RECOVERY PLAN

FOR

NECHAKO WHITE STURGEON

NECHAKO WHITE STURGEON

RECOVERY INITIATIVE

March 2004

Disclaimer

Recovery plans outline reasonable actions that are believed necessary to recover or protect a species. This plan is a co-operative effort among provincial and federal agencies, First Nations, industry, and other stakeholders. The recovery plan does not necessarily represent the views nor the official positions or approval of any individual or agency involved in drafting this document. The plan is subject to modification as new data are collected, if and when changes in species status occur, and upon completion of recovery tasks.

This document should be cited as follows:

Nechako White Sturgeon Recovery Initiative. 2004. Recovery Plan for Nechako White Sturgeon. Prepared by Golder Associates Ltd. 82 pp + App.

TABLE OF CONTENTS

LIST OF FIGURES

APPENDICES

INTRODUCTION

Background

White sturgeon (*Acipenser transmontanus*) have been in decline in British Columbia (BC) for a number of years. In 1991, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed white sturgeon as "vulnerable" (Lane 1991). As both a protective and precautionary approach, in 1994, all recreational harvest of sturgeon was halted in BC. In 1998 the BC Conservation Data Centre (CDC) placed them on their Red-List (Cannings and Ptolemy 1998) meaning they are considered imperilled and in danger of possible extinction if the reasons for the population decline are not addressed. The populations at greatest risk in the province are those in the Nechako, Kootenay, and Columbia systems.

This report summarizes some of the evidence for the decline of the Nechako stock and outlines a course of action to recover it. It is intended that this report be objective in the presentation of facts and present information and conclusions in a balanced and transparent manner. The actions proposed are necessarily precautionary as is consistent with the treatment of a species at risk.

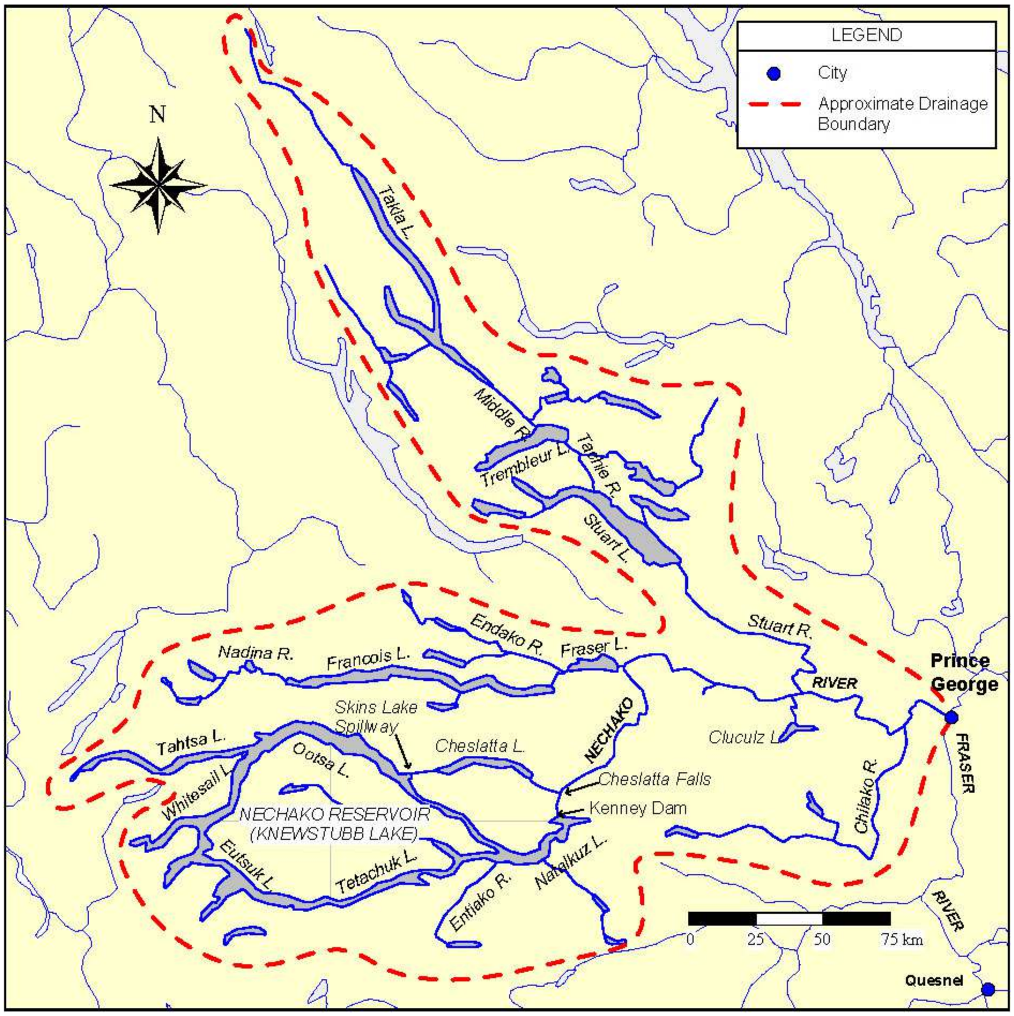
In 1995, the province of BC initiated an intensive five-year Fraser River White Sturgeon Monitoring Program (FRWSMP), the most long-term and comprehensive study conducted in the Fraser system to that date (Figure 1). The goal of the FRWSMP was to gather biological and stock status information thereby enabling the regulatory agencies to better manage and protect this important species. This program gathered data on life history (growth, reproduction, age distribution, etc.), habitat use, population genetics (stock structure), movement patterns, and population size. The results of the five-year program are summarized in a comprehensive report (RL&L 2000) that forms the basis of management and protective actions that are now underway for this important species. In September of 2000, the catch and release sport fishery for white sturgeon on the Nechako River was closed.

Figure 1 Study Area for the Fraser River White Sturgeon Monitoring Program

Information collected on the sturgeon inhabiting the Nechako River indicated that they are genetically distinct with few individuals in the population. Additionally, monitoring radio tagged sturgeon captured in the Stuart River and Stuart Lake has shown that those fish move between the areas of capture and the Nechako River and overwinter in habitat downstream of Vanderhoof. This suggests that there is one stock of white sturgeon that inhabits this watershed. The low abundance of juveniles observed indicates that either adults are unsuccessful at spawning, or their eggs or progeny are unsuccessful in surviving the early years of life. This was observed both in the Nechako and Stuart rivers. Although it is not known which of these is the case, the indication is that if uncorrected, it will eventually lead to extinction of sturgeon in the Nechako River. The Nechako River population structure was markedly similar to other populations that inhabit regulated river systems (*e.g.*, Kootenay and Columbia rivers). This stock structure is the signature of a population heading for extinction. For the purposes of recovery planning, the Nechako white sturgeon stock is considered to be all fish found in the Nechako system, including the Stuart River and Nautley River systems downstream to, but not including, the Fraser River at Prince George (Figure 2).

The Nechako White Sturgeon Recovery Plan attempts to fulfill the spirit of the newly passed federal Species at Risk Act (SARA, Bill C-5; Government of Canada 2002) by identifying risks and data gaps, defining population recovery objectives and options, and recommending adaptive management actions and monitoring requirements. White sturgeon in Canada where officially listed as endangered by COSEWIC on November 22, 2003. Due to the critical status of this stock, recovery planning was undertaken in anticipation of it being listed as endangered. This plan also takes advantage of the knowledge and experience gained by recovery efforts directed at other BC white sturgeon populations in decline (*i.e.*, the Kootenay and Columbia). This plan forms the basis of all Nechako white sturgeon recovery efforts. It is expected that the Recovery Plan will provide the guidance and direction for on-the-ground recovery actions and assigns priorities for specific tasks for the Recovery Team who will implement the actions justified therein. To allow for an adaptive management approach to recovery planning efforts, this document should be viewed as a working document with the full expectation that future works will be dependent on the results of present efforts.

Figure 2 **Nechako Watershed and Geographic Boundary of Nechako White Sturgeon Recovery Initiative**



Nechako White Sturgeon Recovery Initiative

A recovery planning process was initiated for Nechako White Sturgeon by the province in September 2000. Recovery planning will involve two working groups that will interact but not be hierarchical; this structure is consistent with SARA. The intent of the Recovery Planning process is to ensure technical soundness and meaningful participation of the public. The process will be the mechanism for First Nations and stakeholders (interested parties) to become engaged with responsible government agencies in recovery planning in order to build understanding and support for the plan and to facilitate implementation of the plan.

The two principle committees that will oversee the process are:

- the Nechako White Sturgeon Action Planning Group (hereafter referred to as the Action Planning Group); and
- the Nechako White Sturgeon Recovery Team (hereafter referred to as the Recovery Team).

Action Planning Group (APG)

The APG includes representation from various parties with interests in Nechako sturgeon recovery. Regulatory agencies, First Nations, public and industrial stakeholders will all be represented at the APG.

The primary task of the APG is to develop a common vision for sturgeon recovery in the Nechako and to assist the Recovery Team (RT) by acting as a public advocate, which promotes support and implementation of the recovery plan. This will involve providing feedback to the RT regarding socio-economic and environmental impacts of the proposed recovery plan components, and educating and communicating with the broader community.

APG Sub-Committees

APG sub-committees, formed as required, work independently to develop options and alternatives for issues identified by the APG or RT. APG sub-committees report to the APG with recommendations. The APG implements recommendations of sub-committees by consensus.

Communication Sub-Committee

The communication sub-committee is responsible for developing strategies for educating and informing the stakeholders, interested parties and the general public of the goals, plans, and progress of the recovery initiative.

Recovery Team (RT)

The Recovery Team is a technical group whose role is to develop and oversee implementation of the Recovery Plan, and amend the recovery plan as new information is collected. Implementation of action items endorsed by the APG and RT will be sought through negotiation with appropriate regulatory agencies and stakeholders. The criteria considered for membership on the Recovery Team were: a working knowledge of sturgeon biology; experience in streamflow management/ hydraulic engineering; experience in other animal recovery programs or having regulatory role with regard to the protection of fish and their habitats in the Nechako basin.

RT Sub-Committees

RT sub-committees, formed as required and working independently, develop options and alternatives for various issues. An RT member who provides the RT with progress reports on sub-committee tasks chairs each sub-committee. It is the RT's responsibility to ratify, amend, or reject sub-committee recommendations.

Three sub-committees are in place investigating significant issues: conservation fish culture, flow/temperature, and research and monitoring.

Conservation Fish Culture Sub-Committee

The Conservation Fish Culture Sub-Committee provides input to the RT on everything entailed in the artificial production of juveniles for conservation and research purposes.

The sub-committee advises the RT on:

- infrastructure requirements to support the recovery objectives;
- broodstock requirements;
- genetic risks;
- maintenance and artificial reproduction techniques;
- juvenile rearing techniques;
- protocol for maximizing genome viability;
- methods for tracking success of breeding program; and
- permitting and management requirements.

Flow/Temperature Sub-Committee

The Flow/Temperature Sub-Committee analyses existing temperature and flow data to determine whether there are relationships between these factors and recruitment or behaviour patterns of white sturgeon in the Nechako and Stuart systems.

The sub-committee advises the RT on:

- results of a literature review re: potential flow-related management actions;
- any relationship to recruitment from examining Nechako data;
- any relationship to recruitment from examining Stuart data; and
- the hydrograph most suitable for sturgeon recruitment given water availability targets.

Research and Monitoring Sub-Committee

The Research and Monitoring Sub-Committee examines gaps in existing information on the requirements of the Nechako Stock in all of its life stages.

The sub-committee advises the RT on:

- ongoing monitoring of population status and limiting factors;
- research and evaluation of essential habitats important to each life stage;
- research and evaluation of recovery actions based on flow and habitat manipulations; and
- the identification and design of appropriate experiments to address data gaps using fish from the Conservation Fish Culture program.

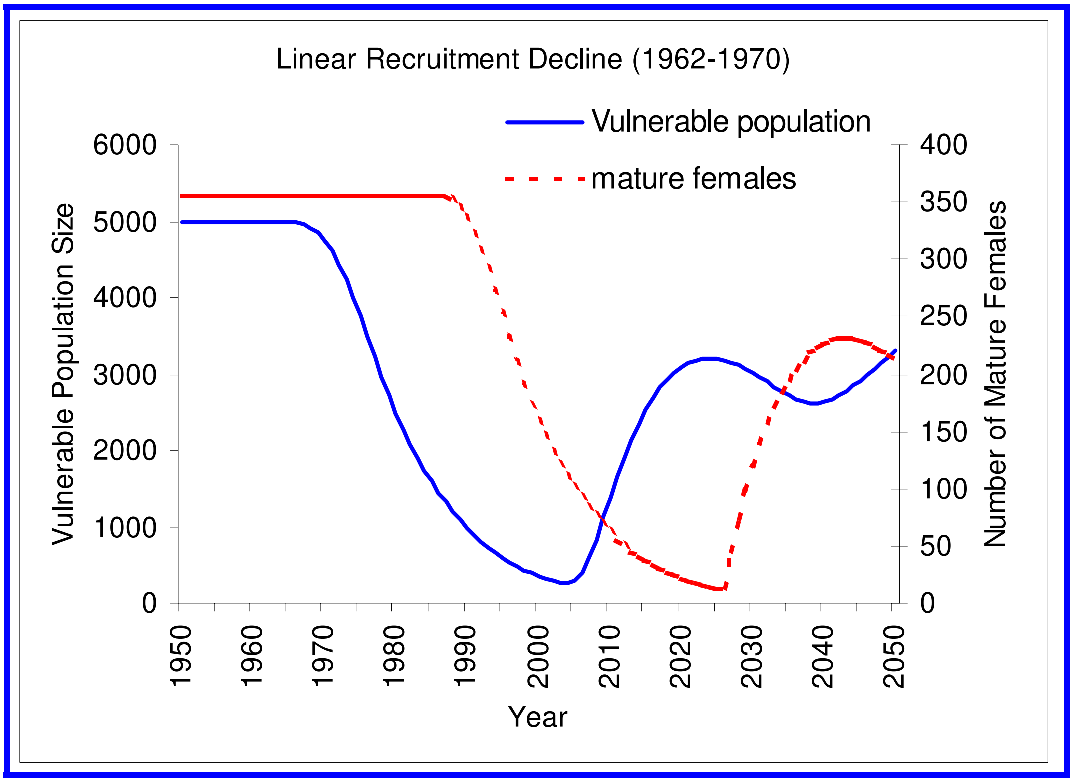
OUTLOOK

All the information collected to date in the Nechako River system indicates there is a significant problem which, if not addressed, will lead to the eventual extinction of this population. Although a significant data gap remains with the assessment of abundance of sturgeon in the Stuart and Nautley River systems, a normal stock structure in these components of the population will not alter the observations on the Nechako River proper. Given the complexity and issues within the watershed, there is no simple solution. There is however, tremendous interest amongst stakeholder groups, scientists, industry, members of the public and implementing agencies in addressing the problem through intensive recovery efforts.

A population dynamics model developed for the Nechako River sturgeon population (Korman and Walters 2001) estimated that there are currently about 150 mature females left in the population and that if the trend continues, this number will decline to 25 by the year 2025 (Figure 3, Korman and Walters 2001). Rapid recovery of juvenile recruitment will not immediately affect spawning population levels until after 2025 because it is estimated that sturgeon do not reach sexual maturity until at least age 25 (Figure 3, Korman and Walters 2001). It should be noted that owing to the size of the Nechako basin (Figure 2), not every habitat has been sampled; however, the information collected to date, even if only a sub-sample of the total population, indicates that the population is in significant difficulty. With the failure of natural recruitment in the Nechako River, modelling analysis indicates the population will decline by an additional 50% within 10 years and 75% within 20 years. Consequently, the model forecasts underscore the urgency for initiating population recovery efforts as soon as possible.

This estimated number of 150 mature females is substantially lower than the endangered status criteria of 2,500 identified by the World Conservation Union (IUCN 1994) and COSEWIC (1998) from surveys of bird, mammal and fish populations around the world.

Figure 3 Modelled Vulnerable Population Size and Number of Mature Females Based on Linear Recruitment Decline



A species is considered endangered when it is facing a very high risk of extinction in the wild in the near future. This category is defined by specific criteria. The criterion of greatest applicability to Nechako sturgeon is "C" which states "Population estimated to number less than 2,500 mature individuals and either:

1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer; or
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals and population structure in the form of either:

   (a) severely fragmented (*i.e.*, no sub-population estimated to contain more than 250 mature individuals), or

   (b) all individuals are in a single subpopulation.

Adult numbers of 50 and 500 have been identified as genetic critical population benchmarks associated with irreversible consequences in U.S. Endangered Species Act assessments (Thompson 1991, McElhany *et al.* 2000, Rieman and Allendorf 2001). Adult numbers less than 500 result in bottlenecks that rapidly reduce genetic diversity. Adult numbers less than 50 result in severe genetic impacts. The size of the Nechako sturgeon population, which includes juveniles and adults, was estimated at 571 fish in 1999 (RL&L 2000). Modelling results project a decline to less than 500 fish (vulnerable population) within 14 years and functional extinction around the year 2044 as numbers fall below 50 fish (Korman and Walters 2001). Given the modelled timelines, effective intervention will be a major challenge before functional extinction occurs since there is no clear understanding of what interventions will be successful.

NECHAKO WATERSHED

The Nechako River system is a valuable and important drainage in north-central BC due to its unique ecological attributes, and because of the benefits the system provides to the human population as a source of food, commerce, and recreation. In addition to the existing white sturgeon population, the system supports ocean and Fraser River commercial fisheries, in-river First Nations subsistence fisheries and recreational fisheries. The Nechako River provides water for agricultural purposes, generates power, hosts various outdoor recreationalists (canoeists, river boats, etc.) and has played a major role in the history and development of this part of the province. There is active interest and participation of area residents in ensuring that the watershed is best managed to allow the complementary values and uses of this system. The Nechako Watershed Council – a group of approximately 23 stakeholders – is an open public process that has been active since 1996 to provide a forum to address water management issues on the Nechako River. The Nechako Fisheries Conservation Program has been in existence since 1987 to manage the delivery of Nechako Reservoir flows to the Nechako River, and to carry out a program of temperature control and chinook research and monitoring. The following is a brief description of the various physical and biophysical attributes of this important river basin.

Hydrological Description

The Nechako River itself is one of the largest tributaries to the Fraser River, which drains 25% of the total river discharge in BC. The Nechako River is 290 km in length and has an average annual discharge of 9×10^9 m^3 (Dorcy and Griggs 1991). The Nechako Watershed covers an area of 52,000 km^2 and drains into the Fraser River at Prince George (Figure 2). Of this area, 32,000 km^2 are drained by the Nechako River and the remainder by the Stuart and Nautley rivers. The Nautley River is the largest tributary to the Nechako River upstream of Vanderhoof and has a drainage area of 6,000 km^2. There are numerous large lakes and rivers throughout the basin. Much of the water from the upper Nechako

River watershed is diverted westward into the Kemano River for hydroelectric generation.

The drainage area above Kenney Dam is 14,000 km^2. A significant portion of this area is in the Tahtsa Range (Coast Mountains). The Tahtsa sub-basin supplies 70 to 80% of the average runoff at Vanderhoof (Rood and Neill 1987).

The impoundment of water into the Nechako Reservoir and the resultant spillway releases have significantly altered the hydrology of the Nechako River system since 1952. A major dam in the Nechako Canyon and nine saddle dams created the reservoir. The reservoir is 90,000 ha in size and includes Knewstubb, Natalkuz, Tetachuck, Ootsa, Whitesail and Tahtsa lakes, and Tahtsa and Intata reaches.

Water is released from the reservoir through two separate structures. Water released for power generation exits westward through the Tahtsa system into an underground tunnel to the powerhouse in Kemano then into the Kemano River. On the eastern end of the reservoir water is released through the Skins Lake Spillway. Flows released from the spillway pass through the Cheslatta River, Cheslatta Lake, and Murray Lake and enter the Nechako River at Cheslatta Falls. Cheslatta Falls is 9 km downstream of Kenney Dam. The only flow in the Nechako River between Kenney Dam and Cheslatta Falls is from local natural inflow. Releases from the Skins Lake Spillway have varied significantly since its construction. In the last two decades, releases from the spillway have contributed 62 m^3/s mean annual flow to the Nechako River. The inflow to the reservoir since 1952 has averaged 195 m^3/s.

Seven distinct reaches have been classified in the 142 km section of the Nechako River from Cheslatta Falls to Vanderhoof (Rood and Neill 1987). Reaches 1 through 4 are upstream of the Nautley River that drains Fraser Lake as well as Francois Lake via the Stellako River. The Nautley River contributes 30 m^3/s mean annual flow to the Nechako River. Reaches 5 to 7 lie in the area between the Nautley River and Vanderhoof.

The hydrological regime of the system has shaped the habitat of each of these seven reaches. Reaches 1 through 6 of the Nechako River are incised and generally confined by bedrock (Rood and Neill 1987). Prior to flow regulation floodplain and back-channels predominate in reaches 4 and 7 while in the remaining reaches floodplain is fragmentary. The substrate in these reaches is generally boulder with cobbles and gravel locally abundant. Reach 4 is predominantly sand substrate. There are also accumulations of sand in reaches 2, 5 and 7. Only Reach 2 has been identified as a source of sediment input (Rood and Neill 1987).

The Nechako River was naturally a fairly sediment-poor system due to the presence of headwater lakes, with bank erosion historically providing the greatest sediment inputs (Rood and Neill 1987). Impoundment initially led to sediment inputs due to erosion in the Murray Cheslatta system caused by the introduction of spillway flows. Additional large inputs of sediment occurred when the Cheslatta Fan formed as a result of two avulsions of the Cheslatta River, one in 1961 and a second in 1972 (in the Nechako Canyon just upstream of Cheslatta Falls). Approximately 0.9M m^3 of material was deposited in the Nechako River of which about half was transported downstream (Hay & Company 2000). The fate of this sediment has not been well studied however, Rood and Neill (1987) identified a decline in active side channels during the period when the avulsions occurred. Sediment inputs from Reach 2 and the Cheslatta avulsions as well as low base flows may also have contributed to the presently shallow channel, as river depth is generally less than 2 m although deep pools are not uncommon.

In the 45 km from Vanderhoof to the confluence with the Stuart River, the Nechako River typically has a low gradient and is slow moving within a confined, meandering channel. There are several small tributaries and one set of rapids (Hulatt Rapids) 15 km upstream of the Stuart River. The river here is generally deeper than that upstream of Vanderhoof. The Stuart River contributes a mean annual flow of 128 m^3/s and has a drainage area of 20,000 km^2, including several large lakes (Stuart, Trembleur and Takla).

The Stuart River enters the Nechako River approximately 90 km upstream from the Nechako-Fraser confluence. There are two rapids, Whitemud and Isle Pierre, at 38 km and 67 km upstream of the Fraser River, respectively.

Biological Description

Preliminary surveys of Cheslatta and Murray lakes were conducted by the province in the early 1950s (Larkin 1952). In the same year a survey of headwater lakes within the drainage was also undertaken by the province (Lyons and Larkin 1952). Detailed information about the biological aquatic resources of the Nechako River system has, for the most part, only been collected for the past 25 to 30 years. Prior to that time, the only standardized and well-reported work was that done by

Fisheries and Oceans Canada (formerly the Department of Fisheries and Oceans) for salmon escapement numbers. In 2000, Norcan Consulting Ltd. completed a report on the historical distribution of white sturgeon in the Nechako Watershed. That report did not include the traditional knowledge possessed by local First Nations. In addition there is very little information on the nature and magnitude of changes that occurred in the fish community composition as a consequence of the construction of the Kenney Dam.

The Nechako system supports a diverse assemblage of fish and other aquatic flora and fauna. There are 20 fish species recorded in the river. The sportfish species include sockeye (*Oncorhynchus nerka*), chinook (*O. tshawytscha*), and coho (*O. kisutch*) salmon, rainbow trout (*O. mykiss*), bull trout (*Salvelinus confluentus*), lake trout (*S. namaycush*), burbot (*Lota lota*), mountain whitefish (*Prosopium williamsoni*), and white sturgeon. Non-game fish species present include various sucker, minnow, and cottid species, as well as Pacific lamprey (*Lampetra tridentatus*) (Hay & Company 2000).

Sockeye salmon are the most economically valuable species with over 350,000 fish entering the Nechako River enroute to the Stuart and Stellako systems. There are also numerous chinook salmon stocks in the Stuart and Nechako systems including one that spawns in the mainstem Nechako River (R. Bailey, Fisheries and Oceans Canada, personal communication). Jaremovic and Rowland (1988) established that flows in the Nechako River appear to have affected chinook salmon abundance over the period 1953 to the 1970's, although data were limited for earlier years. In addition, Bradford (1994) indicated that flows influenced the distribution of salmon within the Nechako River. Since 1980, flows in the Nechako River have been relatively stable and salmon abundance also appears to be stable (NFCP 2003). These sources of information are important because they establish the potential for similar linkages between flow changes and the abundance and distribution of white sturgeon in the watershed.

French and Chambers (1997) model predictions showed that aquatic macrophyte abundance (bottom cover and cross sectional biomass) has increased substantially in the Upper Nechako River (upstream of Nautley River) since the 1952 diversion. There may also have been an increase in macrophyte abundance in the Nechako River between Vanderhoof and Stuart River, which may be a response to a combination of nutrient input (primarily sewage from Vanderhoof and Fort Fraser) and changes in flow regime (French and Chambers 2001).

Benthic invertebrate sampling in 1981 at two locations on the Nechako River showed overall high densities of organisms but relatively low biomass at those sites (Envirocon 1984). Large insects were scarce while chironomid larvae were most abundant. There are no pre-Kemano benthic invertebrate data for the Nechako River that would suggest a change in the benthic invertebrate community has taken place. The reduction in variability of thermal and flow regimes however, tends to result in an increase in productivity but reduced species diversity (Envirocon 1984).

Development in the Watershed

The entire Nechako Watershed has undergone extensive development over the past century. Activities that have had an impact on the watershed include human settlement, forestry, hydroelectric development, and agriculture. The first European settlements were established in the early 1800's with the beginning of the fur trade and subsequently with the gold rush in the late 1850's. After the turn of the last century, settlement increased with the construction of the CN Railway (1907). During World War II, mining exploration and then timber harvesting increased dramatically. In the 1950's lumber became and remains the single most important resource in the region, with mills being established in most towns. Alcan developed hydroelectric facilities and the Nechako Reservoir in the early 1950's. A large portion of the Nechako River floodplain has been cleared for farming. In 1984, the Regional District of Bulkley-Nechako supported 839 farms on 84,000 ha of land. Other developments, such as residential housing, have occurred along many rivers and lakes, particularly adjacent to town sites (Envirocon 1984).

The Kenney Dam, constructed in the Grand Canyon of the Nechako River in the early 1950's, impounded the Nechako Reservoir for the purpose of diverting water to the power generating station at Kemano. The two major tributaries to the Nechako, the Nautley and Stuart rivers, also have supported a high level of logging activity, mining and farming development but to a lesser degree than the Nechako floodplain. The Stuart River is unregulated. The Nautley Watershed is unregulated except for two low weirs on the outlets of Fraser and Burns lakes. Alcan built a weir at the outlet of Fraser Lake in the 1950's using large class rock to prevent lake levels from dropping as a consequence of lower water levels in the Nechako. A low weir was also built on the Endako River at the outlet of Burns Lake by the City of Burns Lake. The weir is a gravel/cobble deposit; details regarding its height and timing of construction are not known.

Flow Regime

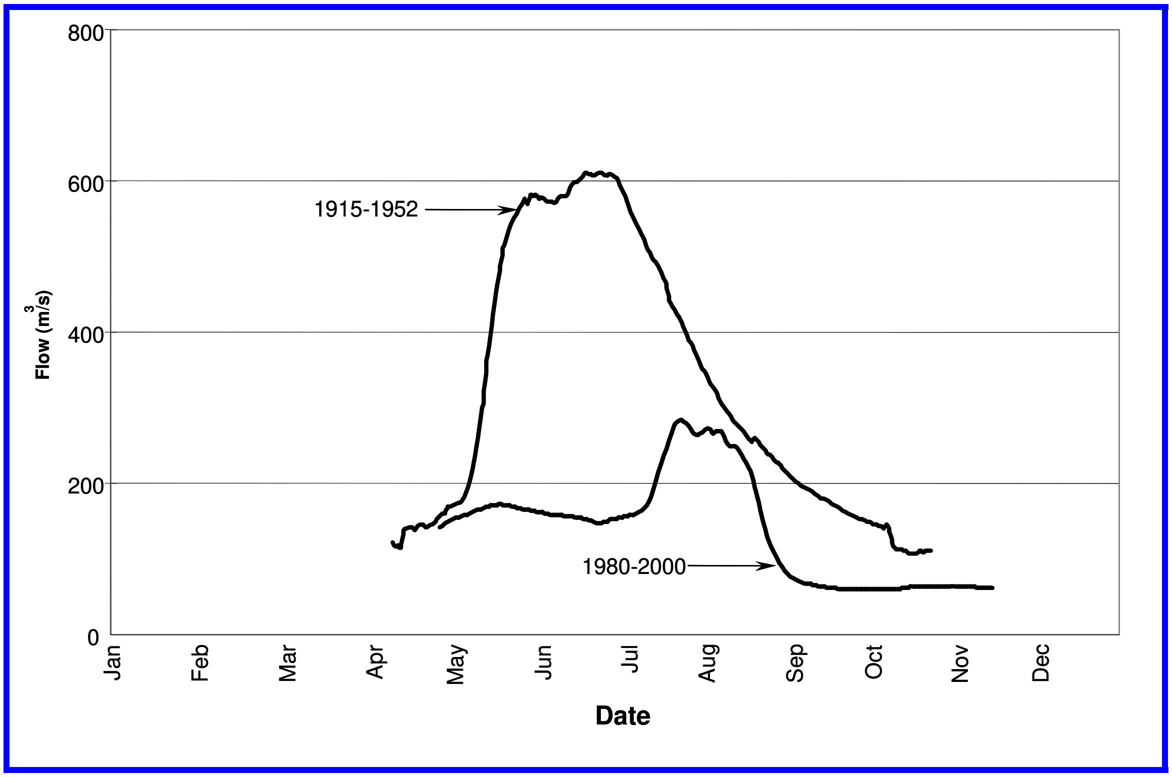
Construction of the Kenney Dam had advanced sufficiently to permit the start of the filling of the reservoir in 1952. The filling period lasted until 1956. During the filling period, mean daily flow of the Nechako River at Cheslatta remained below 115 m^3/s, with a low of 9 m^3/s. The mean annual flow varied from 32 to 95 m^3/s over this period.

Alcan first began producing power from the Kemano Power House in 1954 and the Skins Lake Spillway first began releasing water in 1956. From 1957 to 1961, flows released from the spillway were highly variable with large releases over 300 m^3/s possible in any month of the year. From 1962 to 1980, flows from December to April were constant but ranged between 30 m^3/s and 180 m^3/s. A peak flow occurred between May and August although the magnitude, duration, and exact timing of these peak flows were highly variable.

Beginning in August 1980, releases (termed "Injunction Flows") from the Skins Lake Spillway were determined by conditions prescribed in a legal injunction filed by the regulatory agencies. These flows were the precursor to the current flows from the Skins Lake Spillway. In 1987, after several years of discussion, Alcan and the provincial and federal governments reached a legal agreement that outlined flow requirements from the spillway into the future. These flows are often referred to as the 'Annual Water Allocation', or 'Settlement Agreement Flows' in reference to the 1987 Settlement Agreement.

A comparison of Nechako River flows at Vanderhoof prior to the construction of Kenney Dam with flows since 1980 is illustrated in Figure 4 (Alcan 2001). These flows were implemented to protect sockeye and chinook salmon stocks in the Nechako and Stuart watersheds. The two periods of concern for these species are July and August, peak migration times for sockeye, and year round for chinook to accommodate chinook spawning and rearing in the Nechako mainstem. During the warmer months of July and August, water temperatures can exceed 20°C. Sockeye salmon survival is known to be affected by high temperatures and therefore, to reduce risk of pre-spawning mortality due to heat stress, a water temperature management program is initiated each year with a target of keeping water temperatures just above the confluence of the Nechako and Stuart rivers below 20°C. This is accomplished by releasing greater amounts of water from Skins Lake Spillway in July and August. In late August, releases are reduced prior to the onset of chinook salmon spawning in the Nechako River. A final flow adjustment is typically made in early September, which establishes the flows until the following April. This NFCP flow regime – in place since 1980 - is relatively stable. Flows are set for the remainder of the year to ensure the annual water allocation of 36.8 cms is met and to accommodate other reservoir management requirements such as flood control (NFCP 2003). The rule of thumb is that winter flows cannot be lower than 50% of the chinook spawning flows but are typically closer to 1:1

Figure 4 Historical Mean Daily Nechako River Flow at Vanderhoof



The Nechako Fisheries Conservation Program (NFCP), which oversees flow release decisions, was created in 1987. It includes a Technical Committee made up of one representative each from each of the three parties to the 1987 Settlement Agreement – Alcan, DFO and BC plus an Independent Member. A Steering Committee is made up of one senior representative from each of the three parties.

Operationally, water is released from the reservoir through twin gates at the Skins Lake Spillway and travels down the Cheslatta River for 25 km before reaching Cheslatta and Murray lakes. Cheslatta Lake and Murray Lake together are approximately 50 km long. The Cheslatta River continues downstream from Murray Lake for approximately 1 km to its confluence with the Nechako River at Cheslatta Falls.

Gate changes at Skins Lake Spillway result in rapid changes in flows upstream of Cheslatta and Murray lakes. However, due to the storage capacity of the lakes, flow changes in the Nechako River below Cheslatta Falls (at the outlet of Murray Lake) and farther downstream are more gradual. Storage in the lakes and in the river attenuates the effect of rapid changes in releases at the spillway. For example, after a gate change that increases the release at the spillway by 100 m^3/s, there will be no perceptible change at Cheslatta Falls for about 16 hours and the full effect would not be realized for nine days. The subsequent change in the Nechako River downstream of Cheslatta Falls would be observed one day later at the confluence with the Nautley River, two days later at Vanderhoof and just over two days later at its confluence with the Stuart River. Changes in releases at Skins Lake Spillway, as outlined by the 1987 Agreement, include the following restrictions:

- year round base flow averaging 36.8 cms and average monthly flow of no less than 29.1 cms, with a maximum of 453 cms and minimum 14.2 cms released from Skins Lake Spillway during the Summer Temperature Management Program (STMP) in July and August; and
- within the bounds of the STMP flows, the Skins Lake Spillway releases are managed such that flow in the Nechako River at Cheslatta Falls does not drop below 170 cms and does not exceed 283 cms in July and August (NFCP 2003).

Since 1980, releases from the Nechako Reservoir have been held at approximately 30 m^3/s from September to the latter part of April. Releases are normally increased to 49 m^3/s in late April as a minimum flow for chinook rearing and are maintained at that level until July 10. On July 11, flow releases are increased such that the flow in the Nechako River below Cheslatta Falls is 170 m^3/s by July 20 and it is maintained at this level or greater until late August in an effort to manage water temperatures in the Nechako River at the Stuart River confluence (200 km downstream) to 20°C or less for the protection of migrating sockeye salmon. This can require changes in reservoir releases between 453 m^3/s and 14.2 m^3/s as required for the increase or decrease in river flows based on heating or cooling conditions over the basin.

On or just before August 20, reservoir releases are decreased to 14 m^3/s until early September in order to decrease flows in the Nechako River below Cheslatta Falls to fall spawning flows of approximately 30 m^3/s. The reservoir release is then increased to about 30 m^3/s in the first week of September to maintain the fall spawning and winter incubation flows in the Nechako River.

During years when there is a high snow pack in the basin tributary to the Nechako Reservoir combined with relatively high reservoir levels, additional water can be released from the reservoir for reservoir management. In an effort to minimize flooding of land adjacent to the river, these releases are normally delayed into June so that they do not coincide with naturally occurring high water levels in Nechako River tributaries and the Fraser River.

BIOLOGY AND STATUS

Species Description

The white sturgeon is one of seven sturgeon species inhabiting large temperate river systems across North America (Robins *et al.* 1980). It was first described by Richardson in 1863 from a specimen collected in the Columbia River near Fort Vancouver, Washington (Scott and Crossman 1973).

All sturgeon are characterized by a cartilaginous skeleton and persistent notochord (Scott and Crossman 1973). They possess a tube-like mouth and four barbels located on the ventral surface of a hard, protruding snout. They have five rows of bony plates (scutes): one dorsal, two ventral, and two lateral (Scott and Crossman 1973). Between the rows of scutes denticles make the skin feel rough. The number and arrangement of scutes is diagnostic for white sturgeon: 11 to 14 dorsal, 36 to 48 lateral, and 9 to 12 ventral (Scott and Crossman 1973).

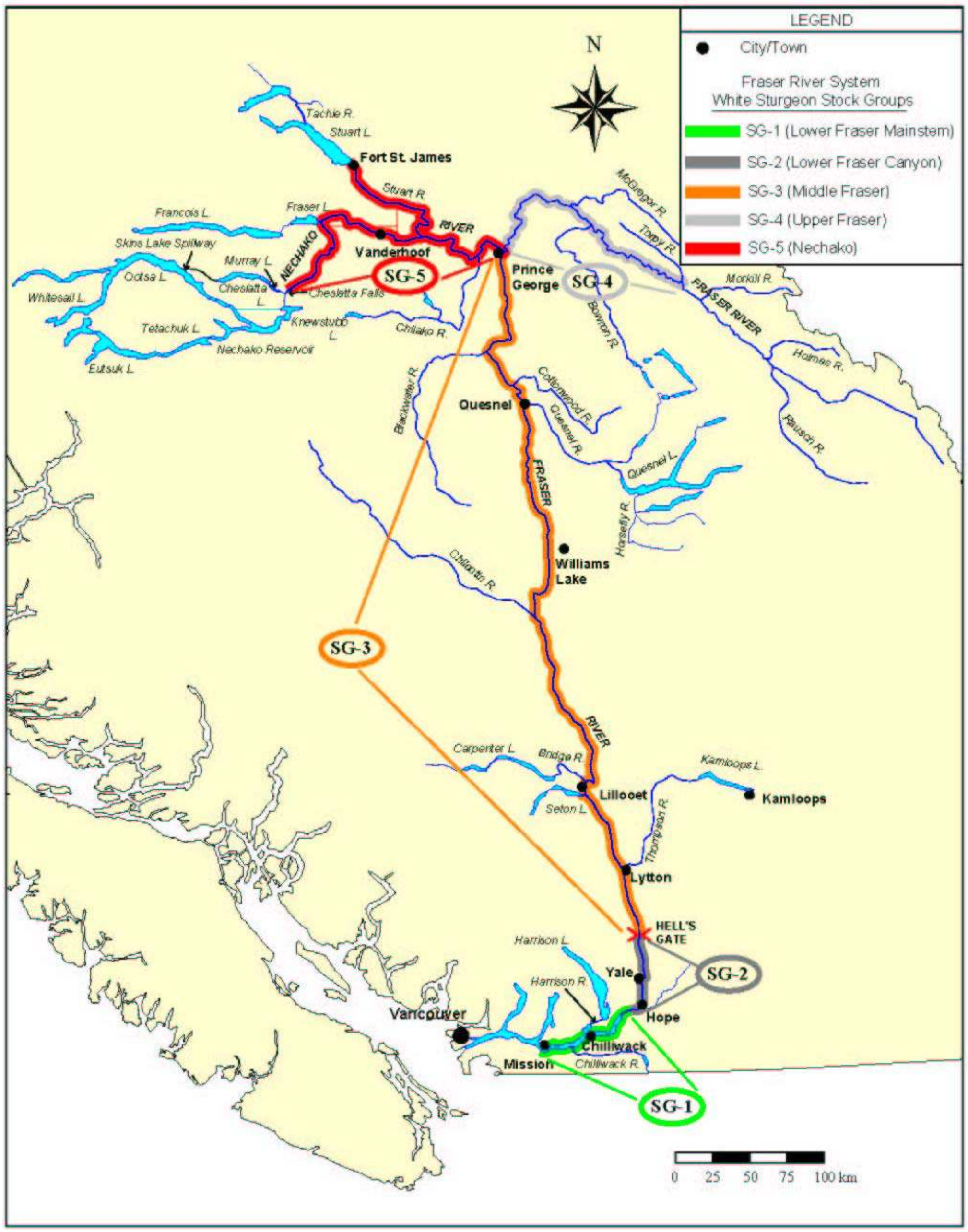
Distribution and Movements

White sturgeon are capable of anadromy and are known to inhabit large rivers, estuaries, and the near-shore ocean from Ensenada, Mexico, to the Aleutian Islands (Scott and Crossman 1973). Significant white sturgeon populations spawn in the Columbia, Fraser, and Sacramento River systems (Scott and Crossman 1973, Lee *et al.* 1980, Lane 1991). Some members of these populations mix in the ocean, however, movement of tagged fish between the three main river systems is infrequent (DeVore *et al.* 1999).

Some white sturgeon populations and individuals complete their life cycle in fresh water, *e.g.*, the Kootenay River population has been isolated upstream of Bonnington Falls for 10,000 years (Northcote 1973). Prior to extensive development, populations with access to the ocean probably included a mixture of anadromous and resident life histories where the incidence of anadromy decreased in the upper river reaches.

Among the significant findings of the FRWSMP was a clear indication that there are at least five distinct stocks of sturgeon in the Fraser Watershed (Figure 5). This conclusion was based on genetic and life history data gathered over the five-year program (Nelson *et al*. 1999, Pollard 2000, RL&L 2000).

Figure 5 Geographical Distribution of White Sturgeon Stock Groups in the Fraser River Drainage



Although the Nechako population was found to be distinct from other Fraser populations, there is still some degree of uncertainty as to the role of the Stuart system for this stock. Work recently conducted by the Ministry of Water, Land and Air Protection (WLAP) showed that white sturgeon captured and radio tagged in Stuart Lake in 2002 moved through the Stuart River into the Nechako River in 2003 and were found in known overwintering areas downstream of Vanderhoof in October 2003 (Cory Williamson, WLAP, personal communication). Movement of white sturgeon between the Stuart and Nechako systems was first documented by RL&L during the five year Fraser River white sturgeon program 1995-1999 (RL&L 2000). Using conventional tag-recapture techniques as well as radio-telemetry, data have shown movement of Nechako and Fraser sturgeon between the two systems, including feeding use of the confluence area of the Nechako River by Fraser sturgeon (RL&L 2000, Golder Associates 2003) . Nechako sturgeon also grow more slowly than most of the other Fraser River populations with the exception of the “Upper Fraser” sturgeon (SG-4) found upstream of Prince George (Figure 5) (RL&L 2000).

Substantial data gaps still exist with respect to the requirements of Nechako sturgeon in some of its life stages (*e.g.*, spawning, rearing). It is also unclear as to how fluctuations in factors such as flow, river stage, and temperature influence the population.

Genetics and Stock Structure

Studies have shown that the Nechako stock group is genetically distinct from the Upper Fraser stock group north of Prince George, and other more southerly Fraser River stock groups. The Nechako stock is believed to be comprised of sturgeon inhabiting a large area including the Stuart and Nautley rivers and their complex series of lakes. It is well documented that sturgeon inhabit these lakes and rivers tributary to the Nechako and are currently considered to be of the same genetic stock. What is not known is how further reductions or the loss of the Nechako component of the stock would impact the genetically distinct stock group, even though it may not alter proposed recovery actions. However, Korman and Walters (2001) suggest that the recruitment failure applies to whatever stock of fish uses the Nechako River and that if some fish reproduce in the Stuart River, there are not enough of these young fish to offset the recruitment failure in the Nechako River. That conclusion is further supported by the most recent radio tagging information that showed that sturgeon caught and tagged in the Stuart River and Stuart Lake moved downstream into the Nechako River and spent the summer and winter in that system.

In 1995, a provincial genetic study was initiated as part of the FRWSMP to describe the population structure and genetic diversity of white sturgeon in British Columbia. This research focussed on the Fraser River, but preliminary assessments of the Upper Columbia and Kootenay populations were also conducted. The genetic study concluded that four biogeographic groups are present in the Fraser River based on the samples available and genetic analyses conducted (Smith *et al*. 2002, Figure 5 this report). This study also supports other genetic work which identified the lower region of the Fraser downstream of Hell's Gate to be significantly more genetically diverse than upstream regions (Brown *et al*. 1992, Anders and Powell 2002).

The results of the study by Smith *et al.* (2002) are conclusive with respect to the Nechako population and indicate that this population is genetically isolated from upper Fraser River populations upstream and downstream of the Nechako River confluence. Specifically, two independent types of genetic markers were applied to DNA tissue samples collected from these river sections including mitochondrial DNA and nuclear DNA microsatellites. Mitochondrial DNA (mtDNA) is a relatively quickly evolving (or mutating) molecule that is maternally inherited (*i.e.*, passed from mother to offspring) as a single unit. For these reasons, variability in mtDNA is frequently assessed in northern temperate freshwater fish populations such as white sturgeon which have not persisted in areas more than 10,000 years or so since the most recent glacial period. Nuclear DNA microsatellites are short repeating sections of neutral (*i.e.*, no selection acting) nuclear DNA which are free to mutate and often do at rapid rates. Each microsatellite can be considered an independent marker (*i.e.*, should not affect variation at other microsatellites), and is inherited biparentally (from both parents). In the case of white sturgeon, the nuclear genome has undergone several polyploidization (*i.e.*, duplication of the genome) events through evolution, resulting in what is believed to be an octoploid genome (eight copies rather than the usual two copies) of nuclear DNA that is now slowly returning to a diploid (two copy) state (Van Eenennaam *et al*. 1998). Thus, the inheritance of different microsatellite markers can vary, and correct interpretation requires appropriate inheritance studies. Such studies were conducted for the white sturgeon study and four microsatellite markers were found to be of use (Smith *et al*. 2002).

Both the mtDNA and microsatellite data provided useful information for describing white sturgeon population structure in British Columbia although mtDNA provided higher resolution for this study (Smith *et al*. 2002). Both genetic markers indicated that the Nechako River group of white sturgeon was distinct from the mid-Fraser section based on significant ($P<0.05$) differences in allele (different forms of the same microsatellite locus) and haplotype (different forms of the same mtDNA site) frequencies among groups. Similarly, highly significant ($P<0.000$) differences were observed between the Nechako and upper Fraser group for mtDNA while differences were not significant ($P=0.189$) using microsatellite markers. Based on a pairwise genetic distance analysis for mtDNA variation, the Fraser River was divided into three main genetic groupings including: (1) a group downstream of Hell's Gate; (2) a group between Hell's Gate and downstream of the Nechako confluence (not including the most upstream section where too few samples could be incorporated for statistical analyses) and the upper Fraser/Nechako group. The sites within these groups were not significantly different ($P>0.05$) with the exception, as previously stated, that the difference between the upper Fraser and Nechako groups was highly significant ($P<0.000$) (Smith *et al*. 2002). The inclusion of the Columbia/Kootenay samples did not alter these relationships within the Fraser River. Another recent study observed two mtDNA haplotypes unique to the Nechako River that occurred in relatively high frequency (combined, they represented 45% of the sample) (Anders and Powell 2002). Unfortunately, the only other Fraser River sample in this study was collected from downstream of Hell's Gate, and no comparisons with upper Fraser River samples could be performed.

While these data cannot conclude that the Nechako River population is completely isolated from the Fraser River mainstem (*i.e.*, requires the presence of alleles unique to each section), it does indicate that gene flow is at best very limited. This conclusion, in addition to the movement and capture data, supports the idea of a partial migration barrier in the lower Nechako River mainstem (Toth *et al*. 2000, Yarmish and Toth 2001). Such a situation, in combination with the lack of observable recruitment, indicates that the Nechako population of white sturgeon cannot be re-colonized through natural means by the Fraser River white sturgeon populations.

Growth, Condition, Maturation, and Survival

Growth, condition, maturation, and survival are sensitive indicators of sturgeon population productivity and key drivers of population size, composition, biomass, reproductive potential, and future trends. In general, faster growth, better condition, increased survival, and earlier maturation all contribute to healthier, more robust populations. Weak, threatened, or endangered populations are generally associated with low values in one or more of these population parameters.

Individuals in river-resident and lake-resident sturgeon populations, such as the Nechako, tend to grow slower and do not attain the large sizes that fish in anadromous populations attain. In northern systems, such as the Nechako, reduced growth of these sturgeon typically results from cooler temperatures, low system productivity, and lack of access to abundant estuarine and marine food resources. The slower growth makes the fish available to predators and other agents of natural mortality for a longer period, entails a longer maturation period and presents a series of energetics challenges.

Maximum sizes of white sturgeon collected during survey sampling in the Nechako were approximately 245 cm. On average, white sturgeon in the Nechako grow 5.9 cm/year through age 30, and 4.0 cm/year for ages 30 to 50, with individual growth rates being highly variable (RL&L 2000). This is similar to growth rates in the Upper Fraser stock, but less than growth in lower Fraser River stocks.

Condition factor is also typically lower for resident versus anadromous white sturgeon populations (Welch and Beamesderfer 1993). Condition factor is an index of fish health based on weight for a given length. Condition factors reported for the Nechako sturgeon are near average for white sturgeon and similar to lower Fraser sturgeon.

Sexual maturity of white sturgeon does not occur until fish are relatively large and advanced in age (Semakula and Larkin 1968, Chapman 1989, Welch and Beamesderfer 1993). Maturation occurs over a wide range of sizes and ages, and substantial differences occur among populations depending on growth. Males typically mature at smaller sizes and ages than females, and may spawn in all or most years following maturation. Females typically mature at larger sizes and older ages and do not spawn every year. Data from the lower Fraser River suggests males first spawn between the ages of 11 and 22, whereas females first spawn from ages 26 to 34 (Semakula and Larkin 1968). More recent data from the Nechako suggests the sturgeon population there matures at a much later age, with males and females not maturing until around 40 years (RL&L 2000). However, evidence suggests this estimate is likely biased toward an older age-at-maturity since the population is ageing with limited recruitment.

Annual survival rates for long-lived fish like sturgeon are typically quite high in the absence of fishing and often exceed 90% (Semakula 1963, Cochnauer 1983, Kohlhorst *et al.* 1991, Beamesderfer *et al.* 1995, DeVore *et al.* 1993). Because sturgeon are so long-lived, population trends are extremely sensitive to very small changes in survival of only a few percent. Most methods of estimating survival are not accurate enough to discern differences this small. Survival rates have not been estimated for the Nechako population in part because of the confounding effects of declining recruitment and the relatively small numbers of fish. However, annual survival rates of 90% or greater are consistent with maximum ages observed in the population. RL&L (2000) reported a maximum age of 88 years from the Nechako sturgeon population.

Food and Feeding

White sturgeon feed primarily on benthic invertebrates and fish; however, they can be selective in their choice of food. Food items are detected with chemo- and electroreceptors located on four sensory barbels under the snout rather than by sight (Brannon *et al.* 1985, Buddington and Christofferson 1985). White sturgeon are also known to actively pursue prey fishes throughout the water column (S. King, Oregon Department of Fish and Wildlife, personal communication). No information is available on food habitats of Nechako sturgeon (collecting gut samples is difficult and stressful for the fish) but juveniles in other white sturgeon populations are reported to eat amphipods, isopods, mysids, clams, snails, small fish (such as sculpins and assorted fry), and fish eggs (McCabe *et al.* 1993). Larger sturgeon feed increasingly on fish and are capable of consuming large prey including adult salmon (McCabe *et al.* 1993, Sprague *et al.* 1993, McAdam 1995).

Diet can vary substantially with time of year as white sturgeon opportunistically feed on seasonally abundant prey items, especially anadromous fish in areas where they are accessible. This food source is most abundant in the fall and likely provides an important energy source for over-wintering with significant implications for spawning frequency and fecundity (Hildebrand and Birch 1996, RL&L 2000). Significant to the Nechako and Stuart rivers is a large annual migration of sockeye salmon through these waters that likely represents a highly important annual food source for sturgeon in this region.

In other systems, principally the Columbia River, many movement and migration patterns appear related to feeding, which along with habitat differences, may explain different movement patterns among lower and upper basin white sturgeon populations. In the lower Columbia River where habitat is relatively homogenous, *e.g.*, marine waters, estuaries, low gradient mainstem areas and reservoirs, white sturgeon move frequently and range widely in search of scattered or mobile food resources. Fish are more sedentary in the upper basin where the river consists of interspersed rapids and pools where fish can hold and feed on prey delivered by the river. The migration behaviour patterns of Nechako River sturgeon suggest they have adopted a feeding strategy to exploit anadromous salmon, *e.g.*, sockeye salmon, which migrate through the system (RL&L 2000).

Spawning Behaviour and Habitat

To date, there has been no confirmation that white sturgeon spawn in the Nechako system although the juvenile sturgeon captured are believed to come from the Nechako River. In June 2003, between 50 and 60 adult sturgeon were observed to be congregating in the Nechako River near Vanderhoof. It is not known if this was a spawning or feeding concentration of sturgeon. A number of fish believed to be mature have been followed but as of yet no spawning events have been documented. As a consequence, the following discussion, by necessity, focuses on spawning behaviour and habitat in other northwest white sturgeon populations.

White sturgeon spawn during spring and early summer by broadcasting eggs over clean, rocky substrate in turbulent river habitats. Fish gather in groups to spawn where several males spawn with each female. Darting, rolling, and breaching activity accompany spawning. Sturgeon populations that live in the lower parts of major river systems undertake upstream spawning migrations beginning in fall or winter while populations in close proximity to spawning sites display more localized movements.

White sturgeon generally spawn at temperatures of 14 to 18°C (Wang 1985). These temperatures correspond with optimums identified during incubation experiments. Based on laboratory experiments with white sturgeon collected from San Francisco Bay, Wang *et al.* (1985, 1987) reported that: (i) the optimum temperature range for incubation was between 14 and 16°C; (ii) successful incubation was observed from 10 to 18°C; (iii) temperatures in excess of 18°C caused substantial abnormalities; and (iv) temperatures below 14°C extended incubation and hatching times, but did not result in developmental abnormalities. RL&L (1997) incubated Columbia River sturgeon wild-caught eggs *in situ* in capsules and showed generally lower hatch success at temperatures exceeding 18°C.

Spawning often occurs later in the year and over more contracted periods in upper basin and northern populations, in part due to colder spring temperatures. In the Arrow Lakes Reservoir and Kootenay River (both of which are highly regulated with altered thermal regimes), sturgeon spawn at temperatures well below optimum temperatures identified from other systems.

Spawning sites appear to be selected based on substrate, water velocity, depth, and other factors that are poorly understood. Preferred spawning substrates are large cobble and rock where fine material has been cleared from interstices by the current (McCabe *et al*. 1989, Parsley *et al*. 1989, Parsley and Beckman 1993). Smaller substrate appears to be used by populations in the Sacramento, Fraser, and Kootenay systems but data on those systems is either limited (Sacramento and Fraser) or suggests use of fine substrate is not successful (Kootenay). Evidence to support the active selection of clean, coarse substrates is available for other sturgeon species, *e.g.*, following the introduction of coarse, clean rock in a known lake sturgeon spawning area, most spawning activity occurred over the new rock substrate (R. Bruch, Wisconsin Department of Natural Resources, personal communication).

High water velocity is a key attribute of spawning site selection. Mean water column velocities typically range from 0.5 to 2.5 m/s (Parsley and Beckman 1993). Parsley *et al.* (1993) have consistently observed greater spawning success in high-discharge years that provided higher velocities. Lower than average spawning velocities, *i.e.*, 0.2 – 1.0 m/s, have been reported for Kootenay white sturgeon but spawning in that system is not successful (Paragamian *et al.* 2001). High velocities scour fine material that can smother eggs, exclude potential predators, and may help disperse larvae. Habitat suitability criteria developed for U.S. populations of white sturgeon indicate 0.8 m/s is the lowest mean column velocity at which suitable spawning habitat is provided; optimal mean column velocities are considered to be above 1.7 m/s (Parsley *et al.* 1993, Parsley and Beckman 1994). RL&L (1996), in reviewing available information on sturgeon spawning requirements, recommended water velocities of greater than 1.5 m/s to provide for sturgeon spawning in the upper Columbia River. In addition to water velocity, variability in flows has been documented as an important cue in the actual commencement of spawning and eggs from spawning events were usually collected during the descending limb of the hydrograph, *i.e.*, when flows were subsiding, after these manipulated flow events.

Spawning site selection also appears related to turbulence (M. Parsley, USGS, personal communication), although this effect is difficult to quantify. Evidence to date suggests white sturgeon spawning often occurs in only a portion of the available area that meets general substrate, velocity, and depth criteria.

White sturgeon spawn at a wide range of depths (0.5 to 50 m) although this does not appear to be a highly critical factor influencing spawning site selection. Spawning depths in the lower Fraser have been documented at 2 to 24 m in 1998 (Perrin *et al.* 1999) and 0.5 to 6.5 m in 1999 (Perrin *et al.* 2000). Parsley and Beckman (1994) proposed a relationship between suitability for spawning and depth that was 0 at depths of 2 m or less, increased linearly from 0 to 1 from 2 m to 4 m, and remained at 1 for all depths from 4 m to at least 25 m (where 0 = low suitability and 1 = high suitability.

Early Life History and Recruitment

Early life history includes incubation, hatching, dispersal, and hiding phases (Parsley *et al.* 2002). Hatching typically occurs 5 to 10 days after spawning depending on temperature (Wang *et al.* 1985), with warmer temperatures shortening the incubation period. Upon hatching, larvae enter a swim-up phase in which they leave the substrate and are suspended in the water column (Brannon *et al.* 1985). This behaviour disperses larval sturgeon downstream into available rearing habitats. The swim-up phase may last 5 or 6 days with time spent in the water column inversely related to water velocity (*i.e.*, larvae spend more time in the water column when flow is low) (Brannon *et al.* 1985, Conte *et al.* 1988). In the Columbia River below Bonneville Dam, white sturgeon larvae are transported over 175 km downstream from spawning areas (McCabe and Tracy 1993); no information exists for the Nechako stock as no larvae have ever been collected in the Nechako system. If larvae were transported similar distances from putative spawning locations in the Vanderhoof or Isle Pierre areas, they may have drifted into the Fraser River. However, under current flow regimes, there are sections downstream of the Isle Pierre and White Mud Rapids where larval drift would settle out. Under historic spring flows, there may have been side channels present that would counter any increased distance in downstream drift associated with the higher flow volumes.

Following dispersal, larvae enter a hiding phase in which they avoid light and seek refuge in the substrate. The hiding stage for white sturgeon generally lasts 20 to 25 days until the yolk is absorbed, after which the fish move out of the substrate to begin exogenous feeding (Parsley *et al.* 2002). Young white sturgeon are believed to remain closely associated with rough substrates throughout their first summer as evidenced by their very low susceptibility to sampling by any method (Parsley *et al*. 2002).

White sturgeon eggs, larvae, and young-of-the-year (YOY) are vulnerable to a variety of mortality factors and first-year survival rates are very low even under optimum conditions. Eggs are vulnerable to extreme temperatures, abrupt temperature changes, suffocation by sediments, mechanical damage, infection, contaminants and fluctuating flows that allow predators access to egg deposition areas (Parsley *et al.* 2002). Larvae are particularly vulnerable to predation at the swim-up stage and factors that increase time spent in the drift, *e.g.*, slower current velocity due to reduced discharge from upstream dams, or visibility, *i.e.*, increased water clarity due to upstream impoundments, will undoubtedly reduce survival (Parsley *et al*. 1993). Larvae may also starve during the transition from endogenous to exogenous feeding, particularly if environmental factors have reduced food availability at this critical time.

Following the first one to two years, mortality of juvenile white sturgeon appears to be low and fish are able to utilize a wide variety of habitats (Parsley *et al.* 1993). Juvenile white sturgeon in the lower Columbia River use many of the same low to moderate velocity habitats as adults and sub-adults. In the lower Fraser River, slough and large backwater habitats adjacent to the mainstem provide important rearing habitats for juvenile white sturgeon (Lane and Rosenau 1995).

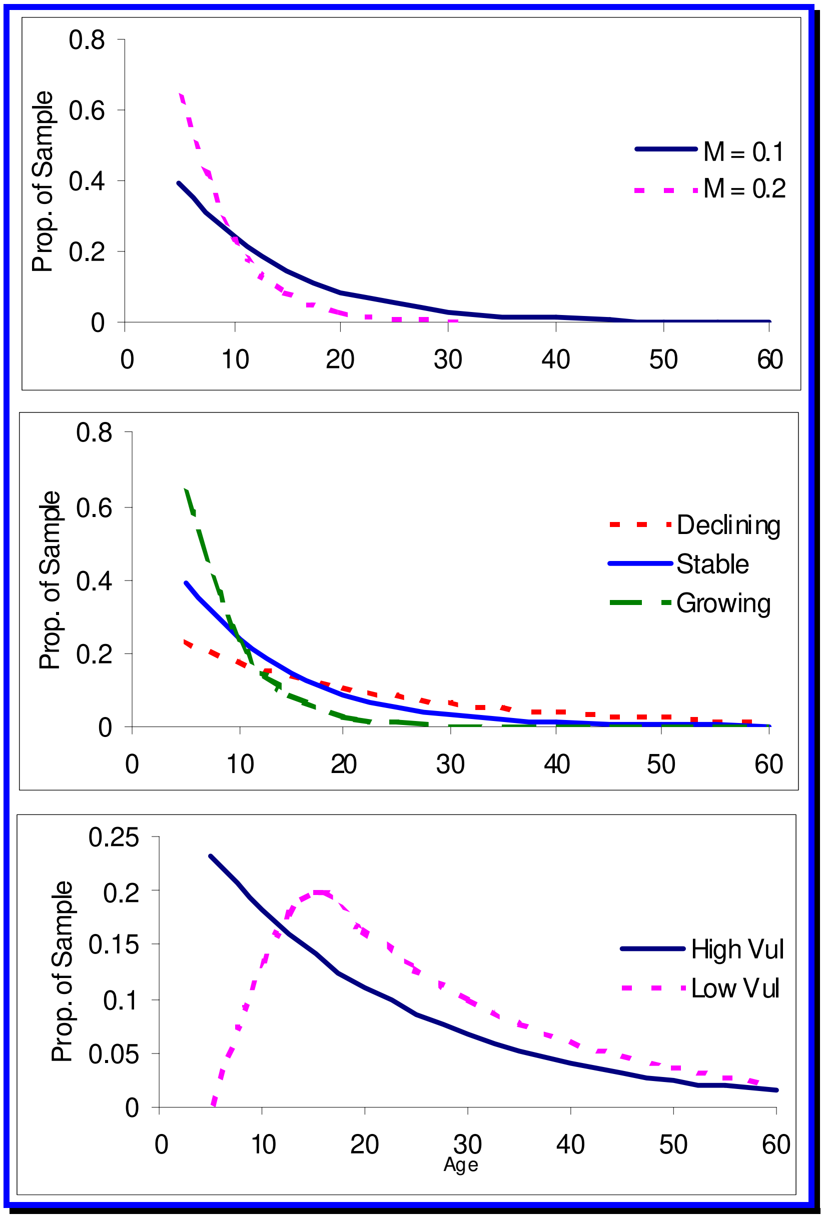
While factors controlling year class strength are poorly understood, recruitment has been widely correlated (positively) with high spring flow volume in many sturgeon species including white sturgeon (Votinov and Kasyanov 1978, Kohlhorst *et al.* 1991, Anders and Beckman 1993). Kohlhorst *et al.* (1991) positively correlated the volume of freshwater flow through the Sacramento-San Joaquin River Estuary with white sturgeon year-class strength. Investigations in the lower Columbia River related high spring flows to the availability of suitable high velocity spawning habitat, to spawning success, and to subsequent recruitment (Anders and Beckman 1993).

EVIDENCE FOR RECRUITMENT FAILURE

Considerable data support the finding that juvenile recruitment to the Nechako River white sturgeon population is very low and insufficient to prevent extinction of the stock. This assessment of recruitment failure is based on: 1) differences in the age composition between the Nechako and Fraser River stocks; 2) shifts in the age composition for the Nechako stock over time; and 3) differences in catch rates of Nechako juvenile fish over time.

To properly interpret age composition data, it is important to recognize that such data inherently contain information about mortality, recruitment, and age-specific vulnerability (Figure 6; Korman and Walters 2001). If the population size is assumed to be stable over time, the slope of the age composition-frequency distribution reflects the mortality rate from one age to the next, *i.e.*, the steeper the slope then the greater the mortality rate (Figure 6, top). Differences in age composition between two populations may also result from trends in recruitment rates (Figure 6, middle). An expanding population, where the recruitment rate is greater than what is required to maintain existing population levels, will have an over-representation of younger fish; this appears as a steeper slope in the age-composition frequency curve. A declining population will have an under-representation of younger fish, which reduces the slope of the age-composition curve. The shape of the age-frequency curve may also reflect differences in the vulnerability of different aged fish to the sampling gear (Figure 6, bottom). If young fish are under-represented in the sampling, the age-composition curve will have a right-skewed, dome-shaped appearance.

Figure 6 **Effects of Mortality Rate (top), Recruitment Rate (middle) and Age-specific Vulnerability to Sampling Gear (bottom) on Age Composition Data**



Age Composition of Nechako Stock versus Fraser River Stocks

The strongest evidence of juvenile recruitment problems in the Nechako River stock comes from a comparison of its age composition data with data from other Fraser River sturgeon populations (Figure 7; based on sampling between 1995 and 1999; RL&L 2000). The absence of younger fish in the Nechako is most apparent; few fish younger than 25 years were caught with the modal age being 35 to 40 years. The under-representation of fish younger than 5 years seen in all populations is the result of low sampling efficiency for very young fish.

The lack of young fish in the Nechako compared to every other Fraser population can be interpreted two ways: (1) the Nechako stock has suffered severe recruitment failure for about 25 years; or (2) Nechako juveniles are not as vulnerable to sampling (behaviour, residence in habitats like lakes or the lower river where sampling would not detect them, under-sampling of environments like the Stuart River, etc.) compared to the Fraser River stocks. This second interpretation is unlikely considering the wide variety of habitat conditions over which the sampling successfully captured juveniles downstream from the Nechako. It is important to note however, that there is no scientific way, with the available data, to categorically reject the proposition that juvenile Nechako sturgeon exist but have not been sampled.

Historical Changes in Nechako Stock Age Composition

A comparison of age composition of Nechako River sturgeon from samples taken in 1982 (Dixon 1986), with more recent data from the 1995-1999 sampling (RL&L 2000) clearly shows a shift in age structure that is consistent with the hypothesis of a near-complete recruitment failure occurring since at least 1973 (Figure 8; Korman and Walters 2001). When the comparison of Dixon (1986) and RL&L (2000) data is corrected for gear type and the year of capture is standardized, the most common age in the Dixon (1982) samples is 17 to 18 yrs compared to 32 years for RL&L (2000) data, indicating that the dominant age from the 1982 sampling shows up at the correct age in samples taken 15 years later (*i.e.*, 1997). If there had been significant juvenile recruitment between these dates, the modal age in the 1995-1999 sampling would have been lower. Differences in age composition between the 1982 and 1995 to 1999 samples therefore provide strong evidence of a recruitment failure in the Nechako River stock and are likely not due to changes in sampling methodology.

Figure 7 **Comparison of Age Composition Between Fraser River Stock Groups (SG1-4) and the Nechako River Drainage Stock Group (SG-5)**

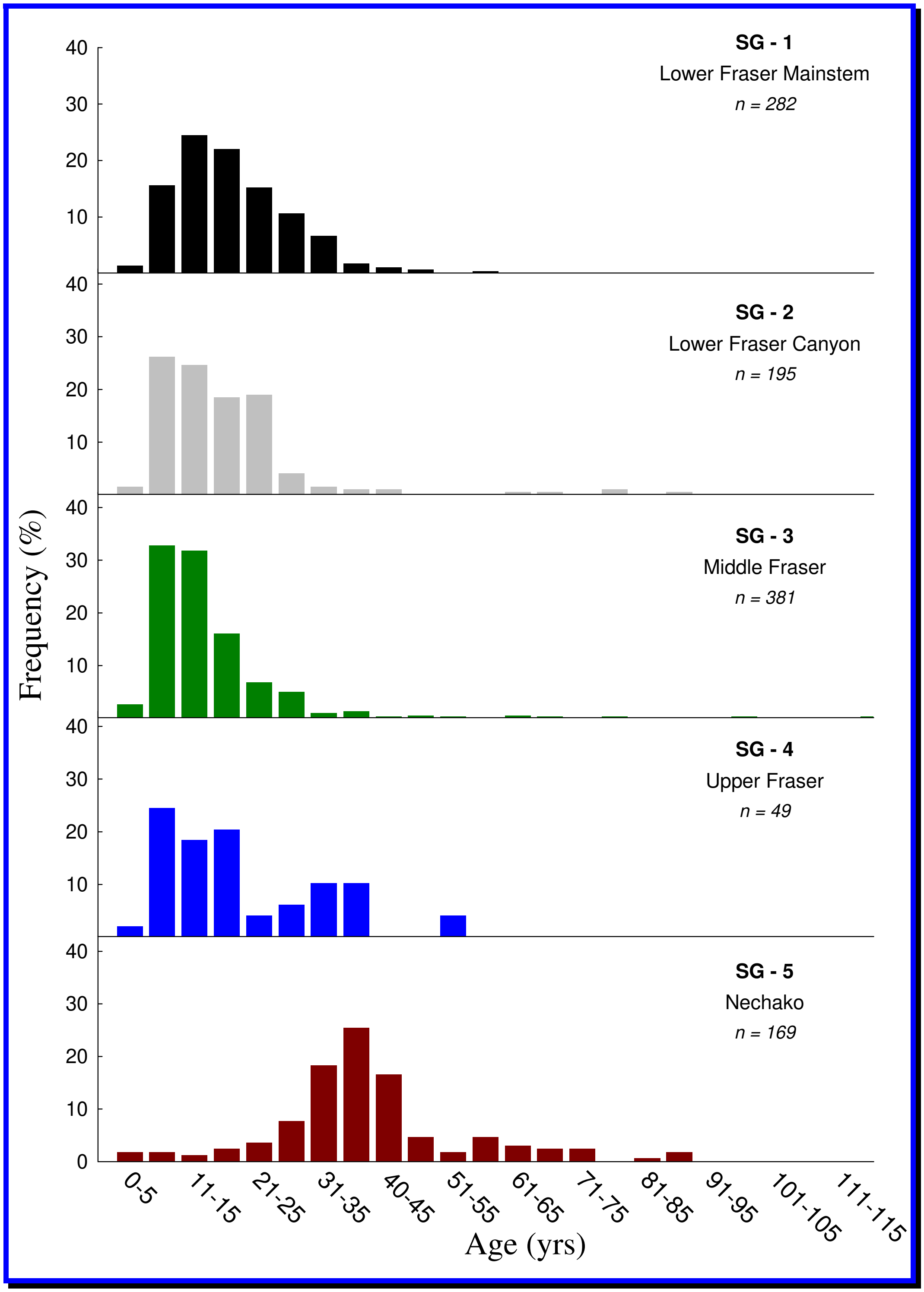
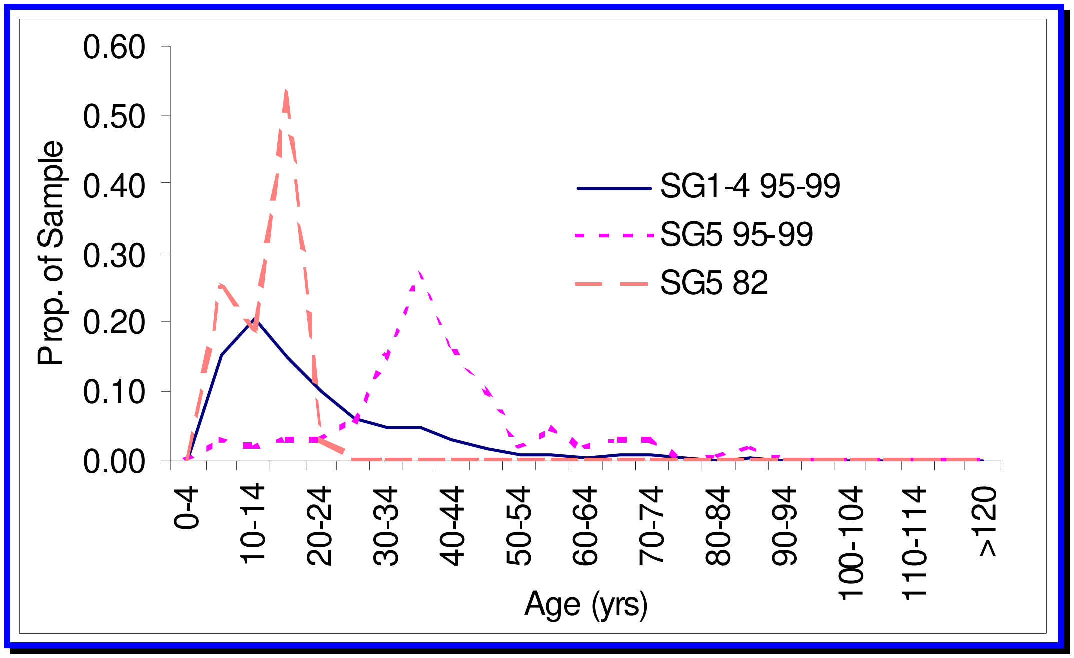


Figure 8 **Comparison of Age Composition for the Aggregate of Fraser River Stocks (SG1-4) and the Nechako Stock (SG-5) Based on Data Collected Between 1995 and 1999, and 1982**



Interpretations of Decline in Catch Rates from 1982 to 1999

August Catch-Per-Unit-Effort (CPUE) sampling in the Nechako River declined by roughly half from 1982 to 1999 (Triton 2000) despite concentrating the netting during the most productive times (night). The decline is even more severe if June-July sampling results for 1999 are included in the calculation of average CPUE (typically not recommended considering how common it is for fish catchability to change through the seasons). Although the 1982 sampling protocol could not be replicated in 1999, conservative corrections for this limitation make the decline in juvenile catch even more extreme, rather than less so. Therefore, this decline in CPUE, when considered in tandem with other very strong evidence from age composition data, is consistent with supporting a marked decline in juvenile recruitment.

POTENTIAL CAUSES OF RECRUITMENT FAILURE

Participants at an October 2000 workshop developed an initial list of potential factors and mechanisms that may have led to the recruitment failure of juvenile sturgeon in the Nechako River (Korman and Walters 2001). This list has been further developed and elaborated upon in this document, and translated into working hypotheses. Potential hypotheses have each been evaluated by comparing the timing of changes in the proposed mechanism relative to the estimated timing of recruitment failure (estimated by back-calculation of recruitment rates from the age composition data). Management actions, research requirements, and rehabilitation costs associated with each recruitment impact hypothesis were discussed.

Many of the hypotheses proposed are related to changes in flow. There is a significant body of literature that has documented the consequences of regulating a river, *e.g.*, for hydropower, flood control, agriculture, on sturgeon reproduction and recruitment (Alekperov 1969, Khoroshko 1972, Votinov and Kas'yanov 1978, Cochnauer *et al*. 1985, Parsely *et al*. 1993, Parsely and Beckman 1994, Lepla and Chandler 1997, Nilo *et al*. 1997, Paragamian *et al*. 2001). Changes in the timing and quantity of spring freshet and winter flows, altered habitat characteristics, availability of food items, susceptibility to predation, and barriers (physical or flow-related) are some of the mechanisms that can affect the viability of sturgeon in regulated systems.

A description of each hypothesis and their relative priority for action is presented below. It should be noted that an adaptive management approach is required to evaluate and quantify the significance of each of these hypotheses. It should also be noted that many of these hypotheses and actions associated with understanding their relative importance are inter-related:

1. Altered Thermal Regime

Hypothesis: Alterations to thermal regime in the Nechako River have lead to decline in recruitment resulting in a) a reduction or elimination of spawning events, and/or b) a change in the bioenergetic requirements of young sturgeon leading to reduced survival rate.

Priority: High

Actions: Investigate changes in thermograph especially during recruitment-sensitive life history phases. If changes are observed, investigate how these changes could affect spawning success or juvenile survival, including possible implications on habitat.

- Examine thermograph; pre- and post-recruitment failure;
- Examine thermograph; pre- and post-dam construction;
- Model historic temperatures;
- Examine rate of temperature change;
- Examine absolute difference in temperature;
- Examine peak temperature; and
- Examine and compare temperature trends in the Stuart River.

2. Changes in Hydrograph

Hypothesis: Declines in recruitment of Nechako white sturgeon have been directly related to changes in Nechako River hydrograph.

Background: Diversion of flows for power generation since 1952 and subsequent changes and variation in the flow delivery schedule have significantly altered the hydrograph in the Nechako River. Discharge no longer follows a natural seasonal pattern while the spring freshet has become increasingly attenuated with increased diversions. Seasonality in the hydrograph, especially high spring flows followed by a declining hydrograph, may be a requirement for stimulating a spawning event.

Priority: High

Actions: Investigate relationship between flow and recruitment.

- Conduct regression analysis of flow versus recruitment. A spring freshet is believed to be an important component of the hydrograph but recreating this pattern for a single year may not stimulate a spawning response because sturgeon may require more than one year of bioenergetic preparation for spawning (this

is based on the apparent lack of response of the population to the high flows in 1976);
- Monitor for positive recruitment response as a result of the high flows that occurred in 1997 and the peaking spring freshet flows that occurred in 2002, which were larger than could be accomplished with any type of reservoir release flow manipulation. The observation of a positive recruitment response would be some direct evidence that higher flows are beneficial to sturgeon;
- Assess whether elevated flows during the summer months resulting from the Summer Management Temperature Program (SMTP) potentially interfere with cues used by young sturgeon that may be critical to their survival;
- Consider aspects regarding changes to the hydrograph in the Nechako River including the effects of reducing the mean annual discharge (MAD);
- Combine flow, thermal, and other physical data sets to determine possible relationships; and
- Define the optimal flow regime for Nechako sturgeon.

3. Natural Seasonal Patterns

Hypothesis: Stimulation of spawning and successful recruitment of Nechako white sturgeon may require consecutive years of high spring Nechako flows.

Background: The Nechako discharge is a factor in many of the hypotheses for the recruitment failure. This hypothesis acknowledges that previous singular high flow events in the Nechako River did not appear to result in a strong year class of sturgeon. It is also acknowledged that factors other than flows are likely involved in the final maturation process. A period of high flow may also be required to initiate physiological changes during the winter prior to spawning, and a second consecutive event may be required to stimulate spawning and enhance juvenile survival.

Priority: High

Actions: Investigate relationship between flow pattern and recruitment and opportunities to alter flows and temperature targets based on sturgeon needs.

- Implement a juvenile capture and monitoring program to determine if there has been any significant spawning or recruitment response resulting from the high flows

observed in 1997, or the pronounced spring freshet that was observed in the Nechako River in 2002;
- Investigate opportunities to alter the current flow regime prescribed in the 1987 Settlement Agreement that would provide an annual spring freshet in the Nechako River;
- Investigate the opportunities to alter the temperature targets for the NFCP's Summer Temperature Management Program to redistribute flow to create an annual spring freshet; and
- Work with the Nechako Watershed Council and others in supporting efforts to build a Water Release Facility at the Kenney Dam that would allow for the redistribution of 'Freed Up Flows' and the creation of an annual spring freshet.

4. Predation

Hypothesis: Increased predation on juvenile Nechako white sturgeon has led to the observed recruitment failure.

Background: Diversion of flows for power generation since 1952 and subsequent changes and variation in the flow delivery schedule have significantly altered the hydrograph in the Nechako River resulting in a significant change in species richness and diversity. It is believed that with these changes came a significant increase in the relative abundance of cyprinids in the Nechako River and their increased predation on sturgeon eggs and/or juveniles has resulted in sturgeon recruitment failure.

Priority: High

Action: Investigate possible predator/prey interaction:

- Conduct literature search to investigate what is known about sturgeon predation;
- Investigate relationship between turbidity and predation of sturgeon;
- Determine whether vulnerability changes with size;
- Examine relationship between predator density/species richness and diversity/community changes and flow changes;
- Examine relationship between predator density and flow changes;
- Determine composition of predator populations;
- Examine data for possible relationships between predator populations and other fish species;

- Research potential of reduced predation by modifying turbidity, river flow, and habitat;
- Implement predatory stomach content study to record the incidence of juvenile sturgeon presence;
- Investigate the effectiveness of predator control programs on other water systems;
- Carry out lab studies to determine if predators are successful at capture of juvenile sturgeon; and
- Consider options for predator control on the Nechako River, including during the critical spawning and rearing phases.

5. Food Resources for Juveniles

Hypothesis: Decreased food abundance has affected the growth of juvenile Nechako white sturgeon leading to recruitment failure.

Background: Changes in aquatic fauna and flora may have resulted from changes in habitat caused by diversion of flows for power generation since 1952 and subsequent changes and variation in the flow delivery schedule. Changes in aquatic fauna also may have resulted from shoreline development and land use changes that have limited availability of food for juveniles, especially Young-of-the-Year, resulting in increased mortality.

Priority: Moderate

Action: Review literature to identify juvenile food sources.

6. Physical Regime Affecting Turbidity and Sedimentation Rates

Hypothesis: Declines in turbidity and suspended sediments has led to increased predation of juvenile Nechako white sturgeon causing recruitment failure.

Background: Diversion of flows for power generation since 1952 and subsequent changes and variation in the flow delivery schedule have significantly altered the hydrograph in the Nechako River resulting in a significant reduction in the transport of sediment. Reduced turbidity could in turn increase the level of predation on juvenile sturgeon by other fish species and lower juvenile survival rates. Changes in flow regime alone may not result in sustainable increases in turbidity without additional rehabilitation measures that increase sediment delivery to the Nechako River.

Priority: Moderate

Action:
- Examine literature for relationship between turbidity and recruitment;
- Carry out lab studies to investigate the effect of turbidity on survival success of juveniles in the presence of a predator;
- Establish turbidity monitoring program at sites along the Nechako River.

7. Macrophyte Development

Hypothesis: Increased macrophyte growth in the Nechako River has negatively affected recruitment of Nechako white sturgeon.

Background: Reductions in peak flows, increase in sewage loads, agricultural development, forestry activities and other land use changes have resulted in significant macrophyte development in the Nechako River. The annual growth and decay of this material has increased biological oxygen demand and reduced dissolved oxygen concentration near the river bed to levels that could affect survival of juvenile Nechako white sturgeon.

Priority: Moderate

Action: Investigate relationship between macrophyte population and recruitment.

- Investigate the preferred habitat of juvenile sturgeon and the likely overlap of areas of depleted dissolved oxygen levels in the Nechako River;
- Investigate the incidence of depleted dissolved oxygen levels in areas where macrophyte beds and sturgeon habitat overlap.

8. Changes in Channel Morphology

Hypothesis: Changes in the Nechako hydrograph and sediment inputs have altered the channel morphology in a manner that affects spawning and recruitment of Nechako white sturgeon.

Background: Reduced frequency and magnitude in peak flows in the Nechako River may have increased the percentage of sand and finer material on the river bed, and reduced floodplain habitat for juvenile rearing, resulting in increased juvenile mortality and/or reduced egg survival.

Priority: Moderate

Action: Investigate change in channel morphology and substrate composition, and relationship to Nechako white sturgeon life history phases and recruitment.

- Review literature regarding channel morphology in the Nechako River;
- Analyze historical air photos to quantify changes in flood plain habitat;
- Compare fluvial changes to changes in recruitment;
- Quantify the reduction in frequency and magnitude of peak flows in the Nechako River;
- Quantify if changes in the river bed have occurred, and if it has resulted in increases in sand and fine deposits;
- Investigate survival rate of eggs under varying sediment deposition conditions;
- Investigate the sinking rate of newly released sturgeon eggs under existing Nechako River conditions and turbidity;
- Estimate larval drift distance under various scenarios of length of time of larval swim up and water velocities;
- Calculate probable larval settlement areas based on larval drift distance and possible spawning areas;
- Develop other mechanistic theories that would explain why increased percentage of sand and fines on river bed would increase mortality of juvenile sturgeon; and
- Investigate habitat modifications and enhancements that would improve life-stage-specific survival and spawning conditions.

9. Loss of Spawning Habitat

Hypothesis: Loss of spawning habitat in the canyon section of the Nechako River, at and above Cheslatta Falls, has led to Nechako white sturgeon recruitment failure.

Background: If traditional spawning areas for sturgeon were located adjacent to the canyon section of the Nechako River, *i.e.*, near Cheslatta Falls, flow reductions would have eliminated this habitat. The loss of such habitat would have resulted in an immediate decline in recruitment that does not match the steady linear decline based on back-calculated recruitment rates.

Priority: Low

Action: Work with the Nechako Watershed Council and other stakeholders in supporting efforts to build a Water Release

Facility at the Kenney Dam that would rewater the Nechako Canyon and Cheslatta Fan year round and deliver a flow more similar to a natural hydrograph.

10. Spawning Cycle Periodicity

Hypothesis: Nechako white sturgeon recruitment is directly linked to cyclical abundance patterns of sockeye salmon, which has contributed to their recruitment declines.

Background: If sturgeon spawning events are tied to cyclical patterns in the returns of sockeye salmon to the Nechako and Stuart systems, spawning may not occur every year. This hypothesis does not explain the historical decline in sturgeon recruitment but could be responsible for the lack of a response to the 1976 high flow event. However, as there is no hint of periodicity in the age composition data, spawning events are probably not tied to cycles of salmon abundance.

Priority: Low

Action: Compare the historical abundance of salmon migrating through the Nechako River to the index of recruitment success.

11. Mortality Due to Harvest

Hypothesis: Nechako white sturgeon recruitment failure is due to historic over harvest or low but sustained harvest after the onset of recruitment failure.

Background: Excessive harvest rates could have reduced the spawning stock to the point that juvenile recruitment became spawner-limited. This hypothesis was considered unlikely as harvest would reduce the abundance of all fish vulnerable to the fishery and could not explain the skewed age composition. However, annual incidental mortality of adults at the current low abundance could have a large incremental influence on the ability of the population to successfully spawn, relative to times of higher abundance. Continued intentional or incidental catch may further reduce the current population and potential recovery.

Priority: Low

Action: Examine fishing mortality and communicate the need to avoid all harm to sturgeon for the foreseeable future.

- Work with First Nation communities to explain the need to release all sturgeon caught as quickly and safely as possible;
- Model the impact of various fishing mortality scenarios on Nechako sturgeon and assess the resulting recruitment patterns observed to determine the likelihood of spawner-limitation;
- Model the impact of various fishing mortality scenarios on the current Nechako sturgeon stock to assess the impact on sturgeon spawning success and the contribution to loss of remaining genetic stock;
- Ensure the Action Planning Group and responsible agencies communicate and enforce compliance with the prohibition of killing Nechako stock sturgeon; and,
- Improve the estimate of incidental mortality throughout the Nechako stock area.

12. Land Development

Hypothesis: Land development in the Nechako Watershed has led to recruitment failure of Nechako white sturgeon.

Background: Increased land use along the Nechako River was hypothesized to cause changes in runoff patterns, temperature regimes, and tributary health, possibly affecting the abundance of fish that are eaten by sturgeon.

Priority: Low

Action: Examine the changes over time in land use adjacent to the Nechako River.

- Examine the historical trends in tributary-produced prey abundance; and,
- Carry out assessment of land use changes resulting in loss of off-channel and riparian zone habitat.

CONSERVATION MEASURES

Inventory and Research

The earliest study of Nechako sturgeon, carried out in 1982, contributed to the baseline set of data. It was not until a more comprehensive collection of data was gathered starting in 1995 as part of the 5-year Fraser River sturgeon study, that it appeared that Nechako sturgeon recruitment was significantly absent. This latter study investigated Nechako River sturgeon age composition, distribution, abundance, habitat use, and movements. It is through this work that the imperilled status of the Nechako population was documented. It is on the basis of these data, as well as an on-going adult monitoring program that the decision was made to proceed with the development of a recovery plan process for Nechako sturgeon.

Listings

In November 1991, the BC Conservation Data Centre (BC CDC), which systematically collects and disseminates information on the rare and endangered plants, animals and plant communities of BC, designated white sturgeon in BC as Blue-Listed or S3 Ranking (Cannings 1993). This designation indicates a species is rare or uncommon, or that it may be susceptible to large-scale disturbances, *e.g.*, may have lost extensive peripheral populations. In December 1994, upon further review of new data, this ranking was upgraded to Red-Listed or S2 (threatened or endangered). This provincial S2 Ranking considers white sturgeon to be imperilled because of rarity, making it vulnerable to extirpation or extinction. At that time, white sturgeon in BC were separated into four populations for monitoring purposes. These were the Fraser, Nechako, Kootenay, and Columbia populations. The Fraser River population was classed as S2 (imperilled). The Nechako, Kootenay, and Columbia stocks were classed as S1 (critically imperilled) based on data from existing studies and perceived threats. The Federal government has recently brought the Species At Risk Act (SARA) into law, which will provide for the protection and recovery of designated species and their habitats. The listing of species under SARA would be based on status assessments and designations by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC).

The BC Ministry of Water, Land and Air Protection prepared a white sturgeon status report and submitted it to COSEWIC in January 2003 as part of a request to review the status of white sturgeon in BC. In November 2003, COSEWIC downlisted white sturgeon in BC to endangered status.

Convention on International Trade in Endangered Species

An international Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora provides umbrella protection against illegal or unsustainable international trade. In 1998, parties to CITES (including Canada) placed all of the world's previously unlisted sturgeon species on the list in response to the increasing demands of the international caviar trade and collapse of the Caspian Sea sturgeon fisheries. CITES would likely have minimal consequences for Nechako sturgeon given that movement across an international border for the purpose of recovery efforts, *e.g.*, moving fish to U.S. hatchery, is deemed highly unlikely. However, the listing does raise the profile of the problem for regulatory agencies, industry, and the general public. If sturgeon parts (*i.e.*, fin ray samples or DNA samples) are sent to the US for study, a CITES permit will then be required.

Fishery Regulation

In 1994, the recreational harvest of sturgeon became illegal in BC, and many First Nations voluntarily stopped their sustenance harvesting; catch-and-release fishing was still permitted at this time. In September 2000, all sturgeon fishing in the Nechako system, including catch-and-release, was made illegal. There are presently still documented cases of incidental catch and kill of white sturgeon in the Nechako River system that have taken place in sustenance fisheries. It is hoped that with further education efforts there will be a progressive decline of this adult mortality source.

Water Management

At present, the level of knowledge regarding spawning (timing, location, duration, success) and rearing of Nechako sturgeon is still quite limited. Consequently, it is necessary to rely on other well-documented populations in BC that have been affected by ecological changes similar to those which have occurred in the Nechako system. This lack of knowledge of some aspects of Nechako sturgeon life history contrasts sharply with the knowledge gained through monitoring efforts on sturgeon populations in the Upper Columbia and Kootenay rivers in south-east BC.

Currently, there are no conservation flows specifically designed for sturgeon on the Nechako River. The BC and federal governments and Alcan Inc. agreed to long term Nechako River flow delivery in a legal agreement in 1987 (1987 Settlement Agreement). The flow delivery schedule has remained relatively unchanged since 1980. Daily decisions on the release of water from the Nechako Reservoir, which ultimately makes its way to the Nechako River, are made by the Nechako Fisheries Conservation Program Technical Committee. This committee is made up of one representative each from the BC Ministry of Water, Land and Air Protection, Fisheries and Oceans Canada, Alcan Inc., and an Independent Member. The flow regime established by the Settlement Agreement and the management process ensures the annual water allocation is delivered, and ensures that other reservoir management requirements are met, such as flood control and dam safety.

RECOVERY GOAL AND OBJECTIVES

Goal and Objectives

The goal of this recovery plan is to ensure the persistence and viability of a naturally-reproducing population of white sturgeon in the Nechako system and restore opportunities for beneficial use, if and when feasible.

Short-, medium-, and long-term objectives are identified and are consistent with the need to phase in and modify recovery measures based on fish status updates, results of research, monitoring and recovery efforts, and constraints on implementing a large and potentially expensive effort. The short-, medium- and long-term recovery objectives and timelines consider the current status and predicted modelling of future recruitment patterns if no intervention is undertaken. As the management approach to recovery planning is adaptive, these objectives and timelines will be revisited on an annual basis as new information is collected and possible changes to priorities evaluated.

The **short-term** objective is to continue assessing the population status and prevent further reductions in white sturgeon distribution, abundance, and genetic diversity within the Nechako system; **short-term** refers to the next 5 years (2003 to 2007).

The **medium-term** objective is to identify recruitment bottlenecks and establish technically feasible measures that reduce or eliminate these limitations; **medium-term** refers to the next 10 years (2003 to 2012).

The **long-term** objective is to re-establish a natural population age structure and reach target abundance levels. If consistent with SARA, First Nations constitutionally protected right to fish will be examined and may become a long-term objective; **long-term** refers to the next 50 years (2003 to 2052).

Strategy

Recovery objectives will be addressed using four main strategies:

1. Sources of adult mortality must be controlled in order to meet short- and medium-term objectives. The population status is too fragile to support any anthropogenic mortality sources. Continuing fishery restrictions are a key element of this strategy.

2. Conservation fish culture is essential to preserve the remaining population diversity in the absence of juvenile recruitment and to help identify the mechanism(s) that are preventing successful recruitment. Conservation fish culture is a short- to medium-term strategy. Fish culture measures are crucial since the population will steadily decline toward certain functional extinction. Genetic and life history diversity will therefore diminish and be too low to sustain the population even if suitable habitat conditions are restored at a future date. Cultured offspring of wild adults can bypass the current recruitment bottleneck to provide a source of new fish in the existing population. Cultured fish can be important "tools" to investigate natural recruitment limitations, mortality factors, important habitats, feeding and predation.

3. Re-establishment of natural recruitment is key to meeting long-term recovery objectives. Recovery will require effective improvements in recruitment and survival based on correction of those factors that are responsible for the current absence of juveniles. This may include any of the hypothesized mechanisms identified in this report. As many of the hypotheses are flow-related, it is possible that necessary measures might involve modifications to the annual flow regime in the Nechako River and/or enhancement of important habitats. Because the history of hatchery programs is inconsistent with long-term preservation of undomesticated fish populations, continued reliance on a hatchery program risks gradual erosion of sturgeon diversity and productivity and only delays the disappearance of the native sturgeon population.

4. Ongoing adaptation of the recovery program based on careful research and detailed monitoring of sturgeon status, limiting factors, and potential recovery to address short-, medium-, and long-term objectives. Presently, the design of an effective long-term recovery program is constrained by the paucity of data on the requirements of Nechako sturgeon in all of its life stages and the factors that currently prevent the population from being self sustaining. This deficiency precludes identification and selection of appropriate restoration measures. Research and evaluation efforts must be aggressive owing to the critical status of the population and the inherent time lag in implementing research findings as recovery measures. Experimental evaluations of alternatives based on a structured and prioritized approach to understand plausible mechanisms driving the key hypotheses is necessary. Sturgeon culture will provide effective test subjects for many of these research and evaluation studies.

Achieving long-term objectives will depend on the success of restoring those conditions now preventing the sustainable natural production of Nechako white sturgeon. It may be possible to restore a natural population that is not sufficiently productive to provide a harvestable surplus for First Nations. In this event, difficult and controversial decisions will have to be made regarding the use of hatchery fish to provide harvest opportunities that mitigate for the loss of natural production. Use of hatchery fish for mitigation will depend on compatibility with species conservation goals.

Targets

Recovery targets are interim benchmarks by which progress toward recovery will be measured. Targets identified in this plan are based on population viability guidelines identified in the scientific literature and are similar to those adopted in recovery plans for other vulnerable sturgeon populations in North America. Targets for Nechako River white sturgeon include:

1. Minimum adult population size of 2,500.

The desired adult population size of 2,500 is based on COSEWIC criteria. This number is an interim target pending studies of habitat carrying capacity within the recovery area and may change based on actual capacity assessments. This number is also consistent with fish population viability guidelines applied in U.S. Endangered Species Act assessments. For instance, genetic guidelines generally suggest a minimum effective population size of at least 500 adults and a census population of several times the effective population size to avoid loss of genetic diversity (Thompson 1991).

2. Natural recruitment and juvenile population size sufficient to support desired adult population size.

Sufficient natural recruitment and juvenile population size is required to support the desired adult population size.

3. ***Stable or increasing trends in adult and juvenile numbers.***

Stable or increasing trends require recruitment rates that exceed natural mortality rates. Higher mortality rates require greater numbers of juveniles to ensure that adult population size remains stable or increases.

4. ***Stable size and age distribution.***

Stable population numbers and age-class distribution demonstrate effective long-term recovery effects. Stable sizes and ages reflect the longevity and normal population structure of sturgeon as well as providing the population resilience needed to sustain these fish over the long-term.

5. ***Genetic diversity (including rare allele frequencies) similar to current levels.***

Stable genetic diversity similar to existing levels ensures that sufficient variability is preserved to allow white sturgeon to use the available array of environments, protect against short-term spatial and temporal changes in the environment, and provide the raw material for surviving long-term environmental changes (McElhany *et al.* 2000).

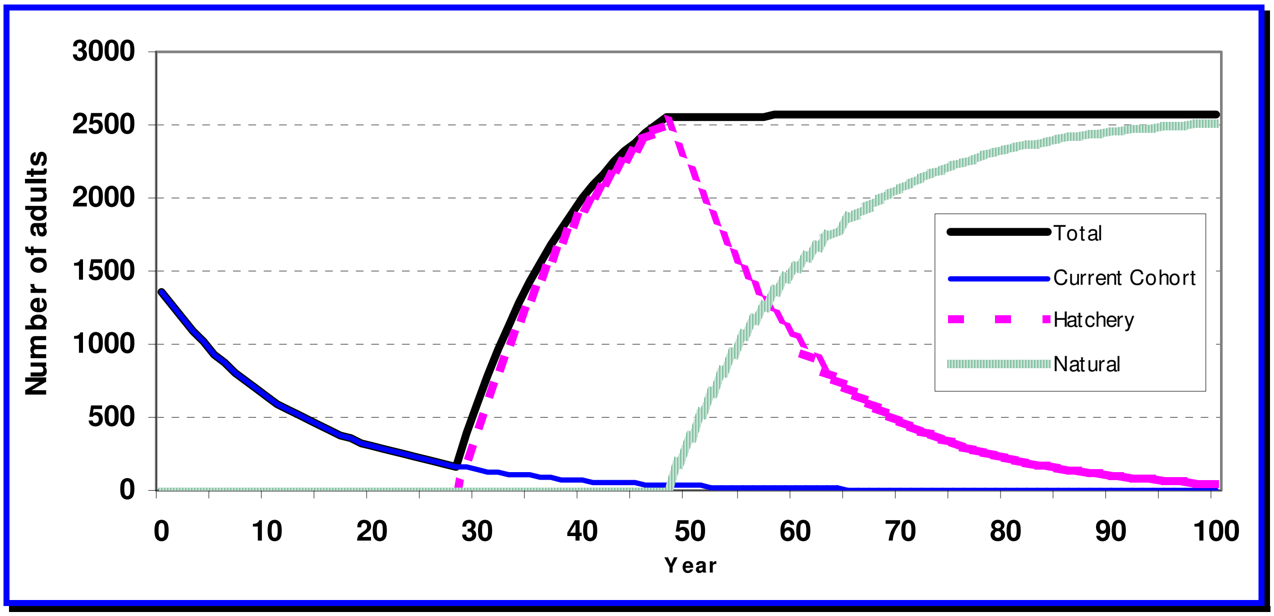
6. ***Long-term fishery objectives will be reached when natural production rates are sufficient to support at least minimal sustenance fishery uses or incidental impacts of white sturgeon monitoring programs.***

This recovery plan does not identify specific ecosystem function targets or benchmarks but recognizes that efforts to restore sturgeon populations through natural production will likely benefit other components of the native aquatic community.

Expected Response

Sturgeon recovery efforts will ideally produce a population trajectory not unlike that depicted in Figure 9. This trajectory was produced by an age-structure population demographic model using hypothetical cultured and wild sturgeon recruitment rates with current data on abundance, growth, maturation, and adult survival. This exercise highlights the long-term nature of this program. The trajectories optimistically assume that natural recruitment can be restored within 30 years. Figure 9 also refers to a scenario which will halt releases of cultured sturgeon when natural recruitment is restored. Based on an approximate 30 year age of full maturation, adult numbers are projected to decline to very low levels over the next 30 years even with the immediate release of cultured juveniles. After that, adult numbers build rapidly as cultured sturgeon mature. Significant adult recruitment of naturally-spawned fish occurs after 50 years and culture releases are scaled back as natural numbers increase. A stable adult population is reached at about 50 years with naturally-produced adults comprising an increasing percentage of the total after 50 to 100 years.

Figure 9 Projected Future Wild and Cultured Population of White Sturgeon



The next 5 to 20 years represent the most critical period in recovery of Nechako sturgeon because of the current lack of juvenile and sub-adult fish and the corresponding declining numbers of potential female spawners. The extended interval of low adult numbers will result in a very low reproductive potential for the Nechako population. Of immediate concern is the concurrent difficulty associated with collecting mature fish used as spawning broodstock in hatchery operation.

Priority Recovery Activities

The following key activities for the recovery of Nechako sturgeon are prioritized below.

Conservation Fish Culture

1. ***Preserve the remaining population diversity in the absence of juvenile recruitment.***

Conservation fish culture is imperative to the future success of any recovery efforts for Nechako sturgeon. Considering the low population at present, it is critical that genetic diversity of the Nechako stock be maintained until such time that natural recruitment can be sustained. Reproductively mature females in the population are few and the population will steadily decline toward certain functional extinction. Without intervention, genetic and life history diversity is expected to diminish and be too low to sustain the population even if suitable habitat conditions are restored at a future date. An important element of conservation fish culture will be a careful examination of genetic risks and their relative magnitudes in the context of eventual extinction of the Nechako stock.

Water Management

1. ***Define flow requirements necessary to promote natural spawning, incubation, rearing, recruitment, and survival of Nechako River sturgeon.***

Specific flow requirements for successful recruitment are poorly understood. This will be developed from a review of existing information and the results of the spawning and juvenile studies suggested for implementation. This study requirement will likely not be achieved until significantly more data have been collected. An outcome of this exercise could be an evaluation of the feasibility of flow augmentation to benefit Nechako white sturgeon. The development of an experimental flow augmentation strategy to benefit Nechako sturgeon is difficult at this stage since the factors limiting sturgeon survival are currently unknown. There is a need, however, to carefully examine the current flow delivery schedule and assess the feasibility of modifying flows in a manner that would benefit sturgeon and other fish species.

Water Quality and Habitat

1. Evaluate restoration of the natural temperature regime of the Nechako River.

Temperature modelling has suggested measurable changes have occurred in the temperature regime of the Nechako compared to pre-dam conditions. The Summer Temperature Management Program (STMP) was designed in 1982 and has been successfully implemented since 1983 but similar temperature regulating actions have taken place since 1980. The STMP is undertaken to protect migrating salmon by preventing mean daily water temperatures in the Nechako River upstream of the Stuart River confluence from exceeding 20ºC between July 20 and August 20. This objective is met by regulating releases from the Skins Lake Spillway to reduce the likelihood of temperatures above 20°C in the Nechako River, upstream of the confluence of the Stuart River. When weather forecasts predict a warming trend, additional water is released. The increased volume of water takes longer to heat and therefore, temperature can be controlled. The implications of this program are significant in that the occurrence of elevated river temperatures in the summer are recognized as a problem for migrating/spawning salmon, and potentially for sturgeon as well. Further evaluation of the changes to the thermal regime are required to make these investigations specific to the needs of white sturgeon, for example attention should be focussed on areas where white sturgeon are known to reside and during periods of the year (*e.g.*, spring) when temperatures are known to affect spawning. In conjunction with the evaluation of the effects of flow manipulations to benefit physical habitat, this exercise should also evaluate the thermal effects of any flow options being considered.

2. Evaluation of changes to the turbidity regime.

High turbidity levels are associated with freshet flows and/or high rainfall events, and have been hypothesized as important to white sturgeon recruitment. Although high turbidity has been linked to lower predation rates on juvenile white sturgeon in laboratory experiments, effects on recruitment have not been confirmed to date. Although the Nechako River historically may not have had high turbidity levels due to the presence of headwater lakes and dilution of tributary inputs from higher mainstem flows, high turbidities are notable during high flow events under the current regime. Opportunities to increase sediment transport at key life history phases should therefore be explored to increase survival.

3. Investigate changes to the geomorphology of the Nechako River.

Changes to the channel geomorphology were noted by Rood and Neill (1987). These and other changes to the channel are hypothesized to have an effect on white sturgeon recruitment. There may be some correlation between the timing of the Cheslatta avulsions with recruitment declines. Changes in the channel geomorphology, therefore, need to be investigated to evaluate their temporal correlation to historic changes in recruitment. In addition, the identification of changes to specific physical habitats important to white sturgeon should provide information about potential restoration opportunities.

Population Assessment, Monitoring, and Research

1. Protect existing sturgeon stocks using available regulatory mechanisms and planning processes.

Existing regulatory mechanisms are adequate for protection of sturgeon and their habitats. The education of First Nations fisherman regarding safe release of sturgeon caught incidental to their salmon harvest, needs to be continued.

2. Periodic adult stock assessments.

Population status and trends should be monitored with periodic stock assessments based on mark-recapture studies. Assessments should include basic biological information needed to monitor population productivity, *i.e.*, length, weight, sex, pectoral fin samples for ageing, sexual maturity, and reproductive stage. Assessments should be repeated at least every 3 to 5 years but may also be conducted annually in association with broodstock collection efforts.

3. Spawning investigations.

To date, no evidence of sturgeon spawning in the Nechako River has been documented although a significantly large number of Nechako sturgeon were observed in the spring of 2002 at a time and location consistent with possible spawning behaviour activity. This basic life history information is critical to understanding the population status and whether spawning actually occurs in the Nechako. This work would be a continuation of monitoring done annually since 1995. Physical habitat parameters at egg-collection sites should be measured annually, including water depth, substrate type mean water column velocity and temperature. Predator fish species in the spawning area should be captured, their stomachs removed and examined for the presence of white sturgeon eggs/larvae.

4. Juvenile indexing.

An annual monitoring program should be established to obtain baseline juvenile abundance levels. Standardized sampling protocols should be developed to provide a juvenile year-class abundance index. The success of annual spawning events should be assessed by means of larval YOY and/or juvenile capture programs. This information is necessary to detect significant differences in year-class abundance attributable to physical or biological factors. Natural high flow events that occurred in 1997 and high spring freshet flows that occurred in 2002 must be assessed to determine if there were recruitment responses from these events. This assessment should be undertaken before the fish get too old.

5. Essential habitats.

Identify essential habitats important to each life history stage, describe the characteristics of these habitats and quantify the present availability of these habitat types in the Nechako River. Studies of habitat use could rely on telemetry for juvenile through adult stages and catch-rate data for younger life stages. Habitat use curves should be prepared for specific life stages of Nechako sturgeon and compared to available aquatic habitat through the use of methodologies such as the Instream Flow Incremental Methodology (IFIM). Knowledge of critical life-cycle requirements will be used to evaluate and direct habitat enhancement efforts.

6. Recruitment bottlenecks.

Conduct research to identify early life history stages where juvenile recruitment is failing. This investigation will use a combination of experimental releases of hatchery-reared juveniles of various stages, spawning investigations, juvenile indexing, habitat analyses and predation.

7. Genetic baseline.

Identify genetic characteristics of sturgeon (genetic divergence within range, genetically meaningful management units, extent of hybridization) using electrophoretic or DNA analysis. Existing data allow general comparisons among widely distributed white sturgeon populations but do not provide the information needed to monitor genetic characteristics for changes associated with continued population declines or hatchery-based recovery methods. Detailed genetic data may also provide critical data on numbers of parents contributing to spawning events and effective population sizes and more clearly indicate the relationship between adjacent populations.

8. Population analysis.

Additional work is needed to address limitations in current assessment methods that have significant impacts on population prospects and recovery plan implementation including:

a) Validity of age estimates based on fin ray sections. Recent studies on upper Columbia and Kootenay sturgeon have identified significant under-estimation bias based on this method. Additional work is needed to assess whether biases in estimates of growth, mortality, and age at maturation for Nechako sturgeon may be leading to inaccurate population assessments.

b) Population estimates based on mark-recapture methods. Current estimates will be biased if marked-fish mixing assumptions are violated. Additional analyses would improve power and accuracy of population assessment methods by further evaluating the potential for occurrence of these biases and applying advanced statistical methods to address them.

c) Further surveys of white sturgeon within areas less studied in the Nechako system, including the Stuart and Nautley rivers and their associated lake and river habitats. This work will be critical to developing a better understanding of the role of these systems to the past, present and future health of the Nechako stock.

d) Egg development rates used to back-calculate spawning dates and identify physical conditions that coincided with spawning. Additional laboratory and field work is needed to identify population-specific development rates for the Nechako River.

e) Impact assessment and response tools including computer production models for use in evaluating population viability and potential recovery actions.

9. Community interactions.

Population productivity and habitat capacity depend, in part, on food availability and mortality due to predation. Additional work is needed to:

a) Evaluate potential limitations resulting from predation by species such as bull trout, rainbow trout, northern pikeminnow, suckers, and sculpins.

b) Evaluate potential limitations resulting from food habits and feeding behaviour.

Predation during critical early life history periods can be investigated by sampling potential predators near spawning sites. The availability of hatchery-released juveniles will provide the opportunity in future years to obtain diet data without risk to wild fish.

Information and Education

An important component of the implementation of the technical aspects of the recovery plan, are the many linkages to the broader constituency with interests in white sturgeon and whose activities may affect white sturgeon. Successful implementation of this plan will rely upon this broader constituency and it is therefore important that they continue to be involved in or are aware of the implementation of this plan. It is anticipated that the Action Planning Group will play an active role in communication, education, outreach and fundraising.

IMPLEMENTATION SCHEDULE FOR RECOVERY ACTIONS

Short-Term (within 5 years – 2003 to 2007)

Objective: Assess population status and act to prevent further reduction in sturgeon distribution, numbers, and genetic diversity within the current geographic range.

1. ***Develop/implement pilot fish culture program to maintain adult population abundance and genetic diversity.***

   1a. Evaluate the genetic risks of conservation fish culture and their relative magnitude in the context of extinction of the Nechako stock.

   1b. Develop a breeding plan to facilitate the culture and release of sufficient numbers of juveniles/families to meet minimum conservation target, *i.e.*, maintain existing population size, within recovery area.

   1c. Develop program to culture and release adequate numbers of wild origin, hatchery-reared juveniles to meet conservation target for recovery.

   1d. Develop program to provide adequate numbers of cultured juvenile sturgeon to support research initiatives.

2. ***Evaluate and, where feasible, eliminate direct anthropogenic sources of adult mortality.***

   2a. Identify and reduce/eliminate sources of direct mortality, *e.g.*, poaching.

3. ***Increase early life stage survival through improved water and habitat management.***

   3a. Identify flow needs for sturgeon at specific life stages and locations on the Nechako River.

   3b. Identify and initiate habitat restoration plan and undertake select habitat improvements.

   3c. Carry out flow modelling to investigate future delivery schedules that increase sturgeon survival.

4. ***Track population status and survival rate.***

   4a. Identify methods and establish population monitoring program to track short-term targets 1-3 within recovery areas.

   4b. Undertake program to assess juvenile and adult population abundance and distribution in Nechako River system.

   4c. Assess the abundance and status of white sturgeon in less studies areas of the Nechako system, including the Stuart and Nautley rivers and their associated lakes.

   4d. Carry out analysis to determine the genetic makeup of sturgeon in the Stuart and Nautley systems relative to sturgeon sampled in the Nechako River.

Medium-Term (within 10 years – 2003 to 2012)

Objective: Determine survival bottlenecks and establish feasible response measures to reduce or eliminate limitations.

1. ***Undertake research designed to define survival limitations.***

   1a. Provide research plan for peer review.

   1b. Complete research plan and identify recruitment limitations.

2. ***Increase early life stage survival through improved water, habitat, and fisheries management.***

   2a. Complete the assessment of sturgeon survival response to peaking spring flows that occurred naturally in the Nechako River in 1997 and 2002.

   2b. Complete feasible habitat improvements for the recovery area.

2c. Using identified sturgeon flow needs, initiate feasible flow delivery modifications to increase sturgeon survival in an adaptive management framework.

2d. Work cooperatively with groups developing plans for a Cold Water Release Facility at Kenney Dam for the eventual redistribution of flows that could ultimately benefit sturgeon.

3. Evaluate feasibility of a full-scale conservation fish culture and juvenile release program to address recruitment failure.

3a. Complete full-scale conservation fish culture plan for recovery area including location (assess land acquisition and water suitability), permitting, breeding/genetic plan, supplementation strategy, etc.

3b. Operate conservation fish culture facility to meet conservation targets (increase population to minimum sustainable levels while maintaining genetic diversity) within recovery area.

4. Track habitat conditions and population status within geographic range.

4a. Maintain monitoring program to track habitat conditions and population structure within recovery area.

4b. Monitor juvenile abundance to demonstrate significant probability of population persistence throughout geographic range.

Long-Term (50 years – 2003 to 2052)

Objective: Re-establish natural, self-sustaining population abundance levels, age structure, and beneficial uses through natural recruitment.

1. Maintain adequate survival through optimal water and habitat management programs.

1a. Provide and monitor results of water management regime.

2 . Establish stable population structure.

2a. Provide juvenile abundance adequate to support a self-sustaining population.

2b. Provide an average rate of recruitment that meets that required for population replacement.

2c. Ensure adequate numbers of sexually mature adults are present to meet conservation targets within recovery areas.

3. ***Continue with the conservation fish culture and juvenile release program, as required.***

    3a. Necessary culture facility constructed and operational to meet conservation target within recovery area (until such time as natural recruitment is proven to be sufficient to maintain population).

4. ***Track habitat conditions and population status within geographic range.***

    4a. Maintain monitoring program to track habitat conditions and population structure within recovery area.

    4b. Monitor juvenile abundance to demonstrate significant probability of population persistence throughout recovery area.

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GLOSSARY

Adaptive Management A systematic process for continually improving management policies and practices by learning from the outcomes of *operational programs.*

Adult Same as MATURE.

Age Composition A group of individuals of a certain species that have the same age.

Anecdotal Evidence Information passed along by word-of-mouth but not documented scientifically.

Avulsion A change in the course of a river when the bank is breached or overtopped.

Base Flow The typical flow rate for a given stream at a particular time of year.

Bed Load Streambed materials that are washed downstream and redeposited in a new location.

Biological Productivity A measure of growth in living systems.

Biological Trophic Level Steps in the food chain from plants through plant-eaters to meat-eaters.

Biomass The total weight of a living organism or a population of organisms.

Conservation The management of human use of natural resources so that they may yield the greatest sustainable benefit to current generations while maintaining their potential to meet the needs and aspirations of future generations.

Conservation Aquaculture A hatchery-based, captive culture program designed to preserve the gene pool (genetic variation) and natural age-class structure of wild fish through the release of hatchery-reared juveniles. The program is based on a breeding plan that includes protocols on adult broodstock collection, hatchery spawning and rearing, fish health, and genetics.

Discharge Water flow volume, often used to describe a volume released from a dam.

Effective Population Size An ideal population of a given size in which all parents have an equal expectation of being the parents of any progeny individual.

Electrophoretic Analysis The process in which molecules (such as proteins, DNA, or RNA fragments) can be separated according to size and electrical charge by applying an electric current to them.

Empirical Data Information derived from measurements made in "real life" situations (*e.g.*, field data).

Endangered Any species (or stock) that is likely to become extinct within the foreseeable future throughout all or a significant portion of its range.

Endogenous Refers to feeding on internal food sources, *e.g.*, egg yolk matter or energy reserves, as opposed to feeding externally.

Evolutionary Significant Unit A distinctive group of animals that is uniquely adapted to a particular area or environment and cannot be replaced.

Exogenous Refers to feeding on external food sources as opposed to the utilization of egg yolk matter or energy reserves within a fish.

Extinct Species A species no longer present in its original range or as a distinct species elsewhere.

Extirpation The elimination of a species or subspecies from a particular area, but not from its entire range.

Flow Regime Same as HYDROLOGICAL REGIME.

Functional Extinction Occurs when a population of a species declines to such a degree that it becomes virtually impossible for the population to survive, let alone recover. At such low numbers inbreeding starts to occur.

Genetic Diversity A property of a community of organisms of a certain species, in which members of the community have variations in their chromosomes due to a large number of slightly dissimilar ancestors; this property makes the community in general more resistant to diseases or to changing ecological conditions.

Haplotypes A way of denoting the collective genotype (the genetic constitution of an organism) of a number of closely linked loci (positions) on a chromosome.

Heterozygosity Possessing two different forms of a particular gene, one inherited from each parent.

Hydrograph The recorded variations in stream discharge over time. Useful when comparing effects and changes in stream flow and depth between average natural conditions and altered stream flows (*i.e.*, from dams and diversions).

Hydrological Regime The pattern and volume of river or stream flow throughout the course of a year.

Juvenile A young fish or animal that has not reached sexual maturity.

Limnological The science of the properties of fresh water including water chemistry, density, stratification and physical effects on living organisms.

Mature A fish that is sexually mature and capable of producing eggs or sperm.

Microhabitat Detailed description of where an animal lives.

mtDNA Sequences The pattern or order of mtDNA which is the circular or linear DNA of the mitochondria. It codes for only a small but essential part of the mitochondrial proteins and for other specific genes.

Nucleotide A subunit of DNA or RNA consisting of a nitrogenous base (adenine, guanine, thymine, or cytosine in DNA; adenine, guanine, uracil, or cytosine in RNA), a phosphate molecule, and a sugar molecule (deoxyribose in DNA and ribose in RNA). Thousands of nucleotides are linked to form a DNA or RNA molecule.

Nutrient Dynamics The way nutrients are used and reused, over time and distance, in a biological system.

Population Same as STOCK.

Population Dynamics Model A mathematical description of a population that is designed to fully simulate the life cycle of animals in that population, and that has the ability to project relative effects of different environmental effects or biological characteristics of these animals.

Recovery When the constituent populations of naturally produced fish belonging to an endangered population unit are sufficiently abundant, productive and diverse in terms of life histories and distribution that the listed unit as a whole will be "self-sustaining" into the future.

Recruitment Failure A situation where a population is not able to naturally produce viable off-spring as a consequence of physical (*e.g.*, blocked access to spawning areas, siltation of spawning areas, etc.) or biological (*e.g.*, inadequate numbers of fish, reproductive senescence, etc.) factors.

Recruitment Survival of juveniles until they become a member of the spawning population.

Relative Abundance A comparison of the number in one category to another (*e.g.*, number of one species to another, male to female, young to old, etc.). Typically expressed as a percentage or proportion.

Reservoir Drawdown Removing water from a reservoir and lowering the surface water elevation.

Species A group of individuals that have their major characteristics in common and (usually) can only breed with each other.

Stock A grouping of fish usually based on genetic relationship, geographic distribution, and movement patterns. Also a managed unit of fish.

Stock Status General health of a particular stock of fish in terms of numbers, age-class distribution, condition, distribution, and genetic diversity.

Total Population Total number of individuals, of all age classes, in a population.

Tributary A small stream or river, which enters and increases the volume of the receiving river, lake, or reservoir.

Vulnerable Population Any species (or stock) whose numbers are not so low as to be considered endangered but whose status is such that further reductions in habitat quality, numbers or size distribution may make them endangered.

Year Class All individuals of a fish population spawned and hatched in a given year.

APPENDIX I. RECOVERY TEAM MEMBERS AND CONTRIBUTORS

Current Members (at time of release of Recovery Plan):

- Don Cadden – Ministry of Water, Land and Air Protection
- Cory Williamson - Ministry of Water, Land and Air Protection
- Steve McAdam – Ministry of Water. Land and Air Protection
- Justus Benckhuysen – Alcan, Primary Metal BC
- Dan Bouillon - Alcan, Primary Metal BC
- Brian Toth – Carrier Sekani Tribal Council
- Scott McKenzie – Golder Associates Ltd.
- Byron Nutton – Department of Fisheries and Oceans
- Jason Hwang – Department of Fisheries and Oceans
- Dan Sneep – Department of Fisheries and Oceans

Past Members:

- Ted Down – Ministry of Water, Land and Air Protection
- Jason Yarmish – Lheidli T'enneh First Nation
- Dennis Ableson - Carrier Sekani Tribal Council
- Max Blouw – University of Northern BC

Current and Past Contributers:

- Kevin Conlin - BC Fisheries
- Kathi Zimmerman – FORREX – Forest Research Extension Partnership
- Carla Wainwright – BC Conservation Foundation
- Geoff Chislett - Consultant
- Ted Zimmerman - Ministry of Water, Land and Air Protection
- Dave Barry - Ministry of Environment, Lands and Parks
- Curtiss McLeod – Golder Associates Ltd.
- Steve McFarlane - Department of Fisheries and Oceans
- Juanita Ptolemy – Ministry of Water, Land and Air Protection
- Ken Ashley – Ministry of Water, Land and Air Protection
- Karl Walters – University of British Columbia
- Josh Korman – Ecometric Research Inc.
- Jay Hammond – Golder Associates Ltd.
- Corey Stefura – Golder Associates Ltd.