. We are confident that higher levels of production are achievable, but their extent is uncertain until causation is assigned, which in turn depends on the extent of Bottom-up versus Top-down controls.

The proposal describes an ecosystem-based, interdisciplinary plan involving government, universities, private consultants, and community and not-for-profit groups. Fourteen research and community activities are presented involving some of the newest technologies available and building on significant in-kind contributions and linkages with other research projects. Flow charts are presented to summarize our how each project relates to the Bottom-up and Top-down controls, and summaries of each project are included in Appendix 1.

The Pacific Salmon Foundation will be directly responsible for project management and has agreed to provide Dr. Brian Riddell as continuing Project Director. A project management structure is provided. A Science Advisory Panel, which has assisted in developing the proposal, would continue to provide advice and participate in data management, analyses, and some individual projects. The cost of implementing all the projects and for project management totals $10,770,100 over a projected four years, including substantial one-time costs for some projects. Costs by major activities are (details provided in the proposal):



The funding and implementation schedule for projects is dependent on agreement with the prospective donors. If research on the primary hypothesis commences in spring 2010, then a restoration plan for coho salmon could be implemented by 2013. ***The development of this proposal has created a wave of interest around the Strait of Georgia!***

BACKGROUND

The Strait of Georgia is British Columbia's coastal sea located between Vancouver Island and the provincial mainland. The Georgia Basin area is home to three-quarters of the population of BC, many of whom use the area for a wide variety of recreational and commercial activities. It is also part of a larger ecological zone contiguous with the Puget Sound Basin. The Strait is an extremely rich ecosystem and provides, for example, rearing for juveniles of all seven species of Pacific salmon.

In the past, the Strait was one of the most productive fishing regions in the province for Chinook and coho salmon, but that changed dramatically in the 1990s. Catches that annually numbered in the hundreds of thousands to a million fish decreased to a mere tenth or less of those values and remain depressed through today. Regrettably, these losses have not been explained or addressed, and the public is increasingly concerned about the future of these salmon, the Strait itself, and the economic impacts on local communities.

This proposal has been developed to identify the factors currently limiting the production of Chinook and coho salmon in the Strait of Georgia. It is structured as a set of research teams, uses a combination of new technologies and integrated analyses, and recommends an adaptive management approach to achieve future goals. We believe these approaches provide the greatest likelihood of success in restoring Chinook and coho production and healthy natural ecosystems around the Strait for future generations of people and fish.

RATIONALE FOR PROPOSAL

The interests of the prospective donors can be summarized as follows:

1) Can the loss of Chinook and Coho salmon production in the Strait of Georgia over the past 30 years be explained?
2) If so, can the causes be mitigated?
3) If not, can sustainable catches of Chinook and Coho salmon be increased through restoration of wild salmon populations, or a mixed strategy of enhanced and wild populations?

These questions will be addressed through targeted research, accumulation of local knowledge, and an adaptive management approach (Figure 1). Since the management of natural ecosystems is inherently difficult due to gaps in understanding and high natural variability, an adaptive and flexible process is considered necessary in working towards future goals and to ensure the best use of funds provided.

Figure 1.

This proposal describes an ecosystem-based, interdisciplinary plan involving government, universities, private consultants, communities, and not-for-profit groups. There is a commitment to build and foster community relationships, as much of the ground-level work will be significantly enhanced by the participation and understanding of local communities. The key to successful application of this process is to set a path, learn as we proceed, and be prepared to change to achieve the specified goals. The Science Panel believes fully that this process can be successfully implemented and provide significant understanding of, and future benefits to fish and communities around the Strait.

Causes of the Decline in Coho and Chinook Catches

It is apparent that a number of changes over time have contributed to the decline in catches. For example, over-fishing occurred during the 1980’s and exceeded rates sustainable by natural Chinook and coho salmon. Compounding this, the marine survival ratesof hatchery and wild Chinook and coho declined steadily through that period (Figures 2, 3). The combination of over-fishing and declining survival accelerated the decline. However, reductions in fishing pressure and significant investment in Chinook and coho hatchery production within the Strait (Figure 4) have failed to recover natural populations. Loss of natural habitats (freshwater and marine) has also been implicated.

While scientific and public consultations identified many changes that have occurred over the past few decades, there was little agreement on the causes of the declines. It was also apparent that we lack scientific consensus on processes limiting Chinook and coho production.

Figure 2. Annual patterns of marine survival rates[2] for coho salmon that enter the Strait of Georgia. The four coho populations included are: Black Creek (wild coho, east coast Vancouver Island, Salmon River (wild coho, lower Fraser River at Langley), Inch and Chilliwack (hatchery coho, lower Fraser River). Data provided by the Department of Fisheries and Oceans, Science Branch.

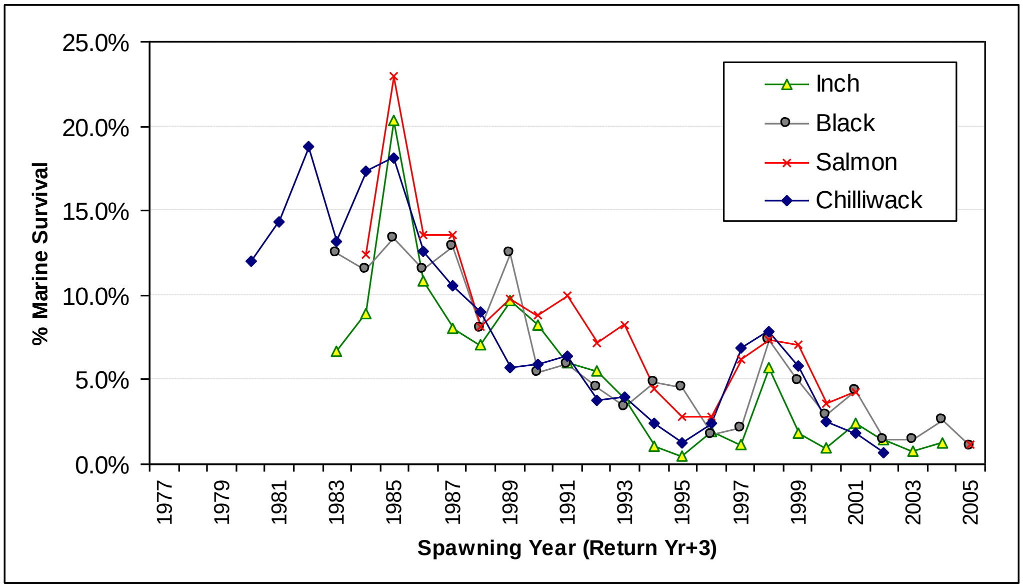
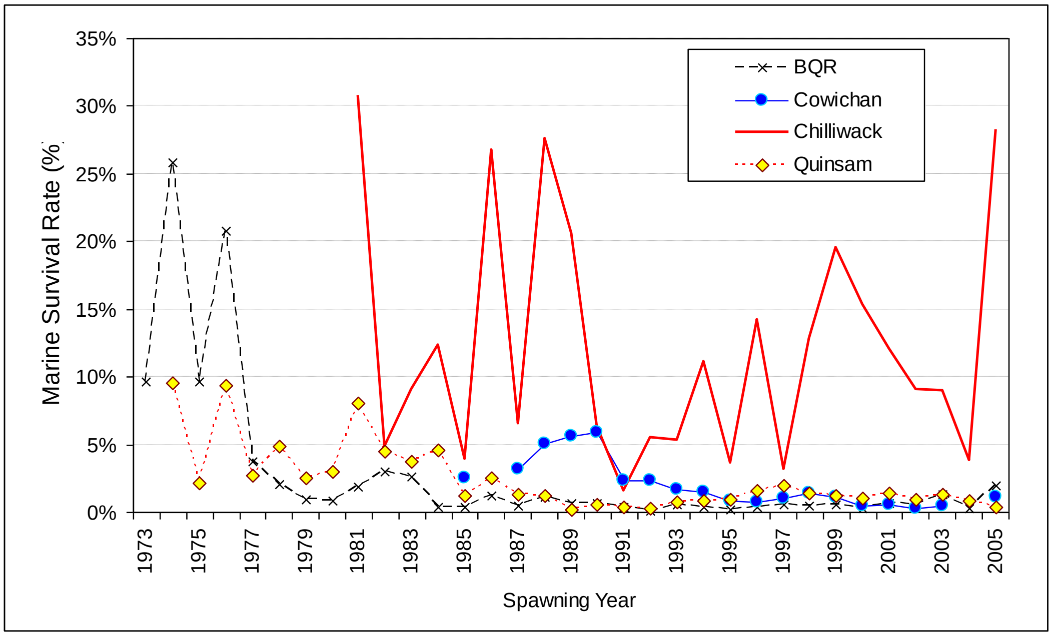
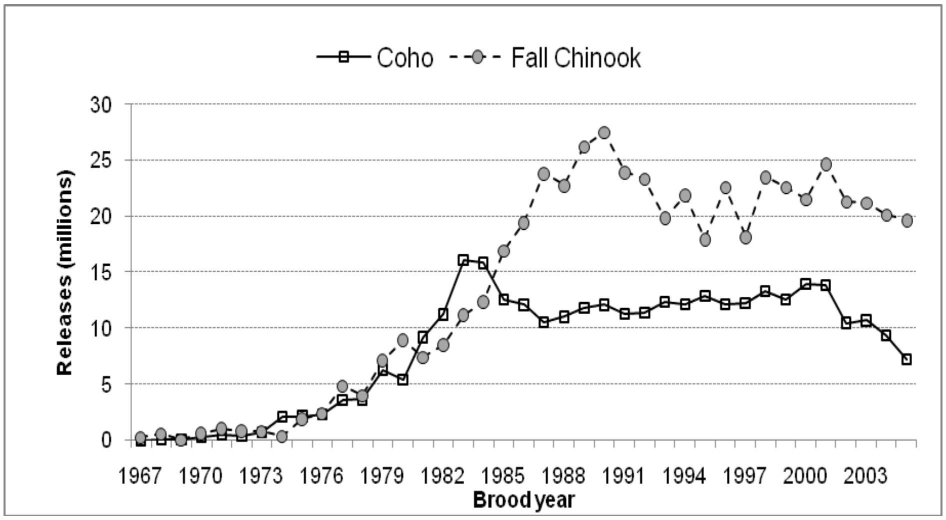


Figure 3. Annual patterns of marine survival rates for Chinook salmon that enter the Strait of Georgia. Chilliwack release hatchery Chinook smolts into the Fraser system but the other three hatcheries release smolts into the western margin of the Strait. Data provided by DFO, Science Branch.



[2] If 100,000 coho smolts went to sea and 1,000 adults are subsequently counted in catches and the spawning population, then the marine survival rate would be (1,000 / 100,000) = 0.01, or 1% survival.

Figure 4. Releases of Chinook and coho salmon into the Strait of Georgia from Canadian hatcheries. Releases of coho salmon are yearling smolts and releases of Fall[3] Chinook are smaller sub-yearling (90 day) smolts. Graph from M. Labelle, PFRCC report (www.fish.bc.ca).



A short list of the primary concerns that were identified included:

- Unknown causes of early marine mortality (there is consensus that mortality rates are highest in the first few months in the strait but little agreement on the mechanisms);

- Changes in the marine ecosystems of the Strait have been significant (as evidenced by the loss of forage fishes, changes in marine plants, increases in the seal populations, changes in the seasonal behaviours of Chinook and coho salmon, warming of the Strait by one degree Celsius over 30 years, and significant increases in pink and chum salmon recently); and

- Production from the major hatcheries is likely competing with wild fish. There was concern why the hatchery produced fish were also showing poor survival and were not sustaining harvests.


Coho salmon

[3] Fall Chinook are a type of Chinook local to the Strait of Georgia. Juveniles go to sea after about 3 months in freshwater (including hatcheries) and adults return to their natal rivers in late August through early October.

Concept Development

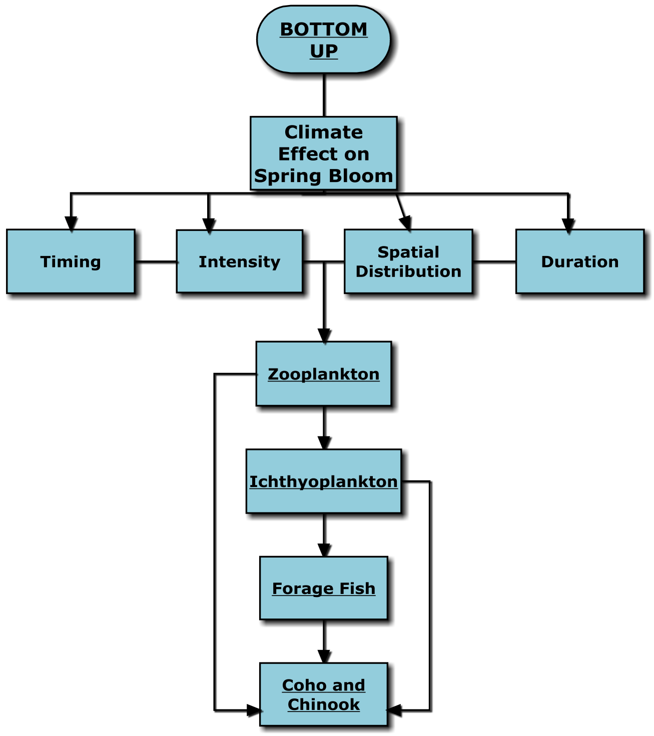
The lack of consensus on causation is common when attempting to assess changes in single species within a complex ecosystem. But some recent studies have provided direction on the likely causes of the declines. The suspected causes fall into two general categories:

1. A decline in quantity and quality of food for juvenile Chinook and coho in their first four months in the Strait; suppressing growth and survival through their first summer and winter at sea. Changes in wind patterns, solar radiation, and freshwater flows (primarily the Fraser River) all affect biological productivity in the spring, ultimately determining the prey availability. These effects may be enhanced by the releases of large numbers of hatchery smolts, competition with other salmon species, and steadily increasing temperature in the Strait.

2. Low survival in the first four months at sea could also result from biological factors such as predation and disease, or interactions between biological and environmental factors. Coho and Chinook juveniles are preyed upon by a variety of predators in the Strait, including lamprey, dogfish, seabirds, and marine mammals. Some pathogenic diseases can kill fish directly, while others weaken them, making them more susceptible to stress and infections, diminishing their ability to acclimate to environmental change, and leading to increased vulnerability to predation.

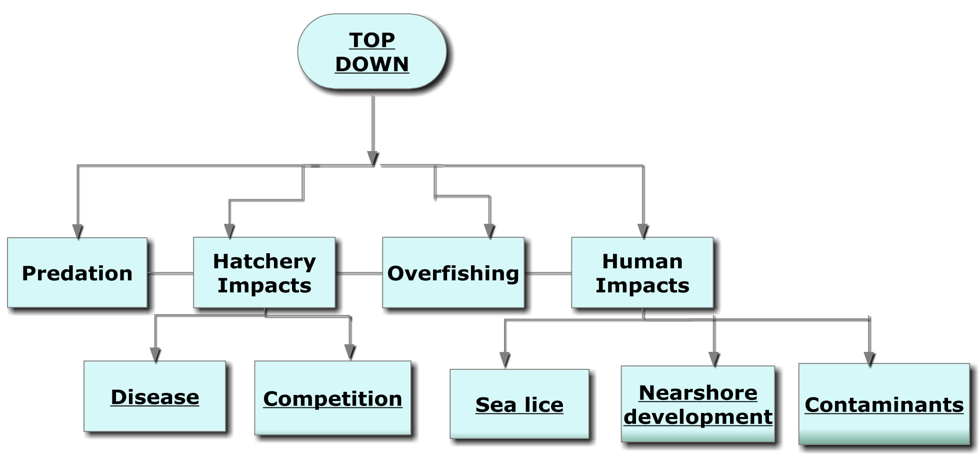
The Science Panel first addressed how to separate the effects of the numerous factors identified. It is proposed to begin at the extremes ***(separating the apples from the oranges)*** and postulate that environmental change has been the overwhelming influence on the production of Chinook and coho salmon in the Strait of Georgia.

In ecological jargon, the extremes to be assessed **(the apple versus the orange)** are referred to "**bottom up**" versus "**top down**" control, both processes that affect production in natural ecosystems.



Bottom-up control simply means that the food that the young fish need is being limited. The mechanism involves annual weather conditions and its effects mediated through the lower levels of the biological production chain. Initially environmental conditions influence the timing, intensity, spatial extent, and duration of plankton blooms (e.g., winter wind determination of the timing of spring blooms in the Strait). Once the primary production (phytoplankton) is initiated, energy is passed through to higher levels (zooplankton and ichthyoplankton, i.e., fish eggs and larvae), upward to small forage fishes and onward to juvenile Chinook and coho salmon.

Top-down control refers to a variety of biological factors that limit Chinook and coho production directly through predation, disease transmission (originating in wild and/or hatchery populations), competition for food, human development impacts, fishing, etc.



Each of these factors may act singularly but usually the effects involve multiple factors that will vary in time, space, and opportunity. While none of these factors are new insights, they are recurring concerns, and most have not been thoroughly explored for salmon within the Strait.

Contrasting the impact of annual variation in weather as the ***primary determinant*** of Chinook and coho production (Bottom-up process) with the more observable biological factors such as the growth in the seal populations is a ***fundamental step*** in determining appropriate restoration actions, and explaining how biological factors interact during years of differing productivity. Biological interactions may have very different consequences depending on what the productivity of the environment is during a year or period of time. *This latter point is not widely appreciated and can be very important.* For example, the consequences of interactions between hatchery and natural juveniles likely could vary substantially depending on the abundance and availability of their food supplies.

If environmental conditions and bottom-up processes primarily control Chinook and coho production, then recommendations for how to restore and sustain production will be fundamentally different than if top-down biological processes are the primary controls.

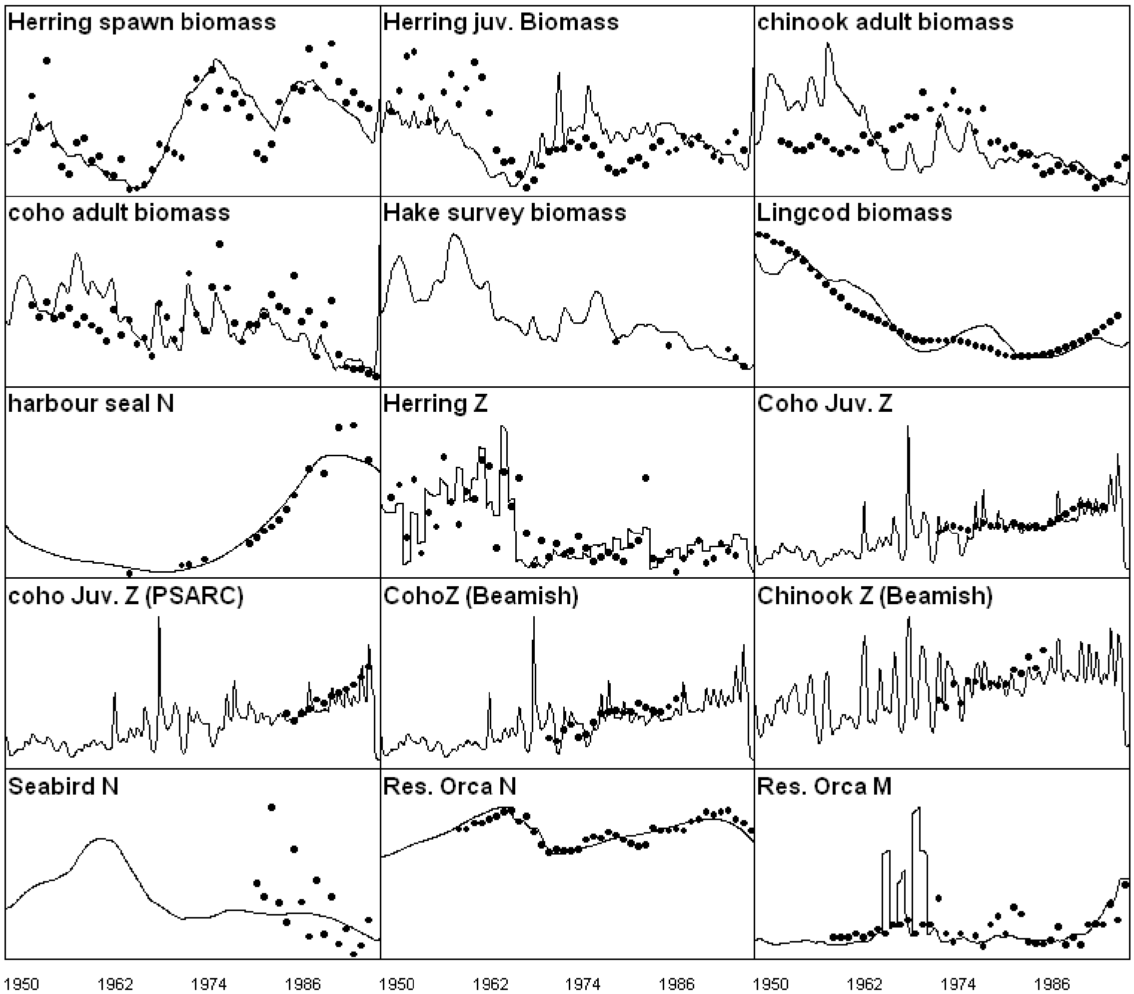
Goals for Coho and Chinook Recovery

The fish community in the Strait of Georgia has changed dramatically over the last 30 years, and it is now unclear whether the abundances in the 1970s are reasonable recovery goals.

Computer models of food web interactions have been used to examine changes in fishing pressure, hatchery stocking, and mortality due to marine mammals (Figure 5). Scientists at UBC were *unable* to reproduce the patterns actually observed (for multiple fish species, including hake, lingcod, herring, and salmon) by changing only these factors. To reproduce the observed trends, they also had to reduce primary productivity, beginning in the late 1970s. Of all the factors considered, the model that best follows the observed trends suggests that the carrying capacity for fishes in the Strait has declined about 50% since 1980. In other words, if all other factors were brought back to 1980 levels, Chinook and coho would only recover to about 50% of their peak abundance.

Such models can be an informative representation of Nature and can identify key sensitivities or unknowns in the development of recovery plans; but only time will tell how much the stock can recover. Given our state of knowledge and the numerous interactions possible, the Science Panel concluded it was inappropriate for them to recommend specific recovery goals. *The more appropriate procedure would be to establish interim restoration targets, and follow the adaptive management cycle as presented in Figure 1. Interim targets for coho salmon would be defined during this proposal period and the adaptive cycle implemented.*

Figure 5. Trends in some key indicators of change in the Georgia Strait, 1950-2000. Dots represent annual estimates, while lines are estimated values from an ecosystem model based on food web interactions and estimated changes in basic productivity and fisheries impacts. Trends graphs labelled "N" are numerical abundances, while trends labelled "Z" are estimated mortality rates from coded-wire tagging analyses.

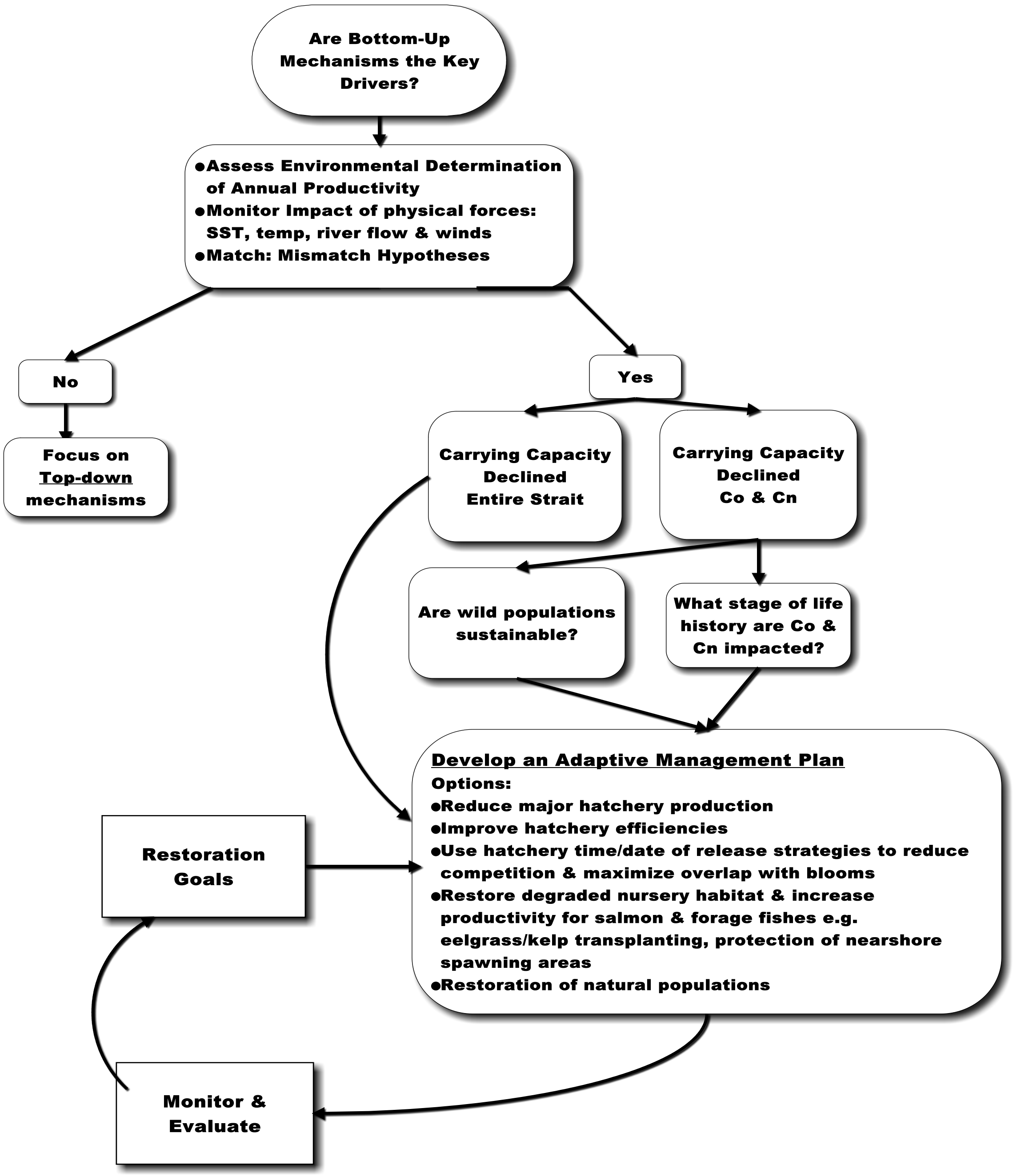


Source: Martell, S.J., Beattie, A.I., Walters, C.J., Nayar, T., Briese, R., 2002. Simulating fisheries management strategies in the Gulf of Georgia ecosystem using Ecopath with Ecosim. In: Pitcher. T., Cochrane, K. (Eds.), The Use of Ecosystem Models to Investigate Multispecies Management Strategies for Capture Fisheries. Fisheries Centre Research Reports 10(2), pp. 16–23

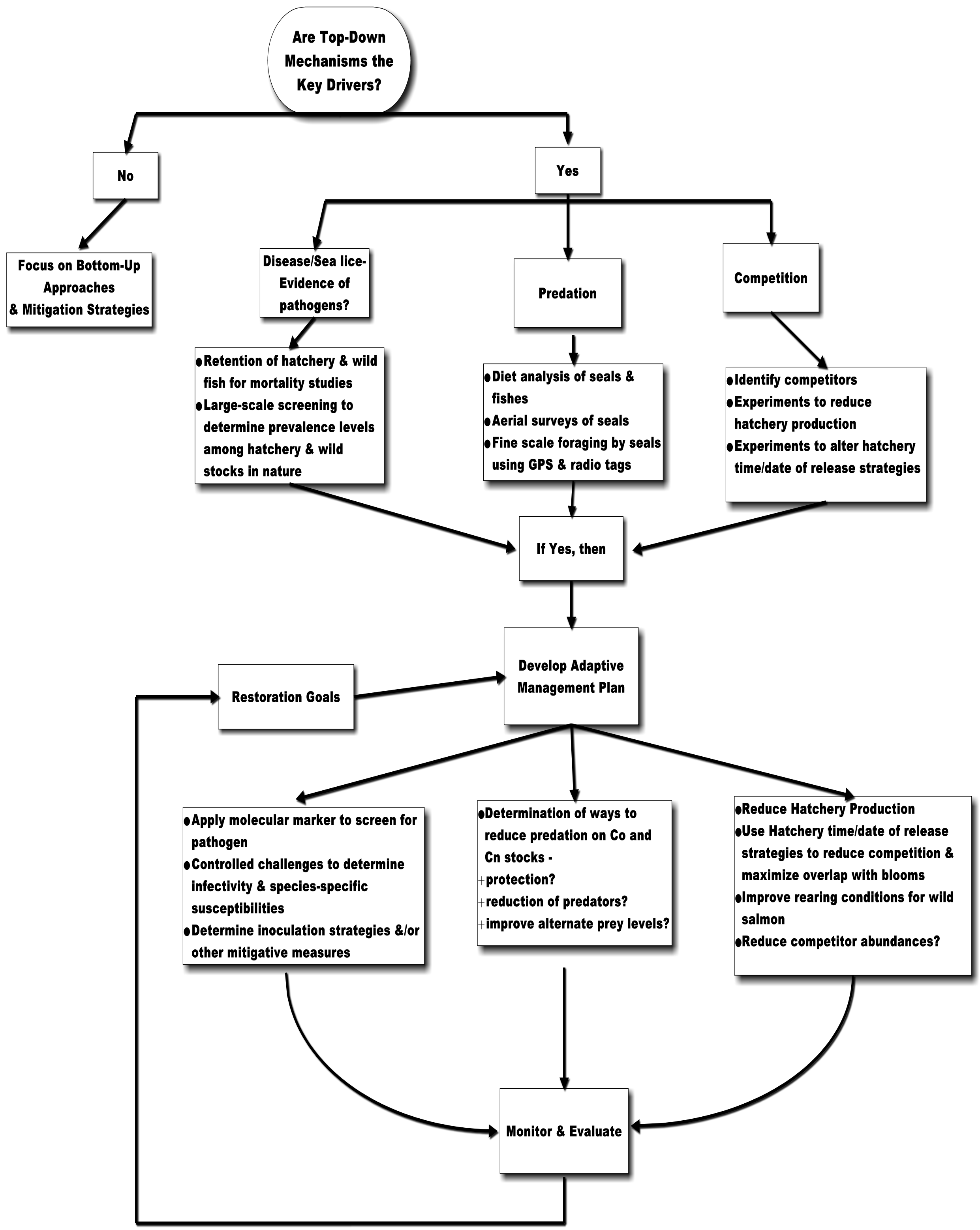
PROPOSAL OUTLINE

The thought process, research studies, and possible mitigation actions in this proposal can be summarized in two flow-charts contrasting "Bottom-up" and "Top-down" mechanisms:

"Bottom-up approach"



"Top-down Approach"



KEY QUESTIONS AND RESEARCH

Our **primary** hypothesis is that environmental factors (e.g., wind patterns, temperature, freshwater runoff) determine the annual biological productivity in the Strait and have resulted in reduced prey availability for coho and Chinook salmon. **Secondarily**, biological interactions enhance the environmental effect. During periods of poor productivity, biological effects are mediated by stress, resulting from competition for food, increased water temperatures, and potentially increased susceptibility to predation and disease. During periods of good productivity, the effects of these biological controls would be lessened but the rate of restoration of natural Chinook and coho salmon is limited by their reproductive and habitat capacities within the Straits.

Primary Hypothesis: Bottom-up processes

Bottom-up processes driven by annual environmental conditions are the primary determinate of Chinook and coho production via early marine survival.

Several lines of evidence suggest that there has been a long-term change in environmental conditions resulting in reduced food supply for juvenile coho and Chinook during their early marine life phase. This evidence includes:

- A shift to an earlier and briefer growing season by the copepod *Neocalanus plumchrus* that has been ongoing since the 1970s. This copepod had historically been the dominant component of the Strait of Georgia zooplankton biomass in April and May, but now reaches its annual peak well before most juvenile coho, Chinook and sockeye enter the Strait.

- Herring, which have also declined in abundance in recent years, have shown range contraction of spawning sites, loss of early and late spawning times, and a steady decrease in size at age since the 1970s. Also reported was a shift in vertical distribution of herring and coho feeding; fish now stay much deeper than they did as late as the 1980s.

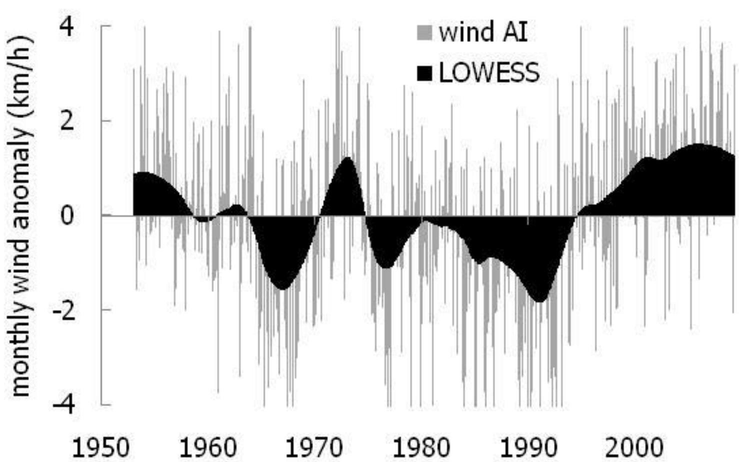
- A significant decline in abundance of fish-feeding marine birds (Christmas bird census) that feed on the same small fishes as coho and Chinook salmon.

- A significant change in the residency of yearling coho salmon in the Strait, as evidenced by the loss of spring 'Bluebacks'. The consensus opinion is that this is likely related to the loss of small forage fishes as their over winter diet.

Several lines of evidence also indicate a relationship with winds as a major determinate of timing and intensity of spring plankton blooms. A recent publication from UBC reported a relationship between high spring winds and delayed spring blooms – nutrients are not available for phytoplankton due to vigorous water mixing by wind, and the bloom is unable to develop in cooler more active surface waters.

A current research project (Dr. Dave Preikshot) has provided evidence of a regime-like change in relative wind speeds in the mid 1990s. Figure 6 shows that when monthly wind anomalies in the Strait of Georgia were examined, there appears to be a low wind regime from 1975 to 1993 and a high wind regime from 1994-2009.

Figure 6. Monthly wind anomalies in the Strait of Georgia (based on winds at Vancouver airport) from January, 1953 to April, 2009 smoothed to demonstrate trends over time. (LOWESS is a smoothing method used to examine signals within the more variable monthly data)



The relationship between productivity in the Strait and climate is likely more complex than just winds. Other critical factors include rising water temperatures, spring sunlight, and variation the freshwater flows (in particular the Fraser River spring freshet). Key projects that are necessary for an integrated and comprehensive examination of the primary hypothesis are presented in the chart on page 17. Short descriptions and rationales for each project proposed are provided in Appendix 1.

Projects 1-4 will determine how changes in physical forces affect the circulation, water properties and primary production throughout the Strait of Georgia system. Project 5 will be a key project to examine different linkages in the food chain and determine how primary production affects zooplankton, ichthyoplankton and forage fish that make up the diet of coho and Chinook. Project 6 will be an initial investigation of the small pelagic fishes (other than herring) in the Strait. Project 7 will provide detailed information on the seasonal and vertical distribution of Chinook and coho juveniles and food organisms immediately after ocean entry. Project 8 will directly assess where and when the coho and Chinook are dying.

Biological Oceanography (Projects 1 to 5)

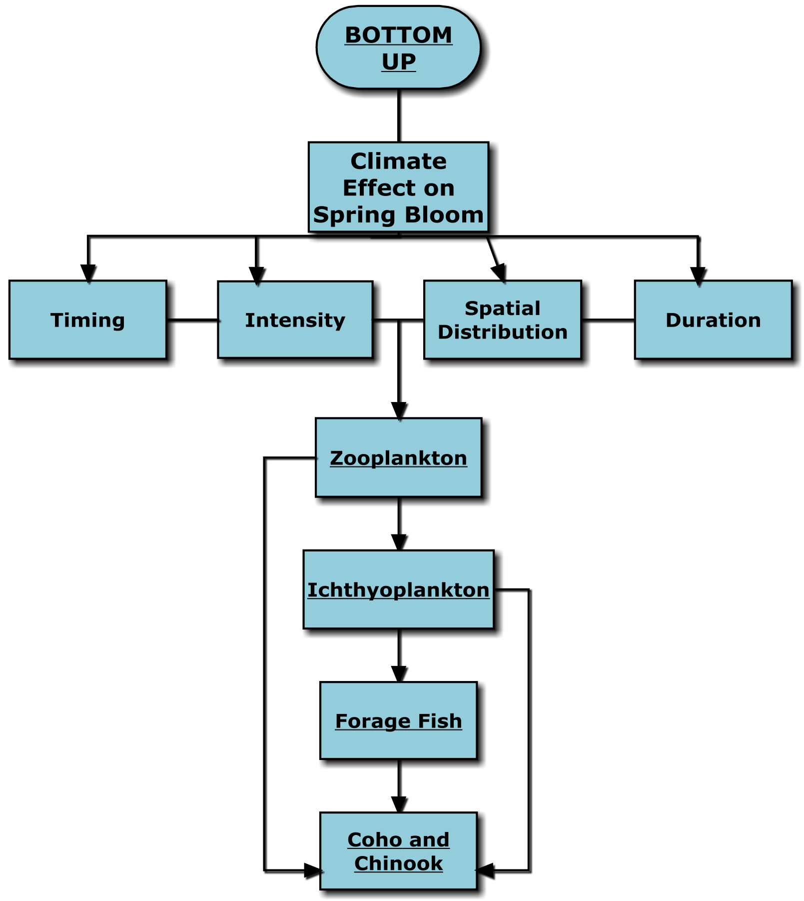
Although many of the physical, chemical, and biological processes that determine productivity within the Strait of Georgia are well documented, the factors affecting interannual variation in these processes and their link to fish production remain unknown. The intermittent, often narrowly focused, studies that have been conducted over the past 30 years have proven inadequate to explain the persistent declines in Chinook and coho salmon. This proposed research will undertake an extensive, 2 to 3 year, fully integrated observational program essential for a fundamental understanding of the dynamics of salmon production. It builds on past research efforts and provides an environmental baseline to achieve this understanding.

The proposed set of projects is more extensive than initially envisioned but provides the needed scientific foundation for all other studies. Newly available technology and a carefully designed plan to simultaneously address all levels of the underlying processes will provide the most comprehensive study yet on the biological oceanography of the Strait of Georgia.

The set of projects is built on two existing weather buoys, two oceanographic arrays (funded to June 2010), expands the localized information from these fixed locations to information throughout the Strait using new ocean glider technology (photo), integrates remote sensing from existing environmental satellites (see Appendix 2), and addresses each level of biological production from phytoplankton to small pelagic fishes. The proposed monitoring and research would be funded initially for two full years. During this time, the PSF will seek additional funds to extend the monitoring component of this work for several additional years.

Project 6 will mobilize community groups involved in mapping and restoration of critical habitats for forage fishes other than herring; such as sand lance and surf smelt. Forage fish represent a valuable ecosystem component essential to marine food chains, connecting zooplankton to a host of secondary predators including Chinook and coho salmon. See Appendix 2 for further details about the B.C. Shore Spawners Alliance.

Key projects under the Bottom-Up category include:



Project 1: Continuous Phytoplankton Monitoring in SoG
Team: A. Pena & D. Masson (DFO/IOS Sidney)
Project 2: Slocum Glider Program
Team: R. Thomson, D. Masson, and T. Curran (DFO/IOS Sidney)
P. LaCroix (Canada Centre for Ocean Gliders, Sidney)
Project 3: Sediment traps and Moored instrument arrays
Team: R. Macdonald, S. Johannessen, R. Thomson (DFO/IOS Sidney)
Project 4: Remote Sensing
Team: G. Borstad (ASL Environmental Services Inc.)

Project 5: Zooplankton & Ichthyoplankton surveys
Team: D.L. Mackas (DFO), J.F. Dower (University of Victoria),
E. Pakhomov (University of British Columbia)

Project 6: Forage fish spawning habitat restoration
Team: R. deGraaf (BMS) & BC Shore Spawners Alliance

Project 7: Juvenile Salmon Surveys
Team: K. Lange and D. Beamish (DFO)
Project 8: Mortality Studies
Team: D. Welch (Kintama Research), T. Farrell (UBC)

Early Marine Survival Studies

Juvenile Pacific salmon enter marine waters of the Strait of Georgia from April until June, depending on the species. Mid-water trawl surveys conducted by the Department of Fisheries and Oceans in July and September provide insight into the population dynamics of juvenile Pacific salmon during their first summer. *It has been suggested though that up to 90% of juvenile Pacific salmon may die within their first eight weeks at sea, and yet no surveys have been conducted during this time in recent years.* Project 7 will examine the early marine survival of juvenile Pacific salmon, focussing on Chinook and coho salmon. The objective is to obtain information on the young juvenile salmon before they move offshore to deeper areas of the Strait of Georgia. Project 8 provides complementary information on the distribution and behaviour of juvenile coho immediately upon ocean entry *and provides the first direct estimates of survival using new, state-of-the-art sonic tag technologies*. The latter is enabled by using new tags that allow researchers to tag coho salmon down to 9.5 cm and track individual fish using fixed arrays of receivers. Additional information on the Pacific Ocean Shelf Tracking project is included in Appendix 2.

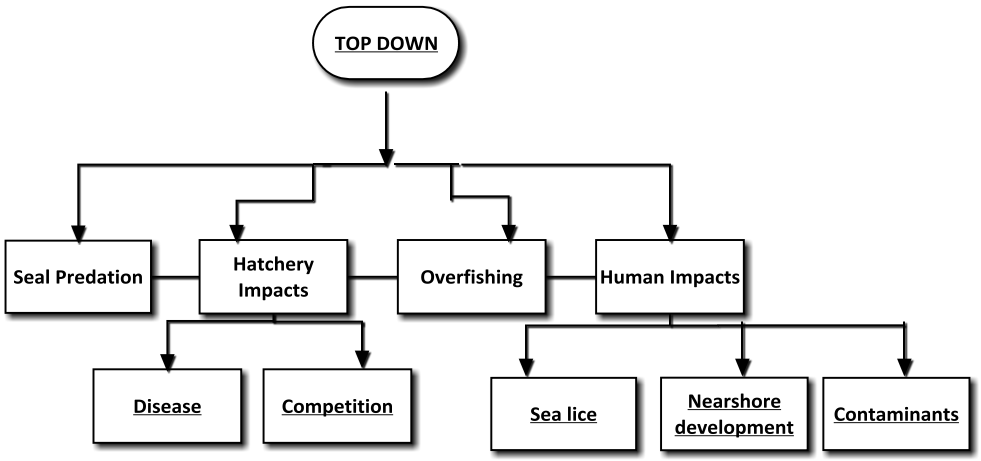
Secondary hypotheses: Top-Down Processes

While environmental forces may determine the annual conditions, Chinook and coho salmon will always be confronted by their biological challenges. The studies recommended from the Top-Down perspective are not based on specific hypotheses but rather by knowledge of biological controls in other ecosystems. Those controls broadly include: disease, predation and competition; each of which are applicable to Chinook and coho salmon in the Strait of Georgia.

Disease and competition are frequently speculated as mechanisms for interactions between hatchery and wild salmonids, but there is very little direct information on these topics. When a fish in the ocean perishes, it simply disappears. Thus, there is no disease/health screening performed on either wild or hatchery salmon in the ocean. The research proposed will involve the most intensive health and disease screening performed on the salmon in the Strait, utilizing the most modern and powerful molecular approaches available.

Competition is frequently equated with diet overlap but the extent of impact depends on the abundance and availability of food and overlap in the distribution of the competing fishes. Both of these possible controls are particularly important given the magnitude of hatchery Chinook and coho released into the Strait. The potential impact of predators is more commonly accepted, and frequently harbour seals are the predator of note in the Strait. The proposed research projects associated with each top-down control are portrayed in the next chart (Key projects under the Top-Down category).

Key Projects Under the Top-Down Category include:



Project 9: Assessing Impact of Marine Mammals on Salmon in SoG
Team: A. Trites (UBC) & students

Project 10: Mortality & Disease Profiles of Wild& Hatchery Fish
Team: K. Miller (DFO), T. Farrell (UBC) & B. Devlin (West Van-DFO)

Project 11: Georgia Basin Coho Salmon Hatchery Program
Team: Quinsam Hatchery (D Ewart), Centre for Aquatic Health Sciences (S. Saksida), Marine Harvest Canada, I. Pearsall and B. Riddell.

Project 12: Sea Lice Studies
Team: Quinsam Hatchery (D Ewart), Centre for Aquatic Health Sciences (S. Saksida), Marine Harvest Canada, I. Pearsall and B. Riddell.

Project 13: Community-Based Nearshore Restoration
Team: Nikki Wright & others (Seagrass Conservation Working Group)

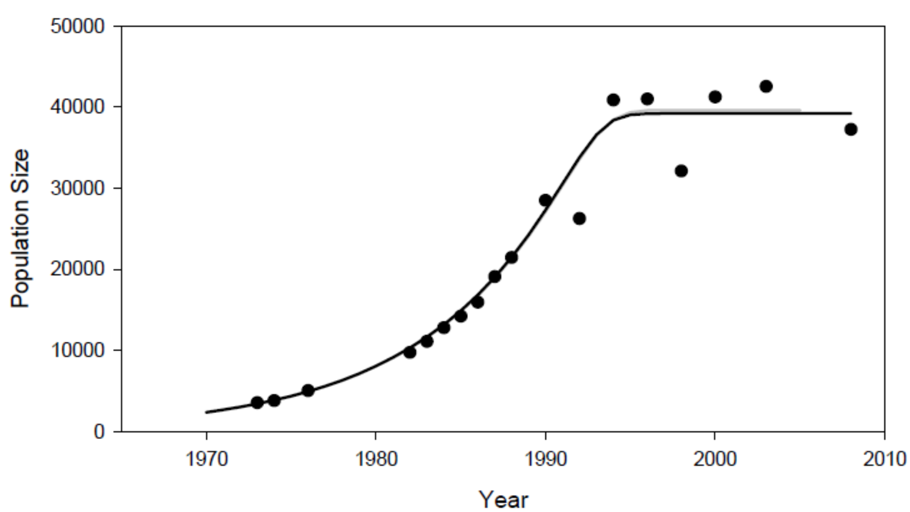
Project 14: Contaminants
Team: Georgia Strait Alliance

Assessing the Impact of Marine Mammals on Salmon in Strait (Project 9)

This project will determine where and how harbour seals capture salmonids (fry, smolts and adults), estimate the amount of salmon consumed, and how predation varies by location and time of year. The research provides a thorough assessment how harbour seals interact with Chinook and coho salmon *using new DNA and tracking technologies not previously available to assess diets and predation by seals*.

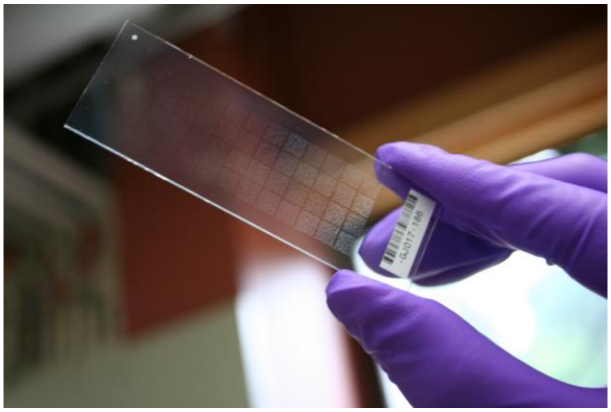
Harbour seals have increased in abundance from a few thousand animals in the Strait during the early 1970s to about 40,000 today (Figure 7). They have long been suspected of negatively affecting BC's salmon stocks but the little that is known about harbour seal diets in British Columbia is now 20 years out of date. Diets based on 1980s samples and based on bones in fecal samples indicated that, on average, 4% of the annual diet of harbour seals was salmon, and herring and hake comprised 75%. The salmonids consumed in the 1980s consisted mainly of adult salmon of unknown species that were taken as they returned to rivers to spawn, especially in estuaries. However, predation on smolts and fry has been documented in the Puntledge River. No studies have been published on the movement or foraging patterns of harbour seals in the Strait of Georgia in relation to juvenile salmonids.

Figure 7. Census population size of harbour seals in the Strait of Georgia (data from P. Olesiuk, Pacific Biological Station).



Mortality and Disease Profiles of Wild & Hatchery Salmon (Project 10)

This project will address whether the disappearance of juvenile Chinook and coho salmon (hatchery and wild) at sea between May and September is a result of disease and/or condition of fish upon entry into the ocean. It involves three projects assessing the health and fitness of hatchery and wild coho salmon using state-of-the-art ecological genomic methods, assessments of natural pathogens, and controlled rearing studies. See Appendix 2 for further details on genomics.



A gene array slide used in genomics research. One gene array can assess at once the expression of all genes in an individual's genome. Currently, salmon arrays contain 44,000 gene transcripts.

Strait of Georgia Coho Hatchery Release Studies (Project 11)

This project examines reductions in the number of hatchery coho released into the Strait to reduce competition with wild coho, and two studies to improve the marine survival rate of hatchery reared coho salmon. Those studies involve inoculation of coho smolts before release, and delayed releases of hatchery coho. The latter two studies could provide means to sustain adult production of hatchery coho while reducing juvenile competition with wild coho salmon.

To maximize the information content from these studies, however, the Science Panel strongly recommends a collaborative program with the Department of Fisheries and Oceans to reduce the numbers of smolts released into the Strait of Georgia in 2011 to 2012 (see below). Further, to compare marine survival rates from hatchery populations, it will be necessary to supplement DFO's wild coho assessment programs.

Decisions to change coho production must involve the Department of Fisheries and Oceans in order to reduce releases from the major hatcheries contributing to the Strait of Georgia. Final values for reductions have yet to be determined.

Brood year	Release Year	Production change	Return Year	Comments
2008	2010	None (current level)	2011	To late in 2009 to change
2009	2011	Target 50% reduction	2012	Use fry releases in 2010 to reduce smolt releases
2010	2012	Target 75% reduction	2013	Maximize reduction but need minimum number of smolts to conduct the studies.
2011	2013	To be determined	2014	PSF will recommend repeating the 75% reduction for a total of three years (3 replicates).

Sea Lice studies (Project 12)

This project will address concerns about salmon aquaculture in the northern Strait of Georgia and lower Johnstone Strait. The study proposed allows the direct exposure of hatchery-reared coho salmon held in net pens proximal to an actively producing salmon farm. The experimental design involves two exposure sites each with four net pens of coded-wire tagged coho and treatment combinations of inoculation and feeds medicated with SLICE® (emamectin benzoate to treat for sea lice). *Coho treated with SLICE should not become infected with sea lice. This design (below) provides a direct comparison of infected and uninfected coho released from the same environments.*

Hatchery Treatments	Feeding regime Normal , not treated	 Medicated, SLICE added
Controls (no treatment)	Normal Hatchery fish, normal food (no treatments)	Normal hatchery fish, treated feed to prevent sea lice
Disease prevention (inoculated)	Treated hatchery fish, normal food (inoculated only)	Double treatment against pathogens and sea lice.

Community Based Near-shore Restoration (Project 13)

This project will build on the effort of community groups already restoring eelgrass beds for salmon habitat. In the marine environment, eelgrass beds function as wildlife corridors for a large array of fish, bird and invertebrate populations. Since 2002, fourteen community stewardship groups in the Strait have been trained in mapping eelgrass habitats. The strategy for 2010 is to transplant test plots in each of ten locations surrounding the Georgia Basin. The sites will be monitored for shoot density and area extent, and use of these eelgrass beds by marine organisms, including juvenile coho and Chinook. See Appendix 2 for further details

Red Rock crab seeking refuge in an established eelgrass bed

regarding the Seagrass Conservation Society and its activities.

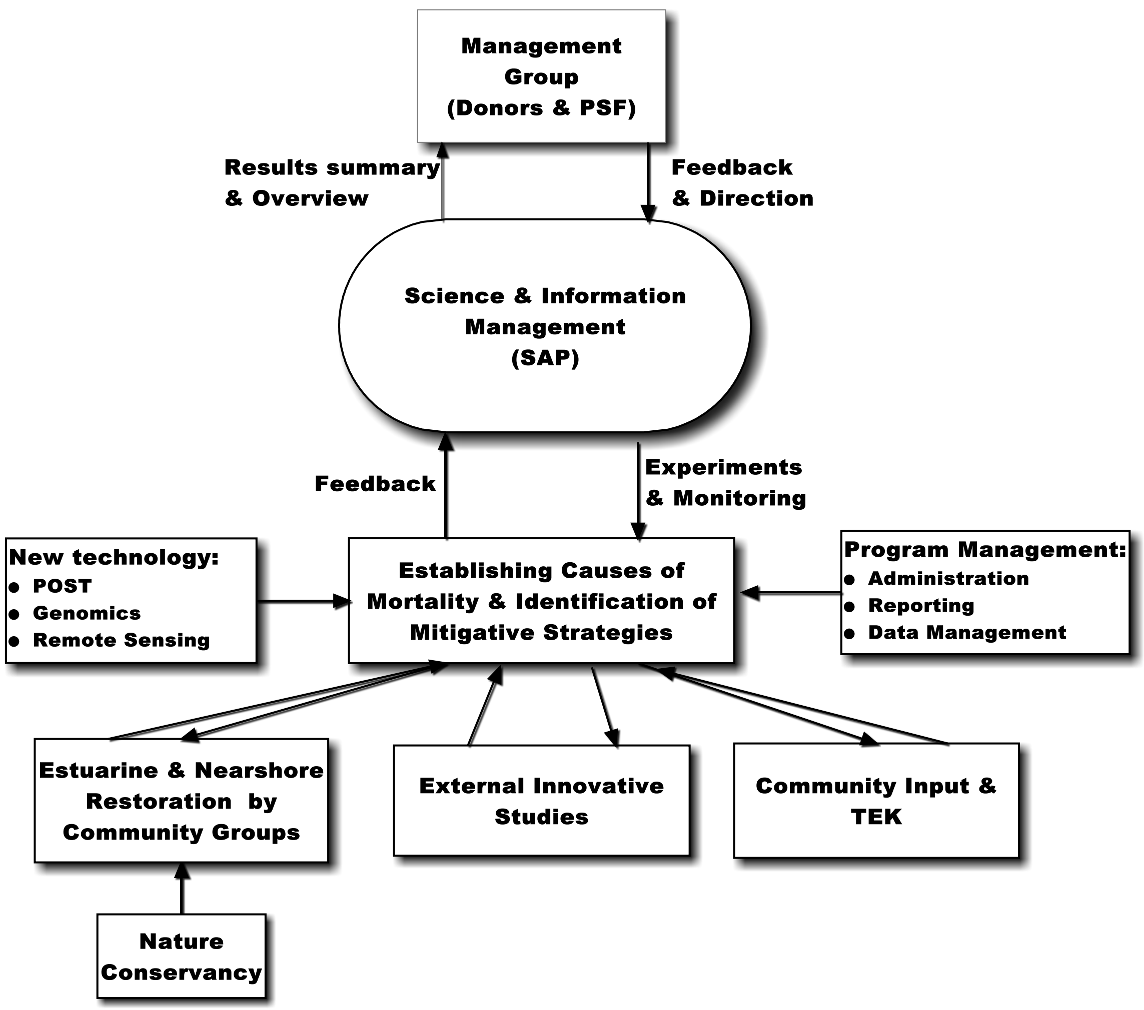
This project is also supported by the Nature Conservancy of Canada (NCC). BC's chapter of NCC has completed large scale Ecoregional Assessments encompassing all of BC's coastal waters, and Natural Area Conservation Plans. These plans highlight the critical threats to terrestrial, freshwater and marine ecosystems and identify the actions necessary to conserve prioritized ecosystem components and associated species. They are willing to make available to us their data for their Ecoregional Assessments and Natural Area Conservation Plans, as well as the monitoring information from their restoration activities in the Campbell River estuary. They are interested in collaborating with the PSF in assessing the value and effectiveness of restoring inter-tidal and sub-tidal lands to restore salmon populations.

Contaminants in the Strait of Georgia (Project 14)

This project will be conducted by the Georgia Strait Alliance organization. Their contract will be to map and document the current state-of-knowledge for contaminants in the Strait, particularly in the Fraser River and lower Strait. Discussions with the head of Environmental Toxicology Laboratory, Environment Canada and with Metro Vancouver both indicated that broad-scale sampling for contaminants in salmon would be extremely expensive and the sub-lethal effects of many contaminants are unknown (particularly the new and emerging pharmaceuticals).

PROJECT MANAGEMENT

A management board (PSF directors, representatives of the donors, and DFO) would be established to oversee the project. Periodic meetings with the Science Advisory Panel (SAP) would allow for information exchange to the management board and feedback to the SAP on direction of research and funding. The SAP will initially remain as it is currently composed and biographies of the members are provided in Appendix 1. Dr. Verena Tunnicliffe (Canada Research Chair in Deep Ocean Research, UVic) is also available in an advisory capacity.



Project management will be a crucial component, including administration, project co-ordination and accounting. Dr. Brian Riddell will continue as project director (in-kind contribution of the PSF) and Dr. Isobel Pearsall (project funded) will continue in the capacity of

Project Co-ordinator. Dr. Dick Beamish would serve as chief scientist for the project. They will be responsible for tracking research activities, monitoring progress, producing overviews for the SAP and Management Board, and providing feedback to the various scientists, First Nations and community groups involved. Dr. Pearsall will also organize yearly community and First Nations roundtables on Vancouver Island and mainland B.C. The Pacific Salmon Foundation will provide administrative and financial services to the project.

Information Management and Infrastructure

Data management will be administered by Dr. Art Tautz. Complex research projects are often deficient in allocating resources for knowledge management. Knowledge management includes the organization of new information, the integration of current knowledge, and the development of an analytic framework for the structured testing of competing hypotheses (i.e. decision support). Further, models of ecosystem behaviour need to be designed to account for variation in both space and time. Only recently has increased computing power been combined with analytical and visualization tools (e.g., Google earth, HectaresBC) to provide for ecosystem calculations at meaningful resolutions and within reasonable time frames.

Another function of the infrastructure system is to create communication products. When recommendations are made to politicians and the public, the messages must be clear and understandable. A well structured knowledge management infrastructure and an effective presentation system will significantly enhance the credibility of any project recommendations.

Some guidelines and activities that would be adopted under the current proposal would be:

1. Data will be stored to allow open access and peer review by other members of the team.
2. A "core" collection of data sets will be made available on the same computer and used by all members of the team. These sets would include hatchery records, escapements, run reconstructions, index systems, bathymetry, wind and current information, etc.
3. Open source software will be encouraged.
4. UBC would provide the server "hub" and programming support for the project.
5. Data should be stored outside of government for a long list of reasons, mostly related to access and cost.
6. All data should be spatially referenced with attached metadata.

Continued Community Networking and Traditional Ecological Knowledge (TEK)

The Georgia Strait Alliance has been supportive and wishes to assist with community networking. They have put us in touch with many key community groups around the Strait. We have proposals from two community networks, but if the project is successful, we would wish to expand community involvement, particularly of the many potential volunteers (many which we met during the community roundtables) who are interested in estuarine restoration initiatives. An additional year to gather traditional local knowledge from community members and First Nations will also greatly assist the documentation and mapping of changes in the

Strait of Georgia. There are also synergies with the *Sea Before Us* initiative at UBC, which proposes to utilize both TEK, anthropological, historical and oceanographic information. We have established an online forum for individuals to send information or observations about changes that they may have noticed in estuarine and marine environments of the Strait of Georgia. Users can subscribe to

http://ca.groups.yahoo.com/group/SOGProgram/join and post messages online.

Estuarine Restoration

One of the proposals in this study is to restore critical marine salmonid habitat- this proposal involves 14 stewardship groups in the Strait of Georgia that are part of the B.C. Community Eelgrass Network under the *S*eagrass Conservation Working Group (SCWG). The SCWG is a consortium of scientists, stewardship groups, governmental agencies and researchers committed to the conservation and protection of seagrasses in B.C. and with an interest in extending their work to the restoration of giant kelp also.

External Innovation

The SAP recommends that a portion of funds be set aside for innovation. These funds would be available through an open competition and allows for the development of “wild cards”- proposals for research studies that may be novel and innovative, potentially providing significant incremental gains to the research programs.

BUSINESS PLAN

This proposal has been scaled to the initial investment suggested to Dr. Riddell with the knowledge that adjustments will be required depending on total funds and the time of availability. As designed this proposal provides:

1. *For the development and implementation of an adaptive recovery plan for coho salmon* production following a limited period of intensive investigation and agreement on interim recovery goals. Coho salmon is the focus for this proposal as their life history provides for the quickest return on results. Some projects will provide information on Chinook also but recovery of Chinook is inherently longer term.
2. A focused program to establish the primary determinants of coho salmon production by simultaneously addressing environmental controls and biological controls mediated by competition, predation, and disease. *The assessment of the key determinants of production is a fundamental first step to determining appropriate restoration actions.*
3. A strong collaborative effort based on new scientific investigations through involvement of universities, NGO’s, and government; and inclusion of community knowledge and efforts around the Strait. *Letters of support from a number of organizations are included in Appendix 1.*

Budget Summaries (full budget on following page)

Total costs over four years and by allotment:

Allotment	Projects	Administration & Management	Comments
One-time costs	$1,845,900*	zero	Start-up of projects can vary between years.
Operating expenses	$3,793,200	$160,000, $500,000, $400,000	Admin. & Management includes: Data processing, Community based projects, Fixed Overhead. Each value is sum of four years.
Ships	$847,000		Canfisco, fixed cost per day + fuel (distributed over two years)
Labour: Contracting Staff & Res.Assoc. Students	 $770,000 $705,000 $899,000	$850,000	Admin. & Management includes: 3 management positions plus analyst, and data management, total cost over four years.
Sum	$8,860,100	$1,910,000	
Cumulative Total	$8,860,100	$10,770,100	

Total costs by year and by allotment:

Allotment		Year 1 (2010)	Year 2 (2011)	Year 3 (2012)	Year 4 (2013)
One-time costs	$1,845,900*				
Project expenses		$2,638,600	$2,658,600	$570,000	$300,000
Ships		$423,500	$423,500		
Admin. & Management		$290,000	$370,000	$375,000	$375,000
Community-based projects		$200,000	$150,000	$150,000	
Sum	$1,845,900*	$3,552,100	$3,602,100	$1,095,000	$675,000
Cumulative Total		$5,398,000	$9,000,100	$10,095,100	$10,770,100

**** One-time costs can be distributed over a couple of years.***

Detailed Budget (Project descriptions in Appendix 1)

			Calendar Year for Projects			
No.	***Project***	***One-time costs***	***2010***	***2011***	***2012***	***2013***
	Environmental hypotheses					
1	Primary Production	58,000	50,000	50,000		
2	Ocean gliders	350,000	225,000	225,000		
3	Sediment arrays	270,000	250,000	250,000		
4	Remote sensing		75,000	75,000	50,000	50,000
5	Zooplankton + Ichthyoplankton	124,500	262,600	262,600		
	Vessel costs (2 vessels)					
	March-July (10 surveys, 3 days)		180,000	180,000		
	Aug-Feb (7 surveys, 3 days)		63,000	63,000		
	Daily food/fuel		40,500	40,500		
6	**Forage fish Mapping & Restoration**		50,000	50,000		
7	**Early marine survival**					
	May-June sampling		250,000	230,000		
	Vessel (40 days)		120,000	120,000		
	Daily food/fuel		20,000	20,000		
8	**Pacific Ocean Salmon Tracking**					
	Fraser River project	200,000	135,000	175,000	115,000	
	Discovery Passage array	523,400	80,000	80,000		
	Lang Creek Coho study	TBD				
9	**Harbour Seals**		350,000	350,000	90,000	
10	**Hatchery fish fitness**					
	Genomics and disease diagnostics		515,000	515,000	65,000	
11	**Hatchery Assessments**					
	Wild Population Assessments		250,000	250,000	250,000	250,000
	Delayed Releases and Fish Health treatments	160,000	110,500	110,500		
12	**Coho Salmon and Aquaculture Interactions**	160,000	85,500	85,500		
13	**SeaGrass Conservation**		50,000	50,000	50,000	
14	**Community Networks**		50,000	50,000	TBD	
	Project Management & Admin					
	Riddell		0	0	0	0
	Beamish		40,000	40,000	40,000	40,000
	Data Management (Tautz)		40,000	40,000	40,000	40,000
	Data Management costs		40,000	40,000	40,000	40,000
	Pearsall		70,000	75,000	80,000	80,000
	Analysis			75,000	75,000	75,000
	Comm/Media/Admins		0	0	0	0
	Overhead (fixed cost)		100,000	100,000	100,000	100,000
	Innovation fund		50,000	50,000	50,000	
	Totals	**1,845,900**	**3,552,100**	**3,652,100**	**1,045,000**	**675,000**
	Cumulative Costs	**1,845,900**	**5,398,000**	**9,050,100**	**10,095,100**	**10,770,100**

DELIVERABLES AND TIME-LINES

The Science Panel is confident that implementation of this proposal will improve the sustainability of Chinook and coho within the Strait of Georgia but the time-line for deliverables is dependent on when the various projects begin. Implementation has significant one-time costs but there is flexibility when specific projects could begin.

Assuming that the environmental studies commence in March 2010, two years of intensive spring/summer surveys would be completed in the fall 2011. The fall 2011 will also be the first year of adult coho returns from any studies conducted on coho smolts in 2010. The first critical review of results could be scheduled for January 2012 and the first adaptive management plan could follow by September 2012. This plan would include interim recovery targets and a monitoring program to assess progress in subsequent years. *The plan should be agreed with users and the government officials by September so that management and enhancement plans can be adjusted for 2013.* Most projects outlined in this proposal would still be proceeding and recovering information in 2012, thus any adjustment to the projects should be carefully weighed by the Project Management Board and the SAP. Changing course too quickly, risks minimizing the value of your investments and our knowledge gain.

How to build a Chinook and coho restoration plan depends on accepting or rejecting the primary hypothesis. If environmental factors have primary control of annual juvenile Chinook and coho production, then resource managers will have very little direct control. Under such uncertainty a diversified set of actions would be an appropriate strategy. For example, small scale diversified enhancement plans involving numerous streams would be preferred to investing in a few large production hatcheries. The outcome of such a diversified plan may be a lower sustainable harvest with less annual variation - as opposed to a “boom or bust” outcome from large production hatcheries.

If environmental factors are not the primary determinant, then biological factors recommended in this proposal address common public concerns, are practical to undertake, and can lead to restoration actions. Predation and competition could be controlled through predator control and alteration of hatchery practices. Disease may be more difficult to control. It is more controllable in hatcheries than in the wild through the screening of broodstock, prophylactic treatments of eggs, reduction of rearing densities, and inoculation. Moreover, if disease is controlled, its incidence in co-mingling wild fish would likely also be reduced. Disease control in natural populations may be difficult to achieve, but disease screening programs may improve our understanding of population dynamics and predictions. Overall, even under control of top-down forces, this proposal should identify positive actions to restore Chinook and coho production in the Strait.

LINKAGES

The development of this proposal has definitely renewed interest in collaboration within the Strait and for taking action to restore Chinook and coho salmon production. The real value of linkages with this proposal will be those developed between the organizations, universities, and the communities involved in planning and execution of these projects.

1. The suite of Bottom-up proposals would be the most comprehensive study of the biological oceanography in the Strait, and the first to link processes from nutrients to juvenile Pacific salmon. The integration with remote sensing could define the future for how to cost-effectively predict Chinook and coho salmon production.
2. Use of sonic tags on juvenile coho provides a direct link with POST (www.postcoml.org) programs and Canada's Ocean Tracking Network (http://oceantrackingnetwork.org/) supported by the National Science and Engineering Research Council (the Pacific Coast portion of OTN will be $6.5 million in the next few years). Investments for this program provide detection capability for 10 years.
3. The proposal provides the first fully integrated study of the environment, the health and fitness of individual salmon, and mortality processes for Pacific salmon in Canada. Studies of early marine survival (immediately after sea entry) provides an essential link with trawl survey research continued by DFO and now providing information into annual variation in early marine recruitment (building on 12 years of research).
4. Specific to Pacific salmon, the proposal provides the first fully integrated and adaptive management program *directed to restore coho production in the Strait of Georgia*. Successful implementation requires co-operation between DFO (including the Salmon Enhancement Program), user groups and researchers. In 2007, the Department of Fisheries and Oceans initiated a research program in the Strait of Georgia. The Departmental program will examine scenarios of what the Strait of Georgia ecosystems may be like in 2030, as a means to examine the impacts of climate change in southern British Columbia. *That program will not conduct research focused on specific issues of changes in Chinook and coho salmon production*. However, at the ecosystem level, many existing DFO programs will contribute (e.g. shellfish, herring, rockfish, and hake surveys; salmon and marine mammal assessments).
5. The proposal will build networks with communities around the Strait by involving conservation groups such as SeaGrass Conservation, BC Shore Spawners Alliance, the Georgia Strait Alliance, the Nature Conservancy of Canada, and local enhancement societies.
6. This proposal is linked to UBC's "Sea of Change" study, DFO's Ecosystem Research Initiative, UVic's Ocean Science program, and Genome BC's "FishManOmics" project, and contains extensive opportunities for student training and development. As well, there is an opportunity to establish a 'Strait of Georgia Centre' at Vancouver Island University, Nanaimo campus to build on community networking and science.
7. Ships are being provided by the Canadian Fishing Company (Canfisco) at a set cost per day including skipper, engineer/deck hand, cook, and daily provisions. Operational costs of fuel are additional.

8. The research in this proposal may have important linkages with the federal government's announce Judicial Inquiry into Fraser sockeye salmon and the Province of BC's new Ocean Strategy. The province of BC very recently approved an Oceans Strategy (Appendix 1) that endorses the maintenance of healthy ecosystems as a key goal. Since these are both very new developments, the extent of linkages remains to be determined.

The development of this proposal has created a wave of interest amongst communities and organizations involved in the Strait. To maintain this interest and build on it for future support, program managers should develop a communication plan including a project website (likely associated with the Pacific Salmon Foundation's site to avoid excessive costs).

IN-KIND CONTRIBUTIONS BY PROJECT

Proponent	**In-kind contributions**	**Value**
IOS/DFO-Pena	Shiptime 15-20K per day & in house technical support $100K per year.	> 150K
IOS/DFO-Macdonald	(1) 2 ADCPs ($120K); (2) 4 ACMs ($80K); (3) Shiptime (at $15-20K per day); (4) Mooring shop ($100K/year); (5) 8 sediment traps; (6) Retrospective analyses of previous trap data in the context of physical forcing	>$400K
IOS/DFO-Thomson	(1) 1 Glider ($150K); (2) Shiptime (at $15-20K per day); (3) In house technical support ($100K/year).	>$300K
IOS/DFO-Mackas	$45K (salaries), $10K (lab facilities at IOS (lab space, microscopes, balances, oven,), $5K (lab facilities at UVic -equipment for fatty acid & C:N analyses), $10K (IT and admin support), $170K (existing equipment- IOS Hydrobios Multinet and bongos $55K, UVic Tucker Trawl $15k, UBC Laser Optical Plankton Counter $100K)	$410K
DFO-Science Branch	$320K per year (ongoing trawl surveys in the Strait of Georgia, DFO)	$640K
UBC-Farrell, Kintama Research	1. Existing Fraser River array 2. Existing POST arrays 3. OTN arrays. CAER User Fees to UBC (tanks, space, animal care technician) at CAER $10 K per year, 50% technician per year $35K per year, 15 VR2s, Oceanographic CTD recorders, fish transport trucks and other field vehicles, two VR100, directional hydrophones to test tags & hand-track fish from boats.	>$3M
UBC-Trites	$140K (>$100k per year, in-house scientific and technical support, >$20k per year, lab facilities, >$20k per year, equipment) and $100K (links with NSERC Strategic Fisheries Network proposal)	$240K
CAER/DFO/UBC Devlin, Farrell, PBS/ DFO-Miller	CAER tank and mesocosm facilities, equipment ($352K), PBS quarantine facilities, molecular genetics equipment ($266K), scientists salaries ($180K)	$698K
Seagrass Cons. Society	Other funding brought in to carry out Strait of Georgia program	$100K
BCSSA	Time contributed by the BC Shore Spawners Association staff	~ $40K
PSF	Program Director, Dr. Brian Riddell ($50,000 per year, PSF)	$200K

OPERATIONS PLAN

The Pacific Salmon Foundation (PSF) will continue to provide program direction and operate in conjunction with the proposed Management Board and Science Panel. Financial management, administration, and office space will be handled by the PSF. Further details on implementation and timing of projects will be determined in consultation with the donors. Implementation can be staged over a couple of years but there are sets of projects that need to be implemented simultaneously. More complete operational plans will be determined once the availability of funds (timing and levels) is determined.

APPENDIX 1

APPENDIX 1.1: FULL PROPOSALS

APPENDIX 1.2: SCIENCE ADVISORY PANEL MEMBERS BIOGRAPHIES

APPENDIX 1.3: LETTERS OF SUPPORT

APPENDIX 1.4: B.C.'S OCEAN & COASTAL STRATEGY- AN OVERVIEW

PACIFIC SALMON FOUNDATION

APPENDIX 1.1: FULL PROPOSALS

Bottom-Up Projects

Project 1 Continuous phytoplankton monitoring in the Strait of Georgia
Team: Angelica Pena and Diane Masson (DFO/IOS Sidney)

Changes in abundance of nutrients and phytoplankton as well as changes in the timing of the spring bloom can potentially impact populations of coho and Chinook. In order to properly monitor the variability of the rapidly varying phytoplankton biomass, continuous measurements in the near surface of the Strait are necessary. The two existing Strait of Georgia weather buoys (Halibut Bank, 49° 20.4' N 123° 43.6' W, and Sentry Shoal, 49° 54.4' N 124° 59.1' W) offer convenient platforms for such measurements. These 2 buoys will be equipped to measure (1m & 10 m depth): temperature, salinity, nitrate concentration and fluorescence. In addition a surface PAR (Photosynthetically Available Radiation) sensor would be installed on each buoy.

Budget
Upfront costs $58K

Program costs: Technical support $50K per year (for one contractor for instrument deployment, maintenance and to process the large volume of multi-sensor data)

In-kind contributions: Shiptime (15-20K per day & in house technical support $100K per year).

Project 2 A Slocum Glider program to examine bottom-up factors of importance to coho and Chinook stocks in the Strait of Georgia
Team: Richard Thomson, Diane Masson, and Terry Curran (DFO/IOS Sidney) and Paul LaCroix (Canada Centre for Ocean Gliders, Sidney)

Changes in factors like nutrients, temperature, winds, currents, timing of phytoplankton blooms, and match-mismatch between phytoplankton and grazers (bottom-up controls) have been proposed as having potential to produce the observed declines in coho and Chinook. A powerful tool to address the question of what has changed in these bottom-up controls is the autonomous oceanic Glider.

This group proposes to deploy autonomous profiling gliders to collect a range of oceanic variables relevant to physical and biological processes in the central Strait of Georgia. One glider would be dedicated to a northwest-southeast (along-axis) oriented swath path and the second to an east-west (cross-axis) swath path. A third glider is needed as part of a three-glider rotation to ensure that at least two gliders are operating in the Strait at any one time. The gliders will be equipped with a Seabird CTD to collect enroute temperature-salinity-depth data, a Wetlabs Triplet sensor package to collect space-time series of chlorophyll fluorescence, dissolved organic matter, and particulates. The data will make it possible to relate physical processes in the Strait with the spatial and temporal variability of phytoplankton concentrations in the upper water column. From these, they can relate physical forcing to the timing and duration of biological processes. This provides detailed information on the bottom-up functioning of the Strait of Georgia within and between years.

Budget

Upfront costs: $350K for two gliders and batteries

Program costs: Total $225K per year: Satellite positioning and data transmission via Iridium Technical support a. contract Paul LaCroix LaCroix to maintain and operate the gliders (+20% overhead) = $100K per year. b. Technical support = $75K/year (salary for contractor to participate in glider deployment and recovery and to process the large volume of multi-sensor data).]

In-kind contributions: (1) 1 Glider ($150K); (2) Shiptime (at $15-20K per day); (3) In house technical support ($100K/year).

Project 3 Use of sediment traps and moored instrument arrays to determine bottom-up controls contributing to coho and Chinook production in the Strait of Georgia

Team: R. Macdonald, S. Johannessen & R. Thomson (DFO/IOS- Sidney)

This team will deploy a suite of moorings in the Strait of Georgia that include sediment traps, current meters, and other geochemical/physical recorders. Sediment traps collect particles that provide a record of biological and geochemical processes in the upper water column that augments periodic sampling cruises, and spans the time between such cruises. For example, short-lived events like blooms will be caught in the sedimenting material, even if missed by ship-based sampling, and the quality of the sedimenting material informs us about what caused the bloom, and how large it was. They will then relate physical and chemical forcing to the timing and duration of biological processes as recorded in traps to provide a view of the bottom-up functioning of the Strait of Georgia.

The incorporation of upward-looking 300 kHz acoustic Doppler current profilers (ADCPs) in the sediment trap moorings will also provide needed information on the currents and acoustic backscatter intensity in the water column overlying the traps. These measurements are critical to understanding the roles of vertical mixing and horizontal advection on the upper ocean processes in the Strait. Intermediate and near-bottom intrusive flow events, which are critical to the supply of nutrients and dissolved oxygen to the Strait of Georgia system, will be recorded by acoustic current meters (ACMs) deployed below the sediment traps. These instruments will also provide valuable information on the intermediate and near-bottom temperatures and salinity. This team will also conduct a retrospective analysis of historical current meter records collected in the Strait.

The team will maintain three moorings in the Strait of Georgia - one of these will be new, with the site chosen in collaboration with the best match for zooplankton and physical data collections, while the other two moorings will continue DFO time series currently scheduled to end in July, 2010.

In addition to measuring currents at the sediment trap locations, it is important to determine the contribution of the northern channels to the water mass exchange between the Strait and the offshore Pacific, as these channels provide additional nutrient input for primary production in the Strait as well as migratory pathways for fish stocks. This team will provide the first direct measurements of the currents and coincident water properties for the northern segment of the Strait of Georgia immediately to the south of Discovery Passage and Sutil Channel, which will enable them to estimate the relative importance of oceanic exchange at the northern end of the strait compared to the southern channels to the strait. These data, and those collected as part of the sediment trap study, will also be used to calibrate, validate, and provide boundary forcing for numerical models of the tidal, wind-, and buoyancy-driven currents in the Strait and will help determine how changes in physical properties effect the circulation, water properties and primary production throughout the Strait of Georgia system.

Budget

Upfront costs $270K (2 sediment traps. 6 acoustic current meters, 2ADCPs)

Program costs: Total $250K per year [Moorings, trap processing & refurbishing (sampling, sieving, re-deployment, processing, refurbishing). Technical support a. $60K/year (salary for contractor to assist with the mooring and instrument preparation, participate in mooring cruises and process the data). b. Post-doc $55/year]

In-kind contributions: (1) 2 ADCPs ($120K); (2) 4 ACMs ($80K); (3) Shiptime (at $15-20K per day); (4) Mooring shop ($100K/year); (5) 8 sediment traps; (6) Retrospective analyses of previous trap data in the context of physical forcing

Project 4 Remote Sensing

Team: Gary Borstad & Leslie Brown, ASL Environmental Sciences

As part of work funded by the Canadian Space Agency, DFO and ASL Environmental Sciences Inc. have assembled two massive satellite-based Sea Surface Temperature and chlorophyll databases for the northeast Pacific including Georgia Strait (Dr. R. Thomson, DFO and Dr. Gary Borstad, ASL Environmental Sciences Inc.). After extensive quality control and data preparation, more than 100 derived indicators such as timing of the spring bloom, date of most rapid warming, and integrated total summer chlorophyll have been produced for Georgia Strait and 27 other well established fisheries zones along the Pacific coast of Canada and the US. PC-based protocols and methodologies have been developed to enable an analyst to quickly compare these satellite-derived SST and colour time series with external datasets. This proposal is to apply these new tools to relevant time series from Georgia Strait (eg. coho growth and survival, weather, runoff, zooplankton) for application to historical Chinook and coho growth and survival, as well as other new time series generated as part of other subprojects.

Budget

Program costs: $75K per year for years 1& 2, $50K per year for years 3&4 (technical analysis, maintenance of databases, reports)

<u>Project 5</u> Roles of zooplankton in bottom-up control of salmon growth and survival in the Strait of Georgia.
Team: Dave L. Mackas (DFO), John F. Dower (University of Victoria), E. Pakhomov (University of British Columbia)

It is hard to imagine a bottom-up control mechanism for pelagic fish that does not involve zooplankton, either as direct prey or as the prey of somewhat larger forage species. Recent time series from the west coast of Vancouver Island demonstrate very strong statistical association between zooplankton (timing and species composition) and coho salmon success (growth in the first marine year, and overall marine survival). The mechanism(s) behind this are not fully known, but appear to involve elements of both food availability (zooplankton abundance, body size, and seasonality) and food quality (fatty acid composition and energy richness per unit zooplankton biomass).

Zooplankton time series from the Strait of Georgia, although long, are very intermittent at both seasonal and interannual time scales. In particular, there has been relatively little sampling since 2006 (when the UBC STRATOGEM program ended), and we lack in nearly all years adequate resolution of zooplankton-fish interactions in the spring and early summer. This project will be an intensive 2 year sampling program in the Strait of Georgia, to run 2011-2012, collecting mesozooplankton, euphausiids and larval fish as well as relevant environmental variables. Zooplankton and micronekton samples will be analyzed for biomass (displacement volume), size composition, community composition (abundance by major species and developmental stage), and also for C:N and lipid content.

<u>Budget</u>
Upfront costs: $124.5K (HydroBios Multinet for depth stratified sampling, a ZooScan image analyzer to provide quick size and composition analysis of the samples, two bongo nets, one microscope, purchase/construction of controlled airflow units for the zooplankton sorting lab)

Program costs: Total $262.6K per year [$32.6K per year ((travel, consumable supplies, equipment maintenance) plus vessel costs. Technical support $230K per year (PhD, technicians, undergrad co-ops)]

In-kind contributions: $45K (salaries), $10K (lab facilities at IOS (lab space, microscopes, balances, oven,), $5K (lab facilities at UVic -equipment for fatty acid & C:N analyses), $10K (IT and admin support), $170K (existing equipment- IOS Hydrobios Multinet and bongos $55K, UVic Tucker Trawl $15k, UBC Laser Optical Plankton Counter $100K)

<u>Project 6:</u> Mapping, Protection and Enhancement of Forage Fish spawning habitat
Team: Ramona deGraaf (BMS), BC Shore Spawners Alliance & volunteers

The forage fish specialists and communities working with the BC Shore Spawners Alliance (BCSSA) are interested in protecting the health of marine ecosystems and the productivity of forage fish to benefit marine populations.

Herring, Pacific sandlance and surf smelt are the most abundant marine forage fishes in the Strait of Georgia/Puget Sound. Pacific sandlance may represent a greater trophic biomass for marine species than herring (D. Penttila, personal communication). Forage fish represent a "valued ecosystem component" essential to marine food chains, connecting zooplankton to a host of secondary predators.

Protecting critical beach spawning and rearing habitats of surf smelt and Pacific sand lance is necessary to sustain forage fish biomass and the predator species reliant on them.

Sand lance and surf smelt require near-shore habitats for their survival. Departments approving development permits lack up-to-date information and are largely unaware of the impact of shoreline development on the survival of forage fish. Protecting beach spawning habitat for Pacific sand lance and surf smelt, has resulted in strict shoreline protection policies in Washington State. Yet, in British Columbia little has been done to inform land-use policies to protect these crucial beach habitats. The majority of important departments and biologists in agencies know very little about intertidal beach spawning forage fishes. Educating agencies responsible for coastal land-use planning in British Columbia about these critical fish species is imperative. Already, vast areas of shoreline in southern British Columbia have been altered and historical spawning grounds lost.

The work of the BC Shore Spawners Alliance (BCSSA) is a result of the growing realization that throughout the Strait of Georgia and in other rapidly developing BC coastal communities, intertidal forage fish spawning habitat was being degraded or lost. Stewardship groups such as the Friends of Semiahmoo Bay Society, Wreck Beach Preservation Society and the West Vancouver Shoreline Preservation Society and Stanley Park Forage Fish Friends are actively working on forage fish surveys, beach restoration and enhancement, and surf smelt recreational fishing issues.

As part of this project, funding would be made available to the BC Shore Spawners Alliance for enhancement and beach restoration activities.

Budget:

Program costs: $50K per year for 2 years: (1. Beach Surveys and developing local strategies, 2. Building the Network in the Strait of Georgia, 3. Building Capacity within Community Groups (e.g. Equipment Grants/Equipment Loan Cupboard and Travel Funds), 4. Training new trainers – Weekend Workshops for Project Coordinators, 5. Production of Educational Materials to Inform Land-Use Policies and Government Agencies)

In-kind contributions: $40K per year (volunteer hours)

<u>Project 7</u> Early marine nearshore surveys for juvenile Pacific salmon in the Strait of Georgia
Team: Krista Lange (DFO), Dick Beamish (DFO)

Juvenile Pacific salmon enter marine waters of the Strait of Georgia from April until June, depending on the species. Midwater trawl surveys conducted by Dick Beamish and Rusty Sweeting in July and September give great insight into the population dynamics of juvenile Pacific salmon during their first marine summer, but little is known about the ecology of these fish from ocean entry until July. It has been suggested that up to 90% of juvenile Pacific salmon may die within their first eight weeks at sea, and yet no surveys have been conducted during this time in recent years.

This project will examine the early marine survival of juvenile coho and Chinook salmon. These early marine surveys would take place in three locations throughout the Strait of Georgia, potentially in the Gulf Islands, Howe Sound, and near Campbell River. Each location would be surveyed for three days in four separate surveys. Surveys will be performed via small purse seine boats that are capable of fishing very nearshore areas where it is hypothesized that juvenile salmon reside during their early marine residence. The focus will be on coho and Chinook salmon, but other salmon and non-salmon species will also be examined to determine potential prey and predator interactions. The objective is to obtain information on the young salmon before they move offshore to deeper areas of the Strait of Georgia where they will be targeted by the trawl surveys (ongoing by Beamish lab). Information on stomach contents, lengths, scales, otoliths and DNA samples will be collected

<u>Budget:</u>
Program costs: $390K per year for 2 years (labour, vessel, May-July sampling)

In-kind contributions: $320K per year (ongoing yearly trawl surveys in the Strait of Georgia by Beamish lab, DFO)

<u>Project 8</u> Direct Mortality Studies of Coho Salmon
Team: Tony Farrell (UBC), Scott Hinch (UBC), Dave Welch (Kintama Research), and John Robb (Kintama Research).

These studies will use acoustic tags implanted in juvenile fish, and receiver arrays (see Appendix 2.3).

Study 1: Where and at what rate are juvenile coho salmon disappearing during their early migration between April and July?
Team: Farrell & Hinch (UBC)

This study will directly asses mortality and migration rates of Inch Creek hatchery juvenile coho salmon in the lower Fraser River, nearshore Fraser Estuary and beyond.

Fish release dates (three) will occur around the spring plankton bloom (but within the smolt period) to test the hypothesis that a fish migration timed to coincide with seafood abundance results in greater juvenile coho survival in the Georgia Strait. A fourth release date could be included using fish translocated to a netpen to avoid some of the nearshore migration and allow acclimation to seawater without predation.

100 fish will be fitted with a new V5 or V6 Vemco 69 kHz acoustic tag and all three release dates. The V5 acoustic tag is the smallest on the market. The movements of these fish will be followed in the rivers and nearshore with the listening lines using VR3/4 69 kHz receivers. The existing POST listening lines (Johnstone Strait, Juan de Fuca, Northern Queen Charlotte Strait) are all VR2's using a 180 kHz frequency and detecting the larger V7 or V9 tags. Thus, to take advantage of these existing arrays (and our other VR2 receivers) to discover the number of fish moving out of Georgia Strait and beyond, larger tags would be implanted in selected, larger coho, as in the past.

Mobile tracking will be used to locate dead fish (ie, a signal that is not moving over time).

This approach can partially capitalize on existing VR2 180 Hz receivers in the Fraser River by pairing them with a VR2 69 Hz receiver. This arrangement will allow several estimates of mortality rate as the fish migrate to the mouth of the Fraser River estuary. Additional mobile tracking of fish leaving the Fraser River will be used as well.

In addition, OTN will be funding a "Tag Effect Study" based at CAER, which will examine comparative survival among tags of different sizes. This study is viewed as in-kind support.

Budget:

Upfront costs: $200K (6 paired VR2 receivers at 180 KHz, mobile tracking receivers)

Program costs: $135K year 1, $175 year 2, $115 year 3 (costs for acoustic tags, receivers, deployment, maintenance, staff)

In-kind contributions: 1. Fraser River array – the existing 6-10 (69 kHz) VR2s in the lower Fraser are Kintama's. Farrell lab has around 15 additional VR2s that could be used with the larger tags. 2. POST arrays (existing) –all are VR2s and are free for us to access. 3.OTN arrays (there are several new ones that OTN is going to give to POST and in theory our fish could pass over all of these): a. Vancouver line 21 VR3-4 receivers ($189 K), initial deployment ($21 K), operations & maintenance over 7 years ($112K). b. Graves Harbor lines: 27 VR3-4 receivers ($318K), initial deployment costs ($27 K), & operations and maintenance costs after deployment up to the end of the OTN seven years ($175 K), c. Prince William Sound lines: 27 VR3-4 receivers ($316 K), initial deployment ($27 K), & operations and maintenance ($148 K), d. Unimak Pass lines: 36 VR3-4 receivers ($403 K), initial deployment ($36 K), operations and maintenance ($191 K)

Other Potential OTN NSERC Pacific in-kind support**:** CAER User Fees to UBC (tanks, space, animal care technician) at CAER $10 K per year**,** 50% technician per year $35K per year**,** Oceanographic CTD recorders, fish transport trucks and other field vehicles**,** two VR100, directional hydrophones that we use to test tags and hand-track fish from boats.

Study 2: To measure marine survival and timing of movements of Coho stocks within the northern Strait of Georgia and through Discovery Passage.
Team: Dave Welch (Kintama Research) and John Robb (Kintama Research).

For this project, tagging and release of mixed coho stocks within the Strait of Georgia will be carried out in late July/early August using ocean-caught juveniles representing a mix of stocks. These smolts should be greater than 130mm, allowing for the use of V7 or V9 tags and 69KHz arrays. These tags are compatible with existing POST array at Northern Strait of Georgia, Queen Charlotte Sound and Juan de Fuca and there would also be additional new arrays placed around Discovery Passage to supplement the existing POST arrays at the Northern Strait of Georgia and Queen Charlotte Strait.

Budget:
Upfront costs: $523,400 (Capital costs of receivers, acoustic releases, tags, boat lease, array deployment and recovery)

Program costs: $80K per year for 2 years (Kintama staffing, boat lease, array permitting, securing Canadian animal care approval of experimental protocols, tagging, array recovery, data delivery & report writing, transportation and overhead)

In-kind contributions: $100K (POST funds to maintain the existing NSOG and QCS lines}

Study 3: To measure localized Coho freshwater and marine survival of hatchery reared stocks released from the Lang Creek Hatchery, Sunshine Coast. NOTE: This study is not included in budget at present and is to be determined.
Team: Dave Welch (Kintama Research) and John Robb (Kintama Research).

For this project, tagging and release of hatchery smolts at Lang Creek will be carried out at the same time that that remainder of the hatchery smolts are released from the Lang Creek facility. These smolts should be greater than 130mm, allowing for the use of V7 or V9 tags and 69KHz arrays. In this case, these tags are compatible with the existing POST array at Northern Strait of Georgia, Queen Charlotte Sound and Juan de Fuca. New arrays would also be placed around Texada Island and Sechelt and Jervis Inlets such that surviving released smolts will cross one or more of the arrays. If the fish are smaller than 130mm, then they would need to use smaller V6 tags and different 180KHz receiver arrays would be needed.

Budget:
Upfront costs: $523,000 (Capital costs of receivers, acoustic releases, tags, boat lease, array deployment and recovery)

Program costs: $80K per year for 2 years (Kintama staffing, boat lease, array permitting, securing Canadian animal care approval of experimental protocols, tagging, array recovery, data delivery & report writing, transportation and overhead)

In-kind contributions: $100K (POST funds to maintain the existing NSOG and QCS lines}

Top-Down Projects

Project 9. Assessing the impact of marine mammals on salmon in Georgia Strait
Team: Andrew Trites (UBC), post-doc, PhD student & research assistants

The dietary information for harbour seals is now 20 years out of date and no studies have been published on the movement or foraging patterns of harbour seals in Georgia Strait. How and where seals capture their prey is unknown beyond the direct observations that some predation occurs in rivers and estuaries. Similarly, the extent to which the distribution and feeding behavior of harbour seals overlaps with those of salmon smolts and adults is unknown, as is the effect that increased numbers of seals have had on salmon stocks over the past 20 years.

Thus, the goal of this project is to determine where and how harbour seals capture salmonids (fry, smolts and adults) within Georgia Strait, and to estimate the amount of salmon consumed and how predation varies by region and time of year. This team will provide a thorough assessment of the role that harbour seals are playing in the lack of recovery of coho and Chinook in British Columbia using new technologies not previously available to assess diets and predation by seals in Georgia Strait.

Diet will be determined from the DNA of prey species contained in harbour seal scats which will be collected monthly from log booms, reefs, islets, sandbars and other substrates where seals haul out. This team will sample most of the major haulouts in Georgia Strait monthly for 2 years and scats will be scanned to determine the presence of coded wire tags from salmon, and otoliths will be removed to determine the size of fish consumed. In addition, aerial surveys will be used to count harbour seals over the same period to determine seasonal distributions relative to salmonid movements, and to determine the proportion of the population that are sampled for dietary analyses. This will allow them to estimate regional consumption of salmonids by harbour seals. In addition, predation studies will be conducted to determine where, when and how harbour seals are capturing salmonids. They will investigate the relationship between duration of feeding trips, density and location of prey, foraging success, and the physical properties of the water column where animals travel. Harbour seals will be fitted with attached micro computers and carry fine-scale tracking devices that record timing of activities and properties of the water column where animals search for food (water temperature and light levels). Each set of instruments will include a VHF-radio tag (to locate animals on shore), a GPS satellite linked tag (to locate animals at sea in real time), and a Daily Diary tag (to reconstruct activities in 3-D during the entire foraging trip). Data analysis will reveal the locations of feeding events, the foraging strategies employed, length of time in patches, foraging habitat, length of feeding trips, oceanographic characteristics of the water column, and activity budgets of foraging harbour seals.

Budget:
Program costs: $350K per year (years 1&2), $90K per year (year 3) (includes PhD, Post-Doc, research assistants, DNA analysis, scat collections, seal captures, aerial surveys, seal instruments, travel).

In-kind contributions: $240K total [$140K (>$100k per year, in-house scientific and technical support, >$20k per year, lab facilities, >$20k per year, equipment) and $100K (links with NSERC Strategic Fisheries Network proposal)]

Project 10: Is the disappearance of juvenile Chinook and coho salmon at sea between May and September a result of disease and/or condition of fish upon entry into the ocean?
Team: Kristi Miller-Saunders (DFO), Tony Farrell (UBC), Bob Devlin (West Van/DFO), Sonja Saksida (CAHS)

The health and condition of salmon smolts upon entry into the Strait of Georgia may be a major factor in their subsequent survival in the first few months at sea. Stress and/or disease can decrease survivorship by 1) altering growth, feeding and activity levels, leading to increased vulnerability to predation and decreased energy reserves for continued migration and over-wintering, 2) inducing an immunosuppressive state, increasing susceptibility to pathogens, and 3) diminishing the ability to acclimate to further environmental change, potentially resulting in osmoregulatory dysfunction, DNA damage, and/or uncontrolled cell death. Fish may become stressed due to suboptimal rearing environments in the river, premature entry into the ocean, or poor ocean feeding conditions. Alternately, disease can result from both pathogenic (viruses, bacteria, parasites) and non-pathogenic (e.g. toxicants, heavy metals, hypoxic environments, genetic factors) sources.

There is mounting evidence that disease, specifically a novel virally-induced disease, may be impacting the survivorship of coho and Chinook salmon in the Strait of Georgia. The disease agent has yet to be fully characterized, but may be associated with mortality in both freshwater and saltwater, and can cause proliferative tumours in the brains of affected salmon. Genomic profiles reveal a powerful physiological response of salmon to this disease afflicting multiple organs. Prevalence level based on tumour incidence was over 40% in out-migrating coho and Chinook smolts in 2008 and 2009. Importantly, disease-associated mortality is indicated by the decreased incidence of tumours from June to September in the Strait of Georgia. Moreover, it is clear that this viral disease is present well before fish reach the ocean.

As declines in Chinook and coho observed over the past 2 decades are mirrored in both wild and hatchery-raised fish, the disease hypothesis can be tested using hatchery fish without impacting large numbers of wild fish.

Three main approaches will be examined:

1. Directly assess inherent mortality rates and disease profiles for juvenile coho salmon prior to and post-entry into seawater using captive individuals held under experimental conditions.

2. Examine the survival of wild coho and Chinook salmon captured from nature, and subsequently held in laboratories.

3. Determine the prevalence levels in nature (freshwater and the Strait of Georgia) of pathogens affecting survivorship in the laboratory studies.

For parts 1 and 2 above, fish will be held in netpens for a 5-month period and monitored for growth, overall mortality rates, and body condition. They will be sampled at regular intervals and tested for the presence of pathogens, brain tumours, evidence of stress, osmoregulatory capacity, and the expression of molecular genetic and other disease markers. Moribund fish will be similarly assessed throughout the experiment. For part 1, the experimental design will utilize different hatchery populations of coho and chinook salmon to determine whether effects can be generalized: Year 1: Quinsam and Inch Creek (DFO's lower Fraser coho salmon indicator stream monitored for many years), Year 2: Big Qualicum and Chehalis River (a standard strain which can serve as a reference).

The experimental design will also be replicated for three different release times for one or more of the hatchery populations. This approach would tie in with the experimental release of acoustically tagged fish from hatcheries that will be examining the survival relative to coincident release with phytoplankton blooms. Tagging effects on behaviour and survivorship will also be examined within the holding studies in the second year of study.

For part 2, wild fish will be gently collected by purse seine from the Strait at different times post smolt migration and will be held and sampled similarly to the hatchery fish. Assessing the viability of fish collected from the Strait could pinpoint if, and when, a pathogen is being transmitted to the host salmon.

The tumour-associated viral signature in wild salmon was discovered using genomic approaches in an ongoing (to 2010) Genome BC study. Preliminary data based on tumour incidence is suggestive of a role of this disease in early marine mortality in the Strait of Georgia. However, it is clear that not all fish impacted by this uncharacterized viral disease have brain tumours, and it is important to assess the real incidence of the disease in wild fish. They expect that the primary organ affected by this virus is the kidney; hence, they will use the same genomic approaches used previously to determine infection rates in kidney tissue of coho and Chinook salmon in the Strait. By assessing incidence over time, they can gain valuable information on potential disease-associated mortality. Part 3 will require development of a molecular marker to carrying out a broad survey of stocks of salmon that rear in the summer in the Strait, as well as brain dissections of wild fish.

If these studies confirm that disease is a major factor impacting early marine survival of salmon in the Strait of Georgia, this team will begin working with hatchery managers to develop mitigative strategies to control the incidence of disease. The most plausible mitigative action would be to screen hatchery broodstocks for the pathogen(s) that are vertically transmitted, and to select only fish that are pathogen-negative for breeding. Decisions to screen could be based on prevalence levels in returning fish each year. Husbandry practices may also be improved to minimize horizontal transfer of pathogens. There are anti-viral and anti-bacterial treatments that can be done on the eggs as well. While we cannot directly control disease incidence in the wild, reducing the incidence in hatchery fish would, over time, likely also reduce levels in the wild. Moreover, regular screening of smolts and adults would allow managers to adjust escapement estimates according to infection levels. Results from controlled laboratory studies and those based on wild collected fish in multiple years and under multiple environmental regimes will provide the important links with environmental-disease associations necessary to derive these modified escapement estimates.

Budget:
Program costs: $515K per year for 2 years (includes holding costs, labour, microarrays, sampling, processing and screening for: brain dissections, histology, pathology, tumours, stress, osmoregulatory capacity, growth.) $65K for year 3 (analysis).

In-kind contributions: $ 1.12 million for 2009-2011 (Genome BC- Genomics program on early ocean mortality profiling gill, muscle, brain and liver tissues to assess physiological signatures associated with growth, metabolism, diet, starvation, activity, energetics, osmoregulation, stress and disease) plus $490K for 2009-2011 (DFO, which co-funds the above research).

Project 11: Strait of Georgia Coho Hatchery Release Program
Team: Quinsam Hatchery (D. Ewart), Centre for Aquatic Health Sciences (S. Saksida), Marine Harvest Canada, I. Pearsall and B. Riddell.

With the collapse of both marine survivals for all Strait of Georgia coho salmon, including threatened interior Fraser River coho populations, and loss of the once lucrative summer coho fishery, it is proposed to manage hatchery coho salmon production as a tool to test some of underlying mechanisms that regulate coho salmon production in the Strait of Georgia.

Three aspects of the major hatchery production around the Strait of Georgia merit investigation:

1. density-dependent competition with wild salmon;
2. fitness and disease profile of hatchery produced smolts and the utility of inoculations as an experimental treatment to improve the survival of hatchery produced smolts; and
3. the use of delayed releases to reduce competition with wild salmon and improve efficiency of the major hatcheries.

This proposal aims to directly test whether there is competition between hatchery and wild coho salmon. There will be two main experiments:

1) Directly test for competition with wild coho salmon.

Moderated hatchery coho smolt releases from all major hatcheries contributing fish to the Strait of Georgia. Production and marine survival of the reduced hatchery production (target 50% reduction and 75% reduction for 2011 and 2012 release years, respectively) will be compared with natural production from coho indicator stocks within the Strait and Fraser River. The recommended natural systems would be: Black Creek, Salmon River, and interior Thompson coho indicator, a new indicator in the Little Qualicum River, and a stream along the Sunshine

Coast (Lang Creek). Each coho population would be marked with coded-wire tags and a quantitative enumeration of adults conducted. Costs for these programs will be shared between DFO, community programs, and the Pacific Salmon Foundation.

The major investigation must involve the Department of Fisheries and Oceans (DFO) in order to reduce the production of coho smolts from the major hatcheries contributing fish to the Strait of Georgia, and by nature, must occur over several years. Final values for reductions must be finalized with DFO but will occur over this timeframe:

Brood year	Release Year	Production change	Return Year	Comments
2008	2010	None (current level)	2011	To late in 2009 to change
2009	2011	Target 50% reduction	2012	Use fry releases in 2010 to reduce smolt releases
2010	2012	Target 75% reduction	2013	Maximize reduction but need minimum number of smolts to conduct the studies.
2011	2013	To be determined	2014	PSF will recommend repeating the 75% reduction for a total of three years.

For each major hatchery there will be a minimum number of releases determined and all smolts coded-wire tagged and clipped to identify the hatchery production. *No incremental change in tagging is anticipated.*

2. Testing the utility of delayed releases of coho salmon and use of inoculation to increase survivorship of hatchery produced coho.

These studies will directly test whether production of hatchery-reared coho salmon in the Strait of Georgia can be maintained while reducing competition with wild populations and improving efficiency of hatchery production. The studies will involve comparison of control lines within a major hatchery (recommendation is Quinsam Hatchery) versus treated and non-treated groups held in marine net-pens for approximately 3 months (release targeted for the late summer plankton blooms). The study design will compare total marine survival rates based: un-treated control groups, inoculated treatments, and delayed release groups.

The experimental design involves:

1. Untreated control releases from the hatchery (possibly for a couple of release dates) with a minimum coded-wire group of 50k tags (100K total CWT). For each release date, there would be a matched release of treated (vaccinated) coho of the same size and background rearing experience (total treated and coded-wire tag = 100K).

Projected costs involve 200K CWT (PSF could fund incremental costs over existing tagging budget), plus the cost of vaccination of 100K coho. Vaccination costs will differ depending on ipvaccination or bath treatment. **Preliminary allocation of 30K per year Study 1 until full budget review completed.**

2. Net-pen rearing for delayed release of untreated and treated (vaccinated) smolts, each full set of comparisons to be replicated for net-pen site. Each group (i.e., each Net) will consist of 25K coded-wire tagged coho.

Location Site A.

Net 1: Un-treated and released after acclimation (~ 2 weeks) 25K Coho, all CWT	Net 2: Treated and released after acclimation (~ 2 weeks) 25K Coho, all CWT	Net 3: Un-treated and retained for full duration of delay. 25K Coho, all CWT	Net 4: Treated and retained for full duration of delay. 25K Coho, all CWT

Location Site B.

Net 1: Un-treated and released after acclimation (~ 2 weeks) 25K Coho, all CWT	Net 2: Treated and released after acclimation (~ 2 weeks) 25K Coho, all CWT	Net 3: Un-treated and retained for full duration of delay. 25K Coho, all CWT	Net 4: Treated and retained for full duration of delay. 25K Coho, all CWT

Budget:
Upfront costs: $160K (net-pens)

Program cots: $110.5K per year for 2 years (inoculations, labour, feeding, net open maintenance, CWT) plus $250K per year (for 4 years to community groups for escapement monitoring on indicator systems)

In-kind contributions: $30K (B. Riddell time)

Project 12: Aquaculture – Salmon Interaction
Team: Quinsam Hatchery (D. Ewart), Centre for Aquatic Health Sciences (S. Saksida), Marine Harvest Canada, I. Pearsall and B. Riddell.

While the Science Panel did not recommend specific studies of the potential interaction of salmon farms in the northern Strait of Georgia, a design similar to the hatchery net-pen rearing could be used to investigate these concerns. We propose a collaborative study between PSF, DFO, Marine Harvest Canada, and Save our Salmon Foundation (Eric Hobson).

The basic study design would be to use net-pen reared coho salmon at varying distances from an actively producing salmon farm in lower Johnstone Strait to expose these coho to potential infection and then monitor their marine survival, and compare those against results from the other hatchery studies.

The design would compare untreated hatchery fish, inoculated hatchery fish, untreated hatchery fish fed with treated feed, and inoculated hatchery fish with treated feed. The studies would be replicated for two years.

The design would involve four treatments per site, replicated at 2 sites equal distance from an actively producing MHC farm in lower Johnstone Strait:

Hatchery Treatments	Feeding regime Normal , not treated	Medicated, SLICE added
Controls (no treatment)	Normal Hatchery fish, normal food (no treatments)	Normal hatchery fish, treated feed to prevent sea lice
Disease prevention (inoculated)	Treated hatchery fish, normal food (inoculated only)	Double treatment against pathogens and sea lice.

Budget:
Upfront costs: $160K (net pens)

Program cots: Total $85.5K per year for 2 years. (Includes $8K per year (treatment of coho for pathogens), $7,800 per year (non-medicated feeds), $30K per year (medicated feeds), $30K per year(barging of fish, helicopter transport) labour, net pen maintenance, CWTs)

In-kind contributions: $20K (B. Riddell time)

Project 13: Community Based Nearshore Restoration
Team: Nikki Wright and the Seagrass Conservation Group

In the marine environment, eelgrass beds function as wildlife corridors for a large array of fish, bird and invertebrate populations. They have been described as “salmon highways”, providing respite from strong ocean currents and predators, and as nutrient rich nurseries for young marine organisms. Over the last two decades, the values of these estuaries to marine wildlife and people have been well documented, and there is concern over the loss of many eelgrass beds in the Strait of Georgia.

Coastal community groups are in a prime position to take on more of a responsibility for locating, assessing and assisting with transplanting eelgrass. Since 2002, twenty-seven community stewardship groups have been trained in mapping eelgrass (*Zostera marina*) habitats along the BC coast. Fourteen of those groups are active around the Strait of Georgia. The strategy for 2010 is to transplant test plots of 500-1,000 shoots in each of ten locations surrounding the Georgia Basin. For this proposal, a team of Worker’s Compensation Board (WCB) qualified SCUBA divers, with a dive tender and Cynthia Durance, the SCWG science advisor would work with the project coordinator in each of the ten coastal communities to undertake site assessments, the transplants and subsequent monitoring after six months of the transplant. Then the sites will be monitored for shoot density and area extent. Based on the monitoring data, further funding and planning will proceed to install larger transplants in the same locations. On-going assessment of the use of these eelgrass beds by marine organisms, including juvenile coho and Chinook will be undertaken. A backgrounder for the Seagrass Conservation Group is given in Appendix 2.

Budget:
Program costs: $150K total (labour, tools, scuba, boat use, training, admin) over 3 years.

In-kind contributions: $100K

Project 14: Contaminants in the Strait of Georgia
Team: Georgia Strait Alliance

Georgia Strait Alliance organization will carry out a contract to map and assess potential contaminant loads throughout the Strait of Georgia.

Budget:
To Be Determined (Project for 2011)

APPENDIX 1.2 SCIENCE ADVISORY PANEL MEMBERS BIOGRAPHIES

Dr. Brian E. Riddell, CEO, Pacific Salmon Foundation, 300 – 1682 West 7th Avenue, Vancouver, B.C. V6J 4S6. Email: brianriddell@shaw.ca or briddell@psf.ca

1979 Ph.D., McGill University, Dept. Biology (Population biology/genetics)

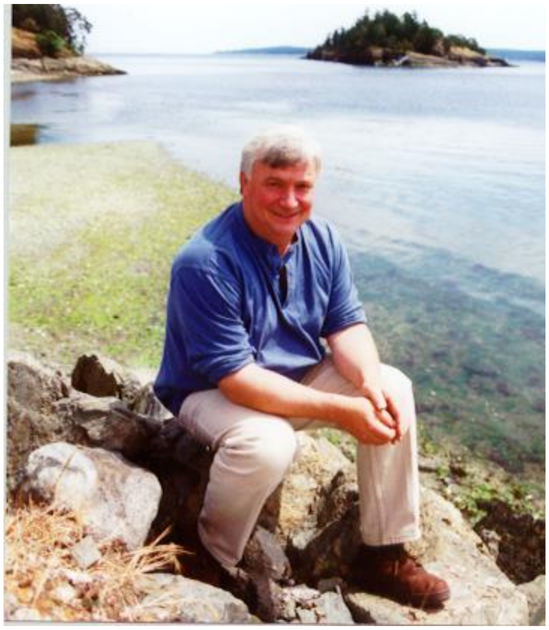
1974 B.Sc., University of Guelph, Dept. Biology (Honours Marine Biology)

After receiving his PhD from McGill University in 1979, Dr. Riddell joined the Science Branch, Department of Fisheries and Oceans, at the Pacific Biological Station, in Nanaimo BC. However, after thirty years of service to the public service of Canada he recently retired from the Department and accepted the position of CEO and President of the Pacific Salmon Foundation.

In science, Brian is recognized for his work in population genetics of Pacific salmon culminating in the completion of Canada's Policy for the Conservation of Wild Pacific Salmon in June, 2005. However, he is likely best known for his ability to interact with a wide range of organizations and peoples, and his numerous advisory roles. Most notable are his efforts for the Pacific Salmon Treaty (1985) and his chairmanship of the Chinook Technical Committee for 20 years; and work with the US National Research Council (Upstream: Salmon and Society in the Pacific Northwest. 1996) and advising on science and salmon conservation in the Pacific Northwest for over 10 years. Throughout his career, he established a strong reputation for objective accurate advice to senior management and integrity with all users and conservation groups in Canada and throughout the North Pacific region. He has also participated in program management since early in his career, becoming the head of Pacific salmon research and stock assessment in British Columbian and the Yukon in 2005. During his 30 years in the Department, Dr. Riddell has written over 100 papers in the primary scientific literature and secondary literature for the provision of advice.

Dr. Riddell has received a number of awards for his work in salmon conservation and management. Since 1989, Brian has received seven Public Service awards and in 1994 received the **Canada Medal** (125th Year Commemorative Medal).

Dr. Richard J. Beamish O.B.C., C.M., Ph.D., F.R.S.C, Senior Scientist, Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, British Columbia, V9R 5K6. **Richard.Beamish@dfo-mpo.gc.ca**



Dr. Richard Beamish, O.B.C., C.M., Ph.D., F.R.S., is the Senior Scientist at the Pacific Biological Station in Nanaimo, B.C. Dick Beamish was born in 1942 in Toronto, Canada, and started his career as a fisheries biologist in the 1960s. He finished his Ph.D. at the University of Toronto in 1970 and went directly to Woods Hole Oceanographic Institute for a Post Doctoral Fellowship with Dick Backus. He then worked at the Freshwater Institute in Winnipeg for a few years, ending up at the Pacific Biological Station in Nanaimo, British Columbia in the mid-1970s. He was the Head of the Groundfish Section from 1977-1979 and Director from 1980-1993.

He is an Editor for Transactions of the American Fisheries Society, a member of the Science Panel for the North Pacific Research Board, Chairman of the Scientific Steering Committee for the North Pacific Anadromous Fish Commission, an active member of PICES, a member of the Committee for Scientific Cooperation for the Pacific Salmon Commission, the Department's representative on the Pacific Fisheries Resource Conservation Council, one of two scientists on the Deputy Ministers' Science Management Board, a former Canadian Commissioner for the International Pacific Halibut Commission and a Professor at Vancouver Island University.

Dr. Beamish has been honoured with a number of awards including the Order of Canada and the Order of British Columbia. He was made a Fellow of the Royal Society of Canada and recently became the first foreign scientist to be made an honorary member of the fisheries laboratory TINRO in Vladivostok, Russia. He has published over 350 articles with about half in peer reviewed journals.

His research interests have included the discovery of acid rain, age determination and the discovery of the longevity of some of our Pacific fish species, the identification of new lamprey species and the evolutionary relationship between these species, and the effects of climate on fish populations. He was one of the first scientists to write about climate regimes and regime shifts.

Dick is married to Ann and has two daughters, Jennifer and Heather. He is an avid gardener with a large collection of rhododendrons and Japanese maples. As well, he enjoys making chocolates and playing rugby.

Robert H. Devlin, Director, Centre for Aquatic Biotechnology Regulatory Research, Fisheries and Oceans Canada, West Vancouver. E-mail: robert.devlin@dfo-mpo.gc.ca

Bob Devlin studied Zoology and Genetics at the University of British Columbia, and received his doctoral degree in 1984 for research on sex determination and dosage compensation in *Drosophila melanogaster*. After postdoctoral research at Simon Fraser University and the University of Washington, he joined Fisheries and Oceans Canada to engage in molecular genetic and physiology research with salmonids at the West Vancouver Laboratory. He is an Adjunct Professor in Zoology, UBC, and current Director of DFO's Centre for Aquatic Biotechnology Regulatory Research where he oversees research on the production and assessment of transgenic and domesticated salmonids for ecological risk assessments, physiological and genetic studies of fish sex determination, and evaluation of techniques for biological containment of aquacultured fish.

Professor A. P. Farrell, Ph.D., Dir. Fil. h.c. Endowed Research Chair in Sustainable Aquaculture, University of British Columbia. Email: Farrellt@interchange.ubc.ca

Dr. Tony Farrell's academic career started with a 1st class Honours degree in Biology at Bath University, UK (1974) and continued with a Ph.D. degree in Zoology at the University of British Columbia (1979), followed by a 1 year American Heart Association PDF at the University of Southern California Medical School, Los Angeles (1979-80). He was awarded a NSERC University Research Fellowship (URF), which he held in Biology at Mount Allison University, NB (1980-84) and then in Biological Sciences at Simon Fraser University, BC (1984-86). He was promoted to associate professor and received tenure at SFU in 1986, and shortly after he was promoted full professor in 1990. He moved to the University of British Columbia in 2004, where he now holds an endowed research chair in Sustainable Aquaculture as a joint appointment between the Zoology Department and the faculty of Land and Food Systems.

His areas for research, training and teaching are comparative animal physiology, aquaculture and environmental toxicology. His special interest is the cardiorespiratory system of fish - its control and contribution to whole animal function, and how environmental change affects its function. He has been senior research supervisor for >10 PDF's, >20 M.Sc. students, >10 Ph.D. students, >20 technicians and research assistants, and >40 undergraduate student projects. This research activity has been supported by over $10 million in research funding (including collaborative projects) has culminated in over 290 refereed publications (including prestigious journals such as *Science; Proceedings of the National Academy of Science; and Proceedings of the Royal Society London*), 2 co-authored books, 13 book chapters (including key reference texts such as *Handbook of Physiology*), and 11 technical reports to the field.

He is now senior co-editor of the treatise *Fish Physiology,* taking over from Drs. Bill Hoar and Dave Randall, which has resulted in 18 co-edited volumes in the series. This series remains the premier and most influential series in fish physiology. He is editor-in-chief for a new Encyclopedia of Fish Physiology. Also, he serves as an Assistant Editor with the Journal of Fish Biology and serves on the Editorial Boards of Physiological Biochemical Zoology and the Canadian Journal of Zoology, having served previously with the American Journal of Physiology.

He considers himself among the world's leading comparative cardiovascular physiologists, his influential reviews having helped shape a somewhat fragmentary field into a more unified subject. His collective works have resulted in over 5,000 citations, which currently average 500 per year. "Lasting and outstanding contributions to comparative physiology" resulted in an Honorary Doctorate of Science from the University of Göteborg, Sweden (in 2000). He was also honoured with the Murray A. Newman Awards for Significant Achievement in Aquatic Research and Conservation from the Vancouver Aquarium and Marine Science Centre (in 2002) for my applications of basic science to help solve the problem of commercial salmon by-catch. Awards of Excellence followed from the American Fisheries Society for Fisheries Management and Conservation in relation to studies of Fraser River sockeye salmon migration (in 2005) and for Fish Physiology (in 2006). In 2009, he received the 2009 Fry Medal from the Canadian Society of Zoologists, their top honour for an outstanding lifetime contribution to any field of Zoology.

Gordon (Sandy) McFarlane. Scientist Emeritus, Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, British Columbia, V9R 5K6. Email: mcfarlanes@pac.dfo-mpo.gc.ca

Gordon (Sandy) McFarlane's research centers on determining and refining biological parameters (age, growth, mortality, etc.) used in stock assessments; examining climatic and oceanic factors influencing the dynamics (particularly year-class success) of marine fish; and the physical, biological and fisheries oceanographic linkages of large marine ecosystems.

He has studied marine life extensively in the Strait of Georgia for the last 30 years. In addition he has for many years studied the biology and distribution of sharks and skates off Canada's west coast. Previously, he was head of the Marine Fish Population Dynamics Section (1992-2000) and the Groundfish Research Section (1985-1991) at PBS.

He has for many years been a member and advisor to international negotiating teams (INPFC; Can/U.S. Groundfish Committee; PICES; Pacific Hake Scientific Working Group) and has participated in the development and conduct of international research programs. In addition, he has authored over 100 primary publications concerning the biology and assessment of marine resources as well as over 100 technical publications directly related to stock assessments of Pacific marine fishes.

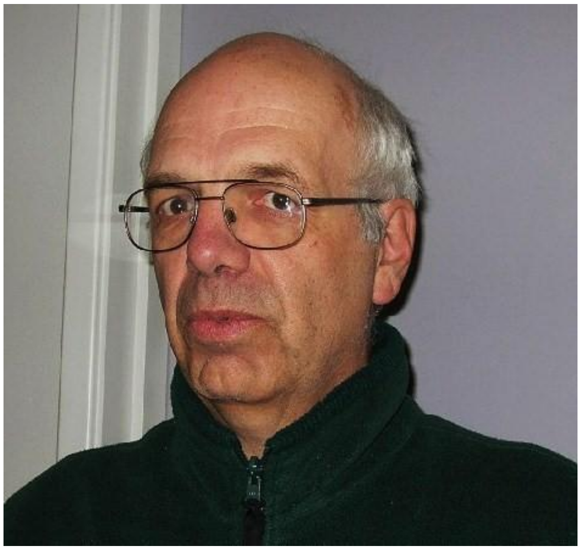
Dr. Kristi Miller, Head of Molecular Genetics, Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, British Columbia, V9R 5K6. Email: Kristi.Miller@dfo-mpo.gc.ca

Dr. Kristi Miller is the head of the Molecular Genetics Section of the Pacific Biological Station (PBS) with the Canadian Department of Fisheries and Oceans (DFO) and holds an adjunct professorship with the University of British Columbia in the Department of Forest Sciences. She received her Master's degree from the University of British Columbia (1984) and PhD from Stanford University (1991).

Dr. Miller has been an internationally recognized leader in the area of molecular genetics for over 15 years, with over 90 publications spanning a broad range of disciplines, including population genetics, molecular biology, immunogenetics, genomics, evolution, fisheries, fish health, and aquaculture. Recently, her program has focussed on the use of functional genomics to elucidate genome-wide physiological signatures in salmon. Her group has used genomics to explore the salmonid host response to pathogens, and identified ways in which viruses co-opt the host immune response to facilitate their own reproduction. Functional genomics research in her lab has also identified signatures in wild migrating salmon associated with stress, viral disease, cancer, growth, starvation, and activity level. Moreover, by combining non-destructive tissue biopsies (for genomics research) and radio-tracking, Dr. Miller's lab has elucidated a potentially new tumour associated virus that exacerbates survival of adult salmon returning to spawn in the river. This same signature is present in smolts.

Dr. Miller serves on the editorial board of Immunogenetics (published in the Netherlands), is a subject editor for the international Coastal Marine Fisheries Journal, was a member of NSERC Discovery Grant Committee GSC-18 for Ecology and Evolution from 2003-2005 and served on the NSERC John C. Polanyi award Committee in 2007. In 2007, she also served as guest Editor for the Journal of Fish Biology on a special issue focused on fish microarrays. She is a member of the International Society of Developmental and Comparative Immunology and the American Fisheries Society. Since 2004, she has reviewed over 350 manuscripts and grants.

Dr. Arthur F Tautz, Science Advisor, Ministry of Environment, UBC. Email: Art.tautz@gov.bc.ca



Dr. Art Tautz obtained a Masters Degree and PhD from the University of British Columbia in fisheries management and mathematical modelling. In his graduate work he was supervised or published with Dr P.A. Larkin, Dr C.S. Holling, Dr W.E Ricker and Dr. Cess Groot. In 1972 he joined the British Columbia Fish and Wildlife Branch and shortly thereafter became the manager of the Fisheries Research Section at UBC. The section is currently part of the world recognized Aquatic Ecosystem Research Lab (AERL) which, in its various forms, has been a productive collaboration of academic and government scientists and decision makers for over 60 years.

In addition to his role as research manager, Dr Tautz became the provincial lead for the Federal Provincial Salmonid Enhancement Program (SEP). He served as the Provincial Anadromous Coordinator (led the provincial steelhead program) for over a decade. In this capacity he coordinated teams responsible for stock monitoring, angling guide legislation, design and implementation of habitat and non-habitat enhancement tools, and who developed policies, regulations and frameworks for commercial and recreational fisheries management.

Throughout his career, a recurring theme has been the development of mathematical models and information systems supporting management decisions in complex biological and political environments. He has served on a variety of ministry information management committees and has championed the development of several innovative systems tools in both the federal and provincial governments. Spatially explicit models of commercial fisheries and their impacts on recreational stocks of steelhead and coho have been of particular interest, as evidenced by his role as the provincial representative Skeena Watershed Committee.

Until his recent retirement, Dr. Tautz served as an advisor on a wide range of strategic committees and boards. He has been the co-chair of the Ministry of Environments' Science committee, a member of the Forest Science Program Board, the Ministry Systems Information Planning Committee, the Ecological Reserves Board, the inter-ministry forest inventory Management Group, and the Advisory Group on Provincial Research Policy for Advanced Education. He has also served for over a decade on the federal PSARC science review panel, the technical review team for Pacific Salmon Foundation, Forest Renewal BC, and the ecoregional planning team for the Nature Conservancy of Canada.

His current research interests include open source Geographic Information systems and databases, resource management in varying environments, the mountain pine beetle epidemic, development of watershed classification systems, hierarchical coding, hydrologic and raster based modelling, visualization and communication tools, and the integration of aquatic conservation values into decision support tools for conservation biology.

Dr. Tautz currently retains an emeritus position at UBC and enjoys sport fishing, music, mountain biking, travel, a spiritual home on Hornby Island, a wife Ann, two daughters and two grandchildren.

Dr. Carl Walters, B. Sc. (Humboldt State) M. Sc., Ph. D. (Colorado State University). Professor of Zoology and Fisheries, University of British Columbia. Email: c.walters@fisheries.ubc.ca

Dr. Carl Walters is currently Professor of Zoology and Fisheries at the University of British Columbia, Vancouver, Canada. Walters received his B. S degree from Humboldt State College, and his M. S. and Ph. D. degrees from Colorado State University. He has worked at the University of British Columbia since 1969.

Dr. Walters is a specialist in fisheries stock assessment, adaptive management, and ecosystem modeling. He uses mathematical modeling and computer simulation techniques to better understand the dynamics of exploited marine ecosystems and to find more effective methods to manage them in the face of natural variability and high uncertainty. He advocates cooperative arrangements between governments and fishing industries to provide improved information for stock assessment and management via methods such as industry-based surveys. His main research work is on the theory of harvesting in natural resource management, with a primary interest in the basic problem of how to behave adaptively in the face of extreme uncertainty. He is one of the main developers of the ecosystem simulation program known as Ecosim, which is being used to test ideas about organization of trophic interactions in marine systems, and the implications of these interactions for sustainable harvesting theory.

He has written over 190 articles and three books, including *Adaptive Management of Renewable Resources (*MacMillan Publishing Company), and *Quantitative Fisheries Stock Assessment and Management (with Ray Hilborn,* Chapman-Hall Publishing Company), and *Fisheries Ecology and Management* (with Steve Martell, Princeton Univ. Press). He also serves on the Editorial Boards of a number of journals, including the *Canadian Journal of Fisheries and Aquatic Sciences, Conservation Ecology, Ecosystems, The Open Fish Science Journal,* and *Marine and Coastal Fisheries.*

Dr. Walters is a Fellow of the Royal Society of Canada (1998) and a Pew Fellow in Marine Conservation (2001). He was also the 2001-2001 Mote Eminent Scholar at Florida State University and the Mote Marine Laboratory. He has received the Volvo Environment Prize, American Fisheries Society Award of Excellence, Timothy Parsons Medal, and the Murray A. Newman Award.

Dr. Andrew Trites, Professor & Director Marine Mammal Research Unit, Fisheries Centre, University of British Columbia. Email: a.trites@fisheries.ubc.ca

Dr. Andrew Trites is a Professor and Director of the Marine Mammal Research Unit in the Fisheries Centre at the University of British Columbia, and is the Research Director for the North Pacific Universities Marine Mammal Research Consortium. He has served as a member of the US Steller Sea Lion Recovery Team, the Canadian Killer Whale Recovery Team, a voting member of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and co-chair of the Marine Mammal Specialist Group for COSEWIC.

Furthering the conservation and understanding of marine mammals, and resolving conflicts between people and marine mammals are central to Dr. Trites' research. His research involves captive studies, field studies and simulation models that range from single species to whole ecosystems.

He established the Marine Mammal Research Unit (MMRU) within the Fisheries Centre (Graduate Studies) to facilitate multi-disciplinary approaches for resolving issues pertaining to marine mammals. His approach has been to combine the talents of marine mammalogists, physiologists, ecologists, engineers, nutritionists, fisheries specialists and oceanographers to find innovative solutions to conservation-based problems. Some of the questions being asked and looked at include: Why are so many species of marine mammals declining in the Bering Sea and Gulf of Alaska while those in British Columbia are thriving, and what effect do the expanding fisheries around the world have on marine mammals? Attempts to resolve these sorts of issues have lead to collaborative studies with faculty and students from other departments at UBC, including: Zoology (Science); Food, Nutrition and Health (Agricultural Sciences); Electrical Engineering; and Chemical and Biological Engineering (Applied Science). At the same time, research clusters have developed and grown within MMRU specializing in nutrition, habitat mapping, ecosystem modeling, behavioral ecology, environmental physiology, dietary analysis, and population dynamics. The clusters involve a dynamic combination of graduate students, post doctoral fellows, technicians and research associates, whose interactions have resulted in world-leading research and academic discourse.

His own research program focuses on: 1) interactions between humans and marine mammals; 2) marine mammals as indicators of ecosystem change; and 3) the natural history and biology of marine mammals. Although his graduate training was in data analysis and simulation modeling, he has since expanded his areas of research to include a large captive research program based at the Vancouver Aquarium, an open ocean research lab in Port Moody housing free-swimming trained sea lions, and an expanding field program in Alaska and British Columbia.

Most of his research is focused on Steller sea lions, harbour seals, northern fur seals and killer whales. Primary areas of investigation with the captive sea lions we house at the Vancouver Aquarium include understanding their nutritional needs, the nutritional value of different types of prey, and seasonal changes in growth and energetics. These lines of research are addressing basic questions that are fundamental to resolving why seals and sea lions populations have drastically declined in Alaska. The animals are also enabling new field techniques to be developed, such as: remotely monitoring stomach temperature to determine when sea lions consume prey at sea, and measuring heart rate to estimate metabolic rates.

He believes strongly in conducting collaborative research within UBC and abroad. As such, he initiated the North Pacific Universities Marine Mammal Research Consortium with Dr. Peter Larkin in 1993. The Consortium is administered in Vancouver at UBC and includes the Universities of Alaska, British Columbia, Washington and Oregon State. It brings together the very best research talents from west coast universities to work together to resolve critical research problems pertaining to marine mammals.

The research program he is leading at UBC has been extremely successful at competing for funding and collaborating with the very best in the world. In a relatively short period of time, they have developed an international reputation for research excellence in the study of marine mammals. Their research-intensive and interdisciplinary approach sets them apart from most other groups and has established UBC as a world leader in their field.

APPENDIX 1.3: LETTERS OF SUPPORT

THE UNIVERSITY OF BRITISH COLUMBIA

Fisheries Centre
2202 Main Mall
Vancouver, BC Canada V6T 1Z4
Tel: 604-822-2731 Fax: 604-822-8934
Email: office@fisheries.ubc.ca
Website: www.fisheries.ubc.ca

October 21, 2009

Pacific Salmon Foundation
300-1682 West 7th Avenue,
Vancouver, BC V6J 4S6

To Dr. Brian Riddell,

On behalf of the Fisheries Centre at UBC, we would like to express our strong support for the Pacific Salmon Foundation's proposed Coho and Chinook program for the Strait of Georgia. This program is of great interest to the Fisheries Centre, which promotes multidisciplinary studies of aquatic ecosystems linked to broad-based collaboration with stakeholders and decision makers. The PSF proposal is multidisciplinary, well structured, and promotes collaboration, not only with other universities and government partners, but also with community groups and NGOs. The focused and novel approach to address declining Coho and Chinook populations at the ecosystem level is both timely and highly necessary.

The Fisheries Centre has a number of complementary programs and tools and we see excellent synergies that would allow us to meet our mutual objectives. Since our centre has been specifically designed for the type of program you are proposing, we are most interested in supporting the initiative. Specifically this includes the involvement of our research team, graduate students and researchers, access to our data and databases, computer visualization tools and meeting rooms, and potential office space for co-located PSF staff. While there are costs associated with the university's involvement, we are confident that a mutually acceptable arrangement can be worked out once a more detailed proposal is developed.

Thank you again for the opportunity to participate in this exciting initiative.

Yours sincerely,

Dr. Rashid Sumaila
Director, UBC Fisheries Centre
o) 604-822-0224
e-mail) r.sumaila@fisheries.ubc.ca

Fisheries and Oceans
Pêches et Océans

Pacific Biological Station
Nanaimo, B.C.
V9T 6N7

Your file Votre référence

Our file Notre référence

October 21st, 2009

Pacific Salmon Foundation
300-1682 West 7th Avenue
Vancouver BC V6J 4S6

To whom it may concern:

On behalf of the Science Sector for Fisheries and Oceans Canada (DFO) Pacific Region, I would like to express support for the Pacific Salmon Foundation's (PSF) proposal to explain changes in Chinook and Coho production in the Strait of Georgia. I have personally been consulted in the development of this proposal and I concur with the project's overall goals and direction. In fact, the central questions have puzzled us for over 20 years without, until now, any real opportunity for resolution.

This project complements other work conducted by DFO in the Strait of Georgia, such as our "Ecosystem Research Initiative" initiated in 2008. A central question of this project is what controls the productivity of the Strait of Georgia. However, the focus is spread across all species and the salmon work is necessarily limited.

I anticipate that DFO staff will be engaged in portions of the PSF's work and their salaries will form an in-kind contribution. The level of DFO involvement will depend, in part, on how closely the final project design matches DFO's priorities and the ability of key staff to commit time to the project.

Sincerely,

L Richards

Dr. Laura Richards
Regional Director Science
Pacific Region

Canada

Brian

Fisheries and Oceans
Pêches et Océans

Regional Director General
Pacific Region
Suite 200 - 401 Burrard Street
Vancouver, B.C.
V6C 3S4

Directeur général régional
Région du Pacifique
Pièce 200 - 401 rue Burrard
Vancouver (C.-B.)
V6C 3S4

Your file Votre référence

Our file Notre référence

OCT 2 3 2009

To whom it may concern,

On behalf of Fisheries and Oceans Canada (DFO) Pacific Region, I would like to express support for the Pacific Salmon Foundation proposal to address limits to production of Chinook and Coho salmon in the Strait of Georgia. I support the project's overall goals and direction. My letter of support complements a similar letter provided by our region's Science Director.

As noted in Laura Richard's letter this project complements other work conducted by DFO in the Strait of Georgia, such as our "Ecosystem Research Initiative," initiated in 2008. A central question of this project is what controls the productivity of the Strait of Georgia.

Our department has a strong relationship with the Pacific Salmon Foundation and I anticipate that DFO staff will be engaged in portions of the PSF's work. Their salaries will form an in-kind contribution. The level of DFO involvement will depend, in part, on how closely the final project design matches DFO's priorities and the ability of key staff to commit time to the project.

Support for this work will allow a full examination of the relevant issues concerning Chinook and Coho in the Strait of Georgia, from which we can all benefit.

Sincerely,

Paul Sprout
Regional Director-General
Pacific Region

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OCT 2 7 2009
PSF

Canada

October 26, 2009

Brian E. Riddell PhD.
CEO/President, Pacific Salmon Foundation,
300-1682 West 7th Avenue,
Vancouver, BC V6J 4S6

Dear Dr. Riddell:

RE: Nature Conservancy of Canada support for the Pacific Salmon Foundation's proposal to address the limits to production of Chinook and Coho salmon in the Strait of Georgia.

I am writing in regards to the proposal by the Pacific Salmon Foundation (PSF) to address the limits to production of Chinook and Coho salmon in the Strait of Georgia and to determine whether there are ways to mitigate effects and restore production. This is a very exciting proposal and our organization looks forward to offering our full support to the PSF and becoming an active partner.

Nature Conservancy of Canada (NCC) is Canada's largest, private non-profit organization working for the direct protection, conservation and restoration of our natural heritage across the country. Since 1962, NCC has protected and undertaken stewardship programs on over 800,000 hectares of ecologically significant lands and water, a quarter of this in British Columbia.

The British Columbia Region of NCC has been actively engaged in marine conservation and salmon restoration through our Science and Planning, Securement, and Stewardship programs. We have completed large scale Ecoregional Assessments encompassing all of BC's coastal waters, and specific Natural Area Conservation Plans for the Haida Gwaii, Central Coast Rainforest, Discovery Pass and Cowichan Valley areas. An additional plan for the Salish Sea region will be completed by February 2010. These plans highlight the critical threats to terrestrial, freshwater and marine ecosystems and identify the actions necessary to conserve prioritized ecosystem components and associated species.

NCC's first BC project was the 1974 acquisition and subsequent restoration of the ecologically rich Mud Bay inter-tidal lands in the Lower Mainland's Boundary Bay area. More recently beginning in 2000, NCC-BC has led a partnership in the Campbell River estuary which has acquired former industrial sites and associated inter-tidal areas and restored them to their former productivity for the benefit of salmon and other wildlife. We are now beginning discussions with potential partners to develop an expanded program to acquire and restore degraded riparian, inter-tidal and sub-tidal lands and will be seeking support for this program from potential partners in the near future.

Nature Conservancy of Canada - British Columbia Region
200 – 825 Broughton Street, Victoria, BC V8W 1E5
Telephone: (250) 479-3191 • Toll Free: 1-888-404-8428 • Fax: (250) 479-0546
Email: bcoffice@natureconservancy.ca • Website: www.natureconservancy.ca/bc

Consistent with our discussions, NCC agrees that our respective program objectives and proposed actions are quite compatible and mutually reinforcing. We would envision making available to the PSF all of the data from our Ecoregional Assessments and Natural Area Conservation Plans, as well as the monitoring information from our restoration activities in the Campbell River estuary. We would like to work with the PSF through your program proposal in assessing the value and effectiveness of restoring inter-tidal and sub-tidal lands to restore salmon populations. We also envision working with you to identify other priority sites for restoration activities to assist in recovering the Georgia Basin's Chinook and Coho.

Please contact me directly should you require further information on the work of NCC in BC and our support for your Foundation's proposal.

Thank-you

Jamie Alley

Jamie Alley,
Regional Vice President for BC
Nature Conservancy of Canada

VANCOUVER ISLAND
UNIVERSITY
Office of the President

October 27, 2009

Brian E. Riddell, Ph.D.
CEO/President, Pacific Salmon Foundation
300-1682 West 7th Avenue
Vancouver, BC V6J 4S6

Dear Dr. Riddell:

We at Vancouver Island University (VIU) are most excited by the news of your plans to explore salmon ecology in the Strait of Georgia through the mounting of a large, interdisciplinary research program. The Strait of Georgia, that most important body of water on both of our doorsteps, is of great significance to us, and we would be most pleased to support your study in any way that we can. We have already had preliminary discussions on how we might build broader relationships between VIU and the PSF, and this research program may be an excellent vehicle to pursue these further. At the ground level, your proposed study fits well with a number of initiatives that we have underway at VIU, and there may be many points of useful intersection between VIU with your research program.

As you know from your several years of co-teaching a fisheries course at VIU, we have a long standing interest in salmon biology and management, subjects with a high profile in several of our teaching areas, for example the Fisheries and Aquaculture Program. The latter program operates a small salmon hatchery just outside of Nanaimo, and staff and students have been collecting coho data there for 25 years. The construction of the Deep Bay Field Station, a branch of our Centre for Shellfish Research (CSR), may provide one set of opportunities to work with you. The Deep Bay Station will be the staging facility for a long term VIU study of Baynes Sound including oceanography, biology and shellfish ecology. Some of the studies that we plan in Baynes Sound could be complementary to your larger program, and the Field Station itself, which will be completed next summer, could be used by your researchers when they are in this part of the Strait of Georgia.

On campus we have several other facilities that might be of use. These include our Analytical Environmental Research Laboratory which is developing sophisticated real-time chemical analyses of air and water, the

. . . 2

CSR's main building which now has two operating laboratories, one for environmental studies and one for genomics. The CSR has a staff of 12 people and is building research capacity in several areas. The new International Center for Sturgeon studies, under construction, will house a modern fish physiology laboratory ideal for work with salmonids. Our Institute for Coastal Research (ICR) takes an interdisciplinary approach to coastal issues, especially those associated with renewable resources including both fisheries and aquaculture. The ICR is staffed with a Canada Research Chair, a Director and a growing number of graduate students and post doctoral fellows.

In addition to facilities and researchers at the research centres, there are many VIU faculty members who would find your Strait of Georgia program a great opportunity for collaborative work. Faculty at VIU have a long standing tradition of including undergraduate students in research wherever possible. Many of our students have participated in research at the DFO Pacific Biological Station and many would certainly be keen to assist your scientists in the field and laboratory as a part of their VIU education.

The proposed Pacific Salmon Foundation's study of the Strait of Georgia and its salmon populations is timely and of great importance to BC's coastal communities. It meshes well with many Vancouver Island University activities, and we would welcome further discussions on how we might help the PSF with its work and also how we might develop closer ties with your organization.

Sincerely,

Ralph Nilson

Ralph Nilson, Ph.D.
President & Vice-Chancellor

RN:bp

Georgia Strait Alliance

"Caring for our Coastal Waters" www.GeorgiaStrait.org

October 27, 2009

To Whom It May Concern:

RE: Letter of Support for research efforts in the Strait of Georgia

I am writing this letter in support of the Pacific Salmon Foundation's research efforts to better understand and find relief for the complex pressures being put on salmon stocks in the Strait of Georgia.

Georgia Strait Alliance (GSA) has been at the forefront of efforts to protect the Strait of Georgia and its adjoining waters for nearly 20 years, through initiatives such as our campaign to transition open net cage fish farms to closed containment technologies, our efforts to get better legal protection for the southern resident orca and our various Best Practices programs, including Stewards of the Strait, and our Guide to Green Boating. We have also worked to help eliminate toxic chemicals from homes and workplaces, and we work with a variety of organizations and local governments to ensure that British Columbians have a healthy marine environment.

The Strait of Georgia is one of the most at risk natural environments in Canada. Ten years ago, a group of US and Canadian scientists declared that we have less than a lifetime to save this beautiful inland sea. Protecting and better understanding the Strait is necessary since no other place across all of Canada supports this kind of diversity of wildlife. The Strait is teeming with thousands of species, including salmon, and its abundance stems largely from habitat in which fresh water mixes with salt.

There are many stresses on the Strait and its salmon, including pollution from land-based sources such as wastewater and agricultural run-off, as well as on water sources, such as ships and boats. We also know that there are other threats to salmon, including open net cage salmon farms, and the ecological changes that are occurring due to climate change.

Better understanding of the processes that occur in the Strait, its biological productivity and how salmon survive once they enter the marine environment is very important to furthering our understanding of why our salmon stocks are in trouble. This knowledge will also help us better understand how the threats listed above are affecting these natural processes and the survival of our wild salmon. However, time is of the essence and all research must be directed to furthering solutions as well as understanding. We do not have the luxury of time for continued study of problems without action to alleviate them.

We offer our support to the Pacific Salmon Foundation and look forward to being part of the conversation that leads to a healthier Strait of Georgia.

Sincerely,

C. Wilhelmson

Christianne Wilhelmson
Managing Director

MAIN OFFICE *membership–correspondence*
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Ph: (250) 753-3459 Fax: (250) 753-2567
gsa@GeorgiaStrait.org

VANCOUVER OFFICE
Suite 607 – 207 W. Hastings St.
Vancouver, BC V6B 1H7
Ph: (604) 633-0530

APPENDIX 1.4: B.C.'S OCEAN & COASTAL STRATEGY

BC'S OCEAN & COASTAL STRATEGY: AN OVERVIEW

Background

The Ministry of Environment is working with staff across the provincial government to build a new ocean and coastal strategy for BC. The strategy will help to focus BC government actions and provide opportunities for maritime stakeholders where it adds value in achieving the following objectives:

- ✓ More and better jobs supported by knowledge, skills, and innovation;
- ✓ Delivering high-quality products and services to world markets;
- ✓ Maintaining and improving the health of the marine environment through ecosystem-based management;
- ✓ Adapting to the impacts of climate change on coastal communities and ecological values; and
- ✓ Collaborating with neighbouring jurisdictions to achieve common ecological, social, and economic goals.

Issues & Opportunities

The BC government's vision for ocean and coastal areas needs to address the following immediate issues and reduce the potential for missed opportunities:

1) *Opportunities for economic development.* Ocean-related economic activities currently contribute $11 billion in GDP and employ 170,000 people in BC, with the potential to more than double their output in less than a decade.
2) *Need for marine fisheries reform.* BC's seafood and saltwater angling industries account for nearly one-fifth of the total ocean economy, but commercial fisheries are failing to meet their economic potential.
3) *Concerns about ocean health.* There is broad support for protecting the health of our ocean and environmental indicators suggest that some concerns may be warranted.
4) *Hardship in coastal communities.* Coastal communities north of Campbell River are facing amongst the worst economic hardship in the province, with climate change adding to their uncertain futures.

Actions & Outcomes

Four Action Plans are now being developed to address each of the key issues and opportunities identified above. These plans will centre around:

BC'S OCEAN & COASTAL STRATEGY: AN OVERVIEW

1) *Growing and greening our ocean and coastal economy by making smart investments in people, technology, and innovation.* Proposed actions will contribute to:
   - Increased economic output from the ocean and coastal zone;
   - Increased employment in the ocean and coastal economy;
   - Reduced out-migration from rural coastal communities; and
   - Increased proportion of energy supply from renewable, clean sources.
2) *Ensuring that BC's marine fisheries are well-managed, sustainable, and remain a significant part of coastal British Columbian economies.* Proposed actions will contribute to:
   - Maintained or increased BC share of the global seafood market;
   - Increased public support for BC's marine fisheries;
   - Increased value of harvested fish;
   - Increased First Nations participation and economic opportunities in BC fisheries; and
   - Increased federal government investment in West Coast fisheries.
3) *Protecting the health of our ocean and the benefits it provides.* Proposed actions will contribute to:
   - Maintained ecosystem services, structure, and function, thereby reducing the potential impacts of hazards (e.g. sea level rise, flooding, erosion, coastal storms) on coastal communities;
   - Maintained biological diversity;
   - Improved marine water quality leading to safer, cleaner beaches and healthier seafood;
   - Increased institutional capacity to respond and adapt to climate change; and
   - Improved public support for government's approach to managing the ocean and coastal environment.
4) *Creating a foundation for health and prosperity in our coastal communities by planning collaboratively for the future.* Proposed actions will contribute to:
   - More timely and efficient review of development proposals;
   - Increased awareness about, and ability to respond to, regional and community level issues and concerns;
   - Improved capacity to involve local residents in decision-making;
   - Increased health and safety of coastal British Columbians;
   - Reduced risk of flood damage due to coastal storm surges, minimizing local government and private requests for disaster financial assistance; and
   - Coastal communities that are more resilient to sea level rise and severe coastal storms.

APPENDIX 2

APPENDIX 2.1: KEY FINDINGS FROM SCIENCE MEETING, APRIL POINT, JULY 2009, AND COMMUNITY ROUNDTABLE MEETINGS, AUGUST & SEPTEMBER 2009.

APPENDIX 2.2: COMMUNITY PROGRAMS

APPENDIX 2.3: DESCRIPTIONS OF TECHNOLOGY

PACIFIC SALMON FOUNDATION

Appendix 2.1: Key Findings from Science Meeting, April Point, July 2009, and Community Roundtable Meetings, August & September 2009.

<u>Key Findings from Science Meeting April Point July 9-10 2009</u>

Question 1: What are the key issues impacting Coho and Chinook survival in the Strait of Georgia?

1.“Carrying Capacity” ... Has it changed and, if so, why?

a. Changes in ecosystem components?
b. Impacts of estuary health on salmon survival?

2. Hatchery-related issues ... included interactions with wild fish, evidence of disease/stress in hatchery fish, loss of genetic diversity, and current management strategies.

3. Causes of early marine mortality (related to 1. above):

a. Predation rates & what are the predators?
b. Examine health & condition of wild fish.
c. Marine distribution by life stage.

4. Human development / activities ... Impacts on estuaries and foreshores, water quality and quantity, contaminants, etc.

5. Is there an adequate assessment capability for key species (not just salmon)?

Question 2: Given unlimited resources, what strategies and approaches could you use to address your key questions? Feel free to think outside the box! Does your strategy have a high probability of effectively answering those questions? What possible results and deliverables might you expect, and what would be the logical next steps?

1. Data collation and retrospective analysis for species within SoG.
2. Collection of knowledge from communities and establish a community network.
3. Hatchery manipulations ... Examine adequacy of current marking programs.
4. Mortality studies ... Predation, fish health and genomics, water quality, etc.
5. Pacific Ocean Shelf Tracking (POST) applications. Studies MUST include assessment of tagging related mortality.
6. Review of assessment processes for wild populations (Key indicators ... how to measure change?)
7. Marine biological surveys ... New synoptic surveys for lower trophic levels, systematic surveys for juvenile salmon, application of new genomic tools.
8. Estuary and near-shore restoration ... “experimental estuaries”?

Question 3: Given the key questions and some of the strategies suggested during Thursday's discussions, examine linkages among your groups that could be exploited to more effectively answer those questions. Can you group put together an applied, practical and interdisciplinary approach?

- Set up a virtual Strait of Georgia Institute?
- Space at IOS, CAHS, VIU?
- Vessels
  - Canfisco vessels- underutilized fishing vessels available for certain periods of year (Dave Morris).
  - VIU CSR has new vessel designed for beach landings (& ATV) (Duane Barker).
  - SFU has C.J. Walters – expensive?
  - Dick Carson - boat available, also CHS seabed mapping.
  - Ricker? Dick and Mark have approx ½ time available on Ricker.

- Other Equipment
  - Courtenay MoE has ROV and 12' inflatable (Art Tautz).
  - Gary Borstad suggested float planes make for a good stable sampling platform.

- Data
  - Mark Trudel noted that there is a database of archival data from plankton sampling in SOG available from Dave Mackas.
  - John Dower mentioned data from samplers attached on BC ferries- apparently can download data directly to a cell phone. Questioned need for one on more northern routes e.g. Powell River ferry.
  - Colin Levings wondered about whether there is any data for bird predation from Doug Bertram etc.
  - Need to determine data mining occurring under DFO's Strait of Georgia ERI and the Sea Before Us initiatives.

- Linkages with other programs/initiatives
  - Ian Perry noted the linkages between this program and the Sea Before Us program at UBC.
  - Al Lill discussed Living Rivers interest in freshwater inputs and estuarine assessment and restoration, kelp bed research, concern about minimum flows in face of climate change. Feels that there is likely little capacity from them in terms of participation in meetings, but sees synergy and hopes that their partners may assist in this program.
  - Brian Riddell suggested we connect with Ducks Unlimited.

- Linkages with other programs/initiatives (contd.)
  - Tony Farrell discussed his NSERC funding coming up. He wants a permanent array on Fraser River. His program has focused on adults only but the new program (under negotiation) would examine smolts too. He could lend expertise regarding individual performance approach (screening hatchery releases, pit tagging, examining survivors etc).

- Kristi Miller-Saunders has $2.3mill from Genomics BC (focus is ¼on adults, ¾ on smolts) for 3 yr program- sampling coho this year, chinook next year, which dovetails well into this program, but wants to beef up early sampling of young fish entering ocean and may look for supplementary funding from us for experimental manipulation work as her $ are for surveys only. E.g. starve fish and find signature for starvation, then use this as a way to perform more controlled searches of the health of young coho and chinook.

- Community support
  - First Nations support important for hatchery manipulations (Sonja Saksida).
  - Duane Barker (VIU) stated that there would be a lot of student interest and possible involvement.
  - Al Lill discussed 1st Nations Legacy involvement in his program and suggested we need something similar- we should look to Cowichan chinook for partnering.
  - Ruby Berry said GSA would assist us in the community networking component.
  - Dick Carson said there are 19 bands and tribal councils in Gulf Islands area- maybe they can bring in some support.
  - PSF space on the naturalist boards on B.C. ferries.

- Other questions/issues
  - Gary Borstad asked who owns equipment that is bought? Brian suggested it would remain with the researcher that had used it.
  - Carol Cross said there is not the capacity in SEP for analysis, study design, and that we would need a communication strategy with hatcheries.
  - Art Tautz asked about data sharing agreements, data management and communication, Brian suggested that PSF should house it.
  - Mark Saunders discussed linkages with DFO and WSP conservation units, freshwater adaptive zones etc.
  - Al Lill asked whether there will be an overarching governance structure.

<u>Duncan Community Meeting. Duncan Travelodge. August 19 2009 7-9pm</u>

Meeting attended by approximately 60 people. Brian spoke first, followed by Nikki Wright, Seagrass Conservation Society, and Paul Rickard (representing recreational fishermen).

Nikki Wright discussed the 27 coastal community groups involved in mapping eelgrass, as well as forage fish spawning sites, and kelp distribution. Mapping is done first so that we can understand what has been lost/ current coverage, followed by restoration work. Discussed replanting of eelgrass and kelp culture. Paul Rickard discussed the Cowichan Chinook rebuilding strategy and the importance of the partnership role with this marine project for moving forward.

Key comments: Much of the discussion focused on water quality and water flows.

Itemized list of points noted:

1) Why do we not use a conservation stamp on salmon, allowing for increased value of the resource?

2) What are the geographic boundaries for the study, given that salmon move out of the Strait? What are the changes in salmon distribution over time? The lack of the blueback fishery came up, and the differences between "in" and "out" years were questioned.

3) Concerns about low water levels for Cowichan Chinook, as well as water pollution and sewage issues. Others asked about the differences in water temperatures between Puget Sound and the SOG. What is the relationship between nearshore morbidity and contaminants, and what are we doing about this? Within this general theme, there were concerns about the transformation of wetlands, and increase in impervious hard surfaces, leading to increased freshwater runoff into the Strait. The decreased salinity apparently affects distribution of bull kelp. Other thoughts were that there is increased turbidity in the Strait (possibly as a result of increased water temperatures)- this was apparently not seen 30 years ago. The fact that pink and chums are less dependent on freshwater habitat was also brought up for discussion.

4) Concerns about the catches in Alaska.

5) Gravel removal e.g. from Fraser River brought up as an issue.

6) Fish farm impacts/sea lice issues brought up for discussion.

7) Some discussion regarding the lack of food resources for smolts. Possible overfishing of herring brought up. Did we overfish herring such that the fishery collapsed, effecting a loss of resident herring and creation of migratory herring stocks? What are the diet differences between pink and chum, and coho and Chinook?

8) Brian was asked whether there is any plan for restoration of the Strait? That this work to restore salmon should be done from the ground, involving community groups and the army of volunteers that are a huge resource out there to do this kind of work. The main problems are a lack of communication structure and funding for these community groups.

9) Hatchery issues came up- are we producing too many hatchery juveniles?

10) Other people noted that we need to think about seal abundance, effects of global warming, effects of log booms destroying eelgrass etc

Nanaimo Community Meeting. Oliver Woods. August 20 2009 7-9pm

Meeting attended by approximately 35 people. Brian spoke first, followed by Diane Sampson and Ken Kirkby, both of the Nile Creek Enhancement Society.

Diane discussed work they are doing together with Nikki Wright's group and Vancouver Island University students to map eelgrass beds. They have noted eelgrass losses in areas where cleaning of rafts occurs at oyster farms. Ken discussed changes noted over time at Nile Creek, including the sudden collapse of pinks, losses of kelp beds (due to green sea urchins and kelp harvesting licences), and their success in restoring these beds, with the assistance of Louie Druehl, and the partnership of Island Scallops Ltd. He emphasized the need to have community support for success of projects such as this.

Discussion of kelp followed: Were losses also attributable to changes in salinity, and could this account for spatial changes in kelp coverage (ie losses did not occur in the exits to the Strait and Juan de Fuca where freshwater inputs were lower as compared to the centre of the Strait). Could the present success of kelp be due to recent increases in salinity? We should also monitor the areas of the Strait where no rehabilitation has been done and see what happens naturally.

Itemized list of points noted:

1) Seal population density came up as a concern e.g. at the Nanaimo estuary, where seals are at high abundance and feeding on coho and Chinook jacks that are feeding on herring.

2) Presence of Dolly Varden noted in the Nanaimo estuary- apparently these were not present in the 1980s. (These are predators of coho smolts as they head out to sea).

3) Concerns about lack of assessment data for different systems, and lack of clarity of how DFO makes the rules and regulations regarding openings given incomplete data.

4) Someone noted that increased numbers of white-sided dolphins occurred in the 1980s, at the same time as coho declined, and that they are present in the spring, at the time when people used to see bluebacks. He suggested that there might be several thousand in the Strait, but DFO staff noted that they had not seen these kind of numbers despite regular research cruises in the Strait.

5) Fish farms and the Run of the River operations both came up in discussion.

6) The hatchery percentage and decline in size of coho brought up in discussion. Are hatcheries really making a difference to production? We brought up idea of using a new hatchery for research only to address some of the pertinent questions regarding hatchery release timing, interactions with wild fish etc.

7) Water pollution/sewage issue brought up- the fact that there is no treatment for sewage in Victoria, and only partial secondary treatment in Nanaimo. The orca is apparently the most toxic animal on earth now.

8) Need for improvement in stock assessment for small and medium streams discussed. These size streams are very important for coho yet we know little about them due to funding cuts.

9) Need to also consider steelhead was discussed, as steelhead collapsed at the same time as coho and Chinook. These fish leave Queen Charlotte Sound area very quickly and the problem also appears to be marine, as there have not been huge differences in freshwater survival. The

change in overall survival has apparently happened too quickly to be a survival problem due to feeding, and is more likely something like predation. It was noted that stocks that migrate quickly out of the Strait tend to do better than local area resident stocks that remain within the SOG. POST arrays have not been able to pick up any potential predators however. Is this a SOG problem during the first summer, or a West Coast of Vancouver Island for the first winter? One idea was to use listening devices in the seal haulout areas to assess their role in this. Assessment of seal scat could be done, but the problem here is that you would not be able to tell the number or size of the fish that had been consumed.

10) Sea lice issue was questioned.

11) What about euphausiids and copepods? These apparently have been far less visible on the water than in the past.

12) Need for more adequate marking of hatchery fish discussed.

Campbell River Community Meeting. Maritime Heritage Centre. September 2 2009 7-9pm

Meeting attended by approximately 50-60 people. Brian spoke first and then opened up the floor for comments. Meeting was energetic and many members of the public gave commentary.

Key comments: Much of the discussion focused on lack of feed for salmon smolts, including concerns with respect to overfishing of herring. Others suggested that we need to step back and focus on the loss of kelp (as a result of warming temperatures, pollutants etc) which is an important nursery area for herring. We need to locate the 1972 report on herring spawn areas and eelgrass beds- will give a good historical perspective. Brian used the term “indicator” for kelp and eelgrass, so one person asked whether there are any measurements of the fertility or chemistry of the waters of the SOG, and whether this was changing due to climate change.

Itemized list of points noted:

1) Discussion of warming of Strait- suggestion of coastal variation, and that some areas in the Northern Strait have possibly cooled.

2) Question as to the potential role of local government, and the extent of municipal boundaries.

3) Water quality mentioned at this meeting- the Strait is “sick” and that issues such as enforcing seals on cruise liners coming into the SOG should be addressed. Concerns with respect to pulp mill effluents and fish farming effects on water quality. One suggestion was that we could look at cores for depositions in estuaries and major rivers.

4) Discussion of krill, kelp, herring and urchin fisheries- and the suggestion that SOG should be a sports fishery centre. Sports fishermen noted that herring are in dire situation up in this region (as well as the birds diving for them) and suggested that overfishing and overharvesting of bait

for salmon is likely a major culprit in the depletion of the salmon stocks. Some discussion that changes in abundance and distribution of bait may be related to changes in distribution of salmon both spatially and by depth within the Strait, as well as changes outside of the Strait. Discussion of krill taken for feed for fish farms and whether it could be farmed. We noted the take of krill from the SOG to be minimal.

5) Again, the lack of a blueback fishery was discussed.

6) Another observation was the loss of crab spawn- used to be seen in a long line from Fransisco Point to Mitlenatch Island, at the time that coho fishing was strong. We noted that this is a major food source for coho.

7) Alaskan salmon catches also came up again- the suggestion given was that observers should be placed on Alaskan fleets, and work done to determine exactly where the fish caught on those vessels came from. Someone noted that the Alaskan fishery is good at ranching salmon and asked what they are doing that is different to in BC. Brian noted that they are not doing anything differently, we are simply not getting the productivity.

8) Some discussion on “where do coho go”. Brian noted that the distribution of Canadian fish is quite well known, with most northern coho found in Hecate Strait, mostly ending up north of Vancouver Island, on WCVI and very few in Alaska. He noted that many more used to stay within the Strait, but that this behaviour changed in the mid 1990s.

9) Another observation was that bivalve aquaculture has increased significantly in the Strait, and the question was whether anyone is looking at the impact of removal of phytoplankton and zooplankton, particularly in local nursery areas for salmon such as the Gulf Islands.

10) The potential impact of fish farms and sea lice was discussed, as well as the usage of SLICE.

11) Questions as to how effective is estuary restoration- someone noted that we should discuss this with Shannon Anderson.

12) Another topic was the extent of the ISA virus, which has been seen in chum.

13) Several people discussed the importance of traditional ecological knowledge (TEK).

14) Greed of humans pinpointed as the major cause, and the need for involving communities living on the water, and contracting out to experts that are not government employees and establishment of an independent panel. Same individual suggested a 10 year moratorium on all fishing for coho and Chinook in those areas that they have disappeared.

Notes from West Vancouver meeting, West Van Community Centre, Sept 8, 2009

Key comments: Very strong belief from participants that open-net pen salmon are the cause of many problems and that they should be required to use closed-containment. Frequent reference to a recent Ford and Myers paper (I will look up to be certain of a "recent" paper that I am not aware of).

Itemized list of points noted:

1) Open-net cage salmon farming are the problem and have caused many of the problems.

2) Are there foreign species in the Strait that have disrupted the ecosystem? Reply was no, but another person then noted White-sided dolphins. Dick then extended discussion to seals and hake.

3) "We have been messing with Mother Nature ..." primary concern was salmon farming but also noted pollution and extensive disruption of habitats (steams and near-shore marine)

4) Study should ensure it also considers Steelhead since they are part of the Strait's ecosystem.

5) Are fish staying in the Straits? We replied that coho and Chinook are not to the extent that they used to. Discussion then focused on loss of prey species and what are the causes of that.

6) Are researchers using new technologies in tags (actually was referring to archival tags)? Response was yes but that the size and duration of battery life has limited applications to some species and life stages. We indicated that PIT and POST tags have been included in discussions to date.

7) Christianne (SoG Alliance) noted that we needed to consider two major factors: climate change and water management, and the cumulative effect of pollutants.

8) "'Body burden of pollutants" in Chinook and coho salmon supports the risk from cumulative effects and has ripple effect to other species such as Killer Whales.

9) Must investigate the physiological state of natural fishes ... are fish entering the Strait capable of survival or are they compromised by warmer temperatures, stress from pollutants, etc. Lead to a discussion of genomics research etc.

10) Need to consider spawning habitats for smaller food species ... sandlance, needlefish, eulachon, and herring. Major loss of bait fish evident in Strait over past decade. Noted work of Ramona deGraf and their work on mapping the spawning areas for these species.

11) PSF should take on role to monitor the recommendations of the BCPSF ... comment targeted at salmon farming recommendations.

12) Project developers should communicate with local politicians at the municipal and regional levels to ensure they understand the impacts of developers etc.

Notes from Sechelt Public meeting, Sechelt Arts Centre, September 9, 2009

Key comments: This meeting was much more of a dialogue with participants directing numerous questions about salmon biology and what the real intent of the "funding" from private individuals was. The discussion carried on late into the evening after the meeting.

1) Mating protocols in the major hatcheries are wrong and reducing fitness of these fish. Strong comment from members of the Chapman Creek Enhancement program.

2) The study should ensure it considers "full watershed assessments" that track all stages of the salmon's life. Impacts many not be in the Strait and you can not determine that without this scope in your study. ... lead to short discussion about studying key indicator watersheds (of course in their area)

3) Extensive eelgrass and kelp along Sechelt. This opens nearshore area to more extensive bird predation (I believe this is the first comment on birds).

4) What is the status of local watersheds ... concern for extensive siltation of lower river/stream sections with the loss of spawning areas for pink and chum salmon. Example of ... have to check on name of stream.

5) Should conduct restoration of numerous small streams that have been impacted by logging. Examples in Area 28 (Howe Sound): Rainy River, McNabb Creek, and McNair.

6) Based on diving observations, noted extensive loss of dogfish in the local areas. Used to be extensive but now none. What has happened elsewhere?

7) Local losses of herring may lead to changes in diets of salmon including cannibalism. Commented that they had observed salmon as food in other salmon.

8) What is the current population size of seals in the Strait and what is their impact on salmon? We noted that this has come up frequently and would likely be included in the project.

9) Must consider fish health issues in the major hatcheries and the use of antibiotics before their release to saltwater. Noted that hatchery fish from the major facilities were unfit physiologically due to fat content and possibly as carriers of disease.

10) Should institute a total moratorium on fishing in the Strait (develop a full area MPA) ... better than more studies and do it short term to examine effect.

Notes from Powell River public meeting, P.R. Recreation Centre, Sept. 10, 2009

Key comments: Much smaller meeting (likely related to later afternoon meeting) and discussion dominated by a few people.

1) Concern that Myrtle Creek project not supported by PSF but that they had done extensive work to protect the biodiversity of fish in that creek. (BR committed to investigate reasons and reply).

2) Very long comment that involved several topics:

a) loss of forage fish and forage fish habitats is major impact

b) near-shore development is an issue

c) loss of local herring spawning has effects on local food sources for salmon

d) need improved survey and mapping of eelgrass beds

e) noted C Walter`s comment at SoS Conference on seal impacts. What are impacts of seals and how well is that known. He noted observations of predation and salmon avoidance of seals in low water periods in late summer and early fall.

3) Use of POST system. Should use local enhancement systems around Powell River to apply tags and expand monitoring arrays, particularly in mouths of local inlets.

4) PSF does not support work of ``for profit organizations``. Will there be opportunities in this project for proposals that are submitted for support?

5) What is the impact of fish farms versus ocean-ranching in Alaska? Is there a role for ocean fertilization in the Strait? Why is Alaska producing so many fish and we are not ... related to salmon farming?

6) Should establish a Strait of Georgia marine park with no commercial fishing, keep recreational fishing, and allow First Nation FSC.

7) Need for extensive gravel restoration in local streams ... particularly in Jervis Inlet (Theodosia River). Develop local restoration programs based on local brood stocks that remain.

8) Personal observations that 1980`s was period when bull kelp disappeared in Davis Bay and there was over-fishing of herring, and salmon farms began in this time period (extensive around that region). In the 1990`s there was a continuous decline in salmon catches locally.

9) Should investigate development of artificial reefs to restore large kelps beds ... successful in Japan.

10) What has been the impact of localized losses of herring throughout the Strait of Georgia? This has been widespread. Is there any opportunity to actually restore localized spawning populations by moving herring within the Straits?

APPENDIX 2.2: COMMUNITY PROGRAMS

Background Information for Seagrass Conservation Society

I. Introduction

> "The discipline of restoration ecology aims to provide a scientifically sound basis for the reconstruction of degraded or destroyed ecosystems, and to produce self-supporting systems that are, to some degree, resilient to subsequent damage." (1)

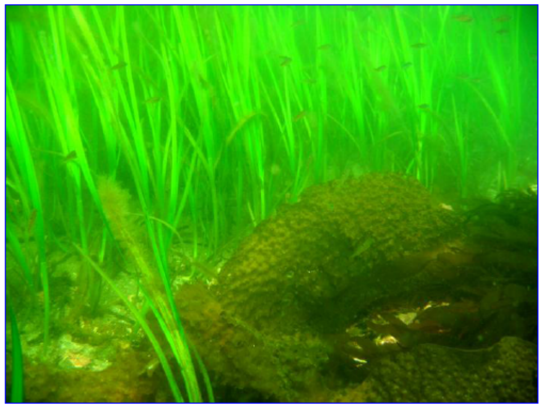
In recent years, there has been a burgeoning interest in what lives in estuaries in British Columbia by those who live, work or play on or near marine waters. Estuaries attract attention for the opportunities they offer to bird watchers and kayakers alike; recreational boaters find respite from the impetuous winds of the open coast; school children wait on the shore to watch the incoming spawning salmon they released as fry the previous year. Over the last two decades, the values of these estuaries to marine wildlife and people have been well documented. (2)

However, there is a paucity of information on the state of health of these rich and biologically diverse ecological resources. Locations of eelgrass beds, for example, from the large flat meadows of the Campbell River estuary to the narrow fringe beds of the Sunshine Coast, have been documented just recently. We may very well be losing much of this valuable habitat before we have a full understanding of its density and distribution.

One thousand volunteers mapped 12,000 hectares of eelgrass habitat since 2002. As these volunteers made use of their GPS units and quadrats to pinpoint the locations and densities of these beds, they realized there were many areas where the plants should be, and weren't. Thus began the movement to bring back these beds to self-supporting systems.

An argument will be made that coastal community groups, who themselves have great resilience, are in a prime position to take on more of a responsibility for locating, assessing and assisting with transplanting lost or damaged eelgrass beds as a net gain in salmonid and other marine species habitats.

In the marine environment, eelgrass beds (*Zostera marina*) function as wildlife corridors for a large array of fish, bird and invertebrate populations. They have been described as "salmon highways", providing respite from strong ocean currents and unrelenting predators, and as nutrient rich nurseries for young marine organisms. Across the globe, seagrass meadows cover about 177,000 square kilometers of coastal waters – larger than the combined area of the Maritime provinces. (3)



A healthy eelgrass meadow Photo: S. Jeffery

II. History of Eelgrass Transplants

In the Pacific Northwest, the history of success for *Zostera marina* transplanting projects was dismal prior to 1985. Initially transplant techniques were used that were developed and successful on the Atlantic coast. However, these techniques were not well suited to the Pacific north coast environment and eelgrass. Many of the early transplants were conducted without a thorough understanding of eelgrass physiology and ecology; the donor stock was not always well suited to the area where they were transplanted, and the biophysical conditions of the transplant site were not always appropriate for the species. (4)

Ron Thom of the Battelle Research Centre in Squim, Washington collected the results of mitigation projects completed from San Francisco Bay through British Columbia from 1974-1990. (5) Total documented plot sizes ranged from 0.1 m^2 to 11,000 m^2. Transplanting methods included plugs of various sizes, individual shoots that were anchored or planted directly into the substrate, and bundles of shoots (planting units).

The most commonly used standard for monitoring the beds was shoot density, which measured plug, shoot or bundle survival. Percentage cover was also used in some cases to indicate the area of substrate covered by the plants. Duration of the monitoring varied widely from a few months to five years. More than half of the 17 projects either failed completely or were only marginally successful. (6) (Table 1: Appendix 1)

Since 1985, knowledge and experience from adaptive management practices have resulted in a higher success rate for focused mitigation and enhancement projects along the Pacific coast. (7) In an assessment of 17 eelgrass transplant projects that were completed between 1985 and 2000 in British Columbia, Cynthia Durance (Precision Identification) rated seven projects as successful, four as failures, and five recently planted projects were deemed most likely successes within several years. Since that time the five recently transplanted sites have been documented as successful. The majority of projects surveyed were motivated by the *No Net Loss* policy of Fisheries and Oceans Canada. The success of one site could not be determined due to an absence of interim monitoring data and the expansion of the surrounding natural eelgrass population. (8)

Factors that led to a higher success rate included the correct selection of physical attributes for the site, including elevation, substrate composition and light and current regime. The selection of the most suitable ecotype or genotype increased the likelihood for success and rate of production. (**Table 2**) The criteria for success included shoot density and area re-vegetated (9).

Table 1: Three Ecotypes on the Coast of B.C. (10)

Ecotype	**Relative leaf size**	**Leaf width (mm)**	**Depth range (m)**	**Seasonal variation in size**	**Current tolerance**
typica	narrow	2 to 5	primarily intertidal	small variation	low
phillipsi	intermediate	4 to 15	0 to -4	large, plant length reduced in winter	moderate
latifolia	large	12 to 20	-0.5 to -10	minimal variation	strongest

Causes for Failures

In all projects assessed over twenty years (1980-2000) in the Pacific Northwest, inappropriate site selection was a major factor contributing to failure. Factors that led to survival failure of the four transplant projects in British Columbia were primarily caused by human activities (dock placement, propeller wash, trampling by kayakers at low tide, dumping of rocks leading to shading by kelp plants) and inappropriate elevation. (11) In addition, coarse substrate and shading may have reduced the success of transplanted eelgrass at several locations.

Combined with the selection of the appropriate ecotype for the donor plants, and barring unforeseen stochastic events, the success rate of restoration projects has climbed steadily since 1985. A comprehensive review of thirty- nine eelgrass restoration efforts in the United States by the National Marine Fisheries Service verifies that knowledge about eelgrass ecology has improved. (12)

Table 2: Summary of Eelgrass Projects in California 1976-1999 (13)

Year	**No. Projects**	**Mean Size (ha)**	**Max. Size (ha)**	**Success (%)**
1976-79	4	0.4	1.6	25
1980-84	3	0.6	107	33
1985-89	12	0.6	3.8	58
1990-94	9	0.3	2.0	56
1995-98	11	1.0	4.8	All pending
1999	2	2.0	4.0	Planned

The projects were considered successful if there was a net increase in eelgrass coverage. Thirty six percent of the projects were considered successful, 13% partially successful; 18% not successful, and

33% were pending the results of monitoring surveys. **Table 4** (Appendix 2) outlines the conclusions from a study of three eelgrass restoration projects in Washington State since 1997. (14)

Key factors that influenced the success of these eelgrass transplants were primarily related to site selection, including substrate, depth, current or wave disturbance, light energy, scale or size of the plot, salinity and temperature. Other factors included proximity to a natural bed, quality of donor stock, time between removal from the donor site and transplanting, mode of spreading (i.e., seeds or rhizomes), grazing by animals, and unusual weather events (e.g., severe storms, freezes). The smaller the project, the greater the success. (15)

III. Criteria for Success

Eelgrass plantings that persist over time and meet the size criterion provide many of the functional attributes of natural eelgrass beds. The definition of functional performance is the measurement of abundance of selected marine animal types (e.g., crabs, eelgrass associated fish, shorebirds) or species (e.g., juvenile Chinook salmon) in the restored site. (16) In British Columbia, the criteria for success are based upon 1. the mean shoot density equals or is greater than the area of adjacent natural beds and 2. area coverage. Projects are thus considered successful if the habitat that was created provided habitat equal in eelgrass productivity (shoot density) to that which it was designed to replace. (17) The BC transplant review found a similar diversity and abundance of fauna in transplanted and natural (control) beds. **Table 5** shows the number of years needed to approximate the shoot density of the donor population at eight transplant sites in British Columbia: (18)

Table 3: Shoot Density (#m-2) of the Donor Population and the Transplants in 2001

Site	Donor Population	Transplants	Years to Achieve
Tsawwassen	82	105	3
Nanaimo – deep	5-20	88	3
Nanaimo – shallow	5-20	6.1	3
Campbelton	84	84	<5
Comox Harbour	30-60*	44	<9
Menzies Bay	32	56	<5
Port McNeil	262	352	<5
Gibsons	14-41	44-56	unknown

* Comox Harbour was naturally re-vegetated

For every eelgrass compensation project, there is a temporal loss. Productivity is lost each time development along the coast affects an eelgrass habitat. The creation of an area greater than that area which is lost may be used to compensate for the temporal loss. (19)

A transplant project aims to achieve:

- A self-sustaining system
- Resilience to disturbance
- A structure similar to natural bed
- Functional performance similar to the natural bed. (20)

In most cases, however, monitoring data for projects is not available to determine the average number of years required to achieve a self-sustaining system most comparable to a natural bed. Although it may seem likely that older transplanted eelgrass beds are functioning similar to that of a natural bed, there remains a paucity of comprehensive data to substantiate this notion. (21) In all cases except one for the transplant sites in British Columbia, the compensation areas attained plant densities comparable to natural populations in less than five years. (22)

The main criteria for successful transplanting lies with site selection with the appropriate biophysical characteristics (salinity, sediment type, current velocity, light/depth, temperature, and pH), using suitable plant donor stock (ecotype), using an appropriate transplanting technique and handling the donor plants with care. (23)

IV. Monitoring Schedule

Eelgrass that has been relocated can live for several months on the energy stored in the rhizomes. In order for them to survive over time, it is essential that they grow roots and branches. Therefore it is important to monitor a transplanted site several months after the transplant to gauge whether there are any physical or biological causes that will affect the success of plant survival. A set schedule following the initial transplant date is also crucial. (24).

Table 4: Monitoring Schedule

Time since transplant (months)	Rationale
6	To demonstrate the survival of transplanted eelgrass
12	To document increased density of transplanted eelgrass
36	To demonstrate that success has been achieved
60	If success at 36 months was partial, to demonstrate complete success

If a transplant fails, in the case of a restoration project in particular, it is critical to determine the reasons before a replanting takes place. Conditions such as suspended sediments during prolonged rainfalls, for example, may limit the available light during a time that the transplanted eelgrass requires the most sunlight. Mean shoot density in a reference site (a natural eelgrass bed situated near a transplant site) varies between years and between seasons, so it is important to compare data between the two sites at the same time. (25)

V. Project Design

Once the goals of an eelgrass transplant project are established, site selection is the next critical step. A site selection model has been created to select optimal areas for eelgrass habitat transplants on the Atlantic coast of the United States. (26) The process is divided into 3 phases. The first phase makes use of available environmental information to formulate a preliminary transplant suitability index, or PTSI, for pre-screening and for eliminating unsuitable sites. The second phase includes field measurements of light availability and bioturbation as well as survival and growth of test transplants; and the third phase pulls the information together to rate the site for its appropriateness for a transplant, ranging from a score of 0 to 2. (27)

The following tables suggest a method for assessing sites in British Columbia by community groups, based on the above mentioned model combined with experience of Cynthia Durance, the SCWG scientific advisor. The method has been designed to be low cost and requires minimal training. *Phase 1* includes measurements of physical attributes, historical data and environmental conditions; *Phase 2* includes measurements of survival and mean densities within test plots, and *Phase 3* rates the final score (PETI or Potential Eelgrass Transplant Index) to determine the suitability for a larger transplant project at the site. The highest score is 28.

Potential Eelgrass Transplant Index

<u>Assessment of Physical Characteristics</u>

Parameters	Range	Assessment Method	Rating Score
Substrate type	Firm sand to soft mud to boulder/cobble	Direct observation	2: entirely fine (Sand and/or mud) 1. mixed (gravel or cobble with sand or mud) 0: entirely coarse (boulders, cobble etc.)
Elevation	0.0 m to - -10m	Direct observation	2: Within range of ecotype 0: Beyond range
Salinity	Freshwater to 42 ppt	Hydrometer	2: 10 to 30 ppt 1: Freshwater year round (Measured on a monthly basis would be recommended)
Current velocity	Waves to stagnant water	Local knowledge	2: Little wave action 0: Steady fetch
Light	1.8 m above MLLW to –30m(this is depth, the plants need about	Local knowledge	Ranges to be determined

	20% of surface light)		
pH	7.3 to 9.0	Lab analysis if wood waste present on surface	2: 7.3 to 9.0 0: 1-6/10-14

ppt – parts per thousand   MLLW – mean low low water
Elevation is dependent upon ecotype of donor plants

Assessment of Site History

Parameters	Range	Assessment Method	Rating Score
Reference site	Close to potential restoration site to non-existent	Maps of subtidal area	2: Close to potential restoration site 1: Not available
Donor site	100 m to non-existent	Maps, boat observation	2: Available: 0: Within 100 m *
Historical records	Accessible and accurate to none	Government agencies	2: Accessible 1: Not accessible or non-existent
Local knowledge	Accessible and accurate to none available	Communications with community members	2: Accessible & accurate 1: Not available

*If a site is less than 100 m from a natural eelgrass meadow, it is considered within the range of natural re-vegetation and receives a rating of 0 (28)

Assessment of Environmental Conditions

Parameters	Range	Assessment Method	Rating Score
Availability of suitable ecotype	*Typica/phillipsi/latifolia*	Direct observation of plant and distribution range	2: Available 1: Not available
Near by land use	None to heavy use	Observation, local knowledge	2: Best practice management 0: Heavy run-off
Activities on the water	None to intense activities (ex: boat anchoring area)	Observation, local knowledge	2: Minimum impact from boats 1: Area of heavy boat traffic
Protection status	None to marine protected area	Government agencies	2: Protected status 1: No protection in place
Type of freshwater inputs	None to heavy flows (ex: heavy flow from stormwater discharges)	Observation Maps	2: Natural 1: Stormwater discharge

.

Test plots would be planted with 500-1,000 shoots at each site to assess the suitability of the site for a larger transplant project. Data on turbidity and salinity would be submitted to the scientific advisor. If 400-500 shoots (~50%) survive after the first year, a larger transplant project could be planned. If there were less than 50% survival, an investigation of the causes would take place.

VI. Summary of Test Plot Transplants (2007)

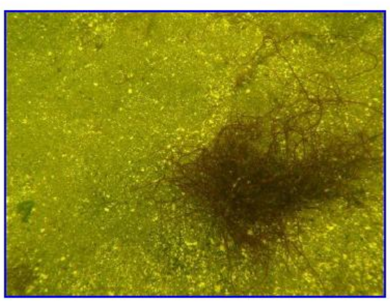
McKenzie Bight

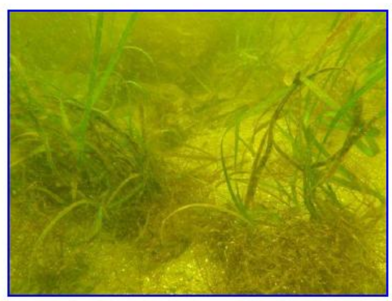
lies in the southern area of Saanich Inlet within the Gowlland Tod Provincial Park, established in 1994 as part of the Commonwealth Nature Legacy. Old logging roads surrounding the Bight within the 1,219-hectare Park now provide hiking trails for visitors.

The WCB Dive Team, with the SCWG scientific advisor assessed an area within the nearshore of the Bight (48° 33.205'N, 123° 30.344'W) and, using the criteria listed above, deemed the site a suitable transplant area for a small number of eelgrass shoots. A small patch of eelgrass was discovered near this site, an indication that conditions within the area are favorable for a transplant.

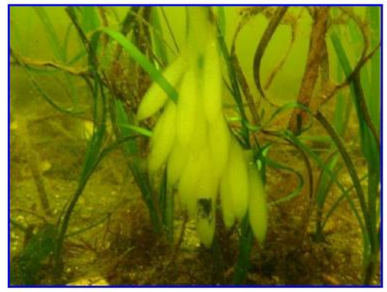
In July, 2007, 700 shoots were harvested from Coles Bay in the Saanich Inlet. The conditions (elevation, salinity, pH, light availability, current velocity and substrate) of the donor site resembled those of the transplant site. The planting was installed in three small plots of approximately 230 shoots each at a density of 10 shoots/metre ^{2}.

Before and Immediately After Transplant

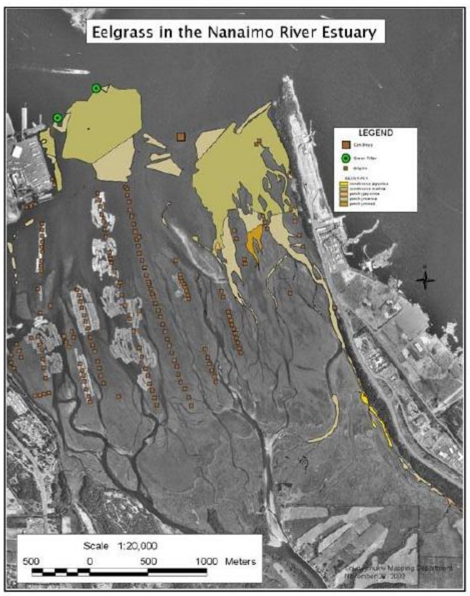




One year after the transplant. This site showed the most marine biodiversity of all the sites at the time of monitoring. The first photo is of a kelp crab, the second of squid eggs deposited on the blades of the transplanted shoots.



Nanaimo River Estuary



is the largest on Vancouver Island and the fifth largest in British Columbia. It is estimated that the majority of the estuary (~1000 ha) was once covered with eelgrass, before urbanization, industrial activity and hydrological changes impacted the area.

Approximately 200 ha of eelgrass habitat were mapped recently by the Snuneymeux First Nations as part of the work of the BC Community Eelgrass Network.

About 200 ha of the estuary are used for log storage, though the size of the storage is decreasing over time. Some of this area has the potential to support eelgrass. The log storage leases are under the jurisdiction of the Provincial Minister of Sustainable Resource Development.

The Snuneymuxw First Nation is located on the Nanaimo River estuary and has taken an active part in decision-making processes regarding the use of the estuary. The First Nation has completed some mapping of resources within the estuary, including eelgrass. They have both GPS and GIS resources and expertise at identifying and mapping resources.

The WCB Team assessed an area within a nearshore channel just south of the Snuneymeux First Nations Reserve (UTM 0432663, 5543573) on the advice of a fisheries biologist who has worked with the Band for many years. Seven hundred shoots were harvested and planted in July of 2007. Three small plots were installed of 200, 300 and 200 shoots in each plot north to south.

Substrate of the channel: After one year, there was no evidence of transplanted eelgrass.

In August of 2007, a compensation eelgrass transplant took place in front of the Snuneymeux Reserve for BC Ferries. Approximately twenty community volunteers came out to help with the project. Because of funding support from the Pacific Salmon Commission, the stewardship component of this event was very successful. Nikki Wright and others on the WCB Dive Team spent time orienting and training the volunteers, emphasizing the importance of their work in helping to restore lost eelgrass habitats.

The transplant area was monitored in August of 2008 and appears to have increased in mean shoot density.

__Squamish River Estuary__

Historically the eelgrass beds in the estuary have provided important habitat to spawning herring, which form an integral component of Squamish Nation culture. The Squamish River Watershed Society, working with Squamish Nation, has a big interest in reestablishing thriving communities of eelgrass, especially in regards to providing herring spawning sites and providing increased habitat for salmonids as well as other marine life that benefits from eelgrass habitats.

Squamish is uniquely situated at the mouth of the Squamish River where it empties into Howe Sound. The town site itself is established on what was once estuarine habitat. In the past the shoreline was a primary spawning ground for herring as there were beds of eelgrass throughout. At this time, the eelgrass populations have declined and there is no firm documentation as to their current location, status, and usage. It is known that the herring continue to migrate annually to Howe Sound seeking places to spawn. Shore birds and diving birds are abundant throughout the estuary and the upper reaches of Howe Sound. The herring are of particular importance to the Squamish Nation both culturally and as part of their current daily life.

Eleven hundred eelgrass shoots were harvested off site and planted in two locations in the estuary in September, 2007. Four hundred were installed at the Nexen Lands (10 U 488301 5503594 8 m) in a 10 m x 4 m plot 42 m from shore with the help of 15 community volunteers, who anchored the shoots to steel washers.

Nexen Land Site

400 shoots were installed in front of the dive flag.

Eelgrass transplants after one year

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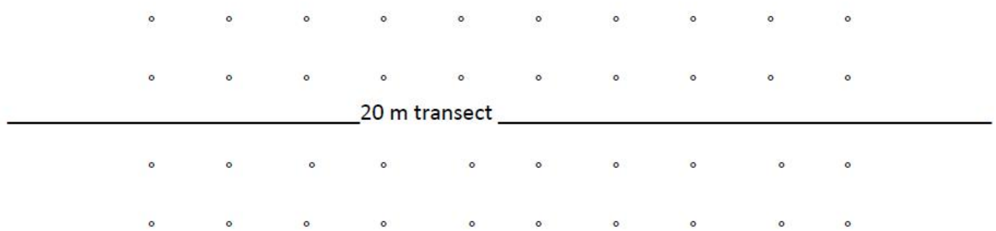
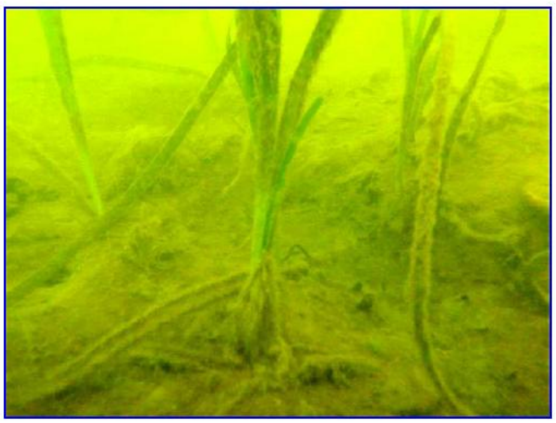
Seven hundred shoots were planted in front of the Squamish First Nations Reserve along a 20 m transect in groups of 10 one metre apart.

Planting Design Example:





New growth arises out of the base of the transplanted shoots.

VII. Monitoring Results

Site	Mean Average # of Shoots/Patch	Area Planted
McKenzie Bight (northern plot)	26.4	23 m^2
McKenzie Bight (southern plot)	24.6	30 m^2
Nanaimo River Estuary	0	70 m^2
Nexen Lands	17.33	40 m^2
Squamish Reserve Site	13.13	70 m^2

The criterion for success is based upon the mean shoot density that equals or is greater than the shoot density at the time of the transplant. Of the five test plots planted, three succeeded in increasing > 50% mean density over one growing season. The range of increase varied from 131% to 264%. Some of the plots in the McKenzie Bight and Squamish sites were coalescing, giving promise that eelgrass meadows were forming. Approximate area coverage for net gain in salmonid habitat for all three sites was 174 m^2.

The Nanaimo site within the channel did not succeed. Speculation is that there may be issues with high turbidity and high current velocity within the channel.

VIII. A Model for Community Based Restoration

"Restoration is the business and the spirit of the 21st century"
Storm Cunningham, author *The Restoration Economy*, 2002

Storm Cunningham, in his book *The Restoration Economy*, describes the 21st century as being at the "tipping point", an inevitable transition from an economy based on new development to one based on restorative development. This economy will be a reflection of a turn in direction, from creating more built environments to restoring old ones, reversing the one-way direction of forests into farms, wetlands into factories. (29)

Examples of a turn towards estuarine conservation/restoration are evident in the United States. The National Oceanic Atmospheric Administration's (NOAA) Community-based Restoration Program (CRP), started in 1996, applies a grass-roots approach to restoration by "actively engaging communities in on-the-ground restoration of fishery habitats around the nation. The CRP emphasizes partnerships and collaborative strategies built around restoring NOAA trust resources and improving the environmental quality of local communities" (30). The national program:

- Provides seed money and technical expertise to help communities restore degraded fishery habitats
- Develops strong partnerships to accomplish sound coastal restoration projects
- Promotes significant community support and volunteer participation
- Instills stewardship and an abiding conservation ethic
- Leverages resources through national, regional, and local partnerships (31)

The CRP is a partnership between environmentalists, the fishing industry and communities that depend on fisheries. In 2002, it expanded its partnerships to include national and regional NGOs that have "resources and expertise in the restoration of marine, estuary and freshwater habitats. (32) In the Pacific Northwest, the CRP has funded wetland and estuarine restoration projects in Washington, Oregon and California.

IX. A Model for the Georgia Basin

> "The depth of site specific knowledge amongst local people is often staggering, and comes from inhabiting a place for many years and becoming active observers and participants in the functions and processes of the ecosystem." (33)

Restoration connects individuals and communities to place. The social engagement required to create a successful restoration project, such as a well designed and executed eelgrass transplant, requires community commitment and creativity, scientific expertise, good working relationships with government agencies, strong partnerships with local and provincial industries and businesses, and excellent communication skills, to name a few factors. *Zostera marina* is being lost due to human impacts along the BC coast; it is the ingenuity, co-operative nature and commitment from communities and science and government working together that will bring them back.

Recommendations

Community conservation groups can successfully carry out eelgrass habitat assessments, transplanting and monitoring projects with professional scientific supervision and with authorization from Fisheries and Oceans Canada. The prototype for such activities is the eelgrass mapping project involving 27 community groups. From 2002-2008 well over 1,000 volunteers mapped over 12,000 hectares of eelgrass habitat from Haida Gwaii to Boundary Bay. They are trained in mapping protocols and received stewardship materials beforehand. Some of the mapping data can be viewed on the Community Mapping Network web site: http://www.bc.ca/atlases/atlas.html

This eelgrass network influences the culture of volunteer based environmental conservation organizations by placing them in an active rather than reactive position regarding shoreline development. Many of the conservation groups use their maps for locating eelgrass habitat to influence decisions regarding the development and use of the nearshore. Progressing from mapping to restoring damaged or destroyed eelgrass habitats can further strengthen the capacity of grass roots stewardship organizations to affect positive environmental change.

It is proposed that this eelgrass network be utilized to make the next step towards habitat restoration. The groups can assist with restoration by providing labour for shoreline work, developing and delivering educational materials and programs, and assisting with monitoring for restoration projects.

The more work that is accomplished by volunteers, the larger the share of the budget the community would receive for the restoration work. Volunteers have a double incentive in knowing that their time, skills and/or equipment are contributing both to habitat renewal and financial support of a community conservation organization.

Volunteer involvement in restoration also increases a community's investment in making sure the restoration site is well stewarded. By making use of the skills and commitment of conservation groups, more can be accomplished. For example, the municipality of White Rock funded a transplant project in 2003 for 100 plants. The Friends of Semiahmoo Bay, a local conservation group, augmented the project. They donated their labour on shore, increased the number of plants transplanted, and raised awareness of the importance of the habitat in the community.

> "Scientific knowledge acquired through actual participation becomes a part of a people's culture, no longer an alien product to be accepted as an article of faith." (34)

7.6 Conclusion

> "Regrettably, we have ample places to examine the slow degradation of an ecosystem, but very few where we can witness and study the reverse – the rebirth of the environment from decades of mistreatment".
>
> Dr. Kennedy Paynter, professor, Univ. of Maryland Chesapeake Biological Lab

A diverse and viable network of volunteer conservationists has an organizational structure that allows for regional input provides the avenue for the dissemination of scientific and local knowledge, and the sharing of resources in the form of field equipment, educational brochures, videos and the like.

The volunteers who participate in the eelgrass network suggested restoring the habitat where they had found it had been historically. The proposed strategy for restoring habitat by conservation organizations is a positive next step to coast wide net gain of this valuable marine resource.

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Appendix 1:

Table 1: Summary of Eelgrass Transplant Projects
San Francisco Bay to British Columbia, 1974-1989 (Thom 1990)

Location	Start Date	Approx. area	Monitoring Duration	Success Rate	Conclusions
Hidden Harbour, BC	1987	1,900 m2	1 year +	28% shoot survival; 23% decrease in transplanted area	Eelgrass can survive in marina, but lush vegetation not expected
Gibsons Harbour, BC	1985	-	4 years +	Low in gravel, cobble; moderate in fine sands	Substrata is critical; water clarity critical
Roberts Bank BC	1981-1983	-	5 years +	Good in most areas	Eelgrass survived best in areas with standing water at low tide
Blaine Marina, WA	1987	-	8 months	8% of plugs evident after 8 months	Steep slope reduced survival; deepest plugs had best growth
Padilla Bay, WA	1988	70 m2	1 year +	Up to 100% survival of shoots in pots; 20% survival of shoots in plots	Donor plots recovered rapidly; potted shoots survived well
Dakota Creek, WA	1988	60 m2	1 year	80% survival at lowest elevations; <30% survival at higher elevations	Coarse substrata; high elevation of tide flat and disturbance by boats affected survival
Sequim Bay, WA	1985	8,000 m2	5 years +	800 m2 of bed remains after 5 years; very dense in surviving area; total shoot abundance = 200,000	Planting methods gave similar results; finer substrata and deeper areas with standing water had greatest survival
Bangor, WA	1987	46 m2 (total of 5 plots	1 year +	4 of 5 plots died; remaining plot is subtidal	Steep slope of intertidal area (where planted) may cause losses
Anderson Pt., Battle Pt., Manchester, WA	1977	Several 1 m2 plots per site	2.5 years	Good survival (plugs, unanchored and anchored shoots)	Techniques give good survival if planted in proper habitat
Smith Cove,	1987, 1988	230 m2 (total	2 years +	No survival by	Drifting sand and silt

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WA		of 147 plots)		March 1989	covered plots
Magnolia Bluff, WA	1988	260 M2	1 year	No survival by April 1989	Drifting sediment covered plots
Seacrest, WA	1988	50 0.6 m2 planters	1 year	Some plants survived in some boxes	-
Puget Sound, WA (several sites)	1974	Various plots, 0.1 –1.5 m2	5-11 months	25-100% cover	Small plots placed in appropriate habitat do well; disturbance by waves reduced survival; all techniques worked well (plugs, anchored and unanchored shoots); long-term success of large-scale projects unproven
Siuslaw River, OR	1976,1977	290 m2 (total of 5 plots)	1 year	90% survival	Low fencing around plots reduced flows and helped survival; standing water at low tide over plots helped survival
Humboldt Bay, CA	1982	-	Several months	Good survival in first several months; severe storms destroyed plots	Transplanting success is enhanced if below-ground production of shoots is good
Bodega Harbor, CA	1984	11,000 m2	2 years	40% survival and 90% cover on tidal flat; 5% survival and 10% cover on channel banks	Low current, low disturbance, low turbidity areas did best
Richmond Harbor, SF Bay, CA	1985	9 m long linear plots (total no. plots = 25)	13 months	Approx. 100% mortality by end of study	Mature transplants did the best; transplant shock may have contributed to the losses

Appendix 2:

Lessons Learned from Three Restoration Projects in Washington State (1997-2001)

• Conduct experimental transplanting should be conducted, when possible, under conditions where the full transplant project will take place. Pre-tested sites may satisfy performance criteria prior to development.
• Monitor newly constructed site for at least two years on a quarterly basis is strongly recommended.
• Select sites with low turbidity, medium-grained sand and moderate organic content
• Select sites with low disturbance from boat wakes, waves, sediment movement, etc.
• Plant on flat areas rather than steep slopes
• Plant in areas that form pools at low tides
• Transplant into an area larger than the target area desired for mitigation
• Minimize holding time of the donor stock. Plant donor plants within a few hours (maximum 24 hours) after removal from the donor site and keep plants under water during transport
• Understand the ecosystem into which the transplants are to be placed and the ecosystem from which the donor stock was taken.

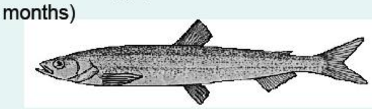
What are forage fish and why are they important?

Forage fish are: super-abundant schooling fishes such as herring, anchovy, sand lance, surf smelt, sardine, capelin and eulachon. These small fish are "forage" or "prey" for 100's of species from birds, marine mammals & fish.

Pacific herring (*Clupea harengus pallasi*)
To 9 in. long; spawn on intertidal and subtidal vegetation

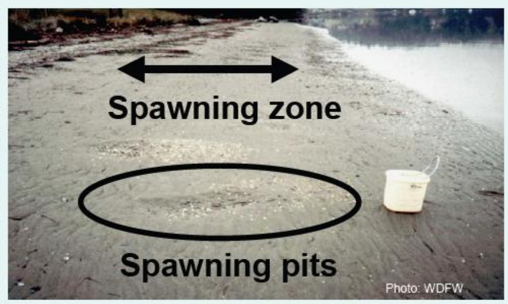
Northern anchovy (*Engraulis mordax*)
To 10 in. long; spawn in the water column (summer months)

Pacific sand lance (*Ammodytes hexapterus*)
To 8 in. long; spawn on sand/gravel beaches



Surf smelt (*Hypomesus pretiosus*)
To 9 in. long; spawn on small gravel/coarse sand beaches

High Intertidal Spawners: Surf smelt and Sand lance



Surf smelt

-Spawn using surf swash during high tides at or within metres of the log line

-Spawning sediments range from coarse gravels to fine pea gravels

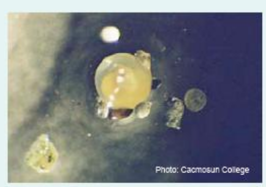
Pacific sand lance

-Spawn in sand pits

-Spawning sediments range from fine gravel to sand

Pea gravel: 2-11mm

Surf smelt egg on gravel



Sand lance egg covered with sand/gravel

Forage Fish Matter! Emerald Sea Research and Consulting Contact us at: emeraldsearesearch@hotmail.com

What eats forage fish? Fuel for the Food Web!

Being the cornerstone of the marine food web, forage fish are the most important fish in the sea. They connect food energy from zooplankton to their predators. These predators (salmon, lingcod and rockfish etc.) are prey for larger animals, such as sea lions and Killer Whales.

Many Marine Mammals:

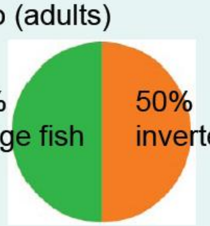
FORAGE FISH

Numerous Sea Birds:

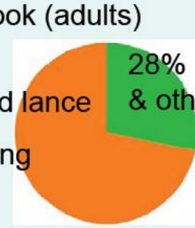
Hundreds of Fish:

BC Salmon Diets: Coho and Chinook

Coho (adults)



Chinook (adults)



Surf Smelt and Pacific sand lance Intertidal Spawning Habitat

1. Beach spawning sediments are largely derived from land. Gravels erode from"feeder bluffs". Streams & creeks provide spawning sediments to beaches. Coastal drift cells distribute spawning substrate along beaches.

2. Vegetation stabilizes slopes & provides crucial shade and a wind break for incubating surf smelt and sand lance eggs.

3. Logs and gently sloping beaches reduce shoreline erosion.

Shoreline Modifications: The Primary Threat to Surf Smelt and Pacific sand lance Spawning Habitat

• Sediment-starved beaches result from:
  culverts diverting stream-borne gravels
  seawalls, bulkheads and dykes physically blocking the transport of eroding gravels from feeder bluffs to beaches
  groins and boat ramps interrupting long-shore sediment transport.

• When shade vegetation is lost, sediment temperatures increase and eggs die.

• Wave action on bulkheads and seawalls scours beaches leaving larger, coarser rocks behind. Beach slopes increase and habitat is lost. Coarse sediments can reduce intertidal and subtidal burrowing habitat for adult sand lance.

• Shoreline armouring (eg. rip-rap) physically buries spawning habitat.

Getting connected with *Forage Fish Matter!*

Our goal: to provide education and training to protect intertidal forage fish spawning habitats.

For over three decades, Mr. Dan Penttila of Washington Department of Fish and Wildlife has worked to protect spawning habitat of surf smelt and sand lance.

In BC, although the ***BC Wild Salmon Policy*** recognizes the need to protect intertidal forage fish spawning habitat, few people in government know about the importance of these fishes and fewer still are doing anything to protect their habitats.

What we are doing:

We offer training workshops, expertise, GIS data entry tool, presentations, and assistance in designing surveys, and educational materials.

Help us protect food for fish! Contact us:

Emeraldsearesearch@hotmail.com or rdegraaf@bms.bc.ca

Field training with Mr. Dan Penttila, WDFW

Stewardship groups in action!

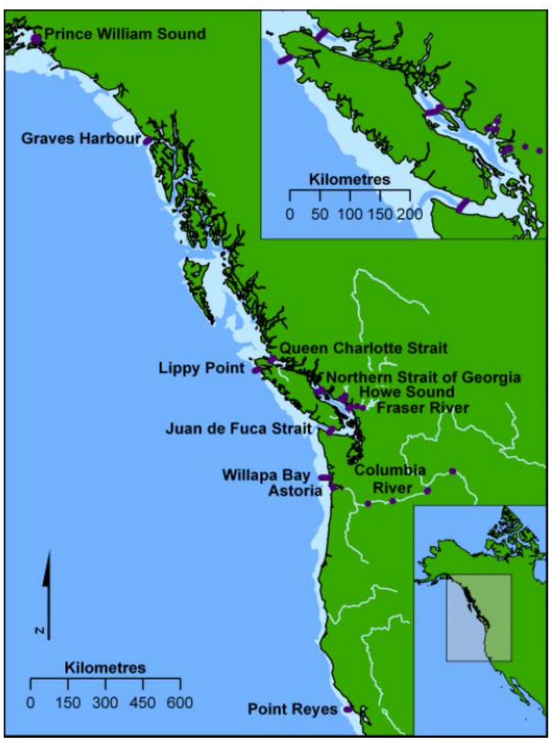
Appendix 2.3: Descriptions of technology –POST, Genomics & Remote sensing

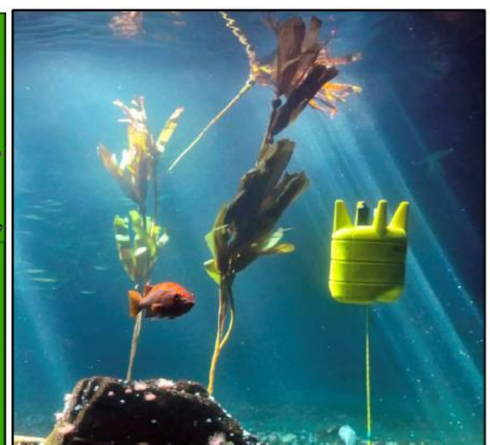
The Pacific Ocean Shelf Tracking (POST) Project is an international non-profit organization hosted by the Vancouver Aquarium and governed by a 13-member Management Board. POST works with federal agencies like Fisheries and Oceans Canada and NOAA, provincial, state, First Nations and local agencies, universities, and other industry and conservation groups to track the movement of marine animals along the West Coast of North America.

<u>New to Ocean Science</u>

- For the first time, juvenile salmon have been tracked from the headwaters of the Columbia River to the seas off Southeast Alaska, a journey of about 2,500km that took over three months to complete.
- Unknown before POST, threatened green sturgeon from California migrate to British Columbia and as far as Alaska – fisheries scientists were surprised as it was previously thought the animals always remained much closer to home.

POST is one of fourteen field projects of the Census of Marine Life, a global network of scientists engaged in a 10-year effort to assess and explain the global distribution, diversity and abundance of life in the oceans.





In partnership with groups such as the Fraser River Sturgeon Conservation Society and Dalhousie's Ocean Tracking Network, POST maintains a broad-scale array of acoustic receivers, or hydrophones, that "curtain off" segments of the coast in British Columbia, Alaska, Washington, Oregon and California.

Scientists and resource managers outfit a variety of marine animals with tiny acoustic transmitters, so their journeys through fresh- and saltwater can be seamlessly and accurately documented. Information gained from tracking these animals contributes to scientific knowledge and its application to the management and conservation of commercially and biologically important marine species.

BENEFITS OF POST
Informing sustainable fisheries management decisions through accurate tracking of animal movements
Contributing valuable information to conservation efforts for Species at Risk Act-listed animals
Providing free and publically accessible data and analytical tools, fostering collaboration and discovery
Adding biological data to platforms like the Global Ocean Observing System's network of observatories

POST focuses its efforts on three main elements requiring annual funding of $2M:

Science – developing new applications for animal tracking, assessing suitability to track other species, combining current and new technologies with other ocean observing tools

Infrastructure – maintaining and expanding the sensor network, data retrieval and data access services

Operations – conducting education and outreach, building partnerships, program management

POST BY THE NUMBERS

- Over **3,000km** of the Pacific Coast of North America is "wired up" with POST lines of acoustic receivers used to track the movements of tagged marine species.
- **10** ocean lines of acoustic receivers, from Prince William Sound, AK to Point Reyes, CA, form the broad POST array. In that stretch, the Fraser, Skeena and Columbia Rivers have "curtains" of acoustic receivers at their mouths and up to 670km upstream.
- More than **400** acoustic receivers make up the entire POST array. Some are permanently anchored and allow data download to happen remotely from the surface, others require physical retrieval from the ocean or river bottom.
- To date, **17** marine and anadromous species have been tracked using POST, including: green sturgeon, white sturgeon, six-gill shark, seven-gill shark, salmon shark, lingcod, jumbo squid, market squid, spotted ratfish, cutthroat and steelhead trout, dolly varden, black rockfish, and chum, coho, sockeye and chinook salmon.
- A **7mm** diameter marks the smallest acoustic tag – no bigger than an almond – used to outfit any of a variety of marine species with the means to track them using POST. The largest tag, **16mm** in diameter, is the size of a lipstick tube and will transmit its unique ID code for up to 10 years.
- More than **20** principal investigators have contributed their data to the ever-growing POST data management system.

POST | PO Box 3232, Vancouver, British Columbia, Canada, V6B 3X8 | 604-659-3590 | www.postcoml.org

Overview of Genomics

Functional Genomics has dramatically changed the breadth and depth of physiological inquiry possible by enabling the survey of 100's of physiological pathways at once. Functional genomics research focuses on the portion of the DNA code that is expressed to make proteins (the RNA). Whereas DNA is inherited and static (meaning that all cells contain the same make-up of DNA), RNA is more transient, and the RNA being expressed by a cell depends on the function of that cell and its physiological state. By examining which RNA transcripts are being turned on to make protein, and which are turned off in any given cell or tissue, we can identify which physiological processes are activated and which are deactivated at any given point in time. Microarrays are the mainstay of functional genomics research, and enable the survey of the expression of 1,000's of genes at once (called gene expression profiling). Microarrays can potentially contain probes for all genes within the genome of an organism.

Behavioural and physiological processes are controlled at the level of gene expression. Hence, in addition to resolving which physiological processes are being stimulated within an individual, microarray studies can also identify the genes that transcriptionally regulate physiological processes of interest. These regulatory genes can serve as important biomarkers for future predictions of conditional states revealed by microarray studies.

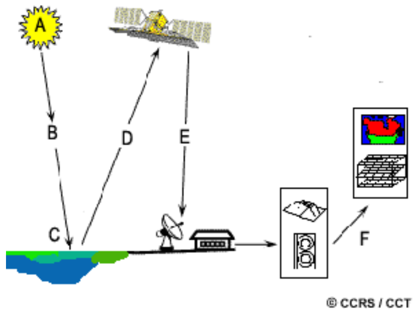
For salmon, we are interested in processes that may exacerbate performance and indirectly or directly lead to enhanced mortality. Conditional states associated with starvation, poor nutrition, osmoregulation (salt balance), disease, metabolism, hypoxia (low oxygen), stress, activity levels, exposure to toxins, and poor response to elevated temperatures are all potentially important to survivorship of smolts upon entry into the ocean.

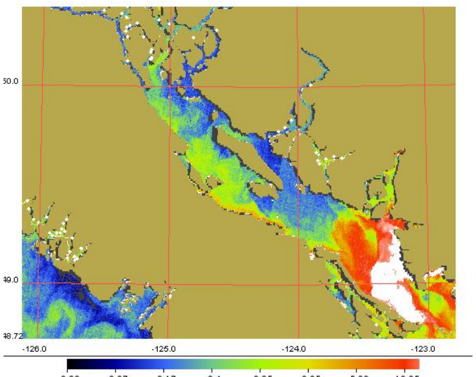
The Molecular Genetics Laboratory at the Pacific Biological Station has been conducting microarray experiments on wild migrating salmon for five years, and has accumulated a tremendous breadth of knowledge on the normal physiological progression associated with salmon migration. Moreover, through genomics studies, they have discovered what may be a novel viral disease afflicting Pacific salmon in southern BC. This viral signature was uncovered in association with high en route and pre-spawning mortality of sockeye salmon in the Fraser River. Moreover, the viral signature was present before fish entered freshwater, and was discovered by combining radio-tracking and non-destructive biopsy sampling of gill tissue. Destructive profiling of multiple organs revealed the signature was present in other tissues, including the brain, and identified strong signals suggestive of both viral and tumour activity. Brain dissections have since revealed tumour-like growths in the optic lobe of a proportion of the affected fish. The decline in incidence of these growths over the first few months in the ocean is suggestive of a potential role of this viral-tumour associated disease in early ocean mortality. These growths have been observed in sockeye, Chinook and coho salmon in the Strait of Georgia.

Fundamentals of Remote Sensing

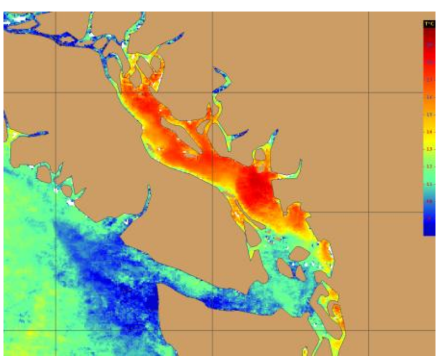
"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information." [1]

Two types of remote sensing systems will be used in this work. In both cases, the satellite is sensing energy reflected or emitted from the earth's surface (D) and transmitting it back to earth (E) for recording and analysis (F). By scanning while the satellite is orbiting earth, sensors acquire data that can be used to produce images or maps.





the Optical sensors measure the colour of the sunlight (A) reflected from the earth's surface (C) to provide quantitative maps of the chlorophyll pigment in ocean phytoplankton and land vegetation. Water with little plant plankton appears blue, while water containing much plant material is green or even red. On land, healthy growing vegetation is green, while dry or dead grass and trees that lose their chlorophyll and turn yellow or brown. These changes can be measured from satellites. In the example shown here for April 23, 2008, high concentrations of chlorophyll are shown as red, while low concentrations are blue. Areas of high suspended sediment from the Fraser River discharge is shown as white. Small white dots are locations of salmon farms.



Thermal sensors on the weather satellites will provide quantitative maps of sea surface temperature, by measuring infrared radiation emitted from the surface (D). The image at left shows the Sea Surface Temperature on August 10, 2008. Red is 18 C^{o}. Blue is 8 C^{o}. Satellite remote sensing is important in many kinds of scientific study because it provides low cost or free data for remote, inaccessible or un-sampled areas. The increasingly long time series are critically important for studies of climate change. The digital data can be manipulated by computer to derive quantitative information for many physical and biological variables.

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[1] Canada Centre for Remote Sensing Tutorial: Fundamentals of Remote Sensing Introduction. Available online at http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/chapter1/01_e.php