Appendix 13

TECHNICAL AND SCIENTIFIC RESEARCH PROJECTS

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PROJECT 1
DISEASES AND PARASITES

OBJECTIVE

A veterinary scientist is required to prepare a technical report evaluating the effects of parasites and diseases on Fraser River sockeye salmon and their role in the 2009 run failure.

SCOPE OF WORK

The veterinary scientist will take a broad view of sockeye diseases and parasites that span the life cycle from egg to adult. The scientist will evaluate the full spectrum of diseases that occur at all life history stages.

The role and impact of parasites and diseases caused by other agents on the overall mortality schedule of Fraser sockeye salmon will be evaluated both qualitatively and quantitatively by review and analysis of fish disease data, the peer-reviewed literature and government documents.

RESEARCHER

Dr. Michael Kent, Professor, Departments of Microbiology and Biomedical Sciences, College of Veterinary Medicine, Oregon State University. His research interests are in fish diseases and parasitology.

BIOGRAPHY

- Aquaculturist, Hubbs-Seaworld Research Institute, San Diego, 1980-1981.
- Staff Research Associate, University of California, San Diego, Office of Animal Resources, 1981-1982
- Ph.D. Graduate Student (Sea Grant Trainee), University of California, Davis, Department of Medicine, School of Veterinary Medicine, 1982-1985
- Research Scientist, Battelle Marine Research Laboratory, Sequim, Washington, 1986-1988.

- Research Scientist, Fish Health, Parasitology, and Genetics Section, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., 1988-1999.
- Head, Fish Health, Parasitology, and Genetics Section, Aquaculture Division, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., 1997-1999.
- Director, Center for Fish Disease Research, Oregon State University, 1999-2007.
- Associate Professor, Departments of Microbiology and Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, 1999-2001.
- Professor, Departments of Microbiology and Fisheries and Wildlife, Oregon State University, 2001-2007.

While with DFO between 1988 and 1999, Dr. Kent worked extensively on sockeye salmon parasitology and diseases.

PROJECT 2
EFFECTS OF CONTAMINANTS ON FRASER RIVER SOCKEYE SALMON

BACKGROUND

An inventory and evaluation of the effects of contaminants in the Fraser River is required to determine their importance on the ecology and survival of Fraser sockeye and to determine their role in the reductions in Fraser sockeye abundance.

OBJECTIVE

To prepare a technical report containing a contaminant inventory and an evaluation of the effects of contaminants on Fraser River sockeye salmon.

SCOPE OF WORK

The Contractor will prepare an inventory of aquatic contaminants in the Fraser River in relation to the distribution of sockeye Conservation Units. This will include an evaluation of pulp mill effluent contaminants, non-point source contaminants, endocrine disruptors and other contaminants. It will also include sewage discharges from the Lower Mainland and other urban centres in the Fraser Watershed.

The Contractor will compare toxicology data for sockeye to Fraser River water quality conditions, in order to evaluate lethal and sub-lethal impacts of aquatic contaminants.

The Contractor will develop an overall assessment for the suite of contaminants and natural substances (e.g. suspended sediments) that are encountered by juvenile and adult sockeye salmon.

The Contractor will evaluate the extent to which reductions in Fraser sockeye abundance are associated with contaminant conditions in the Fraser River.

The Contractor will reference reports prepared by Dr. Peter Ross, Inst. of Ocean Sciences, and the Siska First Nation concerning contaminant concentrations in Fraser sockeye salmon.

RESEARCHER

Don MacDonald, principal of MacDonald Environmental Sciences Limited, Nanaimo, B.C.

BIOGRAPHY

Mr. MacDonald offers scientific expertise in the fields of environmental chemistry, fishery/forestry interactions, water quality/water use interactions, sediment quality assessment, environmental quality guidelines, ecosystem-based management, ecological risk assessment, and natural resource damage assessments.

MacDonald Environmental Sciences Limited (MESL) was formed in 1989 to offer specialized consulting services related to the assessment and management of aquatic and terrestrial ecosystems.

PROJECT 3

FRASER RIVER FRESHWATER ECOLOGY AND STATUS OF SOCKEYE SALMON CONSERVATION UNITS

BACKGROUND

The Contractor is to investigate several aspects of Fraser sockeye ecology, including the status of sockeye conservation units, a review of industrial and urban impacts on freshwater ecology and salmon life history, and an expert assessment of potential impacts from industrial and urban activities on Fraser River sockeye during the last 30 years.

OBJECTIVES

- To evaluate the status of all of the 36 sockeye Conservation Units and sockeye sub-stocks within CUs in the Fraser River Watershed.
- To evaluate Fraser River sockeye salmon ecology and survival in freshwater environments.
- To evaluate industrial and urban activities (except pollution, but including impacts from Mountain Pine Beetle and the associated salvage logging) in the Fraser River Watershed and their potential effects on Fraser sockeye.
- To evaluate the impacts of surfacewater and groundwater diversions on Fraser sockeye production and survival.

SCOPE OF WORK

DFO has identified salmon CUs and has developed a methodology for determining "CU benchmarks." There are 2 CU benchmarks – upper and lower – which can be used to define the status of CUs. To date, the CU benchmark methodology has not been applied to Fraser sockeye CUs. The Contractor will be required to evaluate the DFO methodology to determine its applicability and feasibility for defining the status of Fraser sockeye CUs.

Alternative methodologies for determining CU status, for example those based on escapement, production or other databases, will also be critically evaluated. The Contractor will determine the status of CUs, or if that is not feasible due to information gaps, logical groupings of CUs represented by specific stocks.

Once the status of the CUs has been determined, then hypotheses will be developed to explain the trends and status of the CUs, focusing on industrial and urban stressors pertaining to the freshwater part of the salmon life cycle.

Existing information on freshwater production will be compiled and analyzed, noting the limitations of existing information. Key variables will include:

- Habitat quantity and quality for eggs, alevins, fry, smolts and adults
- Impacts to stock status and potential causes of premature migration of adult (Late Run) sockeye into freshwater
- Extent of en-route mortality and pre-spawning mortality
- Freshwater predation impacts on sockeye smolts and adults
- Impacts of diseases on sockeye smolts and adults in the freshwater environment.

The logging history of the Fraser River watershed will be summarized with particular attention to logging effects adjacent to Fraser sockeye habitats, with potential impacts on sockeye spawning and rearing habitats during the last 30 years. Literature analysis and evaluation of existing data sets will be undertaken to summarize the understanding of logging impacts on Fraser sockeye. The exposure of sockeye CUs to logging impacts will be evaluated in relation to spawning, incubation, rearing and migratory habitats. Lastly, the research will summarize the effects of Fraser Estuary log storage on juvenile and adult sockeye. A review of the potential current and future impacts of Mountain Pine Beetle on Fraser sockeye CUs will be undertaken as a part of this research.

Evaluation of mining impacts on Fraser sockeye requires consideration of historical mines, presently operating mines, mines currently proposed for development and mining exploration activities. Historical mines include gold mines in the central interior

region developed during the Gold Rush, while presently-operating mines include gold-copper properties adjacent to sockeye waterways. Ongoing gravel mining operations in the Lower Fraser River could potentially impact sockeye migratory habitats. The Contractor will evaluate the potential risks to sockeye salmon associated with historic and current mining operations in the Fraser Watershed as well as from mining exploration activities, focusing on evidence of potential impacts on sockeye spawning and rearing habitats during the last 30 years. The Contractor will also note proposed mining operations with potential future impacts.

In regards to the Kemano Project, the Contractor will prepare a summary of the effectiveness of water regulation to achieve temperature objectives of less than 20^{o}C at the Stuart-Nechako confluence during sockeye migrations, and will also assess the status of Stellako and Nadina CUs that are affected by the development.

The Contractor will review all other hydro projects that impact sockeye salmon in the Fraser Watershed, e.g. Bridge-Seton system.

The distribution of Independent Power Projects in relation to sockeye CUs will be determined and mapped by the Contractor, and their potential implications for sockeye habitat and habitat management will be discussed.

The Contractor will review potential effects on migrating sockeye smolts and adults from urbanization. This will include the effects of dredging in the Lower Fraser River below Hope.

The Contractor will evaluate the potential impacts of agricultural activities on sockeye habitats.

RESEARCHER

Dave Marmorek, ESSA Technologies Ltd.

COMPANY PROFILE

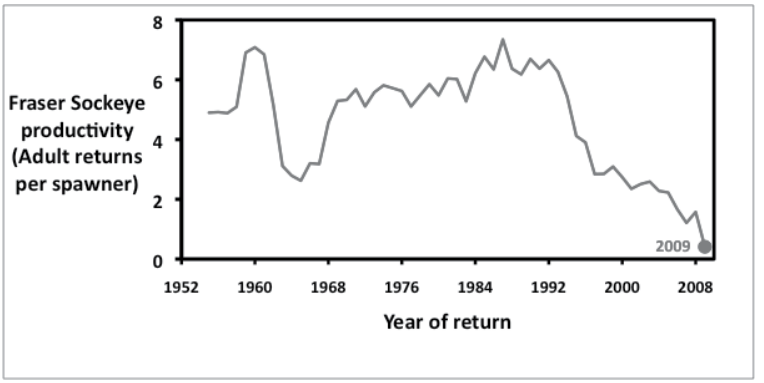
ESSA is an independent Canadian company originally incorporated in 1979 under the name ESSA Environmental and Social Systems Analysts Ltd. Its corporate mission is "to bring together people, science and analytical tools to sustain healthy ecosystems and human communities". The head office is in Vancouver, with regional offices in Victoria, the Greater Toronto Area, and Ottawa. ESSA has a diverse range of clients, from government agencies, development banks and international funding institutions, to the private sector and non-governmental organizations (NGOs). In addition to its North American consulting practice, ESSA maintains an active international focus. ESSA has conducted over 1,800 projects in the fields of environmental and natural resources management. In the environmental services domain, ESSA combines scientific expertise, advanced tools for systems analysis, and innovative communication techniques to provide services for its clients.

PROJECT 4
MARINE ECOLOGY

BACKGROUND

Most Fraser River sockeye salmon spend two years in the marine environment, first passing through the Strait of Georgia, then onto the continental shelf and eventually to the Alaska Gyre. Therefore, the ecology of Fraser River sockeye salmon in the ocean requires study to determine whether there are causal factors to explain: (1) the extremely low productivity associated with the 2009 return, and (2) the general pattern of declining productivity that has been observed during the last 15 years, as shown below:

Fraser River sockeye salmon productivity (adult returns per spawner, all stocks combined).



OBJECTIVE

To prepare a Technical Report that provides a review of the marine ecology of Fraser River sockeye salmon and to determine whether there are oceanographic factors that can explain the reduction in the short- and long-term Fraser sockeye productivity.

SCOPE OF WORK

Topics to be described by the Contractor will be stratified by habitat type: coastal and offshore. Key variables to be analyzed will include:

- Basic life history information about Fraser River sockeye salmon including feeding, growth rates, predation, behaviour and overwintering areas,
- Migration routes of Fraser River sockeye salmon,
- Roles of ocean/climate in determining Fraser River sockeye salmon marine survival,
- Effects of variations in ocean productivity on Fraser River sockeye salmon survival,
- Trends and predictability in the northern diversion rate and causal mechanisms,
- Sockeye food abundance in relation to the potential for food competition and limitation.

The Contractor will review proceedings and reference the Pacific Salmon Commission workshop held on June 15-16, 2010 in Nanaimo: "Pacific Salmon Commission Workshop to Examine the Decline in Survival of Fraser River Sockeye".

Set out below is a draft Table of Contents for the contract report:

The Decline of Fraser River Sockeye Salmon in Relation to North Pacific Marine Ecology

1. Introduction

- Fraser sockeye run failed in 2009 and productivity, measured as recruits per spawner, has been declining since the mid 1980's
- Cohen Commission is preparing a systematic review, based on existing scientific information, including historical data, of the suite of potential factors that may have contributed to the failure of the 2009 Fraser sockeye run and the longer term decline in productivity, including both freshwater and marine factors
- For the 2005 brood year, evidence implicates a marine factor which is associated with the sockeye smolts that entered the coastal marine environment in 2007
- PICES involvement and approach
- Analysis to be stratified into 3 spatial areas: 1. coastal marine (Strait of Georgia, Queen Charlotte Strait/Sound), 2. offshore marine (Alaska Gyre), 3. return migration.

2. Fraser River Sockeye Salmon Marine Life History

2.1 Coastal

- o Distribution and migration
  - o Behaviour
  - o Factors affecting

- o Diet/feeding
- o Growth
- o Survival

2.2 Offshore
- o Distribution and migration
  - o Behaviour
  - o Factors affecting
- o Diet/feeding
- o Growth
- o Survival

2.3 Return Migration
- o Timing
- o Diet/feeding
- o Growth
- o Survival
- o Landfall
- o Trends and predictability in the Johnstone Strait diversion rate and causal mechanisms

3. Oceanographic Conditions – Past and Future
- Brief overview of North Pacific environmental conditions and their influence on Pacific salmon
- North Pacific Ocean regime shifts and inter-annual variability in Fraser River sockeye marine survival
- Effects of ocean productivity variations on sockeye survival
- Evaluation of period between 2007-2009 (analysis of Project Argo data during this period and review of PICES ecosystem status report, 2003-2008)
- Speculation on state of the NE Pacific in 2040-2050 based on output from high resolution coupled ocean-atmosphere model of the Northeast Pacific (NEP5).

4. Discussion
- Can the decline in Fraser sockeye in 2009 be explained by the conditions the fish experienced in the marine environment?
- Is there any evidence for declines in marine productivity or changes in Fraser sockeye distribution that can be associated with the 15 year gradual decrease in Fraser sockey productivity?

RESEARCHERS

Members of the PICES Team on this project will include:

- Dr. Skip McKinnell – Team Leader, Deputy Executive Secretary, PICES
- Dr. Enrique Curchitser – Rutgers University, Ocean/Climate Modeler, and author of the Northeast Pacific hi-resolution ocean model
- Dr. Masahide Kaeriyama – Salmon Biologist, Hokkaido University Graduate School of Fisheries
- Dr. Kees Groot – formerly with DFO, sockeye salmon expert
- Dr. Katherine West Myers, University of Washington's High Seas Salmon Research Program.

COMPANY PROFILE

PICES (http://www.pices.int), the North Pacific Marine Science Organization, is an intergovernmental scientific organization that was established and held its first meetings in 1992. Its present members are Canada, People's Republic of China, Japan, Republic of Korea, Russian Federation, and the United States of America. The purposes of the Organization are as follows:

- Promote and coordinate marine research in the northern North Pacific and adjacent seas, especially northward of 30 degrees North
- Advance scientific knowledge about the ocean environment, global weather and climate change, living resources and their ecosystems, and the impacts of human activities
- Promote the collection and rapid exchange of scientific information on these issues.

The goal is to advance scientific knowledge and capacity available to the members, including information on human activities affecting, and affected by marine ecosystems, and to provide a mechanism for collaboration among scientists in addressing timely and critical scientific questions.

The PICES mission is built upon five central themes: (A) Advancing scientific knowledge; (B) Applying scientific knowledge; (C) Fostering partnerships; (D) Ensuring a modern organization in support of PICES activities; and (E) Distributing PICES scientific knowledge. Specific goals are identified within each of these themes. The actions and activities required to meet each of these goals will change over time, and will be described and updated regularly in Action Plans of PICES' permanent committees.

PROJECT 5

IMPACTS OF SALMON FARMS ON FRASER RIVER SOCKEYE SALMON

BACKGROUND

An evaluation of the impacts of salmon farms on Fraser sockeye is required to determine their importance on the ecology and survival of Fraser sockeye and their potential role in the reductions in Fraser sockeye abundance.

OBJECTIVE

To prepare a technical report containing a review and evaluation of the effects of salmon farms on Fraser River sockeye salmon, including an analysis of the positions taken by the salmon farming industry and critics of sea-cage salmon farming.

SCOPE OF WORK

The Contractor will evaluate the linkage between salmon farm operations and Fraser sockeye spawning returns – past, present, and future. This research will consider the impact on Fraser sockeye of sea lice exposure, farm wastes that affect benthic and pelagic habitat quality, Atlantic salmon escapees and disease (including IHN).

The focus will be on Fraser sockeye – other salmon species will be considered insofar as an argument can be made that they inform the analysis of sockeye. The practicality and outcome of salmon farm management methods for mitigating risks to Fraser sockeye will be evaluated. This will include the use of closed containment systems, scheduling of net pen harvesting to reduce contact with sea lice, re-locating farms, compressing maturation schedules, optimizing densities and the use of SLICE to control sea lice.

The Contractor will evaluate our present ability to estimate the extent to which reductions in Fraser sockeye abundance are associated with salmon farms, taking into account the range of other factors that may affect sockeye abundance.

RESEARCH METHODS AND SOURCES OF INFORMATION

The Contractor will draw on peer-reviewed journal articles, non-peer-reviewed reports and articles ("grey" literature), documents and data obtained by the Commission, and interviews with individual scientists, representatives of the salmon farming industry and NGOs. The report will consider all sources of information, including the international experience.

RESEARCHER

To be determined.

PROJECT 6
DATA SYNTHESIS AND CUMULATIVE IMPACT ANALYSIS

BACKGROUND

The Commission has engaged other Contractors to prepare technical reports covering scientific topics related to the Commission's mandate. A synthesis of this information is required to address cumulative impacts and to evaluate possible causes for the decline of Fraser sockeye salmon.

The Contractor is to integrate the research results of the other Contractors, and to carry out cumulative impact assessment.

OBJECTIVE

To provide data synthesis and integration services to the Cohen Commission and to lead the preparation of cumulative impact analysis involving all of the Science Contractors.

SCOPE OF WORK

Following the submission by Contractors of Progress Reports on November 1, 2010, the Contractor will analyze and organize information on explanatory factors, to assess their correlative strength with patterns of change in sockeye stock productivity during different life history stages. This will involve the preparation of a computer model to track the relative influence of different variables, and their interactions, that can affect Fraser sockeye salmon. This material will be developed and returned to the Contractors by December 15, 2010. The Contractors' Final Reports, which are due December 15, 2010, will be utilized to clarify the full range of factors, and their interactions, that impact Fraser sockeye.

RESEARCHER

Dave Marmorek et al., ESSA Technologies Ltd.

COMPANY PROFILE

ESSA is an independent Canadian company originally incorporated in 1979 under the name ESSA Environmental and Social Systems Analysts Ltd. Its corporate mission is "to bring together people, science and analytical tools to sustain healthy ecosystems and human communities". The head office is in Vancouver, with regional offices in Victoria, the Greater Toronto Area, and Ottawa. ESSA has a diverse range of clients, from government agencies, development banks and international funding institutions, to the private sector and non-governmental organizations (NGOs). In addition to its North American consulting practice, ESSA maintains an active international focus.

ESSA has conducted over 1800 projects in the fields of environmental and natural resources management. In the environmental services domain, ESSA combines scientific expertise, advanced tools for systems analysis, and innovative communication techniques to provide services for its clients.

Additional Methodological Details

Cumulative Impact Analysis. The Contractor will take a life history approach to cumulative impact analysis, examining the suite of stressors potentially affecting each life history stage, and how those stressors have changed over the period of interest (i.e., early 1990's until the present). The Contractor will use the results of each investigator's work to illustrate the magnitude of each stressor over space and time, and its potential for delayed effects on subsequent life history stages (e.g., acquisition of a disease at one life history stage may not cause mortality until other stressors such as high temperatures affect a later life history stage). The intent is to illustrate these *potential* cumulative impacts through a series of integrative frameworks, such as:

a) a life history diagram showing the impacts of different stressors, with arrows of different thickness indicating the strengths of different pathways (including both direct and delayed effects);
b) time series graphs showing changes in a series of indicators for different stressors, placed on a map of the sockeye's life history, showing all indicators on a consistent relative scale (e.g. scaled to 1 based on the maximum value over the time series);
c) similar time series graphs of the changes in productivity indicators for different sockeye salmon stocks; and
d) analyses of the evidence for and against different hypotheses, building on the June 15-17 PSC workshop.

Computer Model. Each of the investigators gathering information on different stressors will assemble indicators of those stressors, organized into a spreadsheet with a consistent format (i.e., stressor by year by stock), specifically the 19 Fraser River sockeye stocks for which productivity indicators have been assembled by the Pacific Salmon Commission. For some stressors (e.g. impacts on freshwater spawning and rearing habitat), these indicators may be stock-specific. For other stressors (e.g. fish farms, oceanographic conditions, mammalian predators) many stocks will need to be grouped, as the independent effects on different stressors are unknown. The ability to explain the patterns of change in both Fraser sockeye stocks and other stocks of interest outside the Fraser (valuable to create contrast) will be explored using a multiple regression approach or perhaps other multivariate techniques. It is expected that there will be some serious challenges in completing this analysis due to both data gaps, and insufficient degrees of freedom for strong statistical inference. However, this effort will serve to illustrate the challenges in deducing the relative impacts of different stressors.

PROJECT 7
FRASER RIVER SOCKEYE FISHERIES AND FISHERIES MANAGEMENT

BACKGROUND

The Contractor is to investigate sockeye fisheries harvesting and fisheries management with a view to informing the Commission about their role in the reduction in Fraser sockeye productivity, and particularly the collapse of the 2009 return.

OBJECTIVES

To prepare a review of fisheries for Fraser sockeye, including First Nations, commercial and recreational fisheries.

To undertake a functional description of fisheries management for Fraser River sockeye salmon.

SCOPE OF WORK

Fisheries Harvesting

The Contractor will summarize the time series of Fraser sockeye fisheries openings in the 3 sectors, First Nations, Commercial, and Recreational, over the period 1980–2009.

First Nations fishery

The Contractor will summarize the food, social, ceremonial and commercial harvest levels of Fraser River sockeye allocated to First Nations (through treaty, fisheries agreement, communal fishing licence or other program or agreement), and the actual harvest levels achieved, according to fishing location and method, for the period 1980-2009. The formal and informal structure of the First Nations fishery will be characterized.

The Contractor will describe and evaluate the accuracy, precision and reliability of methods for making catch estimates.

Commercial fishery

The Contractor will summarize the target and achieved allocations of Fraser River sockeye to the commercial sector, according to fishing method (troll, seine and gillnet), for the last 30 years.

The Contractor will describe and evaluate the accuracy, precision and reliability of methods for making catch estimates.

Recreational fishery

The Contractor will describe and summarize the daily and annual catch limits for recreational fishers of Fraser River sockeye set for the last 30 years.

The Contractor will describe and evaluate the accuracy, precision and reliability of methods for making catch estimates, including consideration of the creel survey.

All sectors

The Contractor will describe and summarize the consequences of non-retention fisheries (First Nations, commercial, recreational) on sockeye physiology, survival and abundance.

Fisheries Management

The Contractor will describe and evaluate the accuracy, precision and reliability of pre-season forecasting methods. This work will include a description of the application of pre-season forecasting in harvest management.

The Contractor will also describe and evaluate the accuracy, precision and reliability of other methods, if any, that are available for pre-season forecasting not historically or currently used by DFO and the Pacific Salmon Commission.

The Contractor will describe and evaluate the accuracy, precision and reliability of in-season run-size abundance estimation methods. This work will include a description of the application of in-season and post-season run-size abundance estimation in harvest management.

The Contractor will also describe and evaluate the accuracy, precision and reliability of other methods, if any, that are available for in-season and post-season run-size abundance estimation not historically or currently used by DFO and the PSC.

The Contractor will describe and evaluate the accuracy, precision and reliability of in-season and post-season escapement enumeration methods used historically and currently by DFO and the PSC.

The Contractor will also describe and evaluate the accuracy, precision and reliability of other methods, if any, that are available for enumerating sockeye not historically or currently used by DFO and the PSC.

The Contractor will analyze historical performance of the in-season assessment process, to include changes in estimates of in-season run sizes, with particular emphasis on how long it has taken within each season to correctly assess the final in-season run size. The key issue to be described is how quickly the in-season assessment process can respond, to meet escapement goals.

The Contractor will evaluate the scientific basis for determining escapement targets. The current and historical effectiveness of fisheries management, including reliance on the Fraser River Sockeye Spawning Initiative (FRSSI), to achieve sockeye escapement goals for individual CUs will be evaluated.

The extent and impact of any overharvesting from 1985 to present will also be evaluated.

Cultus Lake

The Contractor will summarize the current conservation status of the Cultus Lake sockeye population, previously assessed by COSEWIC[1] to be endangered, and will evaluate whether DFO's recovery efforts have been effective in meeting stated recovery objectives. The Contractor will identify what recovery actions were available but not pursued by the Recovery Program.

Comparative Analysis of Bristol Bay (Alaska) and the Fraser River

Fisheries Harvesting

In order to provide a comparison, the Contractor will describe the sockeye salmon fishery in the Fraser River and Bristol Bay, both in freshwater and marine areas, broken down by commercial, First Nations and recreational fishing sectors.

In order to provide a comparison, the Contractor will describe, in a summary fashion, the government agencies, allocations, locations, methods, regulations (including licensing), and levels of harvest related to the sockeye salmon fisheries in the Fraser River and Bristol Bay, both in marine and freshwater areas.

Fisheries Management

The Contractor will identify the key information requirements for sockeye fisheries management in the Fraser River and in Bristol Bay.

The Contractor will contrast the accuracy and precision of pre-season forecasting methods in the Fraser River and Bristol Bay sockeye fisheries. This work will include a description of the application of pre-season forecasting in harvest management.

The Contractor will describe and evaluate the accuracy and precision of in-season run-size abundance estimation methods in the Fraser River and Bristol Bay sockeye fisheries.

[1] Committee on the Status of Endangered Wildlife in Canada.

For both the Fraser River and Bristol Bay fisheries, the Contractor will analyze historical performance of the in-season assessment process, to include changes in estimates of run sizes with particular emphasis on how long it has taken within each season to correctly assess the final in-season run size. The key issue to be described is how quickly the in-season assessment process can respond to errors in preseason forecasts so as to meet escapement goals.

The Contractor will describe and evaluate the accuracy, precision and reliability of in-season and post-season escapement enumeration methods used in the Fraser River and Bristol Bay.

The Contractor will develop rebuilding strategies for Fraser River sockeye.

RESEARCHERS

- Karl K. English (team leader), senior fisheries scientist, and Past President of LGL Limited.
- Robert C. Bocking, fisheries biologist, and Vice-President (Fisheries), LGL Limited.
- Dr. Tim C. Edgell, ecologist and analytical biologist.

COMPANY PROFILE

LGL Limited, incorporated in 1971, is a Canadian company, with offices in Sidney, British Columbia, King City, Ontario, and St. John's, Newfoundland, and wholly-owned subsidiaries in Anchorage, Alaska, and Ellensburg, Washington.

LGL maintains an in-house staff of over 100 professionals with expertise in a broad range of disciplines, including fish, birds, mammals (terrestrial and marine) and freshwater, marine and wetland ecology; disturbance effects; environmental impact assessment and environmental planning; and data analysis.

PROJECT 8
EFFECTS OF PREDATORS ON FRASER RIVER SOCKEYE SALMON

OBJECTIVE

A technical report is required containing an evaluation of the effects of predators on Fraser River sockeye salmon.

SCOPE OF WORK

The Contractors will prepare a description of predation on sockeye salmon across the geographical range of the population, focusing on marine mammal and fish predation on adults and smolts.

A fisheries biologist (Dr. V. Christensen) will prepare an evaluation of freshwater fish predation on alevins, fry and smolts, and marine fish predation on smolts, sub-adults and adults. This evaluation will include a report that includes digital copies of figures and tables.

The marine mammal biologist (Dr. A. Trites) will assume responsibility for integrating the fisheries biologist fish predation assessment with the marine mammal predation assessment. An overall assessment of predation will be developed for the suite of predators that are encountered by juvenile and adult sockeye salmon.

The Contractors will evaluate the extent to which reductions in sockeye abundance are associated with predators in the Fraser River and in the marine areas frequented by Fraser sockeye.

RESEARCHER 1

Dr. Andrew Trites, Professor and Director of the Marine Mammal Research Unit, Fisheries Centre, University of British Columbia, and Research Director for the North Pacific Universities Marine Mammal Research Consortium, Fisheries Centre, U.B.C.

BIOGRAPHY

Dr. Trites' main area of research is the interaction between marine mammals and commercial fisheries. This includes the population biology and bioenergetics of seals, sea lions and whales, and involves a combination of field, captive and computer studies (data analysis and simulation modeling).

RESEARCHER 2

Dr. Villy Christensen, Professor, University of British Columbia Fisheries Centre

BIOGRAPHY

Dr. Christensen works with ecosystem modeling and has a background in fisheries research. His research since 1990 has centered on understanding how human exploitation impacts aquatic ecosystems, and utilizes ecosystem modeling as the main tool.

PROJECT 9
EFFECTS OF CLIMATE CHANGE ON FRASER RIVER SOCKEYE SALMON: LITERATURE COMPILATION AND ANALYSIS

BACKGROUND

A review of the evidence for the occurrence and effects of climate change on Fraser River sockeye is required, to evaluate the importance of the climatic trends on their ecology and survival and to determine the role of climate in the Fraser River sockeye run failure of 2009.

OBJECTIVE

To compile the scientific and grey literature on the documented and projected effects of climate-related variables and climate change on Pacific Salmon with a particular focus on sockeye salmon, and where possible Fraser River sockeye salmon, in freshwater and marine environments across all life stages.

SCOPE OF WORK (1)

The Contractor will compile all published evidence for climate change and climate related effects on sockeye salmon in freshwater and marine habitats across all life stages.

Literature will be compiled from the primary scientific peer-reviewed sources (found using ISI Web of Knowledge and Aquatic Sciences database, and Fisheries Abstracts database) and from grey literature (e.g., technical reports by government and fishery management agencies, theses).

Key words in the literature search will include but not be limited to effects of climate-related variables such as temperature, flow, salinity, pH, currents, primary productivity and species interactions on Fraser River sockeye survival, behaviour and distribution in both freshwater and marine habitats and life stages in each environment.

Literature will also be sought in this compilation related to how Pacific salmon (especially sockeye salmon) are or may be showing potential adaptive responses to climate change, or climate-related variables, and for how potential mitigation measures could be taken by salmon management agencies.

SCOPE OF WORK (2)

The Contractor will review published evidence for climate change effects on Fraser River sockeye in freshwater and marine habitats across all life stages, based on a literature database created by Dr. Scott Hinch (see Scope of Work (1)). The review will also consider projected impacts of climate change on Fraser River sockeye in the future.

The review will look specifically for evidence of the effects of climate-related variables such as temperature, flow, salinity, pH, currents, primary productivity and species interactions on Fraser River sockeye survival, behaviour and distribution. Climate change effects will be separated into freshwater and marine habitats and life stages in each environment.

The review will also look for evidence for potential adaptive responses of Fraser River sockeye to climate change and for potential mitigation measures that could be taken by management agencies.

RESEARCHERS

Scope of Work (1) - Dr. Scott Hinch, Department of Forest Sciences, University of British Columbia.

Scope of Work (2) – Dr. Eduardo Martins, Post-Doctoral Fellow, Department of Forest Sciences, University of British Columbia.

BIOGRAPHIES

Professor Hinch's research program links ecology, behaviour and physiology involving large field and modeling projects. For over a decade, Prof. Hinch has investigated

hypotheses about the role that environmental conditions have on energy utilization strategies in up-river migrating and spawning salmon. He pioneered the use of electromyogram (EMG) physiological telemetry to study reach-specific energetic costs and observe swimming tactics, and developed under water stereovideographic systems to examine precise linkages between behaviour, hydraulic features and energy use.

Dr. Martins is a Post-Doctoral Fellow working with Professor Scott Hinch, UBC Dept. of Forest Sciences. He was senior author of a report on the effects of river temperature and climate warming on stock-specific survival of adult migrating Fraser River sockeye salmon. He recently attended the International Symposium on Climate Change Effects on Fish and Fisheries in Sendai, Japan where he delivered a paper on effects of river temperature and climate warming on Fraser sockeye.

PROJECT 10
FRASER RIVER SOCKEYE PRODUCTION DYNAMICS – DATA COMPILATION, LITERATURE REVIEW, AND REPORTING

BACKGROUND

An evaluation of sockeye production dynamics in the Fraser River is required to evaluate the trends in Fraser sockeye survival, and to compare reductions in Fraser sockeye abundance and productivity with those in other sockeye watersheds.

OBJECTIVES

To prepare a technical report evaluating various aspects of sockeye production dynamics in the Fraser River and other systems, as well as compile and contribute appropriate data to a comparison of time-varying productivity in Fraser sockeye with other sockeye populations.

To undertake analytical evaluations of sockeye production dynamics in the Fraser River and other sockeye systems.

SCOPE OF WORK (1)

The Contractor will procure the relevant up-to-date data sets on Fraser River sockeye, by Conservation Unit, covering the period from the mid-1950's through to the present, and to the extent possible will undertake basic statistical analyses of abundance and productivity by Conservation Unit. The historical temporal and spatial patterns in abundance of Fraser sockeye adult recruits (i.e., catch plus escapement) and productivity (adult recruits per effective female spawner) will be summarized from historical data series, starting with the earliest data available (1950s in many Fraser sockeye Conservation Units) and including the recent decade of data up to the present, which were not included in the Fraser River sockeye part of the Dorner et al. (2008, Can. J. Fish. Aquat. Sci., 65:1842) data set. These data and basic analyses will serve as input to other work to be done with another Contractor and collaborator, Dr. Brigitte Dorner.

To support a comparison of sockeye population dynamics across the geographical range of the species, the Contractor will also obtain up-to-date data over the last decade to add to the Dorner et al. (2008) data set on non-Fraser sockeye populations in North America. That data set ended with the late 1990s/early 2000s. The Contractor will also obtain data on sockeye populations in Asia and determine whether they are of high enough quality to be useable in this context. If so, they will be included in the comparisons across sockeye stocks of time-varying Ricker *'a'* parameter estimates that will be led by another Contractor and collaborator, Dr. Brigitte Dorner. Those comparisons will contrast the production dynamics of Fraser River sockeye with these other sockeye populations.

The Contractor will also review previous research and data on sockeye cyclic dominance, including Fraser and non-Fraser sockeye populations. The relationship between sockeye run failures and timing of sockeye cyclic dominant runs will be reviewed.

The Contractor will also summarize the frequency and effects of over-escapement on subsequent productivity and abundance of adult recruits.

SCOPE OF WORK (2)

The Contractor will undertake analyses of Fraser sockeye abundance and productivity in relation to the distribution of sockeye Conservation Units. This will involve procuring the relevant Fraser River sockeye data sets and performing the appropriate statistical analyses. Effective female spawners will be used as the measure of spawner abundance. Analyses will include standard estimation of parameters for the Ricker spawner-recruit model and use of a Kalman filter with a time-varying *'a'* parameter and a random-walk system equation for describing temporal variations in *'a'*. Dr. Catherine Michielsens at the Pacific Salmon Commission has recently used this Dorner et al. (2008, Can. J. Fish. Aquat. Sci., 65:1842) Kalman filter method to estimate such historical patterns in Fraser sockeye *'a'* parameters, so this step will only be repeated to

the extent that the Contractor will need those numbers to compare with analogous estimates for sockeye populations in non-Fraser systems in Scope of Work (1).

The production dynamics of Fraser River sockeye will be compared to sockeye populations across the geographical range of the species. Production dynamics of all sockeye populations, Fraser as well as non-Fraser, will be described in terms of time series of adult recruits, recruits per spawner (or per effective female spawner in the case of Fraser sockeye), and estimates of the Ricker *'a'* parameter derived from a Kalman filter, which is composed of a time-varying *'a'* parameter and a random-walk system equation.

The analysis will include assessment of the strength and temporal predictability of delayed density-dependent effects, which are not represented in simpler stock recruitment models and productivity trend estimation.

RESEARCHERS

Scope of Work (1) - Dr. Randall M. Peterman, Professor in the School of Resource and Environmental Management at Simon Fraser University, Burnaby, British Columbia.
Scope of Work (2) - Dr. Brigitte Dorner, Post-Doctoral Fellow, Simon Fraser University, Burnaby, British Columbia.

BIOGRAPHIES

Dr. Peterman is a Professor in the School of Resource and Environmental Management at Simon Fraser University (Burnaby, British Columbia, Canada). He holds a Canada Research Chair in Fisheries Risk Assessment and Management and is Director of the Cooperative Resource Management Institute, a unit on campus that facilitates collaboration among university researchers, resource management agencies, and industry. His research focuses on quantitative methods to improve the understanding and management of fish populations, particularly in the presence of uncertainties and conservation risks. His research group specializes in developing and applying quantitative methods to improve fisheries management. Dr. Peterman has served on

various policy advisory groups and helped to write the 1995 United Nations Food and Agriculture Organization's (FAO) "Precautionary Approach to Fisheries."

Dr. Dorner has an M.Sc. in Computing Science (1994, Simon Fraser University), and a Ph.D. in Resource and Environmental Management (2002, Simon Fraser University). She works as a post-doctoral fellow with Dr. Peterman, in dynamics and management of Pacific salmon, including comparative analysis of time trends in salmon productivity. Her areas of specialty include Salmon Ecology, Fisheries Management, Operating Models, Management Strategy Evaluation, Landscape Ecology, Forest Ecology, Spatial Statistics, Spatial Modeling, GIS, and Remote Sensing.

PROJECT 11
FRASER RIVER SOCKEYE SALMON: STATUS OF DFO SCIENCE AND MANAGEMENT

BACKGROUND

Evaluations are needed to assess DFO management and science expenditures over time as they relate to Fraser sockeye salmon.

The demographic of scientists within DFO Science Branch also requires evaluation so that long term capacity to undertake Fraser sockeye science research can be addressed.

OBJECTIVES

To prepare an analysis, including an economic analysis, of DFO activities in Fraser sockeye management.

To present DFO science and research expenditures related to Fraser sockeye.

To undertake an analysis to evaluate DFO's ability to meet its stated management objectives relative to Fraser sockeye.

SCOPE OF WORK

The Contractor will summarize stated DFO management objectives for Fraser sockeye over the period 1985 through to the present.

The Contractor will describe and summarize DFO budgets and expenditures related to sockeye science and management activities for the period 1985 through to the present, estimating expenditures in 2010 dollars so as to provide a basis for comparison.

The Contractor will evaluate the ability of DFO to achieve its stated management objectives for Fraser sockeye over the period 1985 through to the present.

The Contractor will deliver three reports:

- "Evaluation of management expenditures," by October 15, 2010,
- "Description of DFO Fraser River sockeye science and research expenditures," by December 17, 2010, and
- "Description of DFO's ability to carry out applied sockeye research and management," by December 17, 2010.

RESEARCHERS

This investigation will be undertaken by 3 analysts:

- Dr. Edwin Blewett, President of Counterpoint Consulting Inc, holds a PhD in economics from the University of British Columbia (1982) where he specialized in econometrics and statistics, public finance and microeconomic theory. After four years as a senior economist with DFO, Edwin started his consulting practice in 1987. Edwin has a diverse skill set ranging from economic analysis and econometric forecasting to market research and evaluation.
- Bert Ionson is a retired DFO Regional Salmon Manager. Throughout his career he worked with First Nations and commercial and recreational fishermen in the planning and management of their fisheries as well as developers and land owners in fish habitat related issues. As well, in many of these positions, he had a role in developing and implementing fisheries policies (mostly focused on salmon).
- Michael Staley has served as a fisheries advisor to various Aboriginal groups including the B.C. Aboriginal Fisheries Commission, the First Nations Summit Task Groups, the Fraser River Aboriginal Fisheries Secretariat and the First Nations Marine Society. He has been responsible for fisheries analyses and advice to First Nations throughout British Columbia. Since 1995 he has served as a member of the Fraser Panel Technical Committee of the Pacific Salmon Commission.

PROJECT 12
SOCKEYE HABITAT ANALYSIS IN THE LOWER FRASER RIVER AND THE STRAIT OF GEORGIA

BACKGROUND

Information is needed to assess sockeye habitat quality and quantity in the Lower Fraser River and the Strait of Georgia where most Fraser Watershed human development activities are concentrated.

OBJECTIVES

To describe historical trends in development activities in the Lower Fraser and the Strait of Georgia that impact sockeye habitats.

To quantify the sockeye habitats that are exposed to human development activities, including urban impacts and to determine the severity of impacts from those activities.

To describe linkages between Fraser sockeye declines and human development activities in the Lower Fraser River and the Strait of Georgia.

SCOPE OF WORK

Prepare a habitat inventory for sockeye habitats in the Lower Fraser River (below Hope) and identify human activities that could affect them.

Analyze Fraser Estuary development including impacts of larger vessels e.g., oil tankers, proposed expansion of Vancouver Airport Fuel Delivery Project, development of ports, bridges and damage from dredging.

Describe human activities in the Strait of Georgia and identify those which could negatively affect sockeye salmon. Evaluate Coastal Zone protection strategies related to shoreline development, shipping, aquaculture and oil tanker traffic.

Integrate information from Projects 2 and 3 related to sewage runoff, gravel mining and Fraser River channel morphology changes.

Provide a synopsis of water quality conditions in the Strait of Georgia along the sockeye migration routes.

Quantify sockeye food abundance in the Strait of Georgia, in relation to the potential for food competition and limitation.

RESEARCHER

To be decided.