Morice-Nanika Sockeye Recovery

Evaluation of Enhancement Options

OFFICE OF THE WET'SUWET'EN

Wet'suwet'en Fisheries

Cover: Morice Lake; view south. Photo Credit: D. Bustard.

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Technical Report

Submitted to: Pacific Salmon Commission–Northern Fund

Wet'suwet'en Fisheries
Ken Rabnett April 2006

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Table of Contents

MORICE–NANIKA SOCKEYE RECOVERY PLAN

INTRODUCTION

The purpose of this report is to present the known history of sockeye production data, the biological and management information available, enhancement requirements, and potential techniques for the restoration of Morice–Nanika sockeye. This report has been prepared for the Pacific Salmon Commission Northern Fund on behalf of Wet'suwet'en Fisheries.

This report is a background component of the Morice–Nanika Sockeye Recovery Plan (MNSRP) planning table, a Wet'suwet'en Fisheries and Department of Fisheries and Oceans initiative. The MNSRP process provides a framework for aboriginal, government, industry, and public groups to work together towards stock recovery. This report compliments the Morice–Nanika Sockeye Recovery Plan Backgrounder (Rabnett 2005) that describes biophysical, fisheries, cultural, and land use conditions in relation to Morice–Nanika sockeye.

BACKGROUND

The Morice–Nanika sockeye stock is the largest sockeye run in the Bulkley Basin. Since the mid-1950s, Morice–Nanika sockeye abundance has mostly fluctuated at levels below historical escapements and low fry densities are prevalent in relation to Morice Lake juvenile sockeye rearing capacity. Constraints to sockeye production stem from the high exploitation rates above those that can be sustained in the Alaskan, Canadian, and First Nation fisheries and low production from the ultra-oligotrophic Morice Lake. The Morice Lake sockeye stock's spawning and rearing habitat is in its natural condition; it has not been impacted by development activities.

The Wet'suwet'en, whose territory overlies the Bulkley Basin, have fished Morice–Nanika sockeye stocks at Hagwilget and Moricetown Canyons and at numerous terminal sites for at least six thousand years. Morice–Nanika sockeye are critically important for food, social, and ceremonial (FSC) needs and stock restoration is a high priority to the Wet'suwet'en as it is the last anadromous sockeye salmon population remaining on their traditional territory.

Concerns regarding Morice–Nanika sockeye abundance have been raised since the mid-1950s, primarily by the Wet'suwet'en and Department of Fisheries and Oceans (DFO), though their approaches to fisheries and stock restoration have differed. Since the mid-1950s, DFO has made efforts to identify the cause of the decline and to rebuild the sockeye stock. Escapement records indicate that prior to 1954, spawner returns were apparently strong with annual averages in the 1940s of 70,000 sockeye (Cox-Rogers 2000). Since 1954, a forty-year period of marked decline showed annual average returns of between 1,700–9,000 fish. Escapement increased in the 1990s to an annual average of 32,000 sockeye, although since 1998, average escapements have decreased to less than 6,000 fish.

MORICE WATERSHED PLANNING PROCESSES

Within the Morice–Nanika Watershed, there are currently other land use plans or planning processes that are inclusive or semi-inclusive of fish and fish habitat. The six major planning processes include the Morice Lands and Resource Management Plan, the Wet'suwet'en Territorial Stewardship Plan, the Morice and Lakes Innovative Forest Practices Agreement, and the Morice Watershed Fish Sustainability Plan, the Northern B.C. Integrated Fisheries Management Plan, and the Wild Salmon Policy.

The Wet'suwet'en Territorial Stewardship Plan (WTSP) is an initiative being developed by the Office of the Wet'suwet'en on behalf of the thirteen Wet'suwet'en Houses. The purpose of this plan is to support the Wet'suwet'en as stewards of their traditional territories, a portion of which overlie the Morice Watershed. The WTSP is a tool kit based on natural and cultural features that can be used to make balanced resource stewardship decisions, help create economic development, and communicate Wet'suwet'en ecosystem management, cultural knowledge, and values. Major objectives include bridging Wet'suwet'en traditional knowledge and values and the structure of contemporary resource management processes through criteria and indicators. The WTSP will effectively improve opportunities for Wet'suwet'en values and aspirations to be integrated into resource planning and development and facilitate a transitional approach to territorial management and resource stewardship.

The Morice Land and Resource Management Plan (LRMP) was initiated and led by the Ministry of Sustainable Resource Management with land use recommendations completed and publicly presented in 2004. Currently, the recommendations and various substantive issues are being discussed with the Office of the Wet'suwet'en and changes are expected before the LRMP is signed. The sub-regional land use recommendations include creating three categories of land use designations with accompanying management directions for the LRMP area: General Resource Management Zones, Area Specific Resource Management Zones, and Protected Areas. All of these three categories include objectives, measures/indicators, targets, and management statements.

The Morice and Lakes Innovative Forest Practices Agreement is a partnership among seven regional forest licensees to develop socially acceptable plans and practices, which will enhance basic drivers of timber supply, maintain environmental values, implement innovative approaches, affect policy, and transfer learning. The central objective is to develop and implement Sustainable Forest Management Plans (SFMPs) for the Morice and Lakes Timber Supply Areas (TSAs). The Morice SFMP dovetails closely with the Morice LRMP and alongside those management directions, a suite of indicators give planning, implementation, monitoring, and evaluation direction to operational Forest Stewardship Plans (Tesera 2003).

The Morice Watershed Fish Sustainability Plan (WFSP) is a federal and provincial initiative (BC MELP and FOC 2001) that has been led by Community Futures Development Corporation Nadina (CFDC Nadina). The purpose of this planning process is to sustain robust fish populations and fully functioning aquatic ecosystems in the Morice Watershed. Major objectives include providing fish and fish habitat resource information on the watershed scale and developing plans that ensures conservation of fish populations and aquatic ecosystems.

The Policy for the Conservation of Wild Pacific Salmon, commonly known as the Wild Salmon Policy (WSP) is a significant new approach to salmon conservation. The WSP goal is to restore and maintain healthy and diverse salmon populations and their habitats. The goal, objectives, and strategies pertinent to the conservation of wild Pacific salmon will be guided by four principles: conservation, honoring obligations to First Nations, sustainable use, and open process.

The Wild Salmon Policy five-step planning procedure includes:

- Providing an overview report that identifies the conservation units (CU) exploited by fisheries in each planning unit, with information on their biological status, key habitat, and ecosystem constraints. Based on this information, priorities will be established that will be addressed in integrated salmon management plans.
- Identifying resource management options and alternative management options that reflect a realistic range of different approaches addressing management priorities.
- Establishing biological, social, and economic performance indicators that directly relate to the biological, social, and economic objectives.
- Assessing the likely impacts of management alternatives and the relationships to the indicators allowing the likely "net effect" relative to a base case over a projected period.

- Selecting the preferred management alternative. This will involve tradeoffs among different biological, social, and economic indicators due to differences in priorities and managing risk.

The decisions made for each planning unit will collectively form the regional strategic plan for management of fisheries and watersheds. The WSP plan will include activities and management actions to be undertaken over a medium to long-term framework. It will also stipulate explicit biological targets for individual CUs and aggregate CUs, and where appropriate, anticipated timeframes for rebuilding efforts.

The Northern B.C. Salmon Integrated Fisheries Management Plan (IFMP) is an annual fisheries plan directed towards sockeye, coho, pink, chum, chinook, and steelhead salmon in the north and central coast areas. The IFMP contains comprehensive decision guidelines that set out the rationale for management decisions and it considers a number of factors including consultation with advisors, historical practices, and the review of previous years' fishing practices and outcomes.

The IFMP objective for Skeena River sockeye is to ensure that exploitation rates are maintained at sustainable levels. Maintaining wild Skeena River sockeye stocks is the key objective while providing a harvest of the abundant enhanced stocks. Aggregate sockeye stock management is risk adverse to ensure that the exploitation rate of individual stocks does not exceed sustainable levels. For 2005, the Canadian commercial exploitation rate will be guided by estimated run size. For Skeena River sockeye and pink salmon, all ESSR fisheries will operate selectively with live release of all non-target species.

Once a commercial fishery has been conducted at the mouth of the Skeena River, and a sockeye surplus is determined in the Babine River, then an ESSR opportunity may be declared in the Babine River and Lake. Due to uncertainty in estimating escapements, the surplus amount in the river will be half of the estimated over escapement. For allocation purposes, this surplus will be split in half again, and half will be available to the Gitksan Watershed Authority to be harvested in the Babine River, while the other half will be available to the Lake Babine Nation to be harvested at the Babine Fence.

The Morice Watershed Restoration Program (WRP) was a provincial initiative to restore the productive capacity of fisheries, forest, and aquatic resources that had been adversely impacted by past forest harvesting practices. Aquatic and upland restoration efforts were halted in 2001, due to a change in provincial government policies, but interim restoration plans (IRP) were established that delineated restoration objectives and future priority restoration work plans.

As noted above, numerous natural resource planning processes are underway at the watershed or finer scale in Morice Watershed could affect, or be affected by Morice–Nanika Sockeye Recovery Plan activities. Building relationships and identifying ideas and products through planning activities can achieve efficiency in timeframes, content, and participation, and as well, can potentially provide more complete assessment and solutions to complex habitat related problems. The collaboration of fish protection and restoration priorities across plans could provide unique opportunities for funding, priorities, and implementation.

ENVIRONMENTAL SETTING

HYDROLOGY

The Morice Watershed is located in west-central British Columbia south of Houston at 54° 127°40'. The Morice Watershed is part of the Bulkley River basin, which is fed by streams originating in both the Interior Plateau and glacier fields of the Coast Mountains. From the outlet of Morice Lake, the Morice River flows northeastward 80 km to join the Bulkley River near Houston, B.C. The Hazelton Mountains within the Morice watershed are comprised of a complex group of small ranges: the Telkwa Range, the Morice Range, and the northern portion of the Tahtsa Range. Relief is relatively high in these ranges, with rugged peaks partially covered in glacial ice.

Morice River is a sixth order stream with a catchment area of 4,349 km^2 that comprises the southwestern portion of the Bulkley River watershed. Elevations range from approximately 2,740 m at the southwestern border to 560 m at the Bulkley confluence. Morice Lake at 764 m elevation is the largest lake in the system and is the origin of Morice River. Major tributaries include: Atna River, Nanika River, Thautil River, Gosnell Creek, Lamprey Creek, Owen Creek, and Houston Tommy Creek.

Figure 1: Morice and Bulkley Rivers confluence

Annual discharge peaks at 250 to 550 m^3/s during the early summer snowmelt season and after the occasional fall frontal storm; however, much of the flow is buffered by storage in Morice Lake. Morice River represents 86% of the Bulkley River flow at the Bulkley–Morice confluence, with a mean annual flow of 118.1 m^3/s (DFO 1984). Mean discharge of 15 to 25 m^3/s is typical at late winter low-flow conditions (Gottesfeld and Gottesfeld 1990). Morice River at the lake outlet (WSC Station 08ED002) has a mean annual discharge of 77 m^3/s.

The contribution of high elevation snowmelt and ice melt runoff is important in maintaining adequate summer water levels in the mainstem and side channels of Morice and Nanika Rivers. There is a steep precipitation gradient from west to east, as well as from the high alpine to the valley bottom country. Annual total precipitation ranges from at least 2,000 mm in the Coast Mountains to under 500 mm along the lower Morice River.

Four large lakes, Morice, Nanika, Kidprice, and McBride, provide most of the lake storage in the Morice system. Morice Lake lies in a deep trench between the Morice Range to the west and Tahtsa Range to the east. Morice Lake at 764 m elevation is surrounded by glaciated mountains that drop steeply into the lake from elevations ranging from 1,200 to 2,000 m. The glaciated mountains with cascading streams and sharply inclined shores are a conspicuous feature of the lake basin except in the northeastern portion.

The lake is 42 km in length and averages 2 km in width in the south arm and 3 km in width through the north arm. Morice Lake is characterized by two large, deep basins in the southern and northern arms with maximum and mean depths of 236 m and 100 m respectively. The lake has a surface area of 96 km^2 draining a basin area of 1,872 km^2. Morice Lake is relatively cold, with an average summer seasonal surface temperature of 8.15 C^0 (Shortreed and Hume 2004). Shortreed *et al.* (2001) report a water resident time of approximately four years.

The two main lake tributaries are Nanika River and Atna River. Nanika Watershed has a catchment area of 895 km^2 yielding a mean annual flow of 36.6 m^3/s that contributes about 50% of the total water inflow into Morice Lake. Nanika River at the outlet of Kidprice Lake (WSC Station 08ED001) has a mean annual discharge of 29.6 m^3/s, with 82% or 732 km^2 of the watershed lying upstream of this point. The three main lakes, Nanika, Kidprice, and Stepp lakes occupy another trenched valley approximately ten km east of Morice Lake and drain via the Nanika River to Morice Lake. This chain of lakes lies in a proportionally deep and steep-sided valley formed by the surrounding mountains that range from 1,800 to 2,400 m.

Figure 3: Kidprice Lake.
D. Bustard.

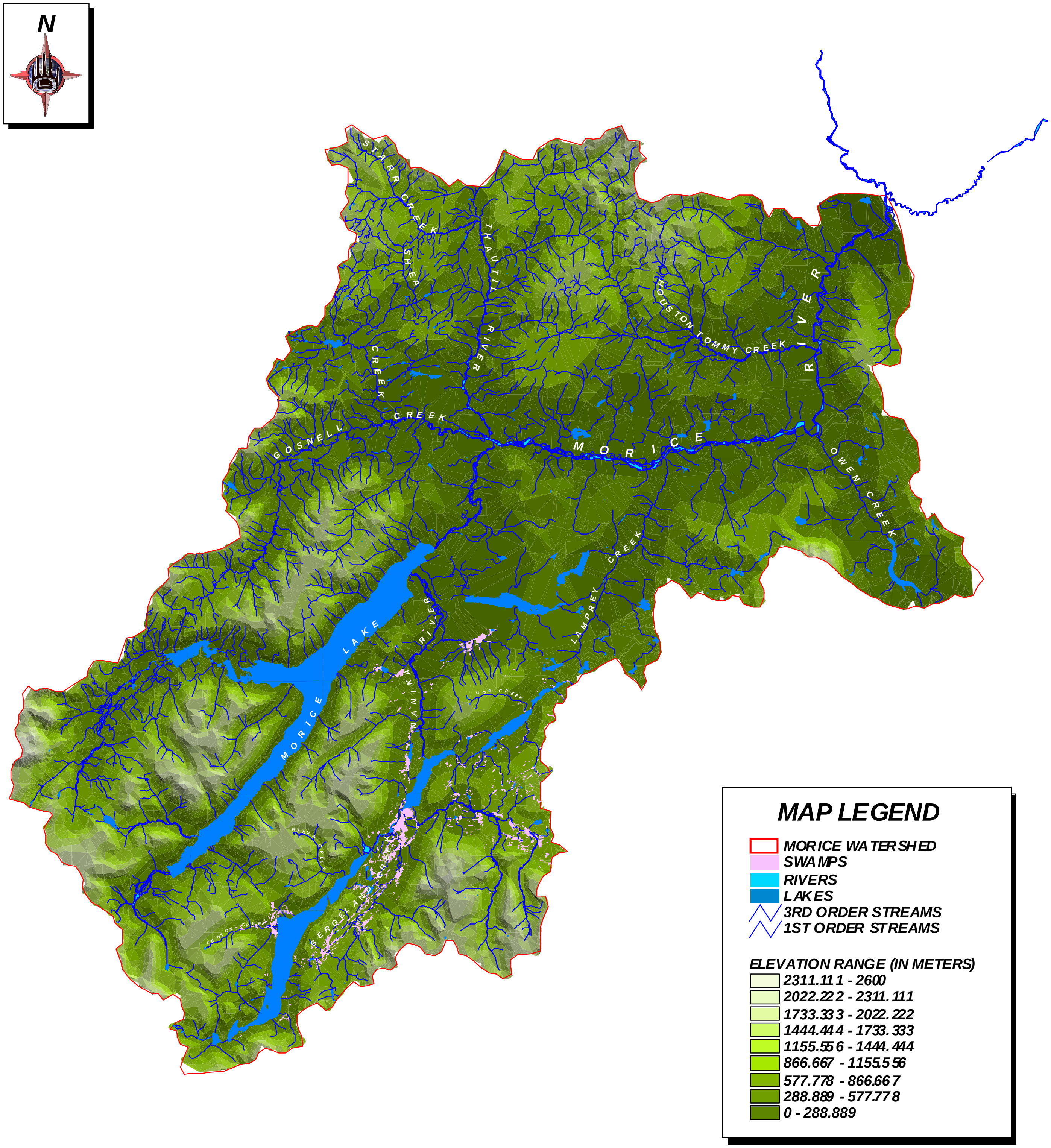
The Atna River drains 243 km^2 consisting for the most part of glaciated mountains in the Kitimat and Morice Ranges. Atna Lake lying at 774 m elevation has a surface area of approximately 5 km^2 and has a maximum depth of 60 m (Envirocon 1984b). Atna Lake possesses glacial drainage characteristics shown by the generally very turbid water that is due to glacial silt discharge from the upper Atna River. The lake outlet area is relatively clear, which is attributed to silt deposition and spring fed streams.

STREAM CHANNELS

The Morice River mainstem is 80 km in length with a very low gradient (<0.2%) and no obstructions to anadromous fish passage over its length. Several studies in the early 1990s conducted by Gottesfeld and Gottesfeld (1990) and Weiland and Schwab (1992) focused on the Morice River channel and floodplain history, as well as elucidating the patterns and processes of channel change. Reach one extends from the outlet of Morice Lake to the Thautil River and is a single-thread channel with a stable channel configuration.

Reach two extends from the Thautil River downstream to Fenton Creek confluence. This reach is characterized as a wandering gravel bed river with one to several channels, frequent channel changes, gravel bars, forested islands, eroding banks, log jams, and a network of seasonally flooded channel remnants over the floodplain (Weiland and Schwab 1992). The bedload of Reach two is coarse (over 97% is coarser than 2 mm), consisting mostly of gravel and cobbles. Reach 2 is considered highly valuable and productive fish habitat. Reach three of the Morice River extends from Fenton Creek to the Bulkley River confluence in a single thread channel that maintains a relatively stable channel configuration.

Figure 4: Morice River, reach 2.
M. Bahr 2000.



MORICE - NANIKA SOCKEYE RECOVERY PLAN

10 0 10 20 30 Kilometers

MAP SCALE - 1:550,000

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The Morice River, downstream of Morice Lake, has several large tributaries that drain mountainous areas; these include the Thautil River, Gosnell Creek, and Houston Tommy Creek. Two lake-headed tributaries, Owen Creek and Lamprey creeks, drain Nadina Mountain and southern plateau areas. McBride Lake, a relatively large lake situated on the Nechako Plateau, drains into Morice Lake just north of Nanika River.

Nanika River is 23 km in length from Morice Lake to Nanika Falls and is commonly divided into four reach zones. Reach one is multi-channelled and approximately four km in length with a floodplain often exceeding 400 m in width. Reach two is confined with a mostly deep, straight channel. Reach three is a multi-channelled reach with numerous islands, gravel bars, and side channels set into a floodplain sometimes wider than 400 meters. Reach four is largely a confined reach with deep fast flows, with Nanika Falls (11 m), a barrier to anadromous fish, at its head.

Lower Atna River, flowing between Atna Lake and Morice Lake, is two km in length and widens in sections to form two small lakes (Envirocon 1984b). The upper lake is shallow with a comparatively wide sedge band along its northern shore, while the lower lake is steep-sided. Between the lakes are two waterfalls, three and four meters high respectively, which are a partial barrier to fish passage for some species; however, salmon can negotiate them.

WATER QUALITY

Water quality data for Morice Lake and Nanika River is available since the 1960s. The most extensive studies conducted to date were during the Kemano Completion research by Envirocon (1984a) and Cleugh and Lawley (1979), which included water temperature, groundwater hydrology, food-frequency analysis, and discharge modelling.

Wilkes and Lloyd (1990) sampled water quality in the lower Morice River from 1983 to 1987 and reported water quality as excellent. Morice River water is soft; the pH is near neutral, while mean alkalinity, a measure of pH buffering capacity, is low. Morice River water is typically very clear, although Total Suspended Solids (TSS) readings can be high during freshets. Nutrient levels throughout much of the watershed are extremely low, in many cases less than the detection limits (Remington 1996).

Dykens and Rysavy (1998) sampled water quality in Fenton and Shea creeks as part of the Skeena Region operational inventory. Sedimentation, channel morphology, water quality, and stream productivity parameters were assessed. Results for Fenton Creek, a third order stream, showed high concentrations of surface fines and an unbalanced benthic invertebrate community due to development activities. Shea Creek, a fifth order lake fed tributary of Gosnell Creek, showed excellence in all parameters. Bahr (2002) sampled water temperature with twenty-five water temperature loggers positioned throughout the drainage for an eighteen-month period.

Finnegan (1995) sampled water temperature at McBride and Owen Creeks, Morice River, and an offchannel area at km 21 (Bustard’s Pond) and has six temperature sites with year round data, a portion of it dates back to 1994. A preliminary evaluation of water temperature in the watershed shows that lake headed tributaries such as Lamprey, Owen, and Shea Creeks are typically two to four degrees warmer than glacial headed tributaries such as upper Gosnell Creek, Thautil River, and Crystal Creek. Bahr’s data (2002) suggests that Morice River warms as it flows downstream from Morice Lake with maximum temperatures showing on the lower Morice River.

MORICE LAKE LIMNOLOGY

Morice Lake limnology is defined as the study of the lake ecosystem and encompasses the integration and the relationships of its physical, chemical, and biotic components. The major Morice lake limnological studies include: the Fisheries Research Board in the late 1940s, the Nanika River Rehabilitation Program in the early 1960s, the Kemano II environmental studies in the 1970s, the pre and post-fertilization surveys in the late 1970s and early 1980s, and the trophic status and juvenile rearing capacity sampling conducted in 1993 and 2002.

In 1944 and 1945, the Fisheries Research Board conducted limnological studies in Morice Lake that included bathymetry, surface and sub-surface temperatures, water transparency, fish species and abundance, and plankton studies. These studies are described in Alderdice and Foerster (1944), Brett (1945), and Brett and Pritchard (1946). Plankton studies identified two species of Cladocera, (*Bosmina longispina* and *Daphnia longispina*) and two species of Copepoda (*Cyclops sp.* and *Epischure sp*.). Plankton haul station locations are not recorded, but species and densities are included in Anonymous (1948).

Limnological surveys on Morice Lake were conducted from 1961 to 1965 as a component of the Nanika River Rehabilitation Program (Crouter and Palmer 1965). The limnological surveys included temperature data, Seechi disc observations, and sampling relative densities of zooplankton (Palmer 1986). As part of the Kemano II environmental studies, the Fisheries and Marine Service initiated a program during 1974–75 to inventory the water chemistry, phytoplankton, zooplankton, zoobenthos, and the morphometry of Morice Lake; this program was reported on by Cleugh and Lawley (1979). Stockner and Shortreed (1979) conducted a limnological program in 1978 on Morice Lake in order to determine the potential for enhancement of sockeye under the auspices of the Lake Enrichment Program.

Morice Lake is dimictic with mixing in the spring and fall, and stratified in the summer and winter. The lake has a relatively small amount of littoral zone, low inorganic nutrient levels, low phytoplankton biomass, and low zooplankton biomass. Morice Lake is considered ultra-oligotrophic with spring overturn phosphorus concentration of 1 μg/L (Shortreed *et al.* 2001). Morice Lake shows high dissolved oxygen content that ranges from 90 to 100% and cool water temperatures. Inflowing streams to the lake have a cooler mean temperature than the lake (Cleugh and Lawley 1979).

Surface temperature observations show that at any time, the shallow north end of the lake is warmer than the south end, though temperatures at 50 m depth throughout the lake show little difference. Thermal stratification tends to be weak with deep mixing common throughout the year (Stockner and Shortreed 1979); this is attributed to strong prevailing winds circulating the lake waters. Shortreed *et al.* (2001) reported that Morice Lake has a deep euphotic zone (19.8 m), a thermocline depth of 25.8 m, a cool epilimnion, a large hypolimnion, and 7.00 pH. Thermoclines tend to be deeper and stronger towards the outlet of the lake.

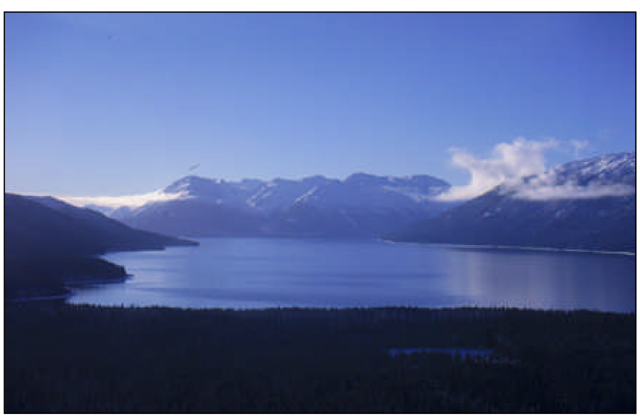


Figure 6: Morice Lake view south
M. Bahr 2000.

In the summer, the lake is glacially turbid in the south and Atna Bay arms, but the glacial gradient tends to comparatively clear water near the outlet (Simpson *et al.* 1981). Palmer's (1986a) data indicated that monthly Seechi disc observations during 1961–65 were most often double the depth in May and June than in July, August, and September. Stockner and Shortreed (1979) samples showed a mean Seechi depth of 5.6 m.

Shortreed and Hume (2004) reported on monthly limnological surveys conducted in Morice Lake during 2002 and 2003. Physical and biological observations were similar to past studies. The warmest surface temperatures (11.5^{o}C) occurred at Station 6, located downstream of the Nanika River. Epilimnetic nitrate concentrations were relatively high during the growing season suggesting that nitrogen and phosphorus are co-limiting nutrients. Chlorophyll (CHL) concentrations were relatively low at 0.44 μg/L with a homogenous vertical CHL profile. Overall, Shortreed and Hume (2004) noted that Morice Lake productivity appears limited primarily by P loading, although its short growing season, cool temperatures, and unstable epilimnion no doubt play a role in its extreme oligotrophy.

MORICE LAKE SOCKEYE SALMON

The Morice Watershed is a biologically rich river system that has considerable and varied high value fish habitat. The watershed is or has been a major producer of chinook, pink, sockeye, and coho salmon, and steelhead trout, which support aboriginal, commercial, and recreational fisheries. Freshwater fish present in the system include rainbow, lake, and cutthroat trout, Dolly Varden and bull trout char, kokanee, whitefish, lamprey, burbot, sculpins, suckers, chub, and shiners.

Kokanee are reported in Morice and Shea lakes. Lake trout are present in Morice, Owen, Atna, and McBride lakes. Mountain whitefish presence is noted in Morice, Atna, Shea, Owen, and Lamprey Lakes. Bustard and Schell (2002) reported that the highest concentrations of juvenile and adult whitefish appear to be in the Morice mainstem, and use of the tributaries appears to be minor. Pygmy whitefish are reported in Owen and Morice Lakes, and lake whitefish are known in McBride and Morice Lakes. Pacific lamprey are abundant and widely distributed throughout the drainage with concentrated spawning occurring in Lamprey Creek, Owen Creek, and Morice River. Bustard and Schell (2002) provide an excellent comprehensive description of Morice fish populations' status, their key habitats by species and life stage, limiting factors to production, and species information gaps.

SOCKEYE LIFE HISTORY

A key theme of sockeye salmon (*Oncorhynchus nerka*) is that they are anadromous and semelparous, meaning they spend a portion of their life in the ocean and return to freshwater to spawn, after which they die, similar to other Pacific salmon. Their habitat includes the freshwater watershed of origin, such as the Morice, and a large portion of the Northeast Pacific Ocean. Sockeye salmon are widely recognized for their distinctive migratory behavior, their unique reproductive and juvenile rearing life histories, and their intimate connection with indigenous and contemporary human cultures.

Each fall, drawn by natural forces, sockeye salmon return to the rivers, which gave them birth. Sockeye typically spawn in tributaries to large lakes such as Nanika River. These streams can vary in type, ranging from small streams to large mainstem rivers, and side-channels. In the Morice, spawning is common along the shorelines of Morice and Atna lakes that have upwelling ground water. Once the salmon reach their spawning grounds, they deposit thousands of fertilized eggs in the gravel. Each female, with a male in attendance, digs a redd. By using her tail, the female creates a depression in which she releases her eggs. At the same time, the male releases a cloud of milt. When the female starts to prepare her second nest, she covers the first nest with gravel that protects the eggs from predators. This process is repeated several times until the female has spawned all her eggs.

Adult salmon die following their long journey and spawning. Their carcasses provide nourishment and winter food for birds and wildlife, and provide nutrients to the river or lake for the next generation of salmon and other fish. As the salmon eggs lie in the gravel they develop an eye and over months, the embryo develops and hatches as an alevin. The alevin carries a yolk sac that provides food for two to three months. Once the nutrients in the sac are absorbed, the free-swimming fry move up and emerge into the water. The sockeye fry migrate downstream to Morice Lake at a size of approximately 25 to 30 mm. At this small size, sockeye fry are vulnerable to predation by other fishes and birds. The production of food is particularly important at this life stage because faster growth can increase their survival. Once free-swimming, fry usually live in Morice Lake for two years.

Fry ready to enter salt water are called smolts. Smolts typically leave Morice Lake in mid-May when they are in their second or third years in freshwater. Smolts feed and physiologically adapt to the ocean environment in the Skeena Estuary before typically travelling northward, where they spend one to three years in the North Pacific. They return to their home streams to spawn and die.

MORICE LAKE SOCKEYE – STOCK ASSESSMENT AND STATUS

Morice–Nanika sockeye are the most important sockeye stock in the Bulkley Basin. Morice–Nanika sockeye were a large part of the Wet'suwet'en food fishery for at least the last 6,000 years. Currently, the Morice sockeye stock typically makes up 1% of the Skeena sockeye aggregate escapement, whereas in the late 1940s and early 1950s, the Nanika was a major natural producer comprising up to 10% of the total Skeena sockeye escapement. Three factors are believed to currently be limiting production: low escapements and fry recruitment, low in-lake growth, and nutrient limitation.

Assessment History

DFO has assessed the Morice–Nanika sockeye stock since the mid-1940s, and these studies led to mitigation of the migration obstructions in the 1950s and early 1960s with the completion of the Moricetown Canyon fishways on the Bulkley River in 1951; this was followed by removal of the Hagwilget Canyon rock in 1959. The Nanika River Rehabilitation Program (Crouter and Palmer 1965, Palmer 1986a) was conducted in the early 1960s to improve juvenile sockeye production. During the 1970s, Morice–Nanika sockeye studies were conducted under the auspices of the Kemano Completion Project and are for the most part reported in Shepherd (1979) and Envirocon (1984a, 1984b). Pre and post-fertilization surveys centered on the trophic status and juvenile rearing capacity of Morice Lake were conducted in the late 1978, 1980, 1985, 1993, and 2002. In the mid-1990's, the productive potential of the stock was reviewed and updated.

Figure 7: Nanika River outlet, Morice Lake.
M. Bahr 2000.

Population Abundance

Historically, sockeye returning to the Morice Watershed numbered on the order of 50,000 to 70,000 fish and comprised as much as 10% of the total Skeena River escapement (Brett 1952). The average annual escapement estimate for the 1940s was 70,000 fish (Cox-Rogers 2000). In 1954, the population showed an apparent collapse, which extended to all cycles, and remained below 6,000 spawners until the early 1990s, other than in 1965. Uncertainty exists as to what caused the sockeye stock to suddenly decline in the mid-1950s. The precipitous decline occurred when fishing effort on Skeena sockeye stocks were considerably reduced (1952–58) to allow increased sockeye escapement following the 1951 Babine River slide.

The stock increased from 1991 to 1997 with the escapement ranging from 21,000 to 41,000 fish. Since 1998, abundance has fluctuated at low levels generally below 15,000 spawners. Estimated escapements were 3,000 in 2000, 5,000 in 2001, 14,800 in 2002, 16,800 in 2003, 10,200 in 2004, and 9,500 in 2005 (DFO 2006). Despite the good returns in the mid-1990s, recent trends in escapement are still well below the predicted optimum annual escapement of approximately 120,000 sockeye for this stock. Presently, sockeye escapement levels are below 10% of the optimum escapement.

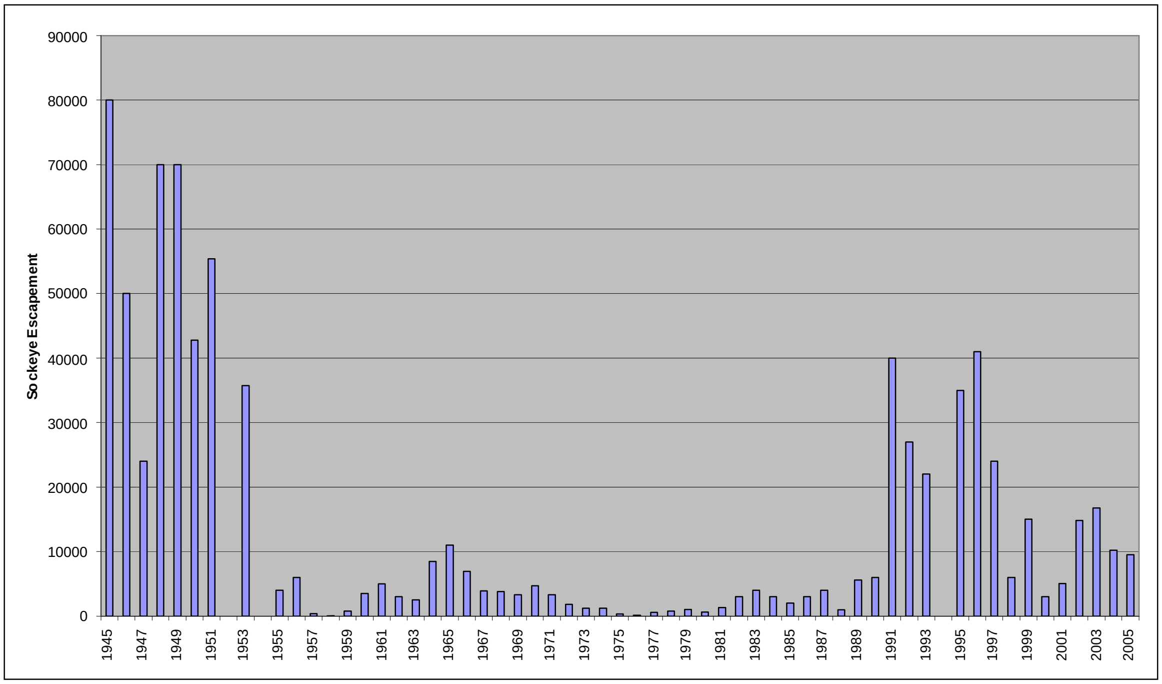


Figure 8: Morice–Nanika sockeye escapement 1945–2005

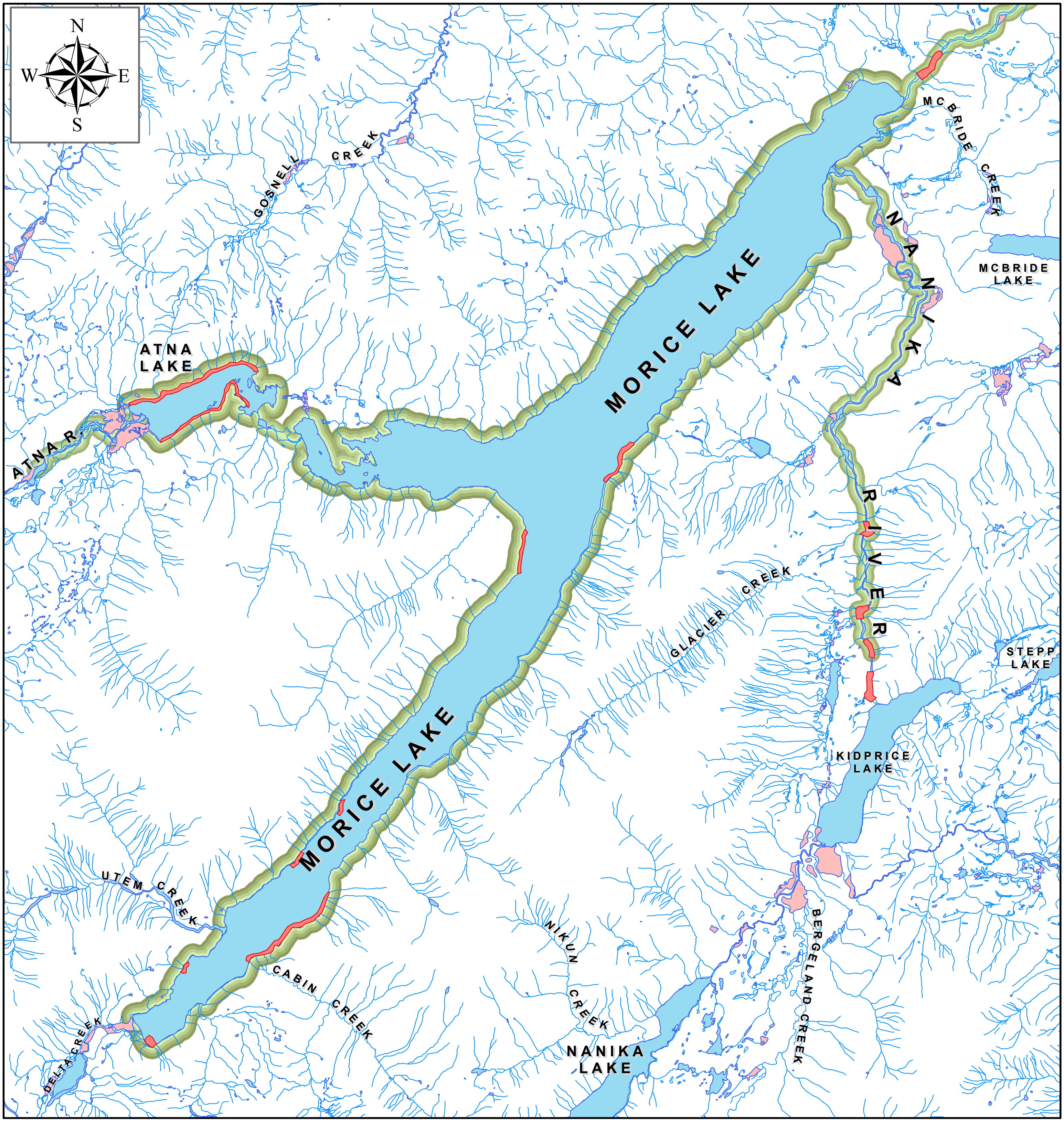
Morice Sockeye Adults & Spawning Traits

The Morice sockeye stock is composed of two sub-components: Nanika River spawners and Morice Lake and Atna lakes beach spawners. Morice–Nanika sockeye usually reach the mouth of the Skeena in late-June to mid-July with a peak in the first week of July (Cox-Rogers 2000). Peak migration of sockeye salmon past the Alcan counting tower near Owen Creek occurred in early to mid-August (Farina 1982).

The main sockeye run usually hold and school in Morice Lake before ascending the Nanika River to the 3 km reach downstream of Nanika Falls where the principal spawning grounds are located (Robertson *et al.* 1979). Secondary Nanika River spawning grounds are scattered downstream to Glacier Creek. Shepherd (1979) noted that Nanika River sockeye peak spawning occurs during the third week of September. Shepherd (1979) presented age data from 1965 to 1975 for Nanika River sockeye that indicated the majority of spawners were five and six year old (90%), both having spent two years (86%) in freshwater. In all study years, egg retentions were low in Nanika sockeye spawners (Shepherd 1979).

Morice Lake sockeye spawners, who are thought to be composed of exclusively beach spawners, utilize scattered beach spawning grounds at the south end of the lake, but the main beach spawning occurs for 3 km north of Cabin Creek (Vernon 1951, Bustard and Schell 2002). Scattered beach spawning also takes place on the west and east shores in the central portion of the lake (Hancock *et al.* 1983).

Studies of sockeye spawners, which appear to be exclusively beach spawners in Atna Lake during 1980, indicated estimates of approximately 400 sockeye spawners based on carcass recovery (Envirocon 1984b). Most of these spawned in the northeast section (Area 4), as opposed to DFO observation in 1961 where most spawning appeared to be in the northwest section. Envirocon (1984b) noted that the age distribution of Atna Lake sockeye differed from Nanika and other non-Morice Skeena stocks. The dominant group (58%) were 5_3's, (two years in



MAP LEGEND

- ADULT MIGRATION & HOLDING
- SOCKEYE SPAWNING AREAS
- CREEKS
- SWAMPS
- WATERBODIES (RIVERS & LAKES)

NANIKA - MORICE SOCKEYE SPAWNING GROUNDS

NANIKA - MORICE SOCKEYE RECOVERY PLAN

0 1.5 3 6 9 12
Kilometers

MAP SCALE - 1:175,000

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freshwater and 3 years in the ocean). The primary difference is with the subdominant group (4_2's) representing approximately 29% of the run that had spent one year and three years in freshwater and the ocean respectively.

Brett (1949) notes sockeye spawning grounds located in Gosnell Creek. Bustard and Schell (2002) mapped all known sockeye river and lake spawning locations; the following map is adapted from their project. Nanika River sockeye spawning grounds are the only ones in the Morice system that have had consistent escapement estimates since the 1950s. Accurate beach spawning counts along Morice and Atna Lake shorelines are difficult due to turbidity and depth. Bustard and Schell (2002) suggested that Morice Lake beach spawning sockeye might comprise a significant component of the Morice sockeye run during some years. This is now backed up by the Moricetown Canyon mark–recapture program that shows 35% of the total sockeye spawn in locations other than Nanika. Many of these are thought to be Morice and Atna lakes beach spawners (Finnegan 2006).

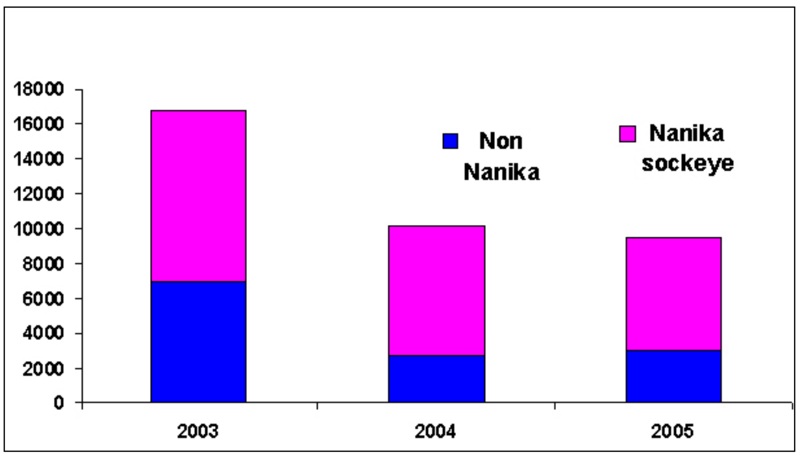

Figure 10: Sockeye composition upstream of Moricetown. B.Finnegan 2006

Finnegan (2006) reports recent sockeye abundance estimates have been generated from the mark-recapture program that is located at Moricetown Canyon. Beach seining at Idiot Rock below the canyon and by dipnet at the fishway allows T-bar anchor tagging that are stratified by weekly periods utilizing numbered tags. Recapture is at the fishway and tag recovery on the various spawning grounds. The aggregate escapement is determined from the Nanika River visual and swim surveys and population estimation uses ML Darroch, Pooled Peterson, and Schaefer methods. The marked to unmarked ratios is determined in the upper Bulkley, on the Nanika River spawning grounds, and in Morice and Atna Lake to account for lake spawners (Finnegan 2006).

Recent helicopter overflights, swims, gillnet surveys, and visual observations have failed to locate Atna Lake spawners. In 2003, assessment surveys observed 500+ spawners on Morice Lake spawning locations; however, none were observed in 2005. Conservation concerns are raised due to the recent depressed state of Morice and Atna lakes sockeye abundance. Bustard and Schell (2002) suggest that estimates of Morice and Atna lake sockeye beach spawners is poorly understood and important to the overall annual Morice escapement assessment.

Shepherd (1979) reported that Morice sockeye have slightly smaller body size than other Skeena sockeye stocks. Most Nanika sockeye (86%) spent two years (sub-3s) in freshwater, and returned mainly as five and six year olds. Bustard and Schell (2002) report that studies conducted on the Atna Lake sockeye population show these salmon spent two years in freshwater and three years in the ocean.

Morice Sockeye Juveniles & Rearing

Morice Lake serves as the freshwater rearing lake for sockeye spawned in the Nanika River, Morice Lake, and possibly an unknown amount from Atna Lake. Morice Lake sockeye juvenile studies were conducted primarily in the 1960s, 1970s, and early 1980s and reported on by Palmer (1986b) Crouter and Palmer (1965), Shepherd (1979) and Envirocon (1984a, 1984b) respectively. Shortreed *et al.* (1998, 2001) and Shortreed and Hume (2004) report on more recent sockeye juvenile sampling conducted in 1993 and 2002. Lake rearing habitat capacity and fry production relationships are presented in Cox-Rogers *et al.* (2004). In Morice Lake, the understanding of juvenile sockeye rearing and smolt production dynamics, such as age and growth, distribution and abundance, movement timing, and predation is still evolving.

Palmer (cited in Shepherd 1979) indicated that the Nanika River natural spawning areas produced unusually high egg to fry survival rates; this is thought to be likely due to the deep and stable warm water flows from Kidprice Lake, which is located approximately 300 m upstream. Following emergence from the spawning gravels, sockeye fry emigrate at night from the Nanika spawning beds into Morice Lake from late-May to late-July, with a peak in mid-June that is usually coincident with peak annual flows (Shepherd 1979). Natural fry from Nanika River that were sampled from 1962 to 1965 had a mean weight of 2.0 g. Palmer (2006) notes that Nanika sockeye had approximately 20% fewer eggs, but larger eggs, than Pinkut sockeye.

The period of fry emergence and migration to Morice Lake is an interval of potentially high vulnerability to predation from larger fish and by birds. Bustard and Schell (2002) suggest that the timing of sockeye fry from their redds and their entrance into Morice Lake is specific and timed to coincide with an increase in plankton production.

Studies in Atna Lake in 1980 indicated that sockeye fry emergence timing is consistent with Nanika River sockeye. Envirocon (1984b) reported sockeye fry are the dominant species (90%) in littoral areas during spring and summer prior to moving into the offshore region of Atna Lake. The mean length of Atna Lake fry increased from 34 mm in early summer to 52 mm in September. Although young of the year sockeye predominated in beach seine and fyke net catches, juvenile sockeye of two other size classes were present. In June, individuals ranging from 60 to 80 mm were yearlings (sub-2 smolts) and fish over 100 mm may have been two-year-old fish (sub-3 smolts).

The size distribution from different Atna Lake sampling areas indicates a larger mean size at the outlet end of Atna Lake and in the lower lake during early and late summer (Envirocon 1984b). This could be due to larger fry downstream movement or an increased growth rate in these habitats. Movement of sockeye fry out of Atna Lake was observed from late May through August with a peak with a peak in early summer. Envirocon (1984b) suggested that these fry probably reared in Morice Lake prior to smolting. The peak sockeye fry downstream migration from Atna Lake likely occurred shortly after ice break-up (Envirocon 1984b).

Figure 11: Atna Lake, view southwest.
M. Bahr 2000.

Shepherd (1979) reviewed the 1960s and 1970s beach seine, tow net, and gill net catch results, which indicated that sockeye rearing distribution was concentrated in the northern portion of the lake. This conclusion is coincident with the relatively high nutrient, and primary production, and secondary production levels documented by Cleugh and Lawley (1979). Nanika River is the only tributary to contribute measurable phosphorous into Morice Lake. In the northern portion of Morice Lake, the water chemistry, the relative greater phytoplankton production, and increased zooplankton feeding on littoral phytoplankton, are substantially influenced by nutrient supply received from the Nanika River (Cleugh and Lawley 1979). This trophic pattern reflects the cold temperature, the low nutrient levels, and the relatively small littoral zone of Morice Lake.

Palmer (1986a) summarized a tow net index of summer fry and yearling sockeye in Morice Lake and a measure of the smolt output. Palmer noted the 1962 and 1963 year classes are the only groups for which complete freshwater production data are available and consequently, freshwater survival estimates cannot be made.

Shortreed *et al.* (1998, 2001) and Shortreed and Hume (2004) reported on fall fry hydroacoustic and fish sampling with trawl in Morice Lake in 1993 and 2002. The objectives were to obtain population estimates of the nursery lake limnetic fish community, obtain estimates of juvenile sockeye size, diet, and biomass, as well as delineate factors limiting their productivity. Shortreed *et al.* (1998, 2001) confirmed earlier studies reporting that age-0 fall fry are the smallest (0.8g) in any sockeye nursery lake in BC. Sockeye stomachs were <30% full and contained mostly bosminids, a less than ideal food source, which indicates extreme oligotrophy.

Morice Lake juvenile sockeye sampling results show age-1 fry and age-2 smolts are low in weight and small in size compared to other Skeena Basin sockeye nursery lakes (Shortreed and Hume 2004). As well, generally low escapement produces low maximum smolt biomass. Review of the 1958 to 1963 data showed that in the five brood years from 1958 to 1963, the proportion of age-2 smolts ranged from 36 to 75% and averaged 46%. Mean size of age-1 fry and age-2 smolts was 3.7 g (range = 2.8–4.8 g) and 7.8 g (range = 6.6–9.5 g) respectively. Trawl caught fall fry density was 69/ha in 1993 and 160/ha in 2002. Currently, sockeye juvenile densities are at 7% of the lake rearing capacity.

In contrast with other Skeena sockeye stocks, which spend one year in freshwater, over 85% of Nanika River sockeye spend two years in Morice Lake, and 90% return as four- (2.2) and five- (2.3) year-olds (Shepherd 1979). Atna Lake sockeye studies indicate that this stock also spends two years in freshwater and most returned after spending three years in the ocean (Envirocon 1984b). In comparison, Shepherd (1979) points out that the majority of Skeena River sockeye (91%) rear for one year in lake systems prior to smolting. The large percentage of two-year-old smolts in Morice Lake is indicative of its low productivity.

Sockeye smolts migrate out of Morice Lake from late April to August with a peak migration in mid-May (Shepherd 1979). Smith and Berezay (1983) corroborated this with smolt migration studies in 1979 and 1980, which showed out-migration was principally complete by June. Kadawaki (cited in Envirocon 1984b) indicated that in 1980, 75% of the smolts migrated during a ten day period in mid-May; this was followed by a secondary peak in late May and only a few smolts were recovered in June.

Observations from juvenile sockeye studies conducted from 1961 to 1966 and noted by Palmer (1986b) include:

1. Smolting age appears to be size dependent. Tow net sampling in Morice Lake immediately before and during smolt migration indicated a smaller average size and a wider size range of yearlings in the lake population than in the out-migrating smolts. There appeared to be a threshold size below which juveniles did not smolt. In some years, at least, this appeared to be about 60-65 mm (2 grams).
2. Smolt sampling and enumeration during the 1961-66 period indicated approximately 50:50 age-1 and age-2 smolts (2.3 million age-1 and 2.2 million age-2). Subsequent sampling of

the Nanika River escapements demonstrated that 89% were returns from age-2 smolts, i.e. survival of age-2 smolts was 8 times better than age-1 smolts.

Young salmonids stay close to the coastline when they reach the estuary. After varying lengths of time, the smolts make a coastal migration northward reaching the northern Gulf of Alaska in the fall. With the onset of winter they migrate south into the open ocean, migrating north and south seasonally as growing adults for one to four years in the Northeast Pacific Ocean foraging on amphipods, fish, squids, and euphausiids. Ocean growth and survival of sockeye can be affected by periodic warm water events (El Nino) and by cyclic changes in ocean conditions.

Factors Limiting Sockeye Production

Since the early 1950s, a major theme of fisheries biologists involved in the Morice system has been identifying the factors that limit sockeye production. Over the last sixty years, enhancement efforts have focused on easing fish passage, increasing fry recruitment, and understanding the trophic status of Morice Lake and the correlates among these factors. Currently, major factors limiting juvenile sockeye production are thought to be the lack of escapement and the relatively low intrinsic productivity of Morice Lake.

Lack of sockeye escapement to the Morice system is mostly due to coastal mixed-stock fisheries and in-river aboriginal fisheries. The estimated exploitation rate has been variable but the overall average rate has been 53%. Similar run timing to the larger and more productive Babine sockeye stock and the nature of the mixed stock fishery impacts Morice sockeye escapement. Hyatt (1983), Shortreed *et al.* (1998, 2001) and Cox-Rogers *et al.* (2004) indicate or suggest that Morice Lake is largely fry-recruitment limited. Since 2000, reductions in the exploitation rate have occurred in all fisheries and these reductions are expected to continue.

Shortreed *et al.* (2001) note that Morice Lake possesses excellent physical conditions for juvenile sockeye; however, the lake is ultra-oligotrophic due to its very low nutrient loading. Morice Lake productivity appears to be limited primarily by P loading, although its short growing season, cool temperatures, and unstable epilimnion no doubt play a role in its extreme oligotrophy (Shortreed *et al.* 2001).

Stockner and Ashley (2003) note that with respect to depressed sockeye stocks, the decline of phosphorus nutrients into sockeye nursery lake systems began in the early part of the twentieth century during times of over-fishing. During that time, many of the nutrients were being put into cans and were not available to replenish the environment. The primary reduction of phosphorus and other nutrients in steams, lakes, and estuaries can be attributed to the decline of fish populations.

Bustard and Schell (2002) report that the main spawning grounds in Nanika River are not considered subject to flooding, redd dewatering, and freezing, although some of the secondary spawning areas, especially downstream of Glacier Creek, may be subject to flooding and severe ice conditions during some years. Beach spawning grounds on Morice and Atna lakes are relatively deep and are likely characterized with a reasonable egg to fry survival rate.

Bustard and Schell (2002) mention they suspect predation may be high on emerging sockeye fry prior to lake entry from bull trout, coho juveniles, rainbow trout, and sculpins present in the upper Nanika River during fry emergence and from lake trout as they enter Morice Lake. Nanika River sockeye fry can sustain significant losses from emergence to Morice Lake. Foerster (1968) mentions predation studies on sockeye fry between emergence and entry into Lakelse Lake ranged between 63 and 84% during four years of study in Scully Creek in the Lakelse Watershed. In Six Mile Creek (Babine Lake), rainbow trout were the major predators, and Foerster estimated for one year that predators decimated approximately 66% of the emerging fry during their migration to the lake.

Potential predator fish species found in Morice Lake include burbot, lake trout, and rainbow trout. Brett and Pritchard (1946) found that 50% of lake trout (*S. namaycush*) stomach contents consisted of age-0 and age-1 salmon. Palmer (2006) notes generally reasonable sockeye fry survival from predators in the Nanika River and Morice Lake during the early 1960s, but visual observations and analysis of Dolly Varden stomach contents showed sockeye smolts were often heavily targeted in the upper Morice River during their out-migration.

Morice Lake possesses relatively low quantities of easily available food for juvenile sockeye, and furthermore, the quality is low to medium. Competition for food resources of juvenile sockeye during lake residence may exist between different age classes. Groot and Margolis (1991) mention this factor could modify juvenile sockeyes' vulnerability to predation, and consequent mortality.

Morice Lake sockeye fry may be important prey for lake trout. Creel surveys conducted on Morice Lake by Envirocon (1984b) in 1979 estimated that the 204 lake trout angled comprised 20% of the sports fishery catch. Lake trout in Atna Lake comprised 28% of the gill net catch; the majority of these were caught in deep water; however some were caught in the littoral area, especially during the evening feeding on sockeye.

MORICE SOCKEYE ENHANCEMENT ACTIVITIES

Morice sockeye enhancement activities in the Morice Watershed have centered on fish access and passage, sockeye fry production, and lake productivity issues. Moricetown Canyon has long been considered an obstruction to fish passage and remedial measures were recommended as early as 1904. In 1929, Department of Fisheries engineers blasted a fish pass out of the falls (B.C. Prov. 1929). The present Moricetown Canyon fishways were constructed prior to the 1951 in-migration and an assessment of the facilities was conducted during the same year (Hourston and Stokes 1952). Concerns regarding the low number of returning Nanika sockeye in 1955 led to the decision to remove obstructions in Hagwilget Canyon and the canyon rocks were blasted before the 1959 in-migration, effectively eliminating the aboriginal fishery in the canyon.

Nanika River Rehabilitation Program

The continuing decline of the Nanika sockeye population, with escapements of less than 1,000 fish for the three consecutive years of 1957 to 1959, initiated the Nanika River Rehabilitation Program. This program, designed to improve Nanika sockeye juvenile production, led to the construction of a pilot hatchery on the lower reach of Nanika River. In operation from 1960 to 1965, the hatchery was not successful, probably due to the use of transplant stock from Pinkut Creek in the Babine system.

The selected stock was unsuitable; Shepherd (1979) indicated emergence was three to four weeks earlier in relation to suitable fry rearing conditions, there were differences in Pinkut adult life history (largely 1.2 and 1.3 fish), and Pinkut fry were small in size and thin compared to Nanika sockeye fry. Fry releases from the hatchery from 1960 to 1965 totalled 27,274,000; the egg to fry mean survival was 61%. The hatchery was closed in 1965 pending evaluation of returns. In 1964, an incubation channel with a capacity of 3,000,000 eggs was constructed and 1,200,000 fry were released in 1965 with an 80% egg to fry survival.

Morice Lake Fertilization

In the late 1970s, the Lake Enrichment Program was initiated by the Fisheries Research Branch with funding provided by the Salmon Enhancement Program. One of the major goals was to increase returns of adult sockeye by adding nutrients into oligotrophic lakes where juvenile sockeye production is apparently food-limited. Pre-fertilization assessments in Morice Lake were undertaken with limnological and lacustrine fish evaluations. Stockner and Shortreed (1979) reported on chemical, physical, and biological results, while Rankin and Ashton (1980) documented zooplankton abundance and species composition. Simpson *et al.* (1981) reported on the juvenile sockeye assessment that was conducted by echo sounding and trawling. Other species were sampled by gillnet, and in late summer, adult sockeye spawners were visually enumerated.

Morice Lake was fertilized in 1980 (18 weeks) and 1985 (16 weeks) with the goal to increase returns of adult sockeye by adding nutrients. Fertilization was applied weekly during the growing season by a DC6 aerial tanker with aqueous solutions of ammonium nitrate and ammonium phosphate with an average N:P ratio of 14.8. Post-fertilization results showed Morice Lake responded positively to fertilization with chlorophyll increased from 0.79 μg/L to 1.18 μg/L, a 35% increase in phytoplankton biomass, as well as a 60% increase in zooplankton biomass, particularly with *Daphnia* and *Eubosmina* (Costella *et al.* 1982).

Fertilization was terminated due to Hyatt (1983) reviewing the follow-up sampling and further benefits. Hyatt (1983) addressed a key point: "Given the information above, I believe we should stand by the position taken in 1981 that treatment of Morice Lake represents a long-shot for aiding sockeye stock recovery until such time as escapements increase to the point where recruiting fry are likely to exhibit pronounced food-limited growth patterns in-lake."

MORICE SOCKEYE ECOLOGICAL ROLE

Morice sockeye salmon returning as adults from the sea to spawn and die provide a very important nutrient link between the marine and freshwater environment. These salmon accumulate over 90% of their biomass during the marine phase of their life cycle (Groot and Margolis 1991). Considerable research has highlighted the important role of anadromous salmon in importing marine–derived nutrients (MDN) to freshwater and riparian ecosystems. These subsidies are thought to support diverse food webs and increase the growth and survival of juvenile salmon during their freshwater residency (Scheuerell *et al.* 2005).

Recent research and reviews (Quinn 2005, Reimchen *et al*. 2003, Wilson and Halupka 1995) has revealed that entire ecosystems benefit in direct and indirect ways from decomposing salmon. Wilson and Halupka (1995) termed salmon a keystone species in recognition of salmon's special role enriching otherwise nutrient-poor systems. Different sockeye life history stages likely play different roles in the various habitats they occupy throughout their life cycle. This viewpoint of salmon intrinsic importance to ecosystem functioning prompts concern for adequate escapement from an ecological perspective. The abundance of returning spawners is critical to maintenance of fish populations rearing in streams and lakes. It follows that salmon are important components of numerous freshwater and marine food webs throughout their life history.

Decreased availability of salmon carcass material can significantly reduce the nutrient influx to natal streams and over time, diminish productivity. The resulting decrease in juvenile fish size can reduce overwinter and marine survival, reduce the number of returning adults, and further reduce stream and lake productivity (Bilby *et al.* 1996). Runs of adult fish may continue to decline, returning fewer nutrients to already nutrient deficient streams and lakes, particularly if combined with overfishing of a now less productive stock. Thus a negative feedback loop from nutrient–food chain impacts can be very significant to lake and stream rearing species. Understanding marine derived nutrient loss may help to explain the continuing decline of Morice–Nanika sockeye.

MORICE SOCKEYE KNOWLEDGE GAPS

Presently, the life history and the factors influencing the sustainability of Morice sockeye populations are only partly understood. Future planning and recovery approaches should attempt to increase the understanding of Morice sockeye life history and their unique characteristics that influence their survival. Bustard and Schell (2002) presented five main knowledge gap themes that are important to stock recovery and management. Those ideas have been rolled into other noted knowledge gaps and are shown below.

1. What are realistic escapement targets for the Nanika River and Morice and Atna lakes assuming 1.0 m^2/spawning pair (West 1987)?
2. What were historical marine nutrient contributions to Morice Lake over the past 250 years?
3. Sockeye smolt tagging information is a priority to determine marine survival, run timing, and exploitation.
4. What is the effect of in-lake predation on sockeye fry and smolts?
5. What is the alevin to smolt out-migration survival rate?
6. What is the marine survival of Morice sockeye smolts, pre-adults, and adults and what are the major factors influencing marine survival?
7. Where are the main migration corridors and migration timing?
8. Can the Northern B.C. Salmon Integrated Fisheries Management Plan (IFMP) and the Wild Salmon Policy adequately protect this stock during the recovery process?
9. At what pre-cautionary rate can this stock be sustainably harvested in the future?
10. What is the realistic fry abundance level and conditions that would allow a "break even" point in regard to costs if a nutrient addition treatment were applied to Morice Lake?

FISHERIES

WET'SUWET'EN TRADITIONAL FISHERY

Wet'suwet'en traditional occupation and use of the Bulkley watershed is extensive and estimated to have been over a period of at least 6,000 years (Allbright 1987). Wet'suwet'en ancestral territory in the Morice River drainage is held by three clans: Gilseyhyu, Laksamshu, and Gitumden. The cultural infrastructure is comprehensive with traditional use features generally covering the landscape.

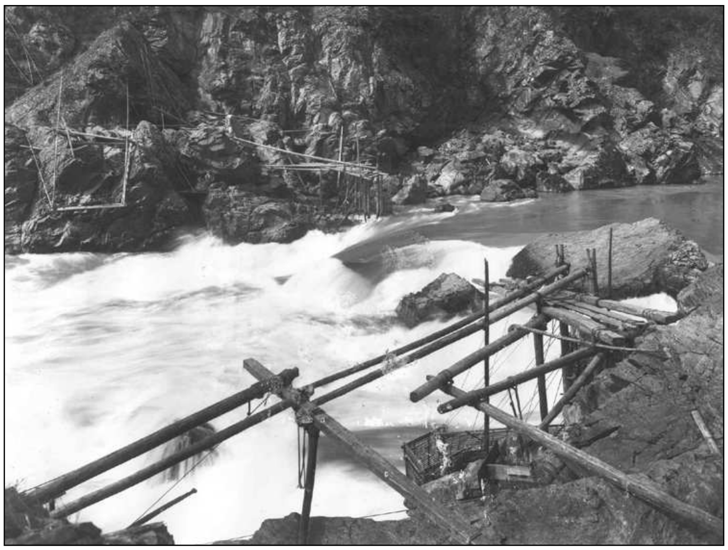

Figure 12: Hagwilget Canyon fishing platforms.
BC Archives.

Wet'suwet'en traditional salmon fisheries within the Morice drainage were documented by Naziel (1997) who recorded some twenty-odd site locations. These included concentrated fishery sites on the Morice River, many of which were adjacent to tributary streams, as well as dispersed sites located on tributary streams and lakes. Rabnett *et al.* (2001) documented traditional fishing sites at Morice Canyon (Tsee Gheniinlii), the Morice–Owen confluence (Bii Wenii C'eek), and the Morice Lake outlet (Lheet lii'nun teezdlii). Undoubtedly, many more sites on the mainstem and tributaries exist; however, few archaeological and (or) cultural heritage studies have been conducted.

The Morice–Nanika sockeye were a large part of the aboriginal food fishery. Moricetown Canyon was the site of the major Wet'suwet'en food fishery until 1824, when a large rockslide in Hagwilget Canyon shifted the fishery location there (Brown 1826). Both canyons had strong food fishery operations until the rock removal in Hagwilget Canyon in 1959 effectively eliminated that location. Traditionally, sockeye salmon were mostly harvested in basket traps and dipnets, but these were banned in 1935 (Palmer 1964) and gaffing was promoted. Gaffing was then introduced as the legal fishing method and used primarily up until the mid-1990s. The current decline of Morice–Nanika sockeye due to high exploitation rates and Morice Lake low-productivity issues, has deeply impacted the Wet'suwet'en First Nation.

Since 2001, the Wet'suwet'en have not directed a food fishery on the Morice–Nanika sockeye stocks. The Native Brotherhood of BC, in conjunction with the United Fisherman and Allied Workers Union, north coast gillnet groups, and fish processing companies have supplied the Wet'suwet'en with 8,000 sockeye (Joseph 2005) since 2001. With this cooperation, reduced harvest rates on the Nanika sockeye stock have been addressed at the terminal fishery (river) level in a way that is more difficult to achieve in the mixed stock fishery. Other in-river aboriginal fisheries that could impact Morice sockeye include the Tsimshian and Gitxsan food, social, and ceremonial fisheries conducted on the Skeena mainstem.

Figure 13: Moricetown Canyon.

Sockeye Importance to the Wet'suwet'en

Salmon are one of the foundations of Wet'suwet'en culture. Sockeye are highly desired by the Wet'suwet'en and the lack of sockeye over the last fifty years has caused hardship. In recent years, the amount of sockeye trucked from the coast has not covered Wet'suwet'en food needs and typically, there are marginal amounts of stored fish supplies, which is causing hardship. Some Wet'suwet'en are losing their self-reliance on harvesting their traditional food that is rooted in salmon. The Wet'suwet'en point out that there is an aboriginal right to fish for individual and community food, social, and ceremonial purposes and to have priority after conservation goals are met, therefore fisheries management has to consider its fiduciary obligations and their concerns. Wet'suwet'en Fisheries is looking for a solution and conclusion to the lack of Morice sockeye.

Figure 14: Moricetown Canyon fishery, 1946.
Fisheries Research Board of Canada.

Figure 15: Beach seining below Moricetown Canyon for mark-recapture sampling.
© Wet'suwet'en Fisheries.

COASTAL SOCKEYE FISHERIES

The Skeena River supports important commercial marine fisheries in Alaskan Districts 101-104 and Canadian Areas 1-5, for sockeye and pink salmon each July and August. Although management of the mixed-stock fishery has evolved considerably since the late 1800s, the incidental catch of non-target species and non-Babine sockeye stocks is a concern. Overlaps in run timing among various salmon stocks and diverse stock productivities preclude the application of a single harvest rate that would provide maximum yields for all stocks (Cox-Rogers 1994).

Morice Lake sockeye run timing is supported by marine tagging data (Aro and McDonald 1968), daily Moricetown Canyon fishway counts that were recorded from 1961-63 and 1966-68 (Harding and Buxton 1971), and DNA data procured from the Tyee Test Fishery (TTF). These studies indicate Morice sockeye are one of the "early" timed Skeena sockeye stocks (primarily the first two weeks of July) but the data are not conclusive as there is variability in run-timing and considerable overlap with the larger early and middle Babine Lake sockeye runs.

Morice sockeye run timing is noted as parallel to the Babine sockeye timing when the commercial fishery is usually increased on the coast with often a consequential high exploitation rate on the Morice sockeye stock. The run timing apparently peaks in the first to third week in July (weeks 71–73). This has resulted in harvest rates that are excessive for other non-Babine salmon stocks such as Morice sockeye, whose run timing overlaps with returns of the larger and typically highly productive Babine sockeye stocks, which peak in weeks 72–75. It is possible that that the second or later portion of the Morice sockeye run is lost.

As stock-specific catch data are lacking in most fisheries, a fishery model is used to estimate exploitation rates for Morice Lake sockeye in the marine and in-river fisheries below Hazelton. Catch data records and escapement data are used to calculate exploitation rates within the Bulkley River. The latter may be biased high for those years where visual escapement records are used. Catch trends for Morice-Nanika sockeye are difficult to quantify as the only available records are for the Wet'suwet'en harvests at Hagwilget and Moricetown Canyons.

Estimated marine exploitation, based on fishery modeling, suggests exploitation has been relatively invariable over time with average decade exploitation rates of 21% to 35% since the 1960's. Cox-Rogers (2006) indicates the overall average 1956-2004 marine exploitation rate is 29%.

Estimated in-river exploitation rates have been a bit more variable with decadal averages of 18% to 41%. The overall average 1956-2004 in-river exploitation rate is 24%. Total average exploitation rates on Morice-Nanika sockeye at 53%, are higher than the estimated sustainable exploitation rate, which for this stock is 35% (Cox-Rogers 2006).

Total estimated exploitation of Morice sockeye including both marine and in-river catches is estimated at 53%. This is close to the Skeena aggregate exploitation rate of 60% noted by Wood (2004), though the 60% only includes marine fisheries. The combined (historical) marine and in-river exploitation rate for Morice (53%) reflects about 30% marine and 23% in-river exploitation. Overall, the Morice sockeye stock has had high exploitation rates documented since the 1950s that have resulted in a depressed stock requiring recovery efforts.

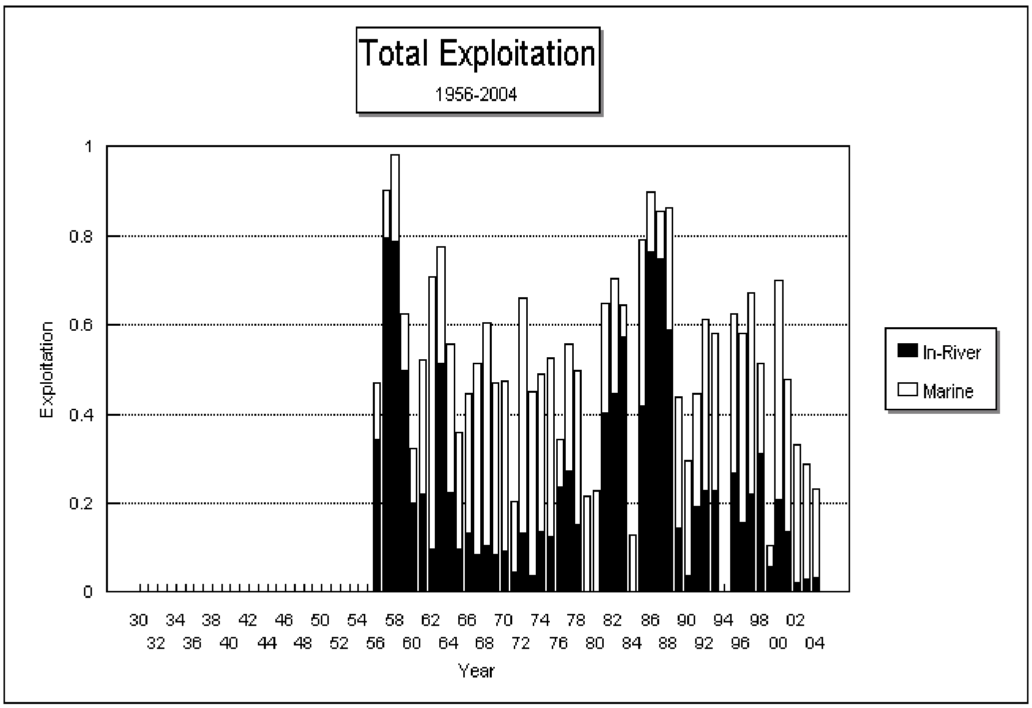

Figure16: Morice Lake sockeye total exploitation rate 1956–2004

MORICE SOCKEYE RECOVERY INITIATIVE

The Morice–Nanika Sockeye Recovery Plan offers an opportunity to link sectorial efforts that may be disconnected at the watershed and coastal levels. This collaborative approach requires a high degree of coordination and planning. The high social, cultural, and economic values of Morice–Nanika sockeye are significant enough that there is strong interest in rebuilding the population.

Over the last few decades knowledge has increased of natural and human-caused sources of variability and uncertainty in managing the Morice Lake sockeye salmon ecosystem. Nevertheless, there remain many uncertainties concerning parts of Morice Lake sockeye life history, rebuilding spawner escapement to historical levels over the long-term, and natural climate variability especially in the marine realm, and as well in the freshwater temperature and discharge regimes.

Uncertainty is a fact of the Morice sockeye salmon recovery process, given the overall potential complications that could result from gaps in the scientific knowledge, various sectorial interests, recovery plan objectives, the pressing Wet'suwet'en time frame to rebuild stocks, and the lack of committed funding resources. Overall, Bulkley watershed societal values and goals desire conserving and maintaining indigenous fish species and their environments throughout the Bulkley basin.

Morice–Nanika Sockeye Recovery Plan

Recovery Goal

Increase the Morice–Nanika sockeye stock to a self-sustaining, natural spawning population ensuring the preservation of its unique biological characteristics.

Recovery Objectives

1. Increase Morice sockeye escapement to improve fry recruitment immediately and into the long-term.
2. Initiate sustained growth in annual sockeye fry recruitment relative to Morice Lake rearing capacity.
3. Increase fry to smolt survival.
4. Inform local communities about the recovery process and encourage involvement.
5. Identify the level of abundance required to support Morice sockeye ecosystem function and sustainable use.

Guiding Principles

The guiding principles are:

1. Conservation of wild Morice sockeye salmon and its habitats.
2. Honoring fiduciary obligations to the Wet'suwet'en
3. Sustainable use
4. Open and transparent process

The objectives are intended to support the long-term goal outcome. This recovery plan will be closely linked to the Wild Salmon Policy in the interest of effectively managing efforts and costs. The Morice–Nanika Sockeye Recovery Plan will include activities and management actions to be undertaken over a short to medium to long-term framework. It will also stipulate explicit biological targets for individual Morice sockeye sub-populations, and where appropriate, anticipated timeframes for rebuilding efforts.

Biological recovery appears feasible if we assume that the trend of reducing the exploitation rate will continue and that it will have a beneficial outcome. Technical enhancement tools are known that have been utilized for similar sockeye population rebuilding. Currently, it is not known what tools the Wet'suwet'en, DFO, and Skeena Fisheries Commission biologists and fishery managers, and the general public are willing to use that will facilitate recovery efforts. This is the next step in the planning process; community values, initiatives, decision-making and support for the recovery program and activities will be critical to success of the recovery planning process.

POTENTIAL MORICE SOCKEYE RESTORATION TECHNIQUES

Currently, major factors limiting Morice Lake sockeye production have been identified as: the lack of spawner escapement, and secondly, the low intrinsic productivity of the Morice Lake rearing habitat.

The Morice–Nanika Sockeye Recovery Planning process has identified two main enhancement tools to facilitate recovery of Morice sockeye stocks. These tools in order of priority are: increasing escapement and if reasonable fry recruitment results, apply inorganic fertilizer nutrient additions to sustain higher lake productivity.

Each of these options has relative degrees of intricate linkages between them, and as well, temporary choices and allowances to reassess the option as various situations unfold. All options, singularly or integrally, could be confounded by biological and environmental variability operating on fluctuating spatial and temporal scales.

INCREASE MORICE SOCKEYE ESCAPEMENT

The highest priority of the Morice–Nanika Sockeye Recovery Plan is to increase the escapement. Resource conservation and protection is regarded as the primary fisheries objective on the Pacific Coast. However, societal factors and economic demands continue to be important considerations and have been important factors in setting the exploitation rate affecting the Morice sockeye stock. Morice sockeye have been in a crisis setting for approximately fifty years; this is thought mostly to relate to conflicting preferences, for whatever ethical, biological, and moral reasons or points of view.

The estimated marine exploitation average decadal exploitation has been 21% to 35% since the 1960's with an overall 1956–2004 average exploitation rate of 29%. Estimated in-river decadal exploitation rates have been 18% to 41% with an overall 1956–2004 average of 24%. Total average exploitation rates of 53% on Morice-Nanika sockeye are higher than the estimated sustainable exploitation rate, which for this stock is 35% (Cox-Rogers 2006).

It is important to remember that the “problem” with Morice sockeye is not land use or habitat degradation, but exploitation of the sockeye stock above and beyond a sustainable level. Since 2000, the overall exploitation rate has declined from 70% to 20%; this trend needs to continue. Optimizing an experimental escapement level that is beneficial to a high abundance of spawners is the most important factor in Morice sockeye enhancement.

Given that fishery managers face multiple objectives that may shift over time with changes in policy and philosophy, it is time to take a focused look at:

1. How can Morice sockeye escapement increase?
2. How will increased Morice escapement affect other non-Babine sockeye stocks, First Nations FSC fisheries, and coastal fisheries targeting Babine enhanced stocks?
3. What solutions can be initiated to deal with those opportunities and challenges?
4. How can in-river sockeye catches be equitably distributed?
5. Are adequate stock assessment programs in position to enumerate the increased escapement?

Understanding and modifying relevant authority structures and cultural processes may be beneficial to the recovery process as it is as much a social undertaking as an ecological one.

Plans for reducing the harvest of Morice sockeye will be supported by the guiding principles noted above.

Several studies (Shortreed *et al.* 1997, Shortreed *et al.* 1998) have investigated Skeena sockeye nursery lakes rearing capacity and have recommended optimum escapement targets to non-Babine systems. Optimum escapement targets is the best estimate of the actual number of spawners required to fully seed sockeye nursery lakes given typical egg–to–fry survival rates. The target will over estimate the optimum escapement if spawning habitat is more limiting than rearing habitat. Shortreed *et al.* (1998) recommended that the optimum escapement for Morice stocks be 120,000 sockeye given the modified PR model data and spawning ground capacity. The mean observed Morice Lake sockeye escapement over the last five years is 11,800 spawners or approximately 10% of the optimum escapement.

It is possible that a continuous increase in Morice–Nanika sockeye escapement will bring the stock up to a self-sustaining, natural spawning population that ensures the preservation of its unique biological characteristics, which is the recovery goal. However, this option will require unknown amounts of patience that could range from the short to long-term. Following the precipitous decline in the early 1950s, the Morice–Nanika sockeye stock did not increase until 1991, then the escapement annually ranged from 21,000 to 41,000 fish until 1997 when it declined.

NUTRIENTS ADDITION IN MORICE LAKE

Background

Shortreed *et al.* (2001) indicate that Morice Lake possesses excellent physical conditions for juvenile sockeye; however, the lake is ultra-oligotrophic due to its very low nutrient loading. Morice Lake productivity appears to be limited primarily by P loading, although its short growing season, cool temperatures, and unstable epilimnion no doubt play a role in its extreme oligotrophy.

Salmon runs have declined over the past century in the Pacific slope areas of North America. Reduced inputs of salmon-derived organic matter and nutrients limit freshwater production and thus establish a negative feedback loop affecting future generations of fish. Concerns that Morice Lake sockeye stocks are on a downward trend due to combined fishing pressure and limiting nutrients has accelerated the concept of rebuilding spawner escapement and in the short-term, replacing carcass-derived nutrients influxes with inorganic fertilization treatments that will increase the likelihood of stock recovery.

Lake enrichment is a salmon habitat restoration and enhancement technique to improve the freshwater rearing conditions of sockeye fry. The forms of nutrient addition include introducing salmon carcasses or applying inorganic fertilizers. Most often inorganic fertilizers have been used since commercial fertilizers weigh less than 2% of salmon carcasses (Ashley and Slaney 1997) and transportation costs are a large part of the total enhancement expenses. Nutrients composed of liquid agricultural-grade ammonium-polyphosphate and urea-ammonium-nitrate fertilizers are added to lake surface waters during the growing season to increase the amount of plankton food for juvenile sockeye. In several fertilized lakes these efforts have mitigated the losses of nutrients that are no longer available to populations with depressed escapements.

Food Web Assumptions

The lake fertilization theory is based on two assumptions. The first is that the size and survival advantages gained by sockeye fry originating from fertilized lakes can be successfully carried into the marine environment, thereby ensuring increased adult survival. The second assumption is that juvenile sockeye biomass in the pelagic zones of lakes is regulated by nutrient availability ("bottom-up" control) and that substantial amounts of the nutrient added at the bottom of a food web will successfully make its way from algae, through zooplankton, to fish (Hyatt *et al.* 2004b).

Hyatt *et al.* (2004b) report that over the past thirty years, studies have verified the food web and the general predictability of bottom-up relationships among nutrients and algae (Stockner and Shortreed 1985), algae and zooplankton (Hanson and Peters 1984), and zooplankton and planktivorous fish (Koenings and Kyle 1997). However, Hyatt *et al.* (2004b) also mention that during the last twenty years, similar studies have found "top-down" processes are significant and tend to reduce bottom-up control. McQueen (2001) reviewed top-down processes that can influence energy transfer up pelagic food webs; Hyatt *et al.* (2004b) pointed out that some of these main factors are:

1. the effects of algal cell size and species composition on relative grazibility of algae by zooplankton,
2. the effects of algal species composition on availability of fatty acids required for enhanced zooplankton growth (Brett *et al.* 2000),
3. the influence of regional diversity pools on the availability of the large-bodied zooplankton most favored by planktivorous fish (Matveev et al. 1994),
4. the effects of diel migration on the availability of zooplankton as prey for juvenile sockeye (Levy 1990),
5. the effects of grazer body size on rates of phosphorous excretion and recycling by zooplankton (Vanni 1996),
6. the rates of nutrient transport and (or) sedimentation caused by predator-induced changes in zooplankton body size and (or) species composition (Taylor and Carter 1997),
7. abundances of invertebrate planktivores that may be expected to reduce grazer abundance and therefore food availability for planktivorous fish (Benndorf 1995),
8. changes in fish-induced transport of phosphorous from the benthos to the pelagic zone (Perez-Fuentetaja *et al.* 1996),
9. potential competitive interactions betweens juvenile sockeye and other pelagic planktivorous fish (Hyatt *et al*. 2004a)

Hyatt *et al.* (2004b) report that given the potential effects of these and other top-down factors, there remains considerable uncertainty about the proportion of fertilizer-induced energy captured by phytoplankton that can successfully move from algae to fish. The research question remains: Can substantial amounts of the photosynthetically fixed energy stimulated by the addition of fertilizers to lakes make its way up the pelagic food web, causing juvenile sockeye to survive better and (or) grow larger?

Trophic levels usually consist of many species competing with each other for available resources. Freshwater food webs are complex in that nutrients and energy of one trophic level are utilized by organisms from different trophic levels. When entire lakes are fertilized to enhance the production and survival of anadromous sockeye, it is almost certain that unexpected results will emerge. Hyatt *et al.* (2004b) note that lake fertilization is likely to yield positive gains in smolt biomass and may even increase marine survival, but problems in regard to the food web are likely.

In summary, food web structures are complex and understanding how they function in Skeena sockeye nursery lakes is growing. The photosynthetic rate (PR) model (Shortreed *et al*. 2000, Cox-Rogers *et al.* 2004) developed to determine juvenile sockeye production potential estimates is based on the importance of bottom-up biological control mechanisms over juvenile sockeye production. The PR model has provided the basic data that enabled the optimum escapement and rearing capacity estimates for Morice Lake sockeye that are used in this study.

Nutrients Addition Research

Nutrient addition to freshwater ecosystems has received an appreciable amount of research attention in Washington, B.C., and Alaska in the last four decades. Over the past 30 years, the Department of Fisheries and Oceans has been experimenting in B.C. with artificially increasing production of sockeye through lake fertilization (Hyatt *et al.* 2004b). Recently in B.C. and Alaska, large-scale lake fertilization programs enhancing sockeye to enable increased commercial fishery catches have been discontinued and the priority for fertilization has shifted to stock rebuilding and recovery initiatives.

Results of fertilization research provide strong evidence that an external nutrient source to ultra-oligotrophic lakes, equivalent to the nutrient influx from returning spawners, is needed to maintain lake productivity. Hyatt *et al.* (2004b) reviewed 24 sockeye salmon (*Oncorhynchus nerka*) nursery lake experiments located in Alaska, B.C., and Idaho that involved whole-lake fertilization with appropriate treatment and control years. They found that: 21 of 21 studies showed that fertilization was associated with increased chlorophyll a concentrations, 16 of 16 studies showed increased zooplankton biomasses, 16 of 16 studies demonstrated increased average smolt weights, and 11 of 13 studies showed increased smolt biomasses.

Studies involving assessments of egg-to-smolt survival were rare, but all (4 of 4) showed increased survival rates. Studies involving increased smolt-to-adult survival (i.e., marine survival) were even rarer, but all (3 of 3) showed that lake fertilization and increased smolt size were associated with increased marine survival. Several fertilization studies reported problems, and some offered solutions. For instance, when whole-lake fertilization stimulated the growth of blue-green algae, fertilizer with higher nitrogen to phosphorus ratios was used to control the problem. Hyatt *et al.* (2004b) report lake fertilization technical problems have been encountered; some are resolved, others are not. By increasing or decreasing the N:P ratio blue-green algae blooms may develop or disappear. These depend on the lake characteristics such as warm, shallow, stable epilimnions or deep and relatively cool water. Ashley and Stockner (2003) provide a protocol for applying limiting nutrients with appropriate nutrient ratios to inland waters.

Conversely, when high nitrogen to phosphorus ratios were associated with blooms of ungrazable diatoms, notably *Rhizosolenia eriensis*, reduced nitrate concentrations were recommended. Some studies showed that when both mysids (large invertebrate planktivores) and juvenile sockeye inhabit the same lake, the sockeye suffer from a competitive disadvantage and mysids consume 80-90% of the available zooplanktonic food production. Hyatt *et al.* (2004b) indicate that the more serious problems have occurred at the zooplankton to sockeye level. These include growth of planktonic grazers such as Holopedium that are less than ideal juvenile sockeye food and competition from mysids. Competition has also been observed from increased stickleback and kokanee populations.

Similarly, a small number of studies demonstrated that competition from sticklebacks (*Gasterosteus aculeatus*) adversely affected sockeye growth rates, and although the problem remains unresolved, ongoing work in lakes containing kokanee (*O. nerka*), suggests that stocked cutthroat trout (*Salmo clarki*) may be capable of controlling stickleback densities through predation. Despite all of these difficulties, in almost all cases, when lakes were fertilized with various mixtures of inorganic nitrogen and phosphorus, pelagic food web bottom-up control was strong enough and predictable enough to ensure that sockeye smolt biomass increased. Hyatt *et al.* (2004b) concluded that sockeye nursery lake fertilization is a technique that can contribute usefully to both the enhancement and conservation of sockeye salmon populations.

Nutrients Addition Considerations

Nutrients addition to Morice Lake is contingent on a variety of assumptions and factors. The first assumption is that a reasonable number of sockeye fry exist and are rearing in Morice Lake. This is dependent on an increase in spawner escapement and assuming egg to fry survival is moderate to high. Hyatt (1983) suggested that Morice Lake fertilization treatment benefits are likely to be achieved when fry recruitments are based on escapements of 5,000 to 10,000 adults or more. The larger the adult escapement, the larger the benefit is likely to be. Nutrient treatment and monitoring carries a fixed cost that is not affected by escapement abundance; however, with less escapement the cost benefit ratio is lower.

Currently, Morice sockeye escapement is at such low abundance that preliminary estimates indicate if the adult recruitment were increased by a 1000 fish, the cost would be approximately $25/fish annually or between $100–200/fish as the project is a multi-year initiative of one sockeye cycle or 5 years. An important nutrients addition factor is committed funding. The total estimated cost is projected at $1.7 million. This estimated cost over nine years includes two years of pre-treatment, five years of fertilization, and two years of post-treatment studies. The anticipated annual treatment cost is $250k, which would include transportation, storage, application, and monitoring costs (Joseph & Cox-Rogers 2006). Pre and post-treatment monitoring is expected to cost $350k over four years. Contingency funds of $100k will likely cover potential cost increases such as transportation.

Another important factor in conducting a successful nutrient enrichment program is detailed project planning. This will involve coordinating increased escapements, pre-treatment limnological and juvenile sockeye data collection and sampling, and legal application and notification requirements. Pre-treatment information is required that will address present juvenile sockeye sizes and in-lake densities, the trophic status of Morice Lake, current juvenile sockeye food limitations, and a cost-benefit study that is sensitive to varying in-lake juvenile sockeye densities and smolt to adult survival rates.

Regulatory agencies such as federal and provincial water quality agencies and Public Medical Health Officers must be notified and any concerns alleviated that revolve around potential nitrate and heavy metal additions. In addition, it is important that downstream water users be notified of any activities that may impact the water quality of their licensed withdrawals. Since nutrient addition is a new concept to people and communities, it is advised that open houses or public meetings be held to explain the rational, the risks, and the benefits of the proposed treatments. Typically, there will be a requirement to monitor ecosystem responses throughout the duration of the fertilization application and for the following year.

In recent years, studies have shown that climate is a significant factor in the survival of salmon. Climate and ocean conditions together form a large part of the background conditions on which salmon return to spawn. Varying climate and ocean conditions may occur on inter-annual and inter-decadal variability, or as a large magnitude naturally occurring event. These natural variations can increase or decrease stock productivity and possibly confound Morice Lake sockeye fertilization efforts and outcomes.

CONCLUSION

There are main two paths to rebuilding Morice Lake sockeye populations to a sustainable level. First, reducing the marine and in-river fisheries exploitation rates to allow more fry recruitment and patiently waiting for the stock to rebuild on its own. A variation on this option is to wait until an increase in escapement occurs and then fertilize Morice Lake. Secondly, reduce the marine and in-river fisheries exploitation rates to allow more fry recruitment and then secure funding to allow pre-treatment data acquisition, lake fertilization, and monitoring of effects. Overall, the only clear and distinct solution with a coherent outcome to the challenges posed by the Morice Lake sockeye recovery situation is to increase sockeye escapement.

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