Babine River Sockeye
Migration & Predation Assessment 2015

Lake Babine Nation Fisheries

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Report Summary

Babine Lake is the largest sockeye nursery lake in the Skeena system and supports over 90% of all returning Skeena River sockeye. The Babine River sockeye late-timed run is the largest wild sockeye run in the Skeena watershed but over the last century it has diminished in size and is considered a remnant of its former high abundance.

Lake Babine Nation conducted large-scale sockeye fisheries at Tsa Tesli, located at the present Babine fence counting site, harvesting sockeye salmon caught in weirs, which spanned the river. Helgeson (1904) described typical sockeye catches at Tse Tesli that were on the order of 750,000 sockeye. Presently, LBN Fisheries has initiated recovery planning for the Babine late sockeye.

The upper Babine River, aka Rainbow Alley, averages 75 m in width and characterized by small and moderate sized gravel with relatively low flow velocities (< 0.03 m/second), stable banks with occasional back eddies, and typically water temperatures are several degrees cooler than Babine Lake surface waters. A conspicuous feature of the channel is the relatively high proportion of the channel where complex sockeye spawning dune formations are present. The lower Babine River is characterized as slightly meandering with an average velocity of 1.1 m/s in the thalweg, though the velocity is doubled as the flow passes through the counting fence structure.

Cox-Rogers and Spilsted (2012) note that escapements to the unenhanced early and late-runs exhibit a long-term declining trend and that escapements have been much lower than historic in the last two to three decades. Both the upper and lower Babine River sockeye spawning grounds are downstream of Babine and Nilkitkwa lakes respectively with newly emerged sockeye fry travelling downstream then actively swimming upstream against the current into their nursery lake.

The 2015 habitat conditions were predominated by the relatively high amount of and length duration of high water levels with 160m3/s occurred from mid-May to mid-June with a 0.45 m variation in river levels resulting primarily from snowmelt. Lower Babine River sockeye fry emerge from their natal gravels from early to late May with upper Babine River sockeye usually emerging at least a week later. Sockeye fry in both the upper and lower river showed a prolonged, non-linear three week emergence period as indicated primarily by stage of yolk sac absorption.

On the upper Babine River, sockeye emigrants swam downstream and congregated in relatively large schools close to Smokehouse Island in Nilkitkwa Lake. Upstream movement saw most fry swimming primarily up the west side against the highwater flows utilizing flooded riparian vegetation or wetlands with large aggregations congregating in off-channel habitat at the old salmon hatchery.

Most lower Babine River fry utilized the west bank of the lower river to migrate upstream and downstream. Overall, these conditions facilitated relatively good upstream fry migration in the upper river, and particularly for those fry upstream of the Babine counting fence in the lower river. By mid-July, few fry were observed in either the lower or upper river sections.

Recent observations over the last several years have noted large amounts of fry congregated downstream of the fence on the west bank of the river that apparently are not successful in migrating upstream past the fence during highwater discharge levels. Observations recorded in May and June, 2015 indicate relatively high velocity flows through the fence structure. Turbulent flows on the downstream side of the fence are the crux, which upstream migrating fry encounter and need to swim through. Essentially, if turbulence is too much for the fish to maintain headway, the fish will be thrown off vertically or horizontally, or both, and fall back losing its swimming trajectory.

Predatory fish potentially affecting Babine River sockeye fry either in the river or the lakes include: steelhead, rainbow trout, Dolly Varden, bull trout, lake trout, burbot, and juvenile coho (smolts). Mammal predation is considered very minor. Avian species known to target sockeye fry in the Babine system include: Bonaparte gulls, Common Merganser ducks, Ring-billed gulls, Harlequin duck, Short-billed gulls (Mew gull), and Black Terns.

Fry sought out overhead and instream cover such as undercut banks, overhanging canopies, and instream vegetation and woody debris as shown in Figure 22 to avoid avian and fish predators. Fry changed colour relatively fast in order to blend with various shades of aquatic vegetation, the substrate, or the flooded forest floor.

The highest observed rates of predation occurred in the upstream migration at locations characterized with a lack of cover including the Cutbank, the west bank of the lower river immediately downstream of the counting fence, and under and adjacent to the Fort Babine Bridge. Fry primarily migrate upstream on the west bank of the upper and lower rivers and basically these fry are running a gauntlet. The most significant predation event is primarily directed on emergent or downstream fry twice daily at the dawn and dusk feeding frenzy by rainbow trout in the upper Babine River.

Skeena Fisheries Commission conducted hydroacoustic surveys of Nilkitkwa Lake and the North Arm of Babine in 2015 (Doire et al. 2016) in order to estimate the total sockeye fry abundance and biomass as well determine the fish species composition of each lake. The 2015 sockeye fry estimate for the North Arm of Babine Lake was approximately 4.2×10^6, which was similar to preliminary estimates generated during the summer and fall of 2013. The 2015 Nilkitkwa Lake sockeye fry abundance estimate of 5.46×10^5 was relatively low compared to estimates for 2011 and 2013, of 9.7×10^5 and 9.8×10^5 respectively.

Environmental factors, conditions, timing, and their interactions as noted in the text are thought to have not been altered more than moderately over the past 110 years and the Babine River remains a biologically diverse and productive ecosystem. However, both the upper and lower Babine River sockeye runs have diminished in abundance. Cox-Rogers and Spilsted (2012) note the lower Babine River sockeye have been steadily diminishing since the early 1950s and upper Babine River sockeye started noticeably decreasing in the late 1960s. Commercial coastal and in-river fisheries exploitation rates have fallen over the last fifteen years for the Babine late run sockeye, yet adult returns have continued to decline.

The lack of an effective fry passage structure at the counting fence is a longstanding problem, which is potentially causing fish mortality on an unknown scale and pace depending on highwater conditions. This fry passage problem is currently being addressed by hydrologists and engineers to design a suitable structure.

This 2015 assessment survey has increased basic understanding and awareness of sockeye fry in the Babine River, and in turn, generates many more basic questions. There continues to be uncertainty whether to attribute the decline to prespawning mortality, unusually poor egg-to-smolt survival, poor fry-to-smolt survival, or as well, to pinpoint factors, including degraded habitat conditions, as the potential cause of these adverse effects.

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1.0 Background

1.1 Purpose

The purpose of this report is to provide Year 1 results of the Babine River Sockeye Migration and Predation Assessment project. Lake Babine Nation Fisheries received support for this project from the Pacific Salmon Commission Northern Endowment Fund (NF-2015-I-55) and in-kind resources and support from DFO North Coast Stock Assessment. The project as proposed is a three year effort intended to address the diminished abundance of Babine River sockeye by increasing understanding and awareness of their juvenile life-history and freshwater environment.

The main project goal is to investigate the behaviour and ecology of Babine River sockeye fry. The project objectives are to determine the:

1. early–life behaviour and migration;
2. current predation factors and significance;
3. fish disease, parasite factors and conditions, and other potential biotic adverse effects.

1.2 Introduction

Babine Lake is the largest sockeye nursery lake in the Skeena system and supports over 90% of all returning Skeena River sockeye. Since the late 1940s, overall sockeye escapements to Babine Lake are known accurately from the counting fence located in the lower Babine River. In general, three distinct overlapping sockeye runs return to Babine Lake each year: early-timed, mid-timed, and late-timed. Late-timing sockeye runs spawn in the upper and lower Babine River and these are the focus of this assessment.

The Babine River sockeye late-timed runs were the largest sockeye runs in the Skeena watershed. Over the last 100 years it has slowly diminished in size and is considered a remnant of its former high abundance. Cox-Rogers and Spilsted (2012) note that escapements to the unenhanced late-runs exhibit a long-term declining trend and escapements have been much lower than historic in the last two to three decades. Cox-Rogers and Spilsted (2012) data presented in Figure 1 shows the aggregate spawning escapement trend from 1950 to 2010 of lower and upper Babine River sockeye.

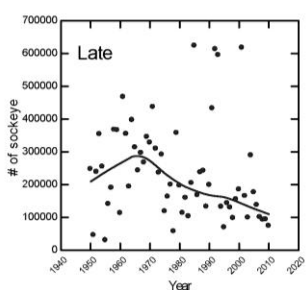

Figure 1. Babine late sockeye escapement trend, 1950 to 2010.

1.3 Context

The large-scale utilization of the abundant and predictable Babine salmon stocks formed the foundation of the Lake Babine Nation (LBN) subsistence economy. Arrangements for management of the fishery were and continue to be deeply interconnected and woven into the fabric of LBN culture. LBN conducted large-scale sockeye fisheries at Tsa Tesli, located on Babine River downstream of Nilkitkwa Lake, utilizing fish caught in weirs as shown in Figure 2 and described by Helgeson (1904). LBN clans also operated weirs located at the inlet and outlet of Nilkitkwa Lake; at the present site of Fort Babine (Wit'at); at Tachek located at the mouth of Fulton River; at Morrison River; and at the mouths of the many sockeye spawning streams as noted by Hackler (1958) and Kobrinsky (1973).

Figure 2. LBN Weirs at Tsa Tesli, Babine River, ca. 1900.

Helgeson (1904) described typical sockeye catches at Tse Tesli that were on the order of 750,000 sockeye. This large scale fishery supported subsistence food and trading into the Skeena, the Fraser, and to a smaller degree, the Peace drainages. For millennia, LBN managed the salmon fisheries, in particular, the sockeye fishery until the early twentieth century, when the advent of commercial coastal fishing prompted federal government intervention and suppression of the ancient LBN management regime (Harris 2001). LBN's fishery management tools allowed for optimal utilization of the salmon resource that is and has been the core of the economy, as well as enabling the fishery system to adapt to the variability of natural population and habitat conditions.

Gottesfeld and Rabnett (2008) note the LBN salmon fisheries maintained and left a fish resource that was diverse and healthy at the incursion of the Skeena commercial fisheries in the late 19th century.

LNB Fisheries in conjunction with Canada DFO has initiated recovery planning for the Babine late sockeye. As well, Lake Babine Nation has established the Babine Critical Cultural Zone to protect extremely valuable sockeye values and their high sensitivity.

1.4 Environmental Setting

The Babine watershed is the largest tributary sub-basin to the Skeena River. Babine Lake and its sub-basins, commonly referred to as the upper Babine watershed, drain an approximate 6,584 km^2 area with the major tributary streams including the Morrison, Fulton, Pinkut, and Sutherland rivers as shown in Figure 1. The remainder of the Babine Lake tributaries consists of relatively small creeks draining directly into Babine Lake. These streams often tend to dry up or exhibit sub-surface flow in parts of their lower reaches and alluvial fans during late summer low flow periods.

The upper Babine watershed has very high fish values and is a major producer of chinook, pink, sockeye, and coho salmon, and steelhead, all of which are fished by the Lake Babine Nation. The resident freshwater fish community includes rainbow trout, cutthroat trout, Dolly Varden, bull trout, lake trout, kokanee, lake and mountain whitefish, burbot, sculpins, suckers, sturgeon, and shiners; the anadromous lamprey eel are also present in the system.

The climate of Babine Lake watershed is typical of the central interior plateau, with cool, moist summers and a relatively deep snow pack accumulating from October to May. Total precipitation on the lake is approximately 540 mm, of which rainfall accounts for 55% (Environment Canada, 2015) as recorded at Topley Landing and Pinkut Creek. Total precipitation increases relatively at upper elevations in the watershed; however, there are no long-term meteorological data records.

Typically Babine River peak discharges occur in May and June due to snowmelt, then decrease until late September, when fall rains and early snowmelt increase stream flows until the end of October. However, recent climate observations have recorded diminished snowfall and warmer winter temperatures resulting in earlier snowmelt and constricted periods of ice on the lake. Stream flows decrease in November and December when precipitation falls as snow, with minimum discharges recorded in January through April, prior to snowmelt.

Fort Babine (Wit'at) located at the outlet of Babine Lake is the site of Water Survey of Canada Station 08EC001 with a 76 year record period. Another hydrological station is located close to the Babine River counting fence near the outlet of Nilkitkwa Lake (Station 08EC013), with a 33 year record (Environment Canada 2015).

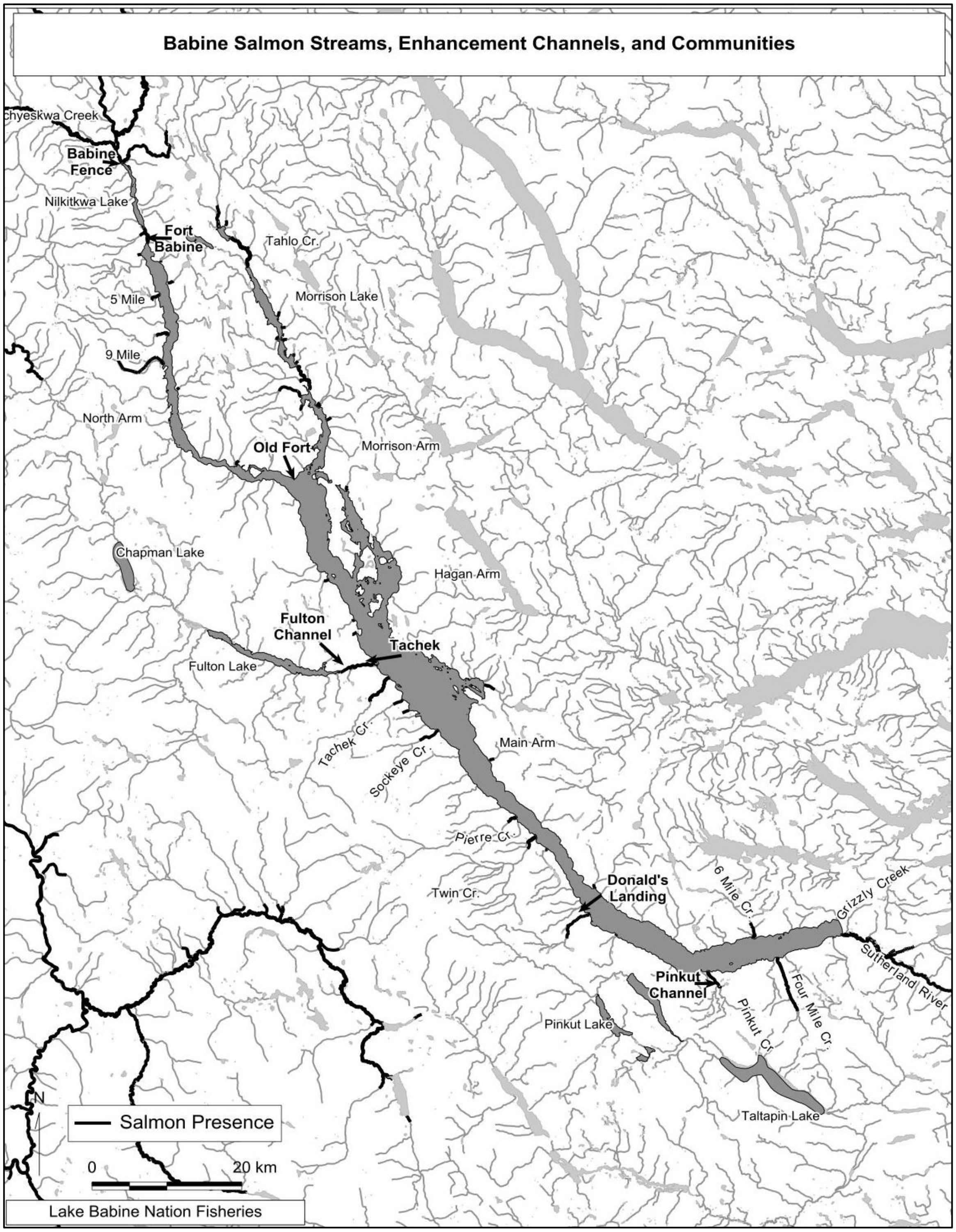

Figure 3. Map shows major sockeye spawning streams and enhancement channels.

Babine Lake is composed of numerous basins whose water bodies are discrete as indicated by various physical factors including seasonal thermal history, time of formation, depth, form, and stability of the thermocline, and timing of ice cover formation and break up. Babine Lake waters flow into Nilkitkwa Lake, which is nearly 9 km in length, on average 0.9 km in width, also multi-basin in character with several small islands, and relatively shallow with extensive littoral areas. Limnological knowledge regarding Nilkitkwa Lake is sparse. Nilkitkwa Lake has a distinct midpoint shallow narrows and is often considered as two lakes – upper and lower Nilkitkwa Lakes. Aro (1954) notes the relatively high flushing rate through Nilkitkwa Lake as 2.5 days at high water periods and 71 days at times of low discharge. Average variation in high and low water levels is approximately 1.5 m on Nilkitkwa Lake.

The upper and lower sections of Babine River are designated as such primarily for fisheries management purposes, especially to record spawner abundance but also in order to increase understanding of these spectacular and unique sockeye stocks. The river is used by Babine chinook, pink, coho, sockeye, and freshwater residents for migratory, spawning, and rearing purposes. The Upper Babine River flows 2.3 km northerly in a slight meander fashion from the north arm of Babine Lake into Nilkitkwa Lake. The upper Babine River is divided into Areas 1 to 3, starting upstream to downstream, for DFO escapement record purposes.

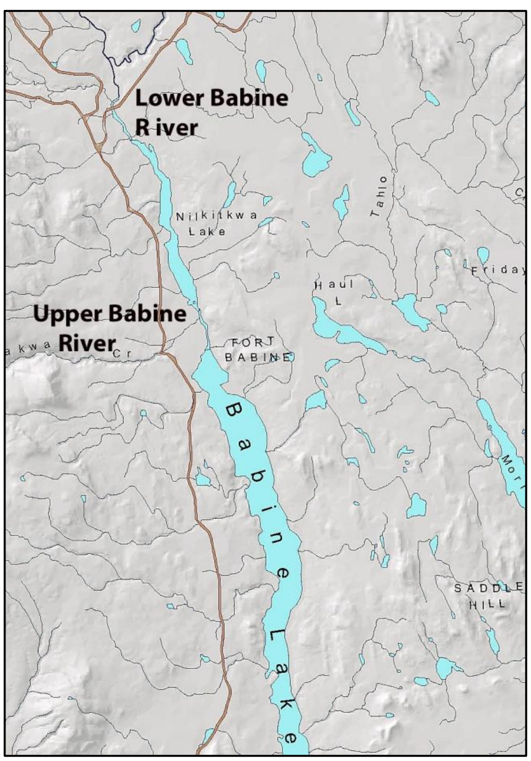

Figure 4. Map shows the north arm of Babine Lake, upper Babine River, Nilkitkwa Lake, and lower Babine River.

The upper Babine River, aka Rainbow Alley, averages 95 m in width and is formed by the Tsezakwa Creek alluvial fan, which has impinged on Babine Lake and formed the upper Babine River and Nilkitkwa Lake as noted by Wilford *et. al.* (2000) and shown in Figure 4 and 6. In this upper section, the substrate is characterized by small and moderate sized gravel with relatively low flow velocities (< 0.03 m/second), stable banks with occasional back eddies. Water temperatures are several degrees cooler than Babine Lake surface waters in the warmer periods and correspondingly warmer in the cold periods, unless wind-mixing in the north arm of Babine Lake is prevalent.

The upper Babine River has seen little study other than McCart (1966) who conducted studies focused on the behaviour and ecology of sockeye fry in 1964 and 1965. Sockeye spawning is heaviest in the mid-section with lesser amounts of spawning throughout the remainder.

Figure 5. Photo shows upper Babine River sockeye dune complex.

A conspicuous feature of the channel is the relatively high proportion of the channel where complex sockeye spawning dune formations are present as shown in Figure 5. These dune formations last from year to year and contribute to the most productive wild sockeye spawning ground in Skeena watershed. The large volume of spawners creates complex enrichment conditions downstream in Nilkitkwa Lake that include relatively large-scale sediment deposition principally composed of fine materials, settling of displaced periphyton biomass, unknown amounts of benthic invertebrate drift, and major amounts of marine-derived nutrients and organic matter.

Figure 6. View southward shows upper Nilkitkwa Lake, upper Babine River, and the north arm of Babine Lake.

Limnological investigations of Nilkitkwa Lake are few; baseline information is considered scanty and present conditions are essentially unknown. Besides the fine material transported into the lake from the massive sockeye spawning events, sediment input from the major contributor, Tsezakwa Creek, is considered relatively high with the majority of sediment movement resulting from episodic avulsion events on its alluvial fan. Unknown amounts of pollutants from both surface and subsurface flows result from the location of the Fort Babine sewage treatment plant on the Tsezakwa Creek fan. Nilkitkwa Lake is considered nutrient rich; however, aquatic ecosystem factors such as phytoplankton succession, primary productivity, and thermal structure are yet to be understood.

The lower Babine River is defined as the river from the outlet of Nilkitkwa Lake downstream 2.2 km to Nichyeskwa Creek. The lower Babine River is divided into Areas 4 and 5 for DFO escapement record purposes. Area 4 starts at the outlet of Nilkitkwa Lake and passes 1.6 km downstream to the Babine River Counting Fence. Area 5 is considered from the counting fence downstream 0.7 km to the Nichyeskwa – Babine confluence. The lower Babine River is characterized as slightly meandering, similar to the upper Babine River in width (60 to 120 m), and shows an average velocity of 1.1 m/s in the thalweg. The channel gradient is controlled by the lake outlet and by downstream bedrock outcrops.

Figure 7. View across lower Babine River & counting fence. Figure 8. View downstream to Nichyeskwa Cr.

In general, the velocity is doubled as the flow passes through the counting fence structure with the substrate composition downstream showing larger materials and rougher water conditions. The east bank is characterized as being relatively smooth with few indentations or features creating backwater conditions. The upper portion of west bank show a slight floodplain, which floods in typical highwater, while the river downstream of the fence is relatively entrenched for the most part. The confluence of the glacially-fed Nichyeskwa Creek creates a relatively large backwater area with a marked gradient increase downstream.

The majority of lower Babine River sockeye spawning is typically from the Boucher Creek confluence downstream for 900 m, while pink spawners heavily utilize the following 400 m downstream. Few sockeye spawners are known to utilize the river downstream of the fence subsequent to the construction of the counting fence in the late 1940s.

1.4 Babine System Sockeye

The upper Babine watershed supports the largest sockeye salmon population in Canada (Gottesfeld and Rabnett 2008). Babine Lake is the largest sockeye nursery lake in BC and currently produces over 90% of the sockeye returns to the Skeena River. As such, it has a relatively long history of field research and is one of the most intensively studied sockeye nursery lakes in the country. Babine sockeye are harvested in marine commercial fisheries in Southeast Alaska and Canada DFO Areas 1-5, as well as in First Nation Food, Social, and Ceremonial (FSC), and First Nations Economic and Excess Surplus to Spawning Requirement (ESSR) fisheries within the Skeena River and within Babine Lake itself (Cox-Rogers and Spilsted 2012).

Babine wild sockeye spawn in hundreds of locations in the 29 spawning streams draining into the lake or river system. Babine sockeye age structure is 4 and 5 year olds. Run timing studies indicate there are three generally distinct runs, with early, mid, and late timing wild and sockeye migrating to 30-plus distinct natal spawning locations (Smith and Jordan 1973). However, within these three run timing categories, there are sockeye stocks with early and late run life histories such as the early and late Tahlo.

Sockeye run timing is related to the magnitude and duration of the Skeena snowmelt freshet. Migration rates of Babine sockeye observed by Takagi and Smith (1973) indicate an average travel time of three weeks from the mouth of the Skeena to the counting fence, although differences in the median travel times were noted for the three runs; the early run took 24.5 days, the middle run 14–18 days, and the late run 21.3 days.

The Babine counting weir located on the upper Babine River was constructed in 1946 and has operated to the present (with the exception of 1948 and 1964); the fence was completely rebuilt in 1966–1967 and replaced again in 1993. The Babine fence provides excellent counts of returning sockeye. In 1945 and 1946 the Fisheries Research Board of Canada built a counting fence to permit total counts of all salmon species.

During the 1966 and 1967 winter, the structure was completely rebuilt and incorporated a new wooden sill, intersecting steel sheet piling on upstream and downstream ends of the sill, and an additional trap and counting station. Importantly, Clarke's (1967) observations in 1966 and subsequent bypass around the fence (that enabled 2 million fry to continue their upstream migration) led to a sockeye fry bypass system being installed on the west side of the fence. This was designed to encourage sockeye fry that swam or were swept below the fence to return upstream to the Nilkitkwa Lake nursery area. In regard to the functioning of this fryway, Shepherd (1979) reported no upstream migration problems during 1976 with no real problems in passing up the ladder:

> "...ladder design and placement appeared to be adequate to salvage the bulk of the LBR sockeye fry, <u>if they are willing to move upstream</u>" (original emphasis).

In 1992 to 1993, the fence was totally rebuilt as shown in Figure 9; the sill was lowered 24" and the bypass structure at the west side of the fence was constructed. Sockeye stock assessment surveys are conducted by both DFO and LBN Fisheries. DFO conducts annual aerial escapement monitoring of selected Babine sockeye tributaries including the Morrison and Sutherland systems as well as the upper and lower Babine River. Three LBN Fisheries stream crews – Fort Babine, Tachek, and Donald's Landing – conduct sockeye spawner enumeration surveys on the major spawning streams with these counts correlated to the Babine fence counts.

Figure 9. View westward across Babine counting fence showing the seven traps.

1.4.1 Babine Enhanced Sockeye

Johnson's investigations (1956, 1958, 1961) into Babine sockeye rearing factors and conditions concluded that sockeye salmon production from Babine Lake was limited by the availability of suitable spawning habitat, and secondly, that the main basin of the lake was underutilized and could support additional sockeye fry. These studies resulted in the construction of the Babine Lake Development

Project (BLDP), an approximate ten million dollar project, consisting of artificial spawning channels and dams providing regulated water flows at Fulton River and Pinkut Creek in the late 1960s. The regulated water flows at Pinkut and Fulton spawning channels provide stable conditions for the incubation of salmon eggs after they have been deposited in the gravel.

Both channels receive flow from upstream lakes, wherein water temperatures can be relatively high during prolonged sunny weather conditions. Pinkut channel has the ability to receive cold water pumped from Babine Lake into the upper channel leg, thereby cooling the water temperature. Both channels have minor amounts of vegetation, which do not provide adequate shading, and occasionally high water temperatures are maintained or exacerbated.

Figure 10. Upper portion of Fulton #2 spawning channel dried up for cleaning, early August 2012.

The Babine spawning channels concept aimed to accommodate 200,000 sockeye spawners, who would produce 100 million fry to rear in Babine Lake; however, annual fry production has averaged 206 million. Maximum spawning capacities at the Fulton channel and river total 381,000 adult, with maximum spawning capacities at Pinkut channel and river totaling 128,000 adults.

Freshwater productivity is monitored and largely determined by adults counted into the Pinkut and Fulton channels, fry counted out of the channels, and by smolt abundance counted at the smolt fence, which is located at the outlet of Nilkitkwa Lake. Most sockeye fry rear for one year in the Babine system with Dombroski's (1952) scale analysis indicating less than 2% spent two years in the lake.

Enhanced sockeye egg-to-fry survival rate has averaged about 50% in normal (disease-free) years; however, the rate shows wide-ranging annual variability. The spawning channels typically account for 89% of fry recruitment into all areas of Babine Lake. Parasitic infections causing prespawning mortality, as well as an unidentified factor causing abnormally low fry-to-smolt survival, have emerged as potentially serious limitations to future fry production from Pinkut and Fulton.

The unidentified factor is possibly Eubothrium. The cestode *Eubothrium salvelini* is a common intestinal parasite of salmonids in northern latitudes and is present in approximately 25% to 30% of Babine Lake sockeye fry. Smith (1973) in the period 1952-71, found that infection incidence among 15 brood years of late-run smolts (from the main part of Babine Lake) ranged from 6 to 45%, averaging 26%. During 1958-71, Eubothrium in early run smolts from the North Arm-Nilkitkwa area ranged from 5 to 46%, averaging 22%.

Smolt emigration estimates are determined by mark-recapture programs utilized from 1951 to 2002 (except 1989 – 1987 brood year) and in 2013 to 2016. Smolts from the North Arm and Nilkitkwa Lake migrate earlier, likely due to earlier ice-out conditions. As smolt density has increased, smolt size has decreased with mean smolt weight decreasing steadily from the early 1970s to 2002, but the average smolt weight is relatively large at between 4 and 5g. Average fry-to-smolt survival does not appear to have changed up to 2002.

1.5 Babine River Sockeye

Late-timing sockeye runs spawn in the upper and lower Babine River and enumerated through the counting fence, counted by mark-recapture techniques from 1976 to 1992, and by visual surveys in other years. Cox-Rogers and Spilsted (2012) note that escapements to the unenhanced early and late-runs exhibit a long-term declining trend and escapements have been much lower than historic in the last two to three decades. Cox-Rogers and Spilsted (2012) data presented in Figure 11 shows the aggregate spawning escapement trend from 1950 to 2010 of lower and upper Babine River sockeye while Figure 12 shows the individual lower and upper run trends.

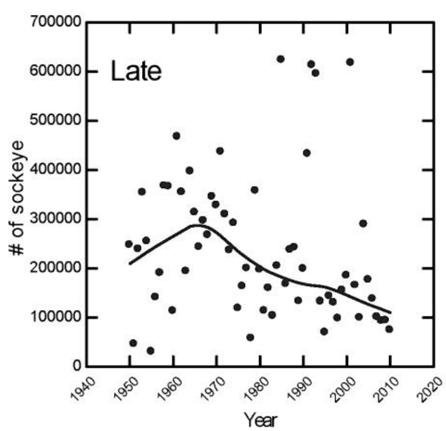

Figure 11. Graph shows late-run, upper and lower Babine River sockeye escapement trend from 1950 to 2010.

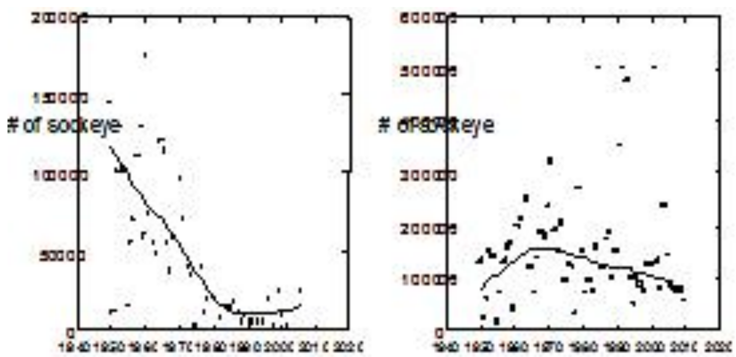

Figure 12. Graph shows lower Babine and upper Babine River sockeye escapement trends from 1950 to 2010.

Lower Babine River **Upper Babine River**

Both the upper and lower Babine River sockeye spawning grounds are downstream of Babine and Nilkitkwa lakes respectively. These locations create excellent spawning and incubation conditions whereby upwelling water is moderated in flow and temperature characteristics. Finnegan (2015) notes that sockeye adults hold in the lower portion of upper Babine River and in Nilkitkwa Lake adjacent to Smokehouse Island and then typically move upstream to spawn in three to four sequential waves. Finnegan's recent observations of adults in lower Babine River do not show noticeable waves of spawners with this factor likely due to the diminished abundance.

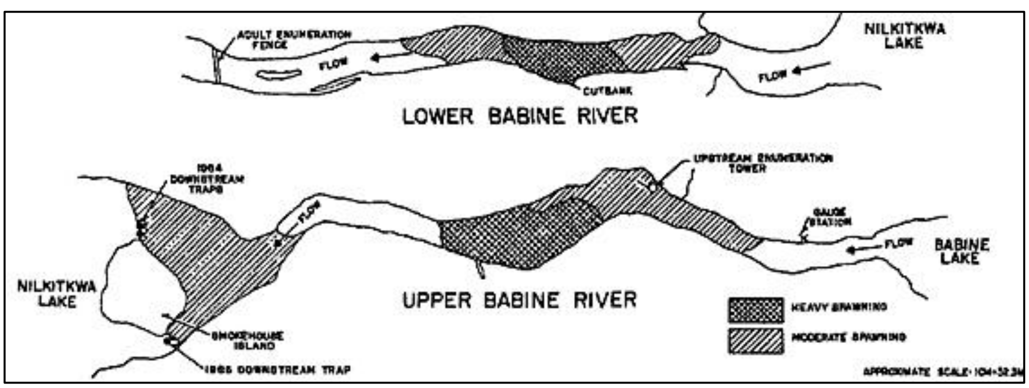

Figure 13. Map shows upper and lower Babine River and spawning areas, ca. mid-1960s.

Of particular note, the emergent sockeye fry travel downstream then actively swim upstream against the current into their respective nursery lake. This genetic adaptation is closely associated with fry reaching upstream nursery lakes concepts as discussed by Hoar (1958), Hartmann et al. (1962), McCart (1967), Clarke (1967), and Brannon (1972). Fry studies focused on the upper river include McCart (1967), and on lower Babine River, Clarke (1967) and Clarke and Smith (1972).

Babine sockeye fry distribution and abundance patterns have been investigated by Johnson (1956, 1958, 1961) and Scarsbrook and McDonald between 1966 and 1977 (Scarsbrook and McDonald 1975, Scarsbrook et al. 1978). McDonald and Hume (1984) summarized fry abundance estimates. Fry feeding ecology, fry production characteristics, juvenile horizontal and vertical migration, parasitology, fry to smolt mortality, and smolt characteristics are comprehensively reviewed in Levy and Hall (1985), Wood et al. (1997), and Wood et al. (1998).

Tag and marking studies reported by Johnson (1956), McCart (1967), Narver and Anderson (1969), and by Wood et al (1998) confirmed that fry originating from the upper Babine River rear primarily within Babine Lake and fry from the lower Babine River utilize Nilkitkwa Lake as their nursery habitat. Spawning escapements to the upper and lower Babine River appear to be limiting fry recruitment to Nilkitkwa Lake and the North Arm. Late-timing escapements and early-migrant smolt abundances remain below average levels recorded before 1960.

Wood et al. (1998) noted that prior to brood year 1966, over 35% of sockeye salmon smolt production from the Babine system were early-migrant smolts, attributed to Nilkitkwa Lake and the north arm of Babine Lake. Early-migrant smolt production, though annually variable, declined dramatically from an average of 11.9 million smolts from brood years prior to 1970, (the year enhanced returns were first exploited), to an average of only 2.7 million during the 1985 to 1994 decade.

The Babine sockeye smolt enumeration facility estimated out-migrating smolt abundance and their condition from the 1959 to 2002 and from the 2013 to 2016 periods. Recent sockeye smolt abundance trend generally follows the trend of decreasing escapements to the upper and lower Babine River, except that the unusually large spawning escapements recorded in brood years 1985, 1992, 1993 and 2001 apparently failed to produce commensurate numbers of smolts. Babine River sockeye smolts typically emigrate as "early migrants" meaning they head downstream prior to the larger sub-population of Babine Lake main basin fry. This implies that current escapements are not adequate to fully seed Nilkitkwa Lake, assuming that the quality of incubation or rearing habitat has not changed.

2.0 Methods

Project methods encompassed pre-field planning, fieldwork and observations, and post-field compilations.

2.1 Pre-field Planning

An office-based overview was compiled and reviewed to identify all known previous investigations of Babine River fry and smolts including archival documents and interviews with knowledgeable fisheries experts. The history of the counting fence including sockeye fry downstream and upstream migration information was pursued and reviewed. Data used included a compilation of the existing fisheries information using the Fish Information Summary System (FISS).

Traditional fisheries knowledge and anecdotal material regarding important Babine River sockeye information were also rolled into the review. General fisheries information relating to sockeye fry emergence and early life migrations was reviewed. A field plan was developed to coordinate activities, field staff time, and included flexibility in regard to sockeye fry emergence and variable field conditions such as snowmelt timing and intensity coupled with high water flows.

2.2 Field Operations

Field methodology was based on the above noted field plan. The initial approach was to repeat selected fry movement and ecology studies conducted in the late 1950s and 1960s and reported on by Clarke (1967) and Clarke and Smith (1972) as well by methodology and observations such as those recorded by Shepherd (1979) in regard to the lower Babine River. Research concerning the upper Babine River was informed by the McCart (1967) study and more recent observations by DFO stock assessment biologists. Observations regarding fry emergence, movement, feeding, predation, and behaviour were recorded along with location coordinates, accompanying photographs or video footage. Habitat features were recorded similarly with an emphasis on quality and quantity of preferred habitat, weather conditions, water quality characteristics, use by fry presence, and use by major predators.

The following field gear was used to collect data:

- Field distances were measured with a Bushnell Yardage Pro laser range finder, hip chain, meter stick, or tape;
- Stream velocities were measured with a Swoffer 2100 Current Meter;
- Location coordinates were recorded with a variety of Garmin GPS receivers;
- Photographs and video footage were taken with various digital cameras
- Various boats with outboard jet motors as well as kayaks for on-water transport;
- Personal safety such as radios, lifejackets, and comfort gear including waders and drysuits;
- Weights were measured to the nearest tenth of a gram with a variety of digital scales.

3.0 Results

3.1 Sockeye Fry Presence & Conditions

Fieldwork was conducted from mid-April through to mid July followed with periodic field days occurring into mid-November, 2015. The field crew consisted of one biologist and four technicians as well as frequent guest appearances by a second volunteer biologist. The Babine sockeye smolt enumeration crew also provided opportunistic anecdotal observations. The first 10 days of fieldwork were characterized by discovery and meaningfulness; for example, the numbers of fry observed from the shore, in-river, kayak, or boat were calibrated by fishing with beach seine or dipnets and fry counted to ascertain what groups of 100, 1,000, or 5,000 fry looked like. For instance to start recording fry, if a biologist or technician thought they were seeing 50 fry, they were more than likely seeing 200 fry. Access by boat and foot was conducted to familiarize fry habitat and selected features.

3.1.1 Environmental Conditions

The 2015 habitat conditions were predominated by the relatively high amount of and length of high water levels, which were noted as above 160m^3/s from mid-May to mid-June corresponded to an average 0.45 m variation in river levels that resulted primarily from snowmelt. Temperatures across B.C. continued to be above average through the month of April.

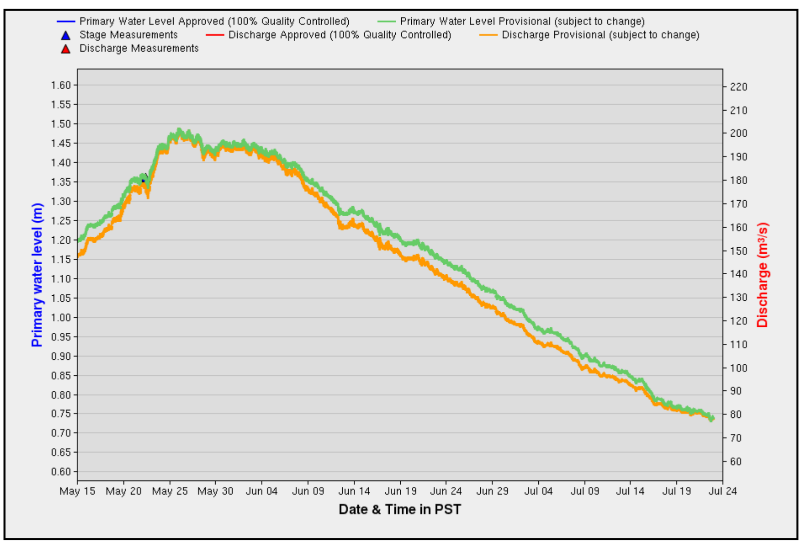

Figure 14. Graph shows water levels and discharge in the lower Babine River, May 15 to July23, 2015. WSC Station 08C013.

Precipitation trends during April included the passage of cold low pressure systems, which resulted in lingering winter-like conditions and snow pack accumulation in the Babine system. May was generally warm with temperatures 2 to 4°C above normal and the snowpack rapidly wasted. Late May and early June saw high flows crest and gradually diminish as shown in Figure 14 above.

These overall highwater conditions set the stage for both increased and decreased opportunities in regard to sockeye fry downstream and upstream migration, diminished and intensified feeding and predation activity, and as well, the ability to conduct fry presence and movement observations. Water temperatures in both upper and lower Babine River fluctuated daily with the morning 2 to 3 C^{o} typically lower than evening temperatures.

Figure 15. Fry shown swimming across flooded forest floor.

What habitat fry used as they developed was a constant learning process. Crew training also included the differentiation between sockeye, pink, and coho fry, their generalized habitat and movements, and particularly their association with sockeye fry communities. For instance, if coho fry were present and moving upstream, sockeye fry would frequently follow them.

Figure 16. Fry shown holding in undercut root bank.

Other salmon utilizing the Babine River include pink and chinook, which both principally spawn in the lower river section. Pinks typically spawn in the 0.7 km section upstream of the counting fence and are considered one of the early pink stocks. Smith and Lucop (1969) report adult pink salmon usually passing through the counting fence on Babine River between August 10th and September 10th, with odd-year pinks typically entering and spawning ten days earlier than even-year pinks. Unpublished records from the early 1960s describing dip and fyke nets positioned across the fence, and their catch, characterize the pink fry migration as relatively early with variable timing and usually tapering off as sockeye fry appear. The pink fry downstream migration is noted as totally nocturnal with the majority of movement occurring on the east side of the river. LBN Fisheries observations of pink fry were few.

Most chinook spawning takes place from the counting fence upstream to Nilkitkwa Lake though in years of high abundance, the upper river is utilized. Shepard's (1975) chinook fry survey results indicated that rearing habitats were utilized in the following order of importance: upper Babine (Rainbow Alley), lower Babine River above the fence, Nilkitkwa Lake, and lower Babine River below the fence. Our study located few chinook fry or smolts.

3.1.2 Sockeye Fry Migration

Unpublished records pertaining to lower Babine River sockeye fry emergence from their natal gravels show a range of dates from early to late May. In the upper Babine River, McCart (1967) notes fry emergence is typically at least a week later than the lower river. Emerged sockeye fry showed as active swimmers in both the upper and lower river sections on May 10, 2015. Fry presence and abundance increased to a maximum number around June 10, 2015. Sub-surface GoPro video footage documented the upstream sockeye fry migration up both the upper and lower river sections.

The number of emerged sockeye fry in the upper and lower rivers was estimated using the 2014 escapement estimates, considering 50% effective spawners each depositing 2,800 eggs with a 30% egg to fry rate. The lower Babine River potentially had just under 10 million fry emerge while the upper river had 34.6 million fry emerge.

Sockeye fry in both the upper and lower river showed somewhat of a peak emergence but also a prolonged, non-linear three week emergence period as indicated primarily by stage of yolk sac absorption. Once yolk is used up, the fry are considered to be "buttoned-up" with observations indicating this was mostly the case by the time fry migrated upstream. Initially, newly emergent fry movement was recorded at dawn and dusk and repeated observation at specific locations suggested downstream migration primarily occurred at night. These results reflect similar findings as recorded by MacDonald (1960) and Clarke (1967).

Figure 17. View up one of four sidechannels in upper Babine River, west bank.

On the upper Babine River, recently emerged sockeye emigrants swam downstream and congregated in relatively large schools close to Smokehouse Island in Nilkitkwa Lake. Upstream movement saw most fry swimming primarily up the west side against the highwater flows utilizing flooded riparian vegetation or wetlands with large aggregations congregating in off-channel habitat at the old salmon hatchery. Sloughs or flooded shoreline openings were observed to have high fry densities, particularly in the early mornings. Few fry used the west bank of the river channel downstream of the hatchery. No fry were observed on the east bank until roughly 0.5 km downstream of the Fort Babine Bridge; however, coho fry were observed migrating upstream along the entire length of the east bank.

The Fort Babine Bridge is the only location without submerged vegetation, indentations, or logs facilitating fry passage. Few fry swam more than 3 meters from the shoreline in the actual river current with the fry utilizing the flooded riparian area as shown for example in Figures 18 and 19 below.

Figure 18. Approximately 14,000 sockeye fry holding in flooded grassy area in upper Babine River.

Of interest, McCart (1967) observed upper river fry moving as far south in the North Arm as Halifax Narrows and Sunnyside, some 30-odd km up Babine Lake. Our study did not observe similar movement even though extensive areas adjacent to Five Mile and Nine Mile creeks were investigated.

Sockeye fry upstream migration on the lower Babine River was generally similar to the upper river section; however, flow velocities are greater and there are moderate amount of areas that do not provide protective overhead or instream cover and or lack riparian vegetation including:

- the "Cutbank" located on the west bank approximately half way between the counting fence and the outlet of Nilkitkwa Lake, is a gravel bank on an outside corner with little vegetation and a quickening of current and is one of the few spots on the lower river where the downstream and subsequent upstream fry migration and relatively moderate avian predation is easily observed;

- the rip-rapped sections upstream and downstream of the counting fence on the west and east banks;
- the forestry road bridge area downstream of the fence where flows approach critical velocities that could impede sockeye fry upstream migration.

Most fry utilized the west bank of the lower river in 2015 for both upstream and downstream movement and this has been the case as recorded in past by various investigators such as Clarke and Smith (1972), McCart (1967), and Shepherd (1979), who noted average trap catches of sockeye fry were over eight times higher on the west bank than on the east shore. Fry swimming upstream in the lower river appeared to swim closer to the river bottom than those in the upper river; however, this may be variable and linked to high water levels and or increased flow velocities. Overall, these conditions facilitated relatively good upstream fry migration in the upper river, and particularly for those fry upstream of the Babine counting fence in the lower river. Fry emerging in the east bank and central portion of the lower river usually have less than 30 minutes to manoeuvre to the west bank or potentially get swept down through the fence possibly past the Nichyeskwa confluence.

Figure 19. Sockeye fry holding in lower Babine River downstream of the counting fence.

Our observations indicate it is not clear whether all upper river fry go downstream into Nilkitkwa Lake and all lower Babine River fry go downstream to or beyond the counting fence, or if only a certain percentage do so. Our observations noted congregations of fry in the floodplain that did not appear to move downstream. Sockeye fry migrating or swept downstream past Nichyeskwa Creek and Nilkitkwa River are currently an unknown story as to: do they swim five or more km upstream or do they develop as stream-rearing sockeye types. By mid-July, few fry were observed in either the lower or upper river sections.

3.1.3 Sockeye Fry Behaviour

Once fry emerge, their behaviour was generally similar in both upper and lower Babine River. The date of emergence is dependent on yolk absorption, which in turn, is thought to be closely related to water temperature. McCart (1967) suggested temperature fluctuations may incite fry to emerge out of the gravels. Complex relationships exist between the time of spawning and fry emerging from redds, among ecological factors such as water temperatures, light, water flow, and their interactions. Miller and Brannon (1982) note that the whole system of life cycle timing windows hinge on the emergence timing from the spawning redds.

Downstream migration was generally marked by individual or small groups of fish with at least a small portion of the yolk sac visible. In contrast as the migration progressed, upstream migration mostly occurred throughout the day with moderate- sized schools that predominantly ranged from 150 to 250 fry. These schools reacted variably when encountering faster water or a shift in the aquatic habitat such as moving closer to the bottom in a dispersed pattern when crossing an incoming tributary stream and then regrouping as a school.

Schools of upstream migrants tended to form dense clouds of fry along the shore when they held their positions, such as downstream of the counting fence, but moved upstream in small groups. Fry behaviour developed on a daily or multi-day basis especially in regard to predator activity. Linked to those observations was how quickly fry could change colour in order to blend with various shades of aquatic vegetation, the substrate, or the flooded forest floor.

Figure 20. View down slough to lower Babine River where sockeye fry held awaiting lower water levels.

Fry were sampled for stomach contents, but unfortunately a failure with handling and care precluded stomach analysis and provided no elucidation regarding fry feeding habits; this will require future investigations. For an interim discussion regarding fry feeding, see McCart (1967), wherein he notes crustacean plankton were the most important food with the highest abundance occurring in mid-

June; insects comprised less than 10% of stomach contents. This could change if there was a mis-match of plankton bloom timing.

Our summary behaviour observations include relatively rapid behavioural development including holding or swimming close to the river banks, changing from nocturnal to daylight swimming, and swimming as individuals followed by schooling.

3.1.4 Babine Fence — Sockeye Fry Migration & Conditions

This study did not specifically focus on sockeye fry migration conditions at the Babine fence; however, fry passage was assessed as a component of the larger investigation regarding the behaviour and ecology of Babine River sockeye fry. This is in difference to the much quoted objectives undertaken by Clarke in 1966 and reported in Clarke and Smith (1972) wherein they 1) estimated numbers of fry passing downstream through the counting fence; 2) identified behavioural mechanisms by which fry might avoid downstream displacement; 3) and examined ways their upstream migration return might be enhanced.

In 1992-93, the fence was totally rebuilt; the sill was lowered 24" and the present structure at the west side of the fence was constructed. The current fence sill is at a similar grade to the river bed upstream and downstream and it was believed that the fryway was not required with the new fence geometry, thus much of the sheet pile and the baffles were removed. At the left (west) bank there are parallel sheet pile walls offset approximately 1 m; this is a component is the former fryway and shown in Figure 21.

It is thought that at least 90% of the downstream and subsequent upstream fry migration occurs on the west bank of the lower Babine River. It is currently unknown but thought to be substantial, what percentage of fry migrate downstream of Babine Fence and hold in back waters or eddies upstream of Nichyeskwa Creek awaiting high flows to recede. As well, it is unknown what percentage of fry get swept downstream past the in the mid-portions of lower Babine. Periodic observations of fry holding in back eddies and slow waters located approximately 3.5 to 7 km downstream of the fence showed roughly 400,000 juvenile sockeye or 4% or the total estimated fry in lower Babine River. These fry are thought to have been swept past the fence through the mid and east sections and were using suitable downstream habitat conditions.

Recent observations over the last several years have noted large amounts of fry congregated downstream of the fence on the west bank of the river that apparently are not successful in migrating upstream past the fence once discharge levels reached approximately 120 m3/s. However, this discharge level is considered provisional and investigations conducted in 2016 will ascertain what discharge levels fry are easily able to swim upstream through the fence structure.

Observations recorded in May and June, 2015 indicate relatively high velocity flows through the fence structure. Typical velocities, at the western side of the fence in the "fry migration panel," measured with a Swoffer current velocity meter averaged:

- 1.31 meters per second (mps) at the surface, mid-panel;
- 1.30 mps at 0.5 m depth, mid-panel;
- 1.96 mps at 0.75 m depth, mid-panel;
- 1.6 mps at the surface, close or adjacent to the outside sheet piling.

At the same time, typical velocities, at the western side of the fence upstream and downstream of the "fry migration panel," measured with a Swoffer averaged:

- 0.15 mps at the surface, upstream 33 m adjacent to the end of the rip-rap;
- 0.18 mps at the surface, downstream 27 m adjacent to the rip-rap bank.

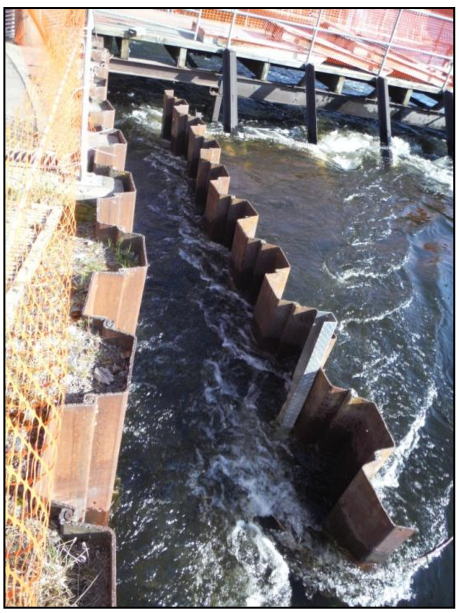

Figure 21. View downstream showing the west bank of Babine counting fence and velocity barrier, which obstructs sockeye fry upstream migration.

In addition to high discharge levels at the fence, debris such as logs, trees, etc is transported downstream and accumulates against the fence traps and fence structure as shown in Figure 22 below. The debris is typically removed once high water levels recede. This accumulated debris can create additional flow velocity flows, which hinders fry passage. Water velocity is a common measure of habitat suitability for salmonids.

Figure 22. View west across Babine counting fence showing debris accumulating against the traps and fence with discharge at ~ 192 m^3/s.

The crux of the matter is the turbulent flows on the downstream side of the fence that upstream migrating fry encounter and need to swim through. Fish tend to avoid flows which have flow features at a spatial and temporal scale that interfere with swimming trajectories (Enders *et al.* 2003; Smith 2003; Liao 2007). Essentially, if turbulence is too much for the fish to maintain headway, the fish will be thrown off vertically, or horizontally, or both, and fall back losing its swimming trajectory. This is what appears to be happening in Figure 23 that shows turbulent flows 3 m downstream of the counting fence off the west bank.

Figure 23. Fry buffeted by turbulent flows 3 m downstream of the counting fence off the west bank.

It is apparent that these high velocity, turbulent flows created by the counting fence structure at high water conditions restrict and or hinder juvenile sockeye passage upstream through the fence structure. There are differing perspectives concerning whether the counting fence is impinging on upstream fry migration or to what degree is fry passage impeded. Currently, DFO has contracted hydrological and engineering studies to assess and increase understanding of fry passage conditions at various discharge levels and recommend measures to alleviate adverse fry passage conditions.

Sockeye fry were not observed attempting to migrate upstream through the counting fence prior to June 1, 2015. Once highwater receded in late June, fry did migrate upstream past the fence with peak numbers of fry ascended during 1100 and 1400 hours, especially on days of high intensity sunlight.

Doire (2016) under the auspices of the Skeena Fisheries Commission conducted a sockeye fry mark and recapture study at the fence utilizing Bismarck Brown Y dye. 10,650 sockeye were captured downstream of the fence over 8 days, dyed, and then recaptured upstream of the fence. However, the dye marking appeared to wear-off and results were inconclusive in regard to determining fry passage at flows ranging from 1.31 mps at the surface to 1.96 mps at 0.75 m depth.

3.2 Sockeye Fry Predation

Activities revolving around sockeye fry predation were conducted in both river sections and in Nilkitkwa and Babine lakes. The question regarding predation on juvenile sockeye in Babine River during their downstream and upstream river migrations and lake rearing period is complex with many interrelated parts and pieces, particularly given the relatively large amounts of fry present and specific locations enable potential predation and mortalities.

Predatory fish potentially affecting Babine River sockeye fry either in the river or the lakes include: steelhead, rainbow trout, Dolly Varden, bull trout, lake trout, burbot, and juvenile coho (smolts). Mammal predation by otters, mink, etc is considered very minor. Avian species known to target sockeye fry in the Babine system include: Bonaparte gulls, Common Merganser ducks, Ring-billed gulls, Harlequin duck, Short-billed gulls (mew gull), and Black Terns. Both Clarke (1967) and McCart (1967) note American robins eating fry at the Cutbank on the lower river.

Unpublished DFO records of bird predation and birds collected by V.I.F. Allen during 1953-54 in the Babine-Nilkitkwa area, as summarized by McCart (1967), are shown below.

Stomach Contents of Selected Birds Preying on Sockeye Fry- Babine Nilkitkwa Area - 1954-54						
Bird Species	No. Stomachs Examined	No. Empty Stomachs	Stomachs with Fish	Stomachs with Sockeye Fry (%)	Total Fry	Average Fry / Stomach
American merganser (Mergus merganser)	8	1	7	25	6	0.7
Ring-billed gull (Lorus delowarensis)	2	0	2	100	19	9.5
Short-billed gull (Larus canus)	7	0	5	43	145	20.7
Bonaparte gull (Larus philadelphia)	10	1	4	20	78	7.8
Black tern (Chilidonias nigra)	6	0	4	17	11	1.8
Harlequin duck (Histrionicus histrionicus)	2	0	1	50	6	3

Our 2015 predation observations and results were generated by:

- continuous shore and boat-based observations from May 10 through to July 5 and periodically through to November 15th;
- three game cams located: downstream of the counting fence (lower river), at the "Cutbank" (lower river), and at a beaver dam complex (upper river);
- underwater GoPro video footage;
- netting rainbow trout in the North Arm, Babine Lake;
- trap sets in the lower and upper river sections including off-channel habitat;
- angling predator fish in the lower river and examining stomach contents.

3.2.1 Avian Predation

Our 2015 observation results indicated that Bonaparte gulls and Common Merganser ducks appeared in moderate numbers closely coinciding with sockeye fry emergence and presence and they increased in number as the abundance of fry increased. The appearance of Bonaparte gulls in spring on the river, signifies sockeye fry are starting to move. The Bonaparte gulls and mergansers are thought to be extremely efficient fishers keying into sockeye fry presence and behaviour. Both the Bonaparte gulls and mergansers densities were higher on the lower river section; however overall, the predation by gulls and mergansers are relatively low considering there were an estimated 10 million fry in the river.

Both the Bonaparte gulls and mergansers densities were higher on the lower river section. Both birds are easily identifiable and breeding in riverside nests. The Bonaparte gull is among the smallest of the gull species with a wingspan of 75 – 80 cm, and in breeding plumage, the adult has a black hood and a short thin dark bill. The merganser duck with dark, iridescent-green heads, their white wing patches, and heavy bodies are relatively easy to identify.

Figure 24. Gull launches off fence railing.

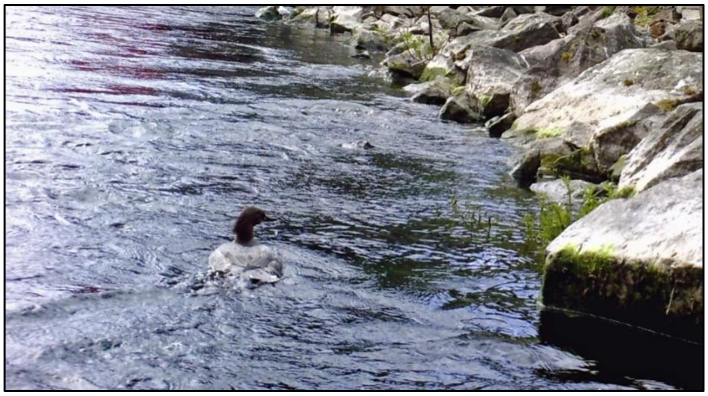

Figure 25. Merganser holding above aggregated fry below fence.

Each bird species used different behavioural tactics to capture and eat fry. For instance, mergansers would typically arrive at 5 AM, float around in pairs for roughly half an hour, fry would start to rise, and the mergansers would start to fish them. By 6 AM, the Bonaparte gulls would arrive and immediately start fishing and eating fry. The gulls would typically fly the river dropping down to fish similar as shown in Figure 24 where the gull is launching itself off the counting fence railing.

The mergansers would float downriver or position themselves on the water to dive in areas of fry aggregation such as just downstream of the counting fence as shown in Figure 25 above, where there would often be up to a dozen fishing; they would then fly back upstream and drift down again, depending on location and fry presence. Being relatively abundant and highly visible, the Bonaparte gulls and mergansers were considered the major avian predators.

3.2.2 Fish Predation

2015 fish predation survey results indicated that steelhead, rainbow trout, bull trout, and lake trout were the major fish eating sockeye fry once they emerged. Monitoring efforts with nets and traps produced moderate results in comparison to angling. Visual observations of rainbow trout and their massive density feeding on the upper Babine River (aka "Rainbow Alley") when sockeye fry are starting to move at dusk and slowing down at dawn almost defies estimates. Needless to say, the newly emerged fry are very vulnerable; however, over 34 million sockeye fry were estimated to emerge from the upper river redds. Coho smolts are historically know to be predators, but our surveys observed few coho smolts.

Thirty rainbow trout were netted at the outlet of Babine Lake to sample stomachs contents for upper river sockeye fry moving into Babine Lake; analysis showed zero fry. Gee traps set throughout the upper and lower rivers predominantly captured coho yearlings, few sockeye fry, and the occasional dace and sculpin. Results from angling predators on lower Babine River showed all but three had moderate to high amounts of sockeye fry in their stomachs.

Figure 26. Sockeye migrating upstream, lower river off west bank roughly 200 m downstream from Nilkitkwa Lake.

An interesting factor regarding fry behaviour was how quickly fry developed on a daily basis especially in regard to general predator activity. Fry sought out overhead and instream cover such as undercut banks, overhanging canopies, and instream vegetation and woody debris as shown in Figure 26 to avoid avian and fish predators. Fry changed colour relatively fast in order to blend with various shades of aquatic vegetation, the substrate, or the flooded forest floor as shown in Figure 27 where fry changed colour to reflect the flooded forest floor.

Figure 27. Sockeye fry blended into the forest floor in major slough, west bank of lower river, 900 m downstream from Nilkitkwa Lake.

The highest observed rates of fry predation occurred during the upstream migrations at locations characterized with a lack of cover including the Cutbank, the west bank of the lower river immediately downstream of the counting fence, and under and adjacent to the Fort Babine Bridge. Fry migrate upstream on the west bank of the upper and lower rivers and basically these fry are running a gauntlet. The most significant predation primarily directed on emergent or downstream fry was the twice daily — dawn and dusk — feeding frenzy by rainbow trout in the upper Babine River.

3.3 Hydroacoustic Surveys — Nilkitkwa Lake and Babine Lake, North Arm

Skeena Fisheries Commission conducted hydroacoustic surveys of Nilkitkwa Lake and the North Arm of Babine in 2015 (Doire *et al*. 2016) in order to estimate the total sockeye fry abundance and biomass as well determine the fish species composition of each lake. Doire *et al*. (2016) results are summarized below.

The 2015 sockeye fry estimate for the North Arm of Babine Lake was approximately 4.2 x 10^6, which was similar to preliminary estimates generated during the summer and fall of 2013; these were approximately 5.4 x 10^6 and 4.2 x 10^6 respectively. The resulting fry per spawner ratios in the upper Babine River for brood years 2012 and 2014 were also very similar. The average length of sockeye fry captured in the trawls was 65 mm with an average weight of 2.8 grams; all sockeye caught were age-0, or young of the year.

The 2015 Nilkitkwa Lake sockeye fry abundance estimate of 5.46 x 10^5 was relatively low compared to estimates for 2011 and 2013, of 9.7 x 10^5 and 9.8 x 10^5 respectively despite a significantly larger sockeye escapement to the Lower Babine River in 2014. Based on the mean weight of 1.8 grams for trawl-caught age-0 sockeye fry, the estimated total biomass for Nilkitkwa Lake age-0 was approximately 980 kg. These results suggest that the age-0 sockeye fry population in Nilkitkwa Lake was substantially smaller in 2015 (brood year 2014) than in 2011 (brood year 2010), and 2013 (brood year 2012).

However, Doire *et al*. (2016) note that slightly overlapping 95% confidence intervals around the hydroacoustic estimates presented make it difficult to draw firm conclusions regarding the relative abundances of fry in Nilkitkwa Lake for the three years surveyed. Wide confidence intervals around hydroacoustic estimates are typical for lakes such as Nilkitkwa with non-uniform distribution of fish targets, whereby most fish targets are located in one end of the lake.

4.0 Summary Discussion

Environmental factors, conditions, timing, and their interactions as noted in the text are thought to have not been altered more than moderately over the past 110 years and the Babine River remains a biologically diverse and productive ecosystem. However, both the upper and lower Babine River sockeye runs have diminished in abundance. Cox-Rogers and Spilsted (2012) note the lower Babine River sockeye have been steadily diminishing since the early 1950s and upper Babine River sockeye started noticeably decreasing in the late 1960s. Commercial coastal and in-river fisheries exploitation rates for the Babine late run sockeye have fallen over the last fifteen years, yet adult returns have continued to decline.

The lack of an effective fry passage structure at the counting fence is a longstanding problem, which is potentially causing fish mortality on an unknown scale and pace depending on highwater conditions. It would be expedient if only one factor could be identified as the source of the problem, such as a lack of an effective fry passage structure, or even ranked with some certainty. However, the basically collapsed Babine River sockeye runs quandary is not easily definable, the suite of stressors is complex, interactive, and mostly unknown, and the ecosystem and its components may not react to any stressor in a single trajectory.

This 2015 assessment survey has increased basic understanding and awareness of sockeye fry in the Babine River, and in turn, generates many more basic questions. There continues to be uncertainty whether to attribute the decline to prespawning mortality, unusually poor egg-to-smolt survival, poor fry-to-smolt survival, or as well, to pinpoint factors, including degraded habitat conditions, as the potential cause of these adverse effects.

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