EXECUTIVE SUMMARY:

Project 3 - Evaluating the Status of Fraser River Sockeye Salmon and Role of Freshwater Ecology in their Decline

Although changes in marine conditions often play a key role in driving salmon population dynamics, freshwater habitats are also important in how sockeye salmon express their resilience. Watershed processes provide a high level of variability in conditions, which helps salmon express diverse life history tactics, metapopulation structure, and genetic / phenotypic diversity. In Bristol Bay, Alaska the diversity of sockeye salmon has been related to maintaining fish population stability across the region and found to benefit ecosystems (by stabilizing inputs to terrestrial nutrient supplies and food webs), and human communities (by stabilizing catch and reducing the number of fisheries closures).

Fraser River sockeye salmon and its component stocks demonstrate considerable life history diversity. Stocks vary migration according to four adult run timing groups, demonstrate 4 year cycles of abundance, and spend different lengths of time in freshwater / at sea. The abundance of Fraser River sockeye salmon is also dominated by a few large stocks, which co-migrate with many smaller stocks which are often less resilient to environmental stressors. Given this structure in abundance, it is often difficult to maximize both harvest and population diversity. Weak stocks that are the target of conservation are often harvested and become threatened when they co-migrate with the strong stocks that are the target of the fishery. Thus, despite their inherent resilience this co-migration illustrates how sockeye salmon are vulnerable.

This report is focused on evaluating changes in freshwater ecology and its role in recent sockeye salmon declines for the Cohen Commission. This work includes examining the status of sockeye salmon populations and habitats, as well as the impacts of human activities on freshwater habitats (i.e., logging, hydroelectricity, urbanization, agriculture, and mining). Changes in freshwater ecology due to natural and human forces are hypothesized as having three pathways of effects. These pathways include effects on the: (1) quantity and quality of spawning habitats; (2) productivity of nursery lakes for rearing; and/or (3) habitat conditions associated with migration of smolts / adults.

To assess the current status of Fraser River sockeye salmon populations, we have been charged with three tasks: (1) summarizing existing delineations of population diversity into Conservation Units (CUs); (2) evaluating Fisheries and Oceans Canada's (DFO) methods for assessing conservation status; and (3) determining the status of Fraser River sockeye salmon CUs. Delineations of Conservation Units were necessary to quantify habitat conditions, analyze landscape level disturbances, and evaluate the relationship between changes in freshwater ecology and changes in productivity. Strategy 1 of the Wild Salmon Policy includes a framework for delineating salmon populations according to three major axes: ecology, life history, and molecular genetics. Using DFO's delineations, we identified 36 Conservation Units (30 lake and 6 river type CUs) within the Fraser River basin. We use four criteria to evaluate alternative methods for assessing conservation status of these CUs: (1) ecological criteria and indicators;

(2) approach for setting benchmarks; (3) data needs and availability; and (4) overall feasibility of implementation. No method is ideal across these criteria; DFO's method and two alternatives have different strengths and weaknesses. An alternative to DFO's method was used to summarize conservation status for 25 of 36 CUs; others were not assessed due to insufficient data. Based on the results of the best available assessments, we found that 17 of 36 Conservation Units have a poor population status and are distributed across all timing groups (Early Stuart – Stuart, Takla / Trembleur; Early Summer – Nahatlatch, Anderson, Francois, Taseko, Bowron, Shuswap Complex; Summer – Stuart, Takla / Trembleur; Late – Cultus, Harrison u/s, Lillooet, Seton, Kamloops; River – Widgeon). The status of 11 CUs is unknown.

The majority of Fraser River sockeye salmon populations rear in large lakes for their first year of life. Given our review of available data, measures of freshwater habitat condition are generally not available across many CUs even though Strategy 2 of the Wild Salmon Policy is charged with developing relevant habitat indicators. Given this gap, we developed direct and surrogate landscape level indicators of the quantity and quality of migration, spawning, and rearing habitats for each sockeye salmon lake-type CU using: (1) mapped habitat features we extracted or derived from readily available GIS data, and (2) lake productivity datasets provided to us by DFO. These indicators included: total spawn extent (m), ratio of lake influence to total spawning extent, nursery lake area (ha), nursery lake productivity (estimated smolts / ha), migration distance (km), average summer air temperature across adult migration (ºC), and average spring air temperature at the nursery lake (ºC). Data were not available to describe basic habitat conditions for the river-type CUs.

Given a general lack of information that could be used to reliably define dynamic changes in condition across sockeye salmon spawning, rearing, and migratory habitats we defined habitat "status" as a combination of the: (1) intrinsic habitat vulnerability and (2) intensity of human stressors on those habitats. We used three independent and static indicators to define intrinsic habitat vulnerability for each sockeye salmon freshwater life-stage. These independent indicators are: (1) migration distance; (2) total area of nursery lakes; and (3) ratio of lake influence to total spawning extent. The placement of an individual CU across these dimensions was used to illustrate its vulnerability to watershed disturbances relative to other CUs in the Fraser River basin. The CUs with the greatest relative habitat vulnerability include (i.e., have long migration distances, a low ratio of lake influence to total spawning extent, and a small to moderate nursery lake area): Early Stuart – Stuart, Takla / Trembleur; Early Summer – Bowron, Fraser; and Summer – Mckinley.

To understand the intensity of human stressors on habitats and assess the potential role of freshwater stressors in recent declines of sockeye salmon we compiled and analyzed the best available data describing six categories of human activities which have the potential to affect sockeye salmon: forestry (e.g., forest harvesting activities, Mountain Pine Beetle disturbance, and log storage), mining, hydroelectricity (large scale and run of river power projects), urbanization upstream of Hope, agriculture, and water use. Next, we developed a spatial layer that represented "zones of influence" on core habitats for migration, spawning, and rearing across each Conservation Unit using DFO's sockeye salmon habitat data (e.g., nursery lakes, spawning locations, monitoring sites, and escapement data). We then intersected the stressor layers with our “zones of influence” layer to summarize the intensity of human stresses on each Conservation Unit.

To assess the intensity, spatial distribution, and temporal patterns of forestry related stressors, we examined the level of forest harvesting over time, density of roads and road-stream crossings, and accumulated level of disturbance due to Mountain Pine Beetle (MPB) across sockeye salmon watersheds. We also examined the best available site specific information to qualitatively assess the impacts of log storage in the lower Fraser River. Our findings indicate that the level of forest harvesting within the last 15 years is less than 10% of the area of sockeye salmon watersheds. Drainage areas upstream of lake inlet spawning, tributary spawning, and nursery lakes tend to be more heavily disturbed than the riparian zones adjacent to spawning downstream of lakes or along migration corridors. There is considerable variation in road development across Conservation Units, which tends to be concentrated in areas adjacent to spawning zones downstream of lakes and along migration corridors. The level of MPB disturbance has increased dramatically since 2003, with the level of disturbance being most dramatic in interior Fraser CUs as opposed to coastal CUs whose watersheds are largely absent of ponderosa and lodgepole pine. The intensity of Mountain Pine Beetle disturbance has been very high; up to 90% of the area in some sockeye salmon watersheds. Variation in the intensity of log storage appears to be larger across reaches than across seasons or years within reaches of the lower Fraser River. Based on past studies, the historic intensity of log storage has not appeared to have significant on juvenile salmon.

To assess the effects of mining, we examined the spatial distribution, number, and types of mines occupying sockeye salmon watersheds in the Fraser River basin (e.g., placer mining, gravel mining, industrial mineral production, metal mining, oil and gas production, coal mining, and exploration related to these production activities). The occurrence of mining activity in the watersheds of spawning streams varies substantially across sockeye salmon CUs. Placer mining is the dominant mining activity and appears to have the highest potential to reduce early freshwater survival. However, the data suggest the impacts of mining on sockeye salmon are likely small and difficult to detect because the contrasts among stocks and strength of the effect relative to other factors is low.

To assess the effects of hydroelectricity, we reviewed scientific studies describing the effects of the Bridge/Seton River power project and Alcan’s Kemano Project, as well as the spatial distribution of small scale hydroelectric operations across sockeye salmon watersheds. The Bridge/Seton River power project can affect migrations of smolts and adults on the Seton Rivers, but adverse effects have been largely mitigated by changes in flow diversions and operations of the powerhouse. Likewise, the Kemano Project affects water temperature on the lower Nechako River, but a temperature compliance program has been implemented to ensure that water temperatures remain suitable for adult passage. Our findings indicate that the history of interaction between IPPs and sockeye salmon is very short and limited in number and spatial extent.

To assess the effects of urbanization upstream of Urban environments have a relatively small footprint within watersheds and riparian zones that influence sockeye salmon, though urban footprints have the most intense interaction with sockeye salmon migration corridors. The extent of urban development along migration corridors is further illustrated by the human population data which shows a similar pattern of concentration.

To assess the effects of agricultural activities (beyond impacts on water quality), we reviewed the spatial distribution of agricultural lands. Compared to other land uses, agriculture has a relatively small footprint within watersheds and riparian zones that influence sockeye salmon spawning and rearing habitats. Agriculture does, however, have a greater interaction with migration corridors.

To assess the effects of water use, we calculated the total allocation of water, density of water allocation restrictions, and distribution of water licenses across uses for all sockeye salmon water sheds. Not surprisingly, high water demand is associated with the greatest concentrations of people across the Fraser River basin. Migration corridors appear to have the greatest allocation of water through licensing and the greatest density of water allocation restrictions, largely allocated to the agricultural sector. The CUs of the Lower Mainland have the highest water allocations.

Given a lack of experimental design in the way population, habitat, and stressor data have been collected, our ability to test for cause and effect relationships between the freshwater environment and Fraser sockeye salmon declines was limited. As a result, we were only able to use a limited set of quantitative techniques and data summaries to assess the role of freshwater influences.

We used three analytical approaches to gain insights into possible hypotheses about the role of freshwater influences on Conservation Units. First, we developed a series of cumulative stressor tables which: (1) aligned the hypothesized stressors to the relevant habitat types and Conservation Units, (2) scored the relative intensity of and trend in disturbance, and (3) summarized the cumulative level of stress on a Conservation Unit. Second, we plotted the measures of cumulative stress against the indicators of habitat vulnerability to generate bivariate plots for each habitat type and Conservation Unit (i.e., a summary of habitat status). Lastly, we developed a “dashboard” summary of the all data available to describe population status, habitat vulnerability, and freshwater stressors specific to each lake Conservation Units across the Fraser River basin.

We undertook three additional analyses to assess whether freshwater habitat conditions have contributed to the recent declines in Fraser River sockeye salmon. First, we summarized key findings from recent research examining alternative hypotheses for the declines in Fraser sockeye salmon. This understanding was important for prioritizing our analytical efforts and developing testable hypotheses that are consistent with these other studies. Second, we analyzed the habitat and stressor data to test whether they could explain declines in productivity. Lastly, for those habitat and stressor variables for which we had time series data (i.e., forest harvesting, Mountain Pine Beetle disturbance, summer air temperatures across adult migration, and spring air temperatures at nursery lakes) we examined correlations with total salmon and juvenile productivity indices.

Due to our inability to rigorously test for cause effect relationships on survival at key life stages we used a “weight of evidence” to reach a conclusion about significance of the role of freshwater influences, drawing upon the data and analyses conducted through this effort. Using this approach we believe that recent declines in Fraser River sockeye salmon are unlikely to be the result of changes in the freshwater environment. An important piece of evidence in reaching this conclusion is that juvenile survival has remained relatively stable across CUs where data are available, even though there is substantial variation in stressor intensity across CUs.

Despite our belief that recent declines are not likely to be directly linked to deterioration in habitat conditions, the protection of freshwater habitats remains important to the conservation of Fraser River sockeye salmon because they contribute to their overall diversity and resilience. Given this context, our recommendations include:

(1) To improve our understanding about survival at critical freshwater life stages, scientists need better estimates of juvenile abundance, overwinter survival, and mortality during smolt outmigration.

(2) To improve our understanding about population status across Conservation Units, scientists need more information about the abundance and distribution of small lake and all river CUs.

(3) To improve our understanding about habitat status across Conservation Units, scientists need information on habitats monitored in a consistent manner on a regular basis across a larger number of rivers and nursery lakes.

(4) To improve our understanding about the population level effects of stressors on freshwater habitats, scientists need more precise estimates of the biological consequences of disturbance as a function of increasing stress.

(5) To improve transparency in the science and related decision making scientists, managers, and the public need information that is more accessible and collected in a way that is more integrated across federal and provincial agencies.