2017 Babine Lake Watershed Sockeye Smolt Enumeration Project – Mark-Recapture

Prepared for the Pacific Salmon Commission by:
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Executive Summary

The Babine Lake Watershed is the principal sockeye salmon (*Oncorhynchus nerka*) rearing area for Skeena River sockeye salmon, producing up to 90% of the sockeye returns to the Skeena River over the last few decades. The Department of Fisheries and Oceans estimated the number of out-migrating Babine Lake Watershed sockeye smolts between the years 1959 and 2002 at a trap located at the outlet of Nilkitkwa Lake. Since the cessation of the project in 2002, the lack of information on the abundance of sockeye salmon smolts in the Babine Lake Watershed has hampered Skeena sockeye management.

In the spring of 2013, 2014 and 2015, the Lake Babine Nation (LBN), in collaboration with the Skeena Fisheries Commission (SFC), successfully resumed the Babine Lake Watershed Sockeye Smolt Enumeration Project using the same smolt trapping facility and mark-recapture protocol employed by the Department of Fisheries and Oceans from 1961 to 2002 (brood years 1959 to 2000). In 2016 and 2017, the LBN Fisheries Department (LBNF) developed the capacity to implement the smolt enumeration monitoring program independently.

In 2017, smolts were trapped on the first day of operations on April 30 with smolt tagging and biosampling commencing on May 01. Tagging and biosampling ceased on June 11 and June 18 respectively and all trap operations ceased on June 21. Daily out-migrating Babine Lake Watershed sockeye smolt population estimates were calculated for the entire 2017 Late Migrant smolt migration season. Early Migrant smolt out-migration is believed to occur shortly after ice-out. Due to periods of extreme cold and low snowpack, very thick Babine Lake ice conditions in spring 2017, including the North Arm of Babine Lake resulted in an unseasonably late ice-out throughout Babine Lake. Due to the late ice-out, it was assumed that a start date of April 30, 2017 would ensure that the entire Early Migrant smolt group would be enumerated. However, the capture of 2,419 smolts on April 30 indicated that the start of the Early Migrant out-migration period was missed which may have largely consisted of smolts holding in Nilkitkwa Lake. Nilkitkwa Lake ice-out was already in an advanced stage by April 19, the date a reconnaissance walk was conducted to assess ice conditions of the Lower Babine River and upstream to the smolt trap, with much of the lower Nilkitkwa Lake basin being ice-free on that date. It has become apparent, based on smolt trap captures in 2016 and 2017, that smolt operations would need to begin by approximately the third week of April to ensure that the entire Babine Lake Early Migrant smolt population is enumerated regardless of Babine Lake and Nilkitkwa Lake ice conditions.

Due to a lack of recaptured tagged smolts from May 01 to May 05, the MacDonald and Smith (1980) Parsimonious model was not able to generate an accurate estimate or accurate confidence intervals (CI) for the Early Migrant group. The Babine Lake North Arm/Nilkitkwa Lake Early Migrant smolt population estimate, based on the Constant Sampling Fraction (CSF) model estimate incorporating a 2.3% expansion of the total estimate for the five day period between May 01 and May 05, was 5,653,423 smolts. The CSF model output does not generate standard errors needed to determine 95% confidence intervals. The Babine Lake main basin Late Migrant population, including smolts from unenhanced populations such as the Tahlo, Morrison, Babine Lake main basin tributaries and the enhanced Pinkut Creek and Fulton River populations, using the Parsimonious model, was estimated to be 103,732,802 ± 4,056,170 smolts. The total sockeye smolt population (Early + Late Migrants) that migrated out of the Babine Lake watershed in the spring of 2017 was therefore estimated to be 109,386,225 smolts.

Late Migrants were found to have higher weight, length, and condition factor than Early Migrants. The prolonged ice-over period, which likely caused the observed delay in Late Migrant smolt out-migration in spring 2017 and resultant increase in freshwater residency, may have provided an opportunity for further growth for Late Migrant populations prior to out-migration.

Smolt production for brood years (BYs) 2011-2015 were negatively correlated with frequency of *E. salvelini* for both Early and Late Migrants respectively ($r = -0.810$, $p < 0.05$ and $r = -0.944$, $p < 0.05$ respectively) suggesting that *E. salvelini* may have a significant negative effect on annual smolt production. Alternatively, the significant negative correlations may indicate that the observed frequency of parasitization was determined by sheer numbers of fry and smolts relative to the number of parasitized intermediate host copepods and *E. sal*velini abundance, not a result of fry and smolt mortality resulting from *E. salvelini* parasitization. It is recommended that the significance of *E. salvelini* to annual smolt production be assessed through further study.

1.0 Introduction

Babine Lake is the largest natural lake in British Columbia, and the Babine Lake Watershed is the principal sockeye salmon (*Oncorhyncus nerka*) rearing area for Skeena River sockeye salmon, producing up to 90% of the sockeye returns to the Skeena River (McKinnell and Rutherford 1994; Wood *et al.*, 1998). This important watershed supports an average yearly harvest of 1.5 million adult sockeye in the commercial (Canada and United States), recreational, and First Nations fisheries and an average annual escapement to spawning of one million adult sockeye, although recent returns have been declining.

There is a long history of intensive scientific study and careful monitoring of Babine Lake Watershed salmon populations. The Department of Fisheries and Oceans (DFO) has monitored the number of adult sockeye returning to the Babine Lake Watershed at the Babine River Adult Salmon Enumeration Facility (counting fence) since 1946, and estimated the number of out-migrating sockeye smolts between 1961 (brood year (BY) 1959) and 2002 (BY 2000) at a smolt enumeration facility (smolt trap) located at the outlet of Nilkitkwa Lake, approximately 9km downstream from the North Arm of Babine Lake. Annual adult sockeye counts, annual smolt enumeration estimates and estimates of annual fry production from the Pinkut and Fulton spawning channels and from Babine Lake watershed sockeye spawning tributaries enabled fisheries managers to estimate Babine Lake watershed fry-to-smolt survival and adult sockeye recruitment (**Error! Reference source not found.**).

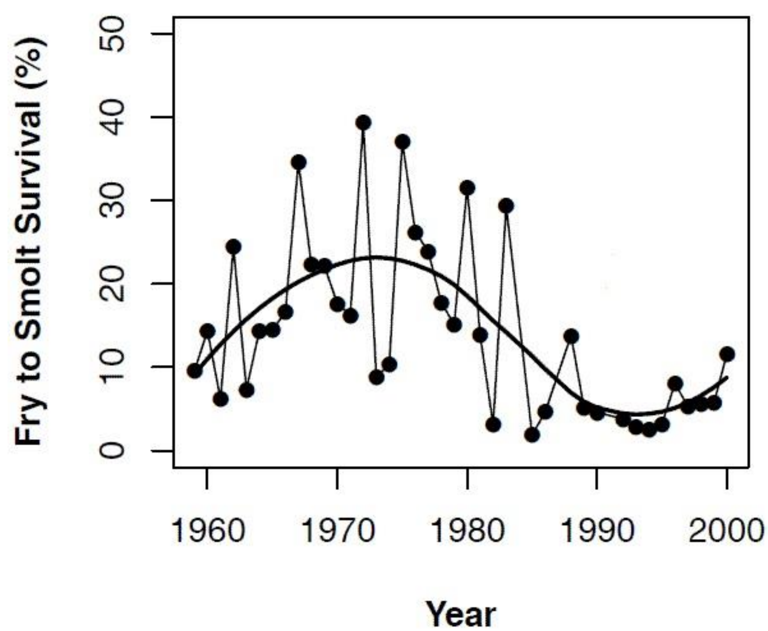


Figure 1. North Arm of Babine Lake/and Nilkitkwa Lake sockeye fry-to-smolt freshwater survival. Data for BY 2001 to BY 2010 are not available due to the discontinuation of the DFO smolt enumeration program. *Figure Courtesy of Cox-Rogers and Spilsted, 2012*.

Pre-2002 data showed a significant decline in Early Migrant fry-to-smolt survival, Early migrant smolts being the products of spawning in the Upper and Lower Babine River and Babine Lake North Arm tributaries, starting in the mid-1980s (Error! Reference source not found.). Adult abine sockeye returns have also declined significantly over the past two decades (**Figure 2**). As Babine Lake Watershed sockeye smolt production for BY 2001 to BY 2010 was not determined due to the discontinuation of the smolt program after 2002, it was not possible to determine to what extent the decreasing adult sockeye returns during this period were due to freshwater versus ocean survival, which hampered the management of Skeena River sockeye fishery. The need to resurrect the Babine smolt enumeration program became clearly apparent after the near-record low adult sockeye return to the Babine River watershed in 2013.

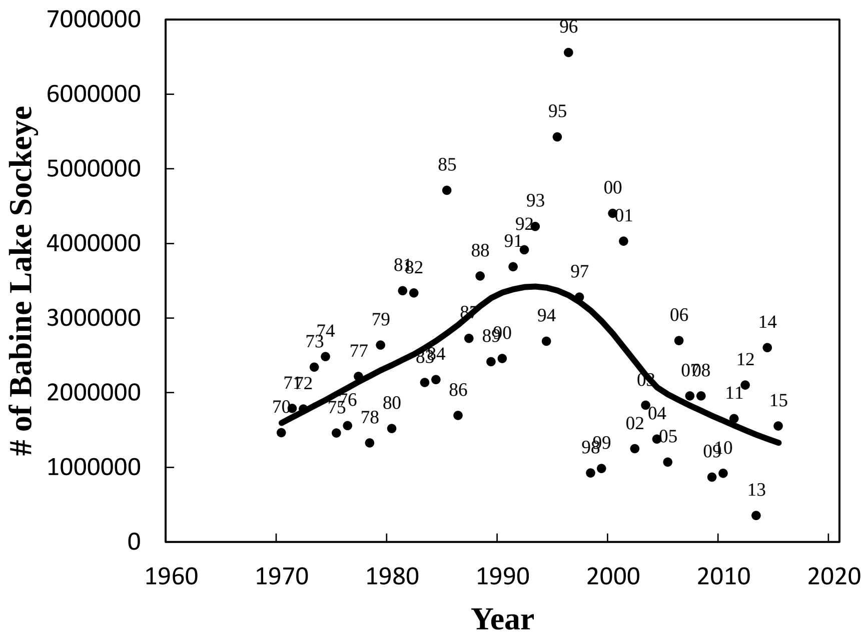


Figure 2. Trends in annual Babine Lake sockeye returns (catch plus escapement), 1970-2015. The trend line is fitted by LOWESS (F=0.5). Updated data from Cox-Rogers and Spilsted 2012. The 2013, 2014, and 2015 data points are interim values. *Courtesy of Doire and Macintyre, 2016.*

The need to identify factors limiting Babine sockeye freshwater survival and production for effective management of the Babine and Skeena watershed sockeye fishery prompted the Lake Babine Nation (LBN) and the Skeena Fisheries Commission to apply for Pacific Salmon Commission (PSC) funding. The Babine smolt enumeration program resumed in the spring of 2013 (Doire and Macintyre, 2014) which has continued annually to 2017, with the Lake Babine Nation implementing and overseeing the smolt enumeration project independently in 2016 and 2017. .

The objectives of the 2017 smolt enumeration project were to implement the methodologies used by DFO from 1961 to 2002 to (1) estimate the daily and total number of Early Migrant and Late Migrant sockeye smolts migrating out of the Babine Lake Watershed; (2) estimate fry-to-smolt freshwater survival; (3) determine the relative health (condition) and frequency of parasitism of

Early Migrant and Late Migrant BY 2015 smolts and (4) identify long-term trends in overall juvenile Babine sockeye health, survival and production during the freshwater rearing phase by augmenting the results obtained earlier for BY 1959 to BY 2000 and BY 2011 to BY 2014.

2.0 Methods

2.1 Study Area

As conducted from 1961 to 2002 and from 2013 to 2016, the 2017 Babine Lake watershed smolt enumeration program was conducted at the DFO smolt enumeration facility (smolt trap), located at the outlet of Nilkitkwa Lake at Universal Transverse Mercator (UTM) coordinates 9U 646706E 6144556N (**Figure 3**). The Babine Lake Watershed is located in the Eastern part of the Skeena River Watershed, approximately 70 km Northeast of Smithers, BC (**Figure 4**).

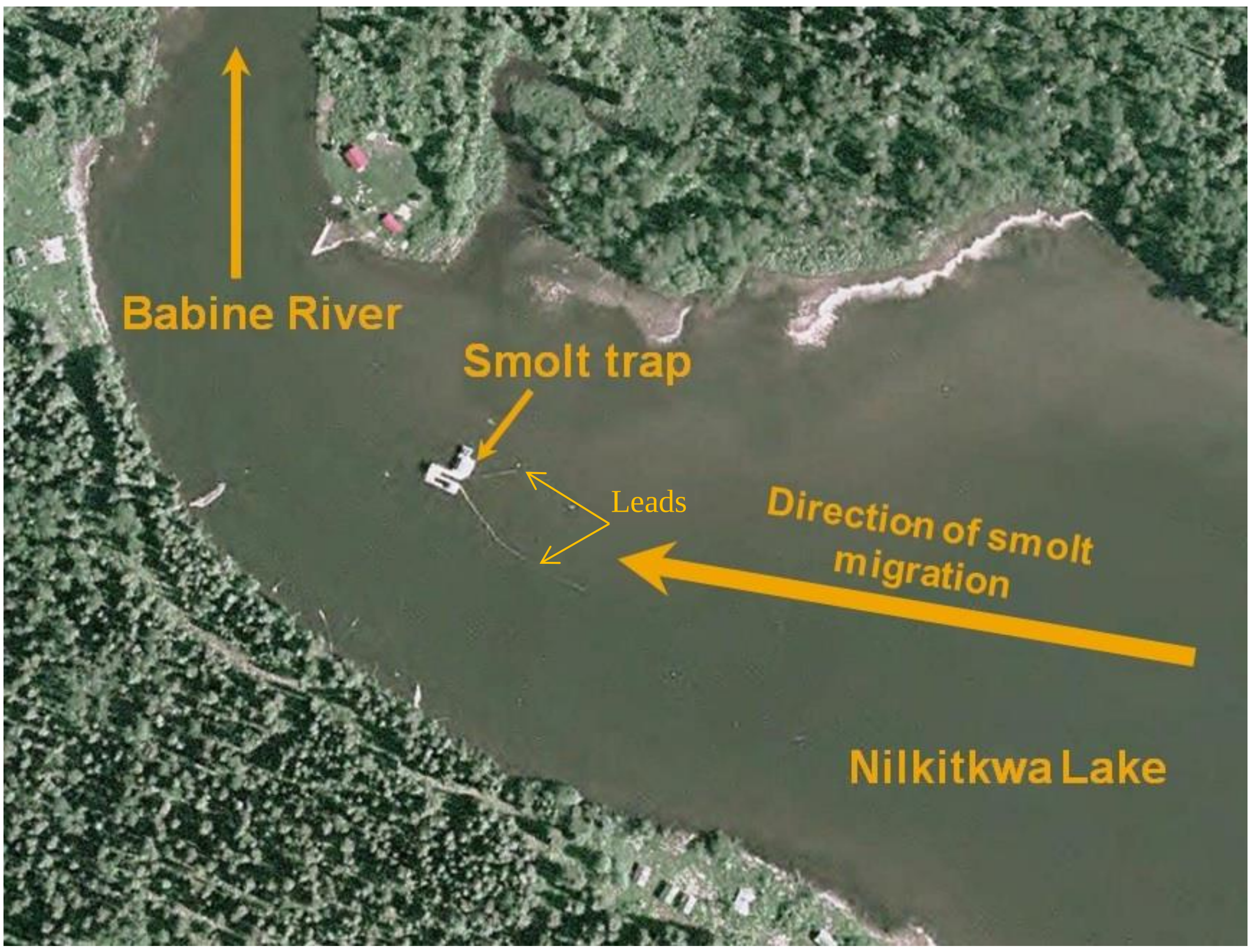


Figure 3. Satellite view of the Babine sockeye smolt enumeration facility, with the associated leads consisting of wooden pilings and chicken wire to draw smolts into the trap**.** *Modified from Doire and Macintyre (2016).*

Figure 4. Map showing the Babine Lake Watershed, and the location of the Babine Sockeye Smolt Enumeration Facility. Map by Gordon Wilson - Gitksan Watershed Authorities.

2.2 Study Protocol

2.2.1 Smolt Trap Description

During their migration to the ocean, all juvenile sockeye rearing within the Babine Lake Watershed travel through the outlet of Nilkitkwa Lake, a portion of which are captured by the DFO smolt enumeration facility when in operation, before entering the Lower Babine River and eventually the Skeena River. The DFO smolt enumeration facility (**Figure 5)** consists of (i) a trap and associated leads, (ii) a wooden walkway platform, (iii) a tagging shed, (iv) a shed where smolts are enumerated and examined for tags, (iv) a shed used to store equipment and collect tissue samples and biological data such as fork length, weight and parasitism frequency and (vi) a gravity-feed water tank which supplies water to the tagging shed and the smolt enumeration/examination shed. The main components of the smolt enumeration facility used by the DFO up to 2002 are still in place and were used for the 2017 smolt enumeration program after some basic maintenance work.

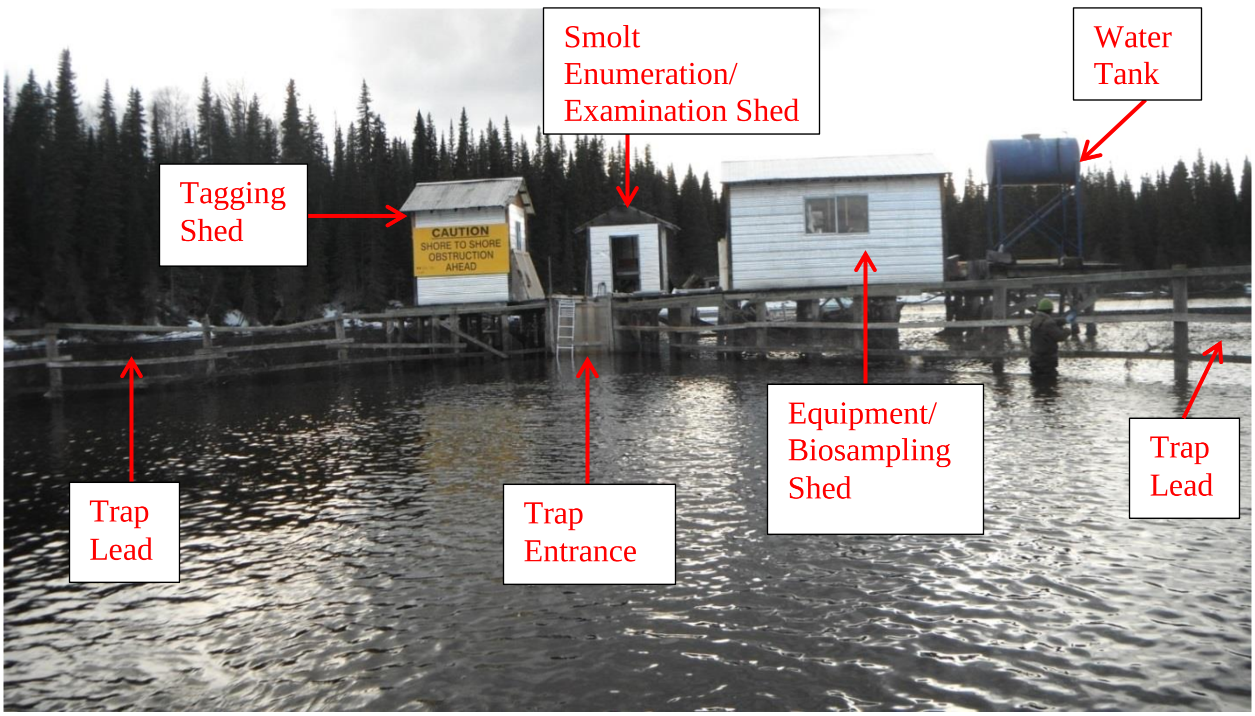


Figure 5. The Babine smolt enumeration facility, viewed facing downstream, showing wooden pilings, chicken wire mesh leads, the various sheds and the smolt trap entrance. Water is pumped into the tank on the right which gravity feeds water to the tagging shed and smolt enumeration/examination shed. *Photo modified from Doire and Macintyre (2016).*

The trap leads funnel smolts into the upstream trap entrance. Smolts swim downstream through the trap entrance and into one of two holding compartments (**Figure 6**). All smolts captured in the holding compartments are dip netted into holding pens (**Figure 7**) where they are held before being transferred to the smolt enumeration/examination shed.

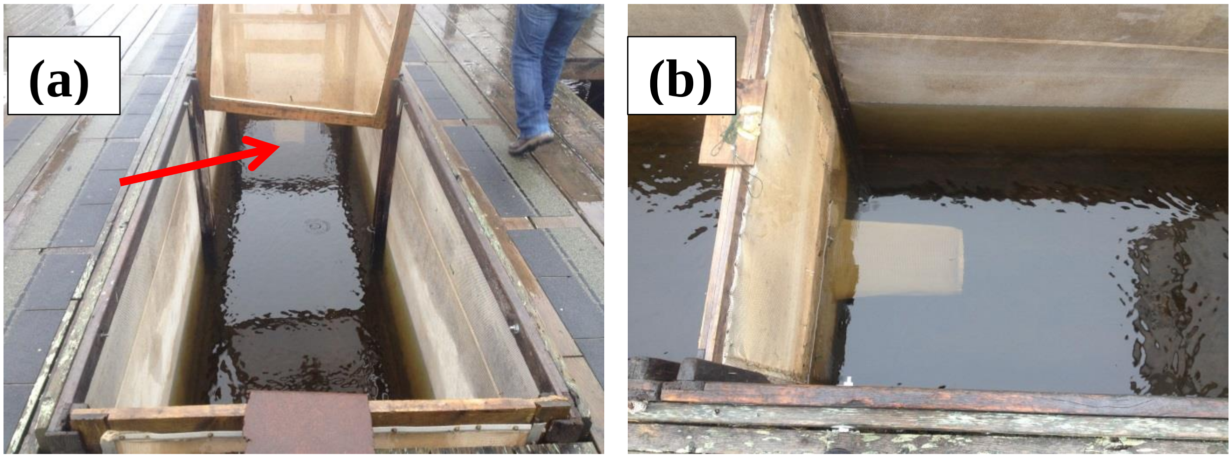


Figure 6. (**a**) The two trap compartments, looking upstream towards the trap entrance, with the middle divider screen raised for trap maintenance. The red arrow indicates the trap entrance of the first, upstream trap compartment screen; (**b**) the middle screen, separating trap compartments 1 and 2, inserted into position. Smolts pass through the cylinder-shaped mesh trap entrance, referred to as a "dinker".

Figure 7. Three of five holding pens that are used to hold smolts until the smolts are enumerated and examined for tags.

2.2.2 Smolt Trap Preparation

Mobilization and preparation of the Babine River smolt trap began on April 26, 2017. Preparation included the installation and repair of chicken wire to the trap leads, inspection and installation of trap and pen mesh, inspection and test-running of all scientific and mechanical equipment including boats, water pumps, water tank aerators, smolt trap plumbing, preparation of data sheets and, with assistance from Dave Southgate, familiarization of smolt tagging, biosampling and mark-recapture estimation protocols. The Upper and Lower Babine River was ice-free and Lower Babine River water levels were sufficient to permit access to the smolt trap by jet boat. Smolt enumeration began on April 30, 2017 with the first smolts being captured on that date. The smolt trap was operated until June 21, 2017, 10 days after the last day of release of tagged smolts on June 11, and by which time the number of smolts captured by the smolt trap had declined to very low numbers (<500 smolts/day).

2.2.3 Temperature, Water Level and Discharge

Air and water temperature were measured daily each morning with a hand-held thermometer. Water level was measured at the smolt trap inlet with a wooden ruler. Discharge data for the Babine River was obtained from Water Survey of Canada (WSC) gauging station 08EC013 located approximately 1.6km downstream of the Babine River smolt enumeration facility.

2.2.4 Volumetric Enumeration and the Mark-Recapture Data Collection

The same mark-recapture sampling techniques and protocol used in previous years, which were extensively developed, documented, and standardized by the DFO, Jordan and Smith (1968), MacDonald and Smith (1980) and MacDonald *et al*. (1987) were used in 2017. The tags used to mark the smolts were color-coded bent staples secured to the back of the smolts, immediately in front of the dorsal fin (**Figure 8**). A total of ten different color codes painted on the bent staples increased the accuracy for determining the day on which a specific recovered smolt was tagged and released. Jordan and Smith (1968) described the tags and the process of tagging in more detail.

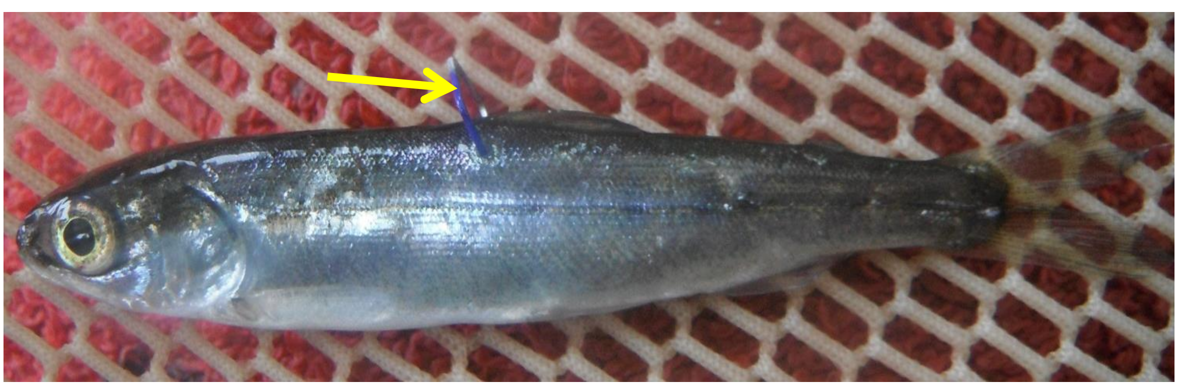


Figure 8. A sockeye smolt marked with a staple tag indicated by the yellow arrow prior to release. *Photo modified from Doire and Macintyre (2016).*

The tagging process included staple preparation, colouring of staple tags with permanent marker, the tagging of partially anaesthetized smolts (lethargy and/or loss of equilibrium) using as minimal amount of Tricaine methanesulfonate (MS 222) as possible (**Figure 9**), and allowing for full recovery of tagged smolts from anesthetic in a flow-through, low velocity recovery pen receiving fresh river water (**Figure 10**). As was performed in 2016, as opposed to only tagging smolts held in holding pens, some of which may have been captured the previous night potentially resulting in stress and subjected to repeated dip netting, smolts that entered the trap overnight and dipped out of the trap the following morning were preferably tagged whenever possible to maximize the representativeness of tagged smolts to untagged smolts.

Figure 9. The tagging of partially anesthetized smolts, visible in the mesh to the left of the tagger, in the tagging shed.

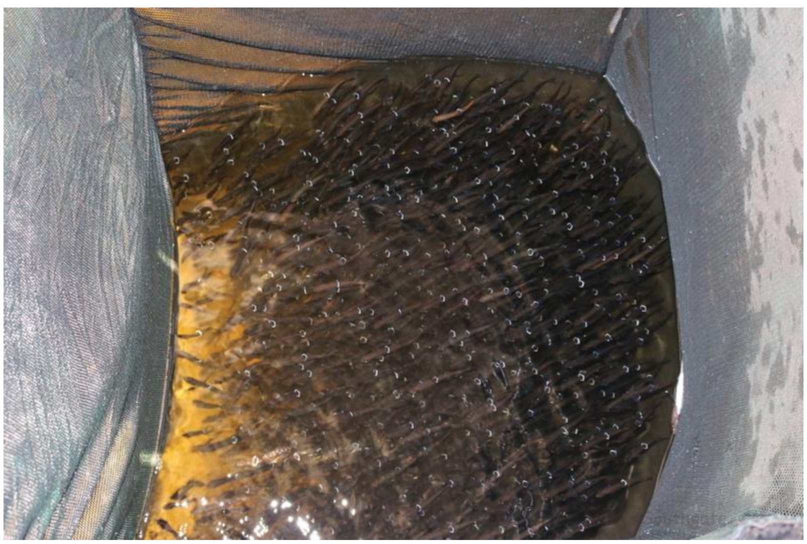


Figure 10. Smolts marked with white coloured staple tags holding in the recovery pen. Tagged smolts are recovered for several hours prior to being released in Nilkitkwa Lake.

Between 1:15PM and 1:30PM, tagged smolts were transferred by dip net from the recovery pen directly into the stainless steel transport tank filled with approximately 500 liters of fresh river water (**Figure 11**). Battery powered aerators were used to maintain dissolved oxygen levels of tank water throughout the transportation and release process.

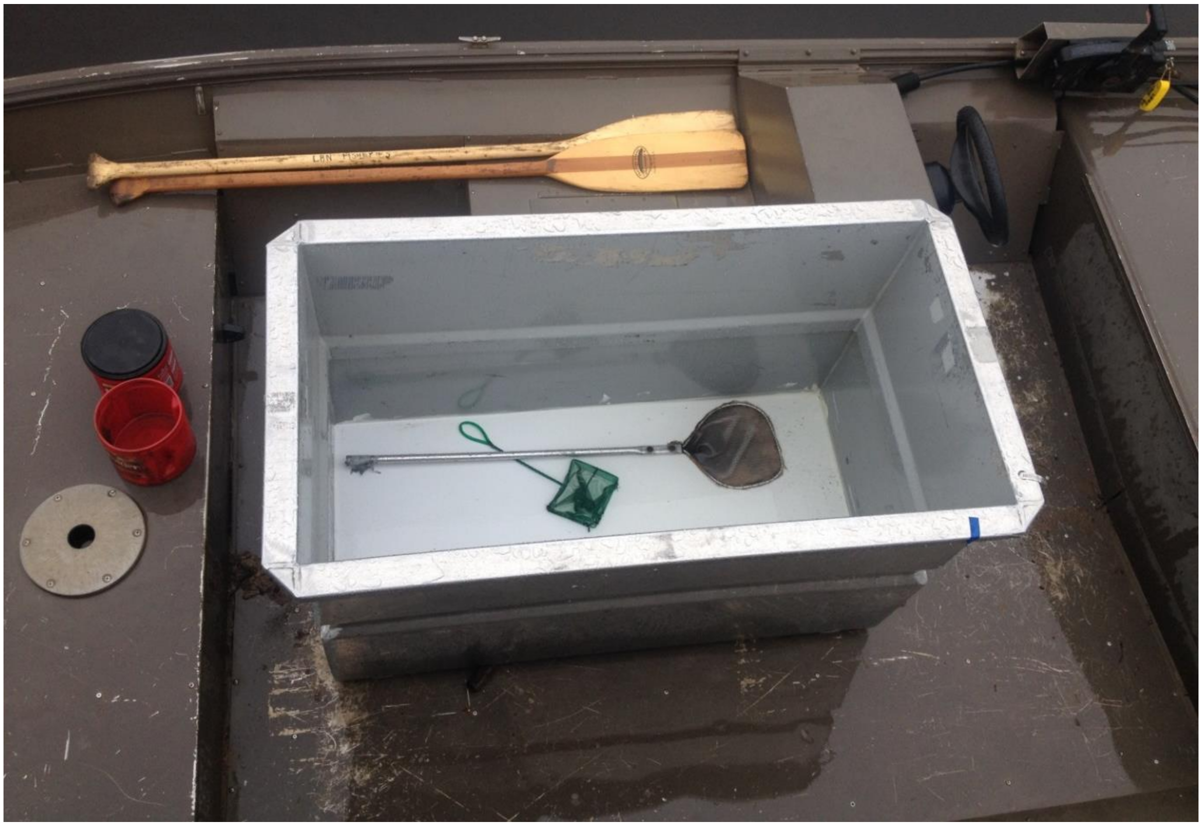


Figure 11. View of the metal tank used to transport over 3,000 tagged sockeye smolts to the release area of Nilkitkwa Lake, 6 to 8 km upstream. Fresh river water was pumped into the tank at the smolt trap until approximately half full. One or two battery-powered aerators aerated the tank water until all smolts had been released.

Tagged smolts were transported by boat to the release area in the southern part of Nilkitkwa Lake, approximately 6km upstream of the smolt enumeration facility, with smolt release beginning by no later than 1:50PM. With the boat moving upstream at approximately a jogging speed (approx. 5km/hr), smolts were gradually released by the small dip nets (**Figure 11**) starting at approximately 6km upstream of the smolt enumeration facility until all smolts had been released at approximately 8 - 9km upstream of the smolt trap. This broad dispersal technique ensured that tagged smolts randomly mixed with unmarked smolts migrating throughout Nilkitkwa Lake to provide the most accurate unbiased mark-recapture estimates as possible.

From the time from tagging to the time of release, all smolt moralities, smolts that appeared weak (not representative of untagged smolt fitness and catchability) and tags that were shed were subtracted from the total number of tagged smolts released for each date.
The total number of smolts captured daily by the DFO smolt enumeration facility was estimated by one designated staff member using a volumetric method whereby smolts were transferred into the calibration bucket (**Figure 12**) to the "full" level indicated by a black painted area within the upper portion of the calibration bucket (**Figure 13**).

Figure 12. The volumetric "calibration" bucket used to quantify smolt numbers. The lower yellow arrow indicates the full mark to which water is added prior to filling with smolts. The upper red arrow indicates the level indicating the full mark to which smolts are added. As soon as the smolt "full" mark is reached, the live smolts are immediately transferred to the counting shed (**Figure 14**) where smolts are examined for tags.

Figure 13. Smolts being transferred from a holding pen into the calibration bucket immediately prior to enumeration and inspection for tags.

To help ensure that calibration buckets did not differ by more than ± 100 smolts/ bucket-load, the total number of smolts per bucket-load was accurately determined for the first 5 bucket-loads at the start of each day. If the total daily catch was equivalent to less than 5 bucket-loads, all smolts were counted individually. If a counted bucket-load exceeded the ± 100 smolts requirement during the calibration process, it was counted as 1 uncalibrated bucket and another bucket would be counted until the ± 100 smolts requirement was met. The calibration process was implemented to ensure that the crew member, responsible for filling the calibration bucket for a given day, consistently filled the bucket to the same level relative to the bucket full-mark to ensure that daily total smolt estimates were accurate. The average calibration number for the five calibrated buckets was used to estimate the number of smolts in subsequent uncalibrated buckets. The last remaining smolts captured for a given day were individually counted unless the level of smolts of the final bucket reached the "full" mark of the calibration bucket, in which case the last bucket was counted as 1 uncalibrated bucket. The average number of smolts per full bucket-load ranged from approximately 1300 – 1600 smolts.

In 2013 there were concerns that an unknown number of tagged smolts may have been missed during the smolt examinations which would have led to an over-estimation of the total number of smolt out-migrants. As was utilized in 2014, 2015 and 2016, a coded-wire tag detector was used to locate tagged smolts immediately following initial visual examination to reduce the chance of tagged smolts going undetected during smolt examinations (**Figure 14**).

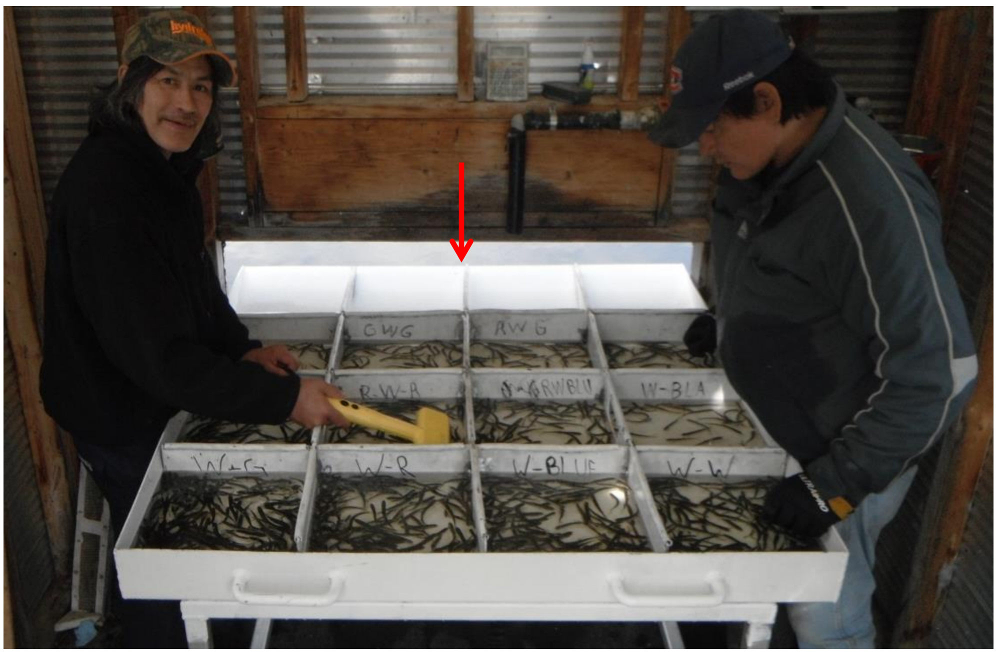


Figure 14. The yellow "T-Wand" coded-wire tag detector being used to locate live tagged smolts. Recaptured tagged smolts are removed and sorted according to tag colour. After examination, the unmarked live smolts are released downstream through the hatch (red arrow) by removing the compartment grid and lifting the back end the sorting tray by the two handles visible at the front of the tray. *Photo modified from Doire and Macintyre (2016).*

2.2.5. Determination of Early Migrant and Late Migrant Transition Dates.

Preliminary estimation of the Early Migrant and Late Migrant transition date was determined by plotting the estimated smolt abundance by date. A declining trend followed by an increasing trend was determined to be the approximate transition date. Confirmation of the transition date was determined from the Parsimonious model which identified the transition date based on a *Chi-square* Test. For the parsimonious model developed by McDonald and Smith (1980), the transition date used to differentiate between the number of estimated Early Migrant and Late Migrant smolts is determined as stated in the parsimonious model output:

> "The 'Transition Date' is the first day of release for which the released smolts show late-run behaviour. This analysis assumes that marked smolts are released the day after they were taken, so the Transition Date is ONE DAY AFTER the START of the LATE RUN".

As the majority of smolts out-migrate under darkness, typically beginning shortly after dusk (8:00pm – 9:00pm) and ending typically three to four hours afterwards (12:00am – 1:00am), the parsimonious model assumes that one calendar day starts from noon and continues to approximately noon the following day when inspection of smolts for tags ends (MacDonald and Smith, 1980). Thus, smolts captured in the smolt enumeration facility during the preceding night (*e.g*. May 11) and any additional smolts captured by the following morning (*e.g*. May 12) represents one calendar day, May 11 in this case. During peak smolt out-migration however, smolts may be captured throughout the day.

The transition day between Early Migrant and Lake Migrant smolts since 2013 (BY 2011) has typically been indicated by a rapid increase in the number of smolts captured at the smolt trap which signifies the arrival of the far more abundant main basin smolt populations. Early Migrant smolts are produced primarily from upper Babine River spawners and, presumably, from lower Babine River spawners, as well as smaller populations in streams tributary to Nilkitkwa Lake and the North Arm. These populations rear as fry in Nilkitkwa Lake and/or the North Arm of Babine Lake. Late Migrant smolts are largely comprised of smolts produced from spawning at the Pinkut River and Fulton River and their spawning enhancement channels, but also include smolts produced from spawning that occurs in a number of streams tributary to the main basin of Babine Lake and tributaries of the Morrison Arm, Tahlo Lake and Morrison Lake. Distinguishing between the number of Early Migrant and Late Migrant smolts provides an opportunity to estimate smolts per spawner and smolt-to-adult survival for upper and lower Babine River populations and smolts per spawner, fry-to-smolt and smolt-to-adult survival for the Fulton and Pinkut enhanced populations.

2.2.6 Biological Sampling

Fifty randomly selected smolts captured at the smolt trap were measured and dissected daily to obtain representative fork length and weight data and to determine the percentage of smolts parasitized by *Eubothrium salvelini*, a parasite which affects the digestive tract of juvenile sockeye in the Babine Lake Watershed. Smolt fork length was measured to the nearest millimeter (mm). Weight was measured to the nearest 0.1 gram (g) using an Ohaus digital scale. An incision was made along the midline of the belly of sacrificed smolts to examine the body cavity and the exterior surfaces of the stomach and intestines for the presence of *E. salvelini*. The Fulton Condition Factor (CF) was determined for each smolt measured and weighed using the following formula as described in Anderson & Newman (1996): $C = (W \div L^3) \times 100{,}000$ where C = Condition Factor, W = weight and L = length.

For biological data used to determine Early Migrant (Early Run smolt) and Late Migrant (Late Run smolt) means for fork length, weight, condition factor and frequency of *E. salvelini* parasitism, the transition date determined by the parsimonious model was used.

In 2017, 25 samples were collected daily for genetic analysis. Tissue samples were collected from the first 25 fish inspected for *E. salvelini* presence. Caudal clips with the whole fin and 3-5mm of caudal peduncle muscle tissue were placed in 2mL vials filled with approximately 1.5mL of ethanol. Vials were labelled 1-25 in the same order of inspection for *E. salvelini* so all DNA samples have associated fork length, weight, and *E. salvelini* presence.

2.2.7 Fry Production and Fry-To-Smolt Survival Estimation

To estimate the number of smolts-per-spawner, total fry production and fry-to-smolt survival, the estimation of effective escapement (number of adults that are observed on the spawning grounds) for all significant sockeye spawning tributaries is required. The number of adults that spawn in the wild (unenhanced) tributaries is determined by a standardized area-under-the-curve (AUC) method used by the DFO and other agencies. Effective escapement for the Pinkut and Fulton spawning channels and the natural portions of these rivers is determined by counting each adult that passes through their respective adult enumeration fences. Though wild tributaries that are known to have had sockeye spawning historically are generally inspected annually, tributaries that are ephemeral (dry in low to moderate water years), or that have escapement that is too low for accurate estimation of the total escapement using the AUC method, may only be assessed at the start of the spawning season (i) if there is sufficient discharge to enable assess to spawners and/or (ii) the presence of sockeye adults warrants monitoring throughout the spawning season.

Main Basin and Tahlo/Morrison spawners that produce the Late Migrant smolts are estimated by adding the counts provided from the Fulton and Pinkut River enhancement channels to the estimated escapement from wild streams and rivers tributary to the Babine Lake Main Basin, Tahlo Lake and Morrison Lake. The wild component of the escapement is adjusted upwards from visual counts following the methods in Wood *et al*. (1995) to account for observer bias in visual surveys and the unaccounted difference between Babine River Adult Enumeration Facility (Babine fence) counts and total escapement estimates upstream of the fence. Babine Lake North Arm and Nilkitkwa Lake spawners (producing the Early Migrant smolts) are estimated in the same manner as the Main Basin wild component. The observed escapements to the upper and lower Babine River and other North Arm and Nilkitkwa Lake systems are adjusted upwards following the methods in Wood *et al*. (1995).

Fry recruitment for the Main Basin is estimated by adding the monitored fry outputs from the Fulton and Pinkut River facilities to the sum of the estimated fry outputs from Babine Lake Main Basin and Tahlo/Morrison wild tributaries. Unenhanced tributary fry production is estimated by multiplying the number of estimated escapement by 233, 233 being the mean number of fry produced per spawner determined by MacDonald and Hume (1984).

Fry recruitment to Babine Lake North Arm/Nilkitkwa Lake is estimated following the same procedure as for the Late Migrant smolt producing wild tributary populations and includes returns to the upper and lower Babine River, Boucher Creek, Tsezakwa Creek, 9-Mile Creek and 5-Mile Creek. As such, the fry recruitment in Babine Lake North Arm/Nilkitkwa Lake follows the escapement estimate for each tributary multiplied by 233 fry per spawner.

2.2.8 Data Analysis

In order to provide updates of the total number of smolts estimated to have passed downstream of the smolt trap each day, a series of calculations were performed daily following established DFO protocol were performed in Microsoft Excel®. Daily estimates were summed to provide updates of the total cumulative estimate for the Early Migrant group and the Late Migrant Group. The estimated 2017 overall total number of smolt out-migrants was obtained by summing the Early Migrant Group estimate with the Late Migrant Group estimate.

The number of smolts captured between May 26thand May 28th was 282,425 on May 26th, 397,096 on May 27th , and 479,730 on May 28th. The rate of smolt capture on these dates during the hours following dusk exceeded the holding capacity of the trap and the amount of time required for staff to properly inspect smolts for tags. . The standard DFO procedure during periods when smolt out-migration exceeds trap holding capacity and time require for examining smolts for tags was applied whereby, in order to maintain sufficient trap holding capacity and properly inspect as many captured smolts as possible for tags, every second bucket was released without being checked for tags. In other words, buckets of smolts checked for tagged smolts and buckets of smolts not checked for tagged smolts were alternated (e.g. checked for tags, not checked, checked, not checked……etc), a technique referred to as "dumping". To estimate the number of tags of each colour in the dumped buckets, the mean number of observed tags of each colour was multiplied by the total number of buckets (the sum of the number of buckets both examined for tags and not examined for tags) as follows:

1) $i = \frac{Tc}{x}$
2) $Te = n + iy$

Where:
i = Average number of tags for a given colour per bucket.
Tc = Tags of one colour counted in the scanned buckets.
x = Total number of counted buckets (sum of checked and unchecked buckets).
y = Number of dumped buckets.
n = the total number of all marked smolts of a given colour observed in checked buckets for a given day, including marked smolts observed in checked buckets during periods of alternating between buckets being assessed for marked smolts and buckets of smolts being released without being checked for tagged smolts.
Te = Expanded number of tags of one colour of all buckets for May 26, 27 and 28 rounded to the nearest tag (whole number).

After the end of the field data collection phase, all mark-recapture data was entered into the parsimonious mark-recapture model developed by MacDonald and Smith (1980) which provided daily estimates, estimates for both the Early Migrant and Late Migrant groups, an overall estimate (Early Migrant + Late Migrant smolt estimates) and standard errors (SE) for each of the three estimates. As conducted in previous years, standard errors for Early Migrant, Late Migrant and total number of out-migrant smolt estimates were multiplied by 1.96, as is applied to single census mark-recapture data (Everhart and Youngs, 1981), to provide the 95% confidence intervals for each of the three estimates.

Microsoft Excel® was used for the plotting of LOESS smoothing curves for continuous data to identify temporal trends in fry-to-smolt survival. The level of correlation between adult sockeye escapement (number of sockeye adults counted on spawning grounds) and subsequent smolt production for each brood year was conducted using historical data provided in Cox-Rogers and Spilsted (2012).

Statistical analysis was performed according to Zar (1984). *Linear Regression-correlation* analysis was performed in MS Excel to determine long-term trends in Late Migrant smolt weights for BY 1950 to BY 2000 and BY 2011 to BY 2015 and to determine trends in Late Migrant smolt weights pre- Babine Lake Development Project (BLDP) (BY 1950 to BY 1969) and post-BLDP (BY 1970 to BY 1995, BY 2011 to BY 2015). Critical values for the t distribution for n-2 degrees of freedom (DF) where $t = r\left\{\sqrt{(n-2)} \div \sqrt{(1-r\text{^}2)}\right\}$ was used to determine whether the slope of the regression was statistically significantly different from 0. Critical *t* values for one-tailed *t*-distributions were used to accept or reject the null hypothesis that *E. salvelini* did not significantly reduce smolt length, weight, condition factor or total annual production of both Early Migrant and Late Migrant smolts.

. Though smolt fitness sample sizes were large, meeting the assumption of an approximately normal data distribution in accordance with the *Central Limit Theorem*, sample mean, median, mode and skewness were assessed to determine the central tendency of the data. Kurtosis of the data distribution was also determined. The *Shapiro Wilk Test* was used to determine if the assumption of approximately normally distributed data was violated for data that had moderate skewness or in cases where Kurtosis values suggested non-normally distributed data. If original data and transformed data distributions were unable to meet the assumption of normality, the R Project for Statistical Computing (“R”) was used to perform the non-parametric *Mann-Whitney U Test* and the *Kruskal Wallis Test* to test for statistically significant differences between Early Migrant and Late Migrant lengths, weights and condition factors. The one-tailed *Mann-Whitney U-test* was applied when testing for the possible negative effects of *E. salvelini* length, weight and condition factor for a given brood year A significance level of $\alpha = 0.05$ was used to identify statistically significance differences or relationships.

3.0 Results and Discussion

3.1 Environmental Data

Due to a lack of snow cover and periods of extreme cold, Babine Lake ice cover over the winter of 2016/2017 became exceptionally thick, with some anecdotal reports claiming the Babine Lake ice to be the thickest observed since the 1940's. The North Arm of Babine Lake was completely frozen on April 19, 2017 (**Figure 15**) when a reconnaissance walk was conducted to assess ice conditions at the boat launch located immediately upstream of the Babine Adult Enumeration Fence, Nilkitkwa Lake and North Arm. Nilkitkwa Lake was also largely still covered in ice on April 19 (**Figure 16**) but large open sections were observed with remaining ice cover appearing thin. It was anticipated that, due to persistent ice-cover in the North Arm of Babine Lake, that smolt out-migration in 2017 would occur later than that of 2016, an exceptionally warm spring when ice-out occurred earlier than in years 2013 to 2015 (Janvier Doire, personal communication).

Figure 15. Thick ice conditions in The North Arm of Babine Lake on April 19, 2017 looking Eastward towards Fort Babine from the Babine Lodge/Mercury Landing boat launch.

Figure 16. Retreating ice in the South Basin of Nilkitkwa Lake on April 19, 2017 looking upstream from a ridge located 500meters upstream of the Smolt Trap.

From May 1st to June 21st, 2017 mean morning air temperature was 8.6°C and ranged from 0°C to 21.6°C (**Figure 17**). From May 1st to June 21st, 2017, mean water temperature was 8.3°C and ranged from 4.4°C to 13.2°C (**Figure 17**). Morning mean water level from May 1st to June 21st 2017 was 124cm and ranged from 62cm to 161cm (**Figure 18**). In mid-May and throughout June 2017 the Water Survey of Canada station 1.6km downstream of the smolt trap recorded higher than average discharge (WSC, 2018, **Figure 19**).

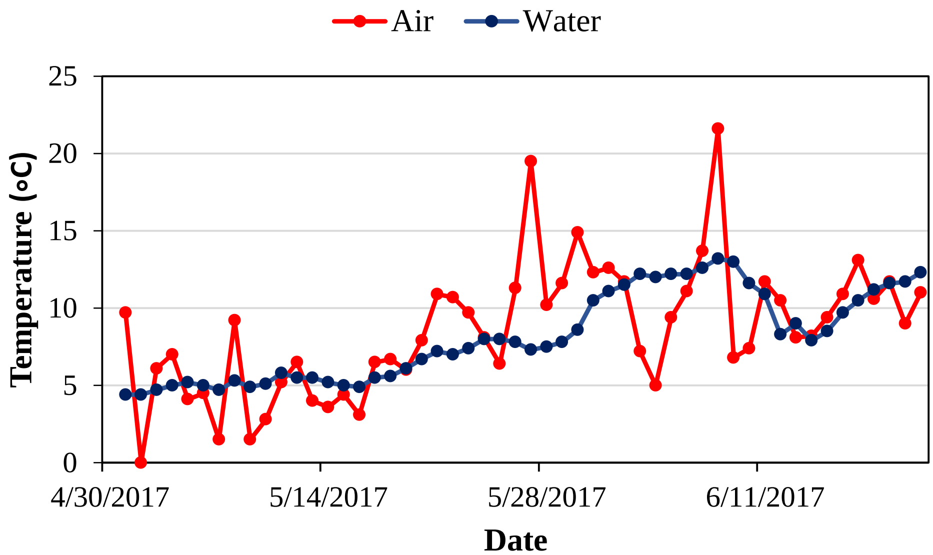


Figure 17. Morning air and water temperature observed at the Babine smolt enumeration facility from May 1, 2017 to June 21, 2017.

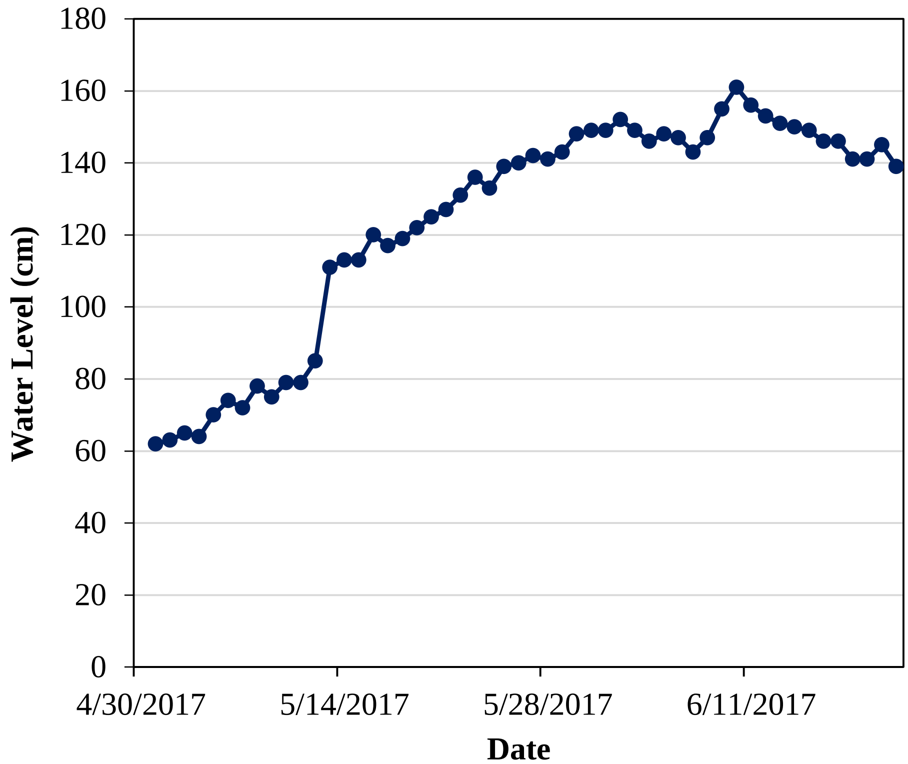


Figure 18. Morning water level observed at the Babine River smolt enumeration facility from May 1, 2017 to June 21, 2017.

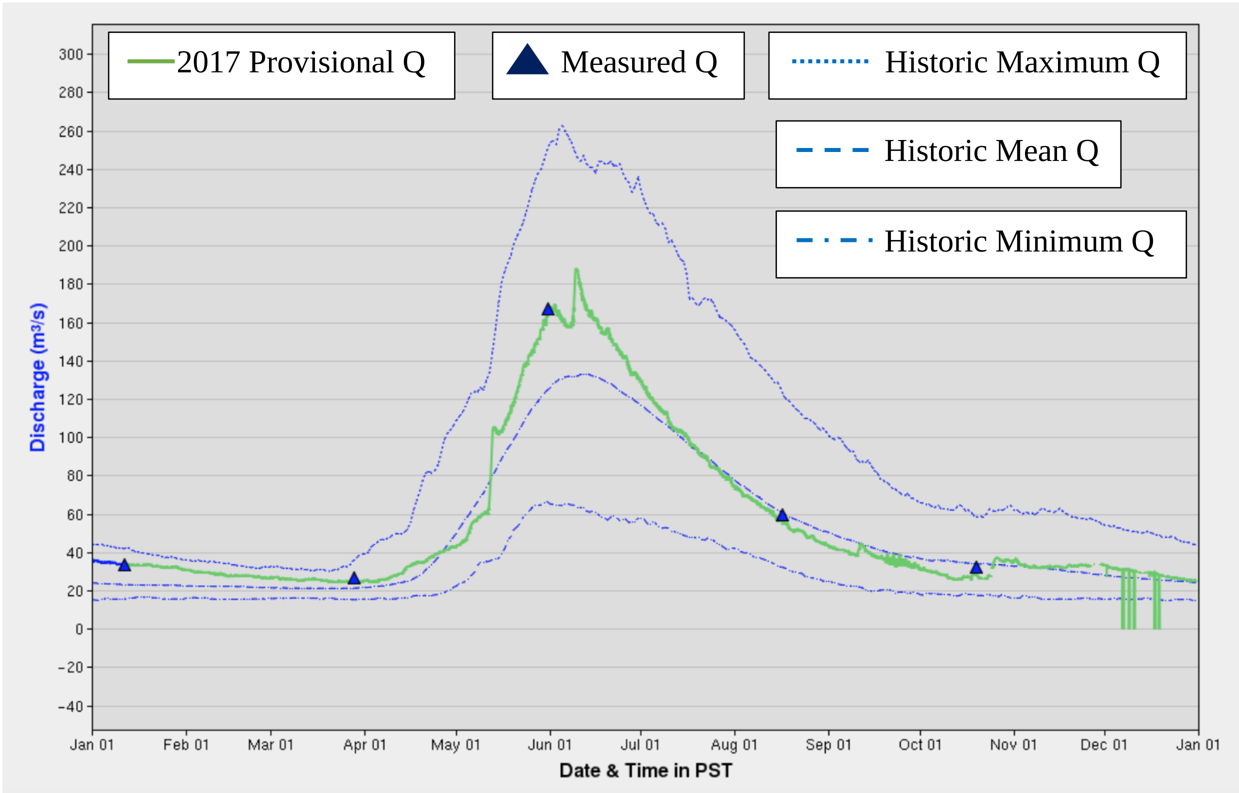


Figure 19. Discharge (Q) recorded in 2017 and historic minimum, mean and maximum discharge data collected since 1972 by the WSC gauging station 08EC013 downstream of the Babine Adult Enumeration Fence. *Graph Modified from WSC.*

3.2 Estimates for Numbers of Babine Lake Smolt Out-migrants

A total of 2,267,460 sockeye smolts were captured and examined for tags between April 30th and June 21st of which 3009 were recaptured tagged smolts (**Table 1**). A total of 57 additional tagged smolts, for an adujusted total of 3066 tags, were estimated to have been in buckets that were not assessed for tags on May 26th, 27th and 28th during periods of intense out-migration in which both the trap holding capacity and ability of the crew to locate tagged smolts in every bucket was exceeded. A total of 101,995 captured smolts were tagged and released from May 1st to June 11th of which 2.95% were recaptured not including the estimated number of tags that would have been observed in dumped buckets. If the estimated number of tags in dumped buckets is included, 3.01% of tagged smolts were recovered.

Table 1. Daily number of tagged sockeye smolts released and total sockeye smolts captured and examined at the Babine smolt enumeration facility between April 30th and June 21th, 2017.

Date (mm/dd/yy)	Number of Tagged Smolts Released	Total # Smolts Captured/ Examined	Date (mm/dd/yy)	Number of Tagged Smolts Released	Total # Smolts Captured/ Examined	Date (mm/dd/yy)	Number of Tagged Smolts Released	Total # Smolts Captured/ Examined
04/30/17	0	2,419	05/18/17	3,047	9,741	06/05/17	2,868	28,135
05/01/17	1,539	5,520	05/19/17	2,988	11,534	06/06/17	2,811	35,085
05/02/17	1,534	3,620	05/20/17	2,958	12,840	06/07/17	2,821	22,050
05/03/17	1,503	10,140	05/21/17	3,024	9,641	06/08/17	2,868	12,125
05/04/17	2,045	9,312	05/22/17	3,055	129,660	06/09/17	1,860	1,799
05/05/17	1,535	151	05/23/17	2,940	73,169	06/10/17	1,421	1,932
05/06/17	1,539	5,528	05/24/17	3,001	13,254	06/11/17	1,489	10,200
05/07/17	2,054	30,942	05/25/17	2,994	119,232	06/12/17	0	5,086
05/08/17	2,823	11,400	05/26/17	3,069	282,425	06/13/17	0	9,615
05/09/17	3,060	17,488	05/27/17	2,647	397,096	06/14/17	0	8,780
05/10/17	3,059	7,250	05/28/17	3,002	479,730	06/15/17	0	6,022
05/11/17	3,045	8,115	05/29/17	2,989	203,287	06/16/17	0	3,646
05/12/17	1,919	2,569	05/30/17	2,934	57,904	06/17/17	0	4,279
05/13/17	1,137	1,311	05/31/17	1,967	32,053	06/18/17	0	2,018
05/14/17	1,528	4,481	06/01/17	3,017	37,301	06/19/17	0	1,055
05/15/17	985	3,223	06/02/17	2,951	74,958	06/20/17	0	575
05/16/17	1,535	5,286	06/03/17	2,702	4,670	06/21/17	0	422
05/17/17	2,866	5,304	06/04/17	2,866	32,082			

On the first day of trap operation (April 30th, 2017), there were enough smolts to begin tagging. Therefore, the daily tagging of smolts began on May 1st and continued until June 11th. Tagging was concluded on the advice of Dave Southgate, after two consecutive days of less than 5,000 smolts. Following the final day of tagging, counting continued for 10 days. Smolt numbers gradually declined following the conclusion of tagging then steeply dropped off to less than 1,000 smolts per day during the last two days of counting. Smolt trap operations were terminated on June 21st, by which time a total of 2,267,453 smolts were captured (**Table 1**). During the peak out-migration, between May 25th-29th, 1,481,770 smolts were captured, which constitutes 65% of the smolts captured (**Table 1**, **Figure 21**).

Table 2. The number of tagged smolts recaptured by date. *Note, estimated tag recoveries during periods of bucket dumping for May 26 to May 28 are not included.*

Indicates Day/Date of release for each colour and 10 day tag cycle
W= White; BLK = Black; R = red; G = green; BLU = Blue.
June 11 = last day of tagging for 2017

Date (mm/dd/yy)	Day	W-W	W-BLK	W-R	W-G	W-BLU	R-W-R	G-W-G	BLU-W-BLU	R-W-BLU	R-W-G	Daily Total Recaps
04/30/17	0	0	0	0	0	0	0	0	0	0	0	0
05/01/17	1	0	0	0	0	0	0	0	0	0	0	0
05/02/17	2	0	0	0	0	0	0	0	0	0	0	0
05/03/17	3	0	0	0	0	0	0	0	0	0	0	0
05/04/17	4	0	0	0	0	0	0	0	0	0	0	0
05/05/17	5	0	0	0	0	0	0	0	0	0	0	0
05/06/17	6	1	0	0	0	0	0	0	0	0	0	1
05/07/17	7	11	7	2	1	0	0	0	0	0	0	21
05/08/17	8	9	5	8	5	3	0	0	0	0	0	30
05/09/17	9	7	7	8	13	5	3	0	1	0	0	44
05/10/17	10	8	3	7	6	5	7	2	1	0	0	39
05/11/17	11	10	13	5	12	15	10	11	14	5	0	95
05/12/17	12	3	5	3	8	1	4	1	9	6	1	41
05/13/17	13	3	1	2	0	0	1	3	3	5	0	18
05/14/17	14	6	5	9	3	5	8	20	22	30	17	125
05/15/17	15	18	12	5	10	8	12	20	43	50	26	204
05/16/17	16	38	28	16	22	6	5	24	37	37	63	276
05/17/17	17	38	16	17	18	2	5	9	26	20	23	174
05/18/17	18	52	33	20	21	11	11	9	18	20	36	231
05/19/17	19	46	25	17	26	13	17	19	14	16	13	206
05/20/17	20	16	14	10	16	12	15	38	27	5	5	158
05/21/17	21	25	13	8	12	12	13	18	23	11	8	143
05/22/17	22	19	5	6	1	5	13	19	32	20	28	148
05/23/17	23	29	10	8	3	4	6	5	17	18	16	116
05/24/17	24	6	6	4	0	0	0	1	1	3	2	23
05/25/17	25	11	23	29	25	2	1	5	3	4	13	116
05/26/17	26	4	4	9	23	29	0	0	0	0	0	69
05/27/17	27	3	4	4	18	15	21	0	1	1	2	69
05/28/17	28	3	3	0	14	10	19	9	1	2	1	62
05/29/17	29	0	0	3	8	6	11	4	18	0	0	50
05/30/17	30	0	0	2	2	2	3	6	11	17	0	43
05/31/17	31	0	0	0	0	3	1	3	5	13	15	40
06/01/17	32	5	0	0	0	0	1	0	0	5	8	19
06/02/17	33	11	19	0	0	1	0	0	0	2	6	39
06/03/17	34	3	6	1	0	0	0	0	0	1	1	12
06/04/17	35	2	6	18	15	0	0	0	0	0	2	43
06/05/17	36	2	4	10	9	16	0	1	0	0	0	42
06/06/17	37	1	0	2	3	6	9	1	0	0	0	22
06/07/17	38	0	0	2	2	9	10	3	1	0	0	27
06/08/17	39	0	0	1	2	4	2	4	1	1	0	15
06/09/17	40	0	0	0	5	1	1	6	1	0	0	14
06/10/17	41	0	0	0	0	2	0	5	9	9	1	26
06/11/17	42	4	0	3	4	3	4	10	27	41	18	114
06/12/17	43	6	4	0	0	1	3	0	4	4	9	31
06/13/17	44	7	18	2	0	2	0	0	1	2	5	37
06/14/17	45	7	11	0	0	0	0	0	0	0	0	18
06/15/17	46	1	1	0	1	0	0	0	0	0	0	3
06/16/17	47	1	0	0	0	0	0	0	0	0	0	1
06/17/17	48	1	2	0	0	0	0	0	0	0	0	3
06/18/17	49	1	0	0	0	0	0	0	0	0	0	1
06/19/17	50	0	0	0	0	0	0	0	0	0	0	0
06/20/17	51	0	0	0	0	0	0	0	0	0	0	0
06/21/17	52	0	0	0	0	0	0	0	0	0	0	0
Sum Totals		418	313	241	308	219	216	256	371	348	319	3009

Following a small peak in early migrant smolts on May 7th, 2017 the daily smolt out-migration declined until May 15th (**Figure 21**). This date approximates the transition between the end of the Early Migrant smolt out-migration from the North Arm of Babine Lake and Nilkitkwa Lake, and the start of Late Migrant smolt out-migration from the main basin of Babine Lake, Hagan Arm, Morrison Arm, Morrison Lake and Tahlo Lake. The transition date was then determined as May 20th using the Parsimonious model which accounts for the intensity of leaving.

The 2017 Early Migrant smolt estimate with standard error (SE) generated by the Parsimonious model based on a transition date of May 20th was 18,500,480 ± 8,377,249. However, the Parsimonious model provided smolt out-migrant estimates for a five day period, spanning May 01 and May 05, during which there were no recaptured smolts. The resulting estimate was exceedingly high and produced a smolt per spawner ratio far greater than what has been observed in all previous years. We therefore considered the Early Migrant smolt estimate and SE generated by the Parsimonious model to be inaccurate. The estimates generated by the Constant Sampling Fraction (CSF)/Excel calculations were considered to be more accurate despite missing the early portion of the Early Migrant group out-migration and no tagged smolts being recaptured between May 01 and May 05. The CSF/Excel estimate was 4,418,501 smolts. Including the actual trap captures from May 01 to May 05, the 2018 Early Migrant group estimate increases slightly to 4,447,244 smolts. To further increase the accuracy of the Early Migrant Group total estimate, the percentage of the daily run that was caught in the trap was calculated for all days where recaptures happened) and plotted to estimate the percentage of smolts that out-migrated from May 01 to May 05 (**Figure 20)**. From day 6 to day 10 (May-6 to May-10) the percentage was nearly identical at an average of 2.3% and was therefore was used to expand the daily sample estimates from days 1 to 5 (May-1 to May-5) to produce daily total run estimates for these days. These were then added to the CSF estimate to produce a final estimate of 5,653,423 smolts for the Early Migrant smolt group in 2017 (**Figure 21**).

Given the uncertainty in the Parsimonious model estimate provided for the Early Migrant smolt group, a pooled, unstratified, unbiased Peterson estimate was generated. The estimate using this method is 4,256,031 ± 199,283. This estimate is lower than the CSF expanded estimate, however since it is pooled (all staple colours treated equally) it incorporates the days with no recaptures. This estimate was provided for additional information only. All further figures and tables use the expanded CSF estimate of 5,653,423 smolts.

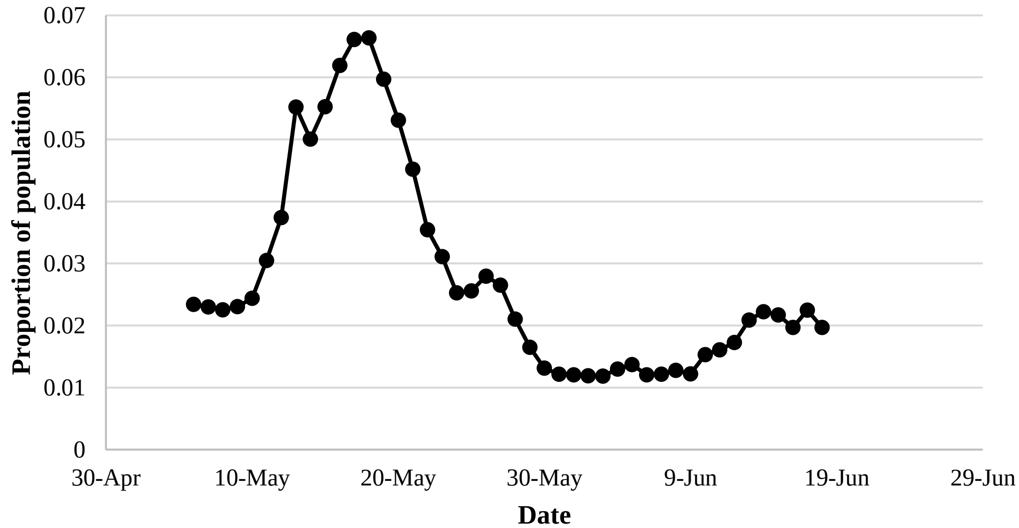


Figure 20: Proportion of daily run estimate caught in the smolt trap, from the CSF model.

The Babine Lake main basin Late Migrant population Parsimonious model estimate, including smolts from unenhanced populations such as the Tahlo, Morrison, Babine Lake main basin tributaries and the enhanced Pinkut Creek and Fulton River populations, was 103,732,802 ± 4,056,170 smolts (**Figure 21**). The total sockeye smolt population parsimonious model estimate (Early + Late Migrants) was 109,017,211 smolts (**Figure 21**).

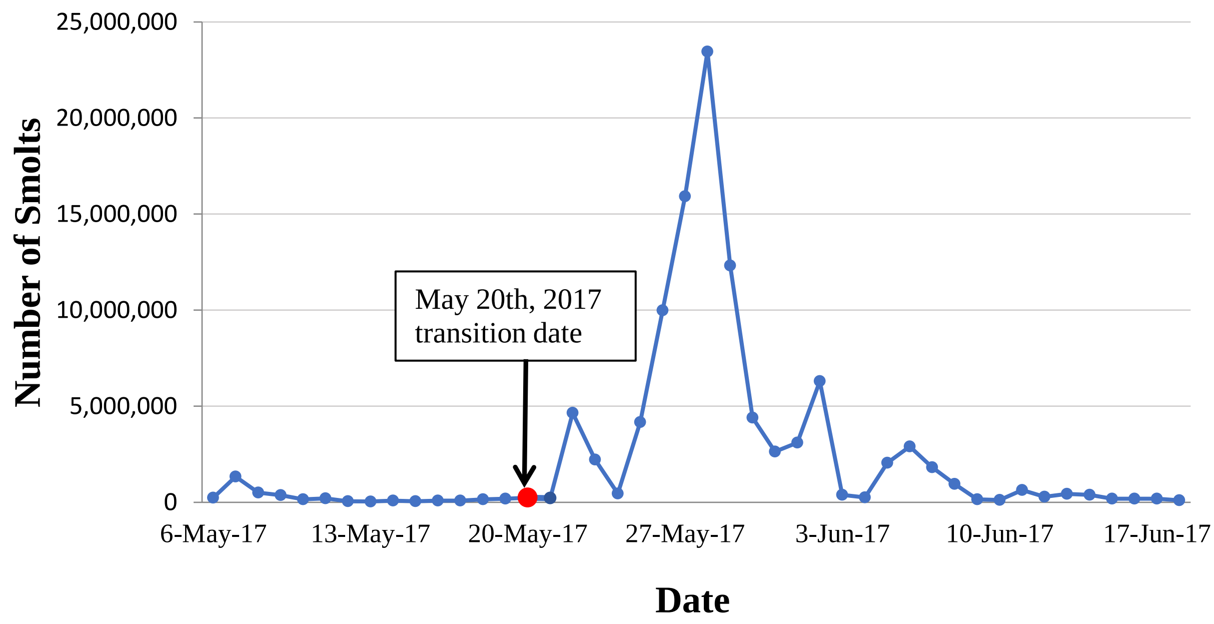


Figure 21. Daily number of smolt out-migrants estimated using the MS excel daily out-migration estimates with data obtained at the lower Babine River smolt trap in May and June 2017.

The Early Migrant, Late Migrant and total number of smolt out-migrants (Early Migrant + Late Migrant groups) estimated using the DFO calculation procedure in MS Excel was 3,808,796, 102,856,196, and 105,917,620 smolts respectively. SE and 95% confidence intervals were not generated in Excel.

As was observed in 2016 for BY 2014, the BY 2015 the confidence interval for the Late Migrant Group estimate of 4% was considerably smaller than the confidence intervals observed for BYs 2011, 2012 and 2013 (**Table 3**). It was postulated by LBNF (2017) that confidence intervals may be influenced by capture efficiency determined by water level. The water level observed in 2017 was approximately 0.5m higher than observed in 2016 for much of the 2017 smolt out-migration period, yet the 95% CI for BY 2015 was lower than for BY 2014. LBNF (2017) also suggested that the condition of tagged smolts, theoretically improved by tagging smolts captured in the morning and held for only a few hours before release, may have improved the representativeness of tagged smolts to that of non-tagged smolts and improved survivability and tag recapture rate. However, the percentage of marked smolts recaptured were very similar for BY 2014 and BY 2015 at 2.86% and 3.01% respectively. No tags were recaptured until May 5th, five days after the first day of tagging (**Table 2**), in comparison to tag recaptures occurring after 3 days in 2016. Later than usual ice-off on Nilkitkwa Lake may contribute to this unusual occurrence as it may indicate a change in the behavior and timing of the Early Migrant out-migration. Out-migration timing and related physiological changes are influenced by photoperiod and temperature (Quinn 2005), hence persistent ice may have contributed to these changes and therefore the unusual timing of the Early Migrant smolt out-migration. The delayed start to out-migration may also account for the later than usual transition date from early to late run smolts.

In contrast to 2016, ice break up on Nilkitkwa Lake and especially the North Arm of Babine Lake was later than usual in 2017. By May 01 the ice in Nilkitkwa Lake was completely gone. Though it is uncertain as to when ice had completely melted in the North Arm of Babine Lake and the Main Basin, it is likely that ice-out occurred later compared to Nilkitkwa Lake, the latter being shallow and receives inflow from the Upper Babine River which generally does not freeze over. Smolts that overwintered in Nilkitkwa Lake may have therefore out-migrated sooner that smolts that reared in the North Arm of Babine Lake which may have delayed the transition date between the Early Migrant and Late migrant smolt populations, it also may have increased the overlap of out-migrating smolt populations (**Figure 17**). If population overlap increased in 2017 due to late ice-off on Nilkitkwa Lake, the change in patterns in the migration could contribute to the unusually high standard error in the early migrant smolt population.

Table 3. Confidence intervals for 2013 to 2016 smolt estimates.

Smolt Out-migrant Group	Brood Year	Smolt Enum-eration Year	Outmigrating Smolt Estimate	Smolt Out-migrant 95% CI	95% CI expressed as Percent of Total Estimate
Early	2011	2013	11,055,413	2,805,675	25
Early	2012	2014	4,259,598	1,885,129	44
Early	2013	2015	1,831,665	1,010,639	55
Early	2014	2016	3,625,574	530,962	15
Early	2015	2017	5,653,423		
Late	2011	2013	112,302,836	14,281,718	13
Late	2012	2014	90,447,943	16,182,862	18
Late	2013	2015	19,883,540	2,594,442	13
Late	2014	2016	53,829,995	3,449,447	6
Late	2015	2017	103,732,802	4,056,270	4
Early + Late	2011	2013	123,358,249	14,554,699	12
Early + Late	2012	2014	94,707,541	16,292,293	17
Early + Late	2013	2015	21,715,205	2,784,335	13
Early + Late	2014	2016	57,455,570	3,490,072	6
Early + Late	2015	2016	109,017,211		

3.3 Smolt Out-migration for Brood Years 2011 to 2015

The total estimated out-migration of BY 2015 sockeye smolts was 109,386,225 (**Table 4**). BY 2015 had the highest escapement of large sockeye since the re-establishment of the mark-recapture program of 762,014 spawners. Though the large sockeye escapement for BY 2015 is slightly higher than the next greatest year, which was BY 2011 with 760,367 sockeye, the number of smolts per spawner is lower for BY 2015. Discharge in the Babine River from mid-June until the end of the calendar year in BY 2011 are well above the historical average, and in some points in August are the historical maximum (WSC, 2018), this may have increased the spawning habitat available, as well as preventing dewatering of eggs and alevin over the fall and winter, potentially increasing egg to fry survival. In the Babine River, discharge for most of the spring and summer in 2015 was higher than average, and just below average from mid-July to October (WSC, 2018). This may have provided good access to spawning habitat, especially in creeks that develop barriers to upstream spawning habitat at lower flows, however it is possible that BY 2015 smolts had higher trap avoidance during their out-migration period as flows during most of that time were above the historical average (**Figure 19**).

Table 4. Total Migrant estimates for brood years 2011 to 2015 and number of smolts per spawner.

Brood Year	Smolt Enumeration Year	Large Sockeye Escapement	Total Estimated Smolts	Number of Smolts per Spawner
2011	2013	760,367	123,358,249	162
2012	2014	702,885	94,707,541	135
2013	2015	307,186	21,715,205	71
2014	2016	670,230	57,455,570	86
2015	2017	762,014	109,017,211	143

The Early Migrant smolt production for BY 2015 (5,653,423) is lower than the historical average (~ 7,000,000), however near average for the recent years (BY 2011 to 2014).

The long-term trend of smolt production is only estimated between BYs 1959 and 2000 as the program was not conducted from BY 2001 to 2010, because of this the trend does not extend to current BYs (**Figure 22** and **Figure 23**).

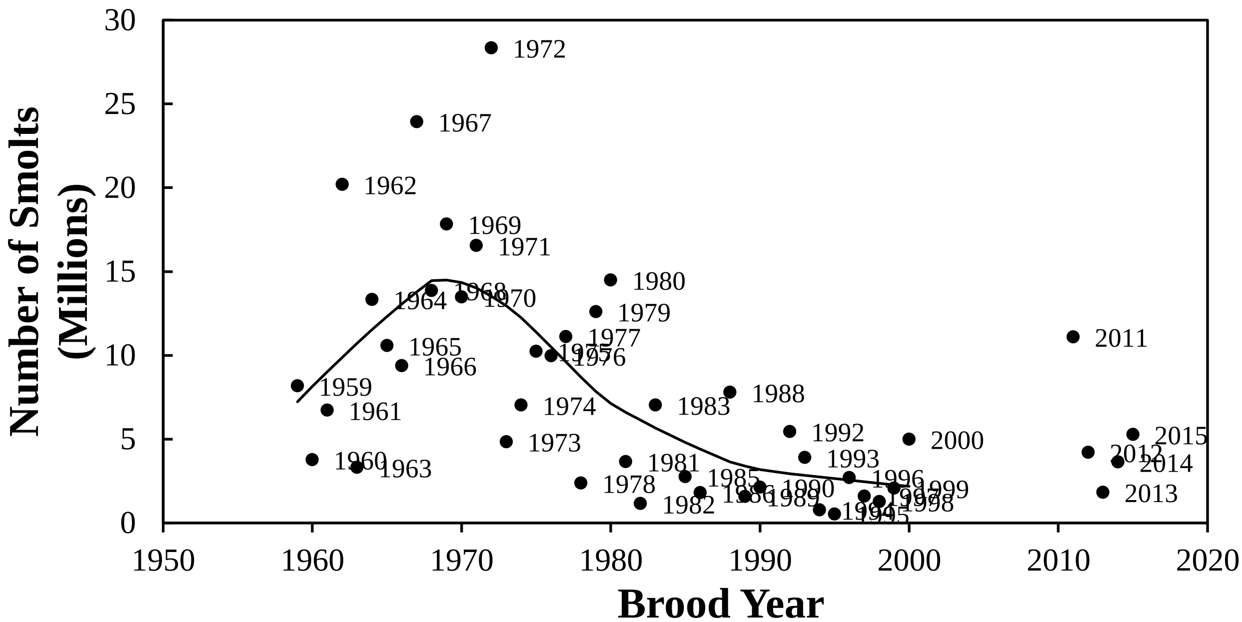


Figure 22. Estimated Early Migrant smolt production from BY 1959 to 2000 and BY 2011 to BY 2014.

BY 2015 Late Migrant smolt production was within historic range (**Figure 23**), the Late Migrant out-migration estimate of approximately 104 million smolts is higher than the historical average of approximately 66 million.

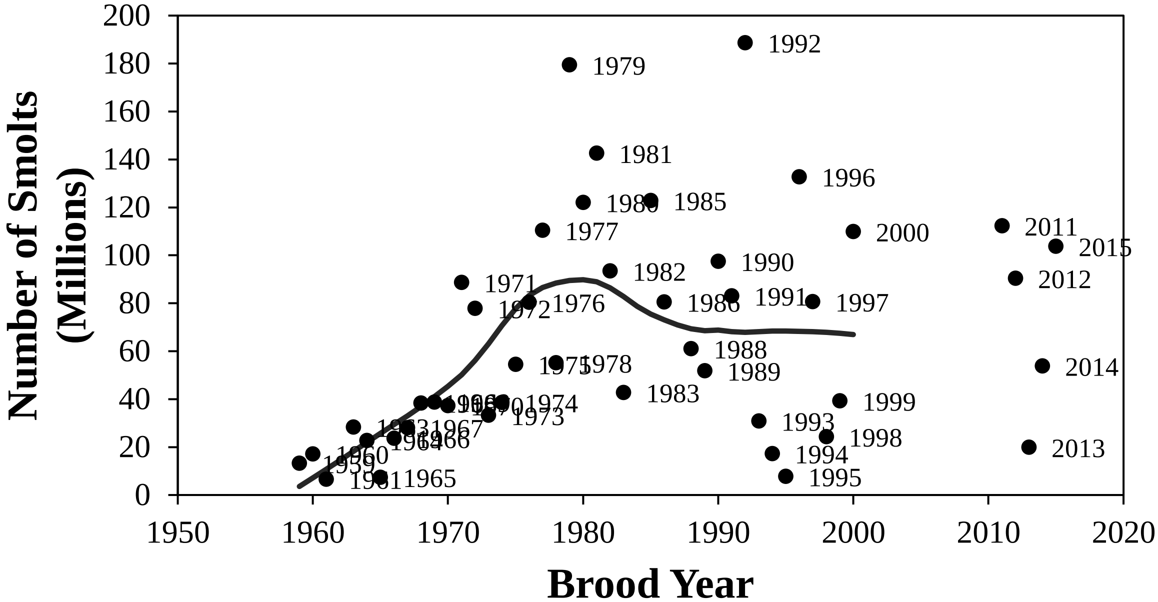


Figure 23. Estimated Late Migrant smolt production for BY 1959 to BY 2000, and BY 2011 to BY 2014.

3.4 Smolt Fitness

3.4.1 Brood Years 2011 – 2014 Length, Weight and Condition

Similar to 2016, the sockeye smolts in 2017 increased in both fork length and weight throughout the out-migration period (**Figure 24**), which may be due to the longer residence time in the rearing lakes and a longer growing season for those smolts out-migrating later in the spring (LBNF 2017).

As in 2016 the frequency of *Eubothrium salvelini* fluctuated highly throughout the season, but had a general downward trend (**Figure 25**). The mean frequency of *E. salvelini* for the Early Migrant smolts was 27%, which is higher than that of the Late Migrant group of 20%. (**Table 5**). The 2017 mean frequencies of *E. salvelini* were lower in both Early and Late Migrant smolts than in 2016, which had frequencies of 44% and 31% respectively. This is contrary to findings in out-migrating smolts from the Babine Watershed between 1952 and 1971, that indicated smolts migrating from Nilkitkwa Lake and the North Arm of Babine Lake, which constitute the Early Migrant run, had a lower mean frequency of *E. salvelini* infection than Late Migrant smolts, or those migrating from the Main Basin of Babine Lake (Smith 1973). These historical mean frequencies of 22% and 26% for Early and Late Migrant smolts respectively are closer to the frequencies observed in 2017 than in 2016, although the data collected between 1952 and 1971 had high inter annual variations of 41% in early Migrants and 39% in Late Migrants. Inter annual variation has remained high since the re-establishment of the program in 2013.

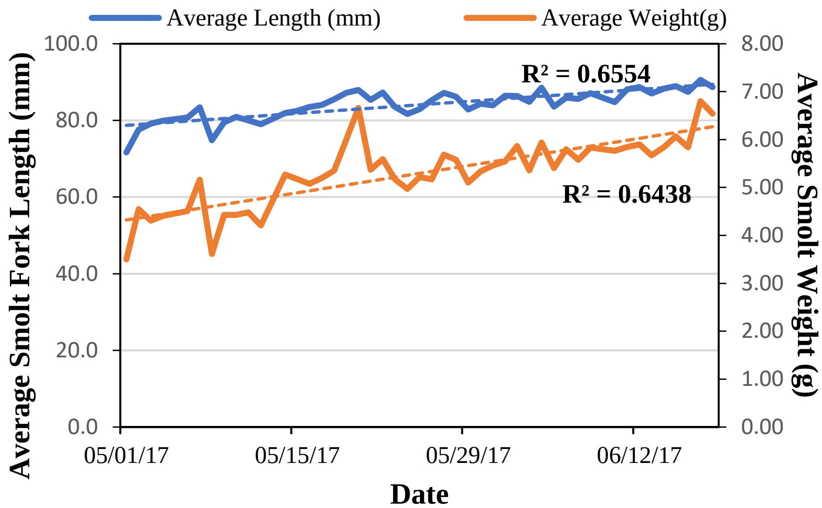


Figure 24. BY 2015 Mean daily smolt fork length and weight.

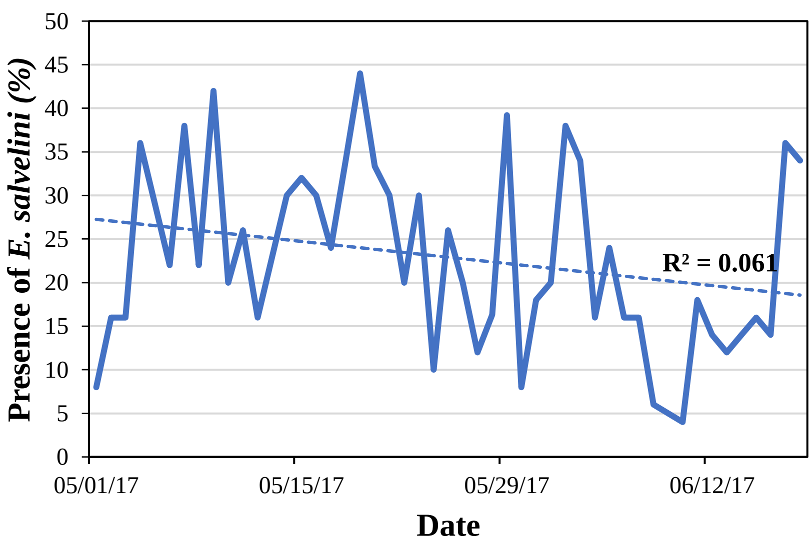


Figure 25. Frequency of *E. salvelini* in BY 2015 smolts during the May to June 2017 smolt out-migration.

The majority of the 2017 smolt fitness data was not normally distributed (Shapiro Wilk Normality Test, $p<0.001$). With the exception of the weights of Early Migrant smolts with *E. salvelini* parasitism and Late Migrant smolts with *E. salvelini* parasitism (Shapiro Wilk Normality Test, $p = 0.2362$ and $p = 0.1151$ respectively).

As with the 2016 results, the 2017 Early Migrants had significantly lower mean fork lengths and weights of 81mm and 4.8g respectively compared to the Late Migrant smolts, which had an average fork length of 86mm and weight of 5.6g (**Table 5**) (Mann-Whitney U test, $p < 0.001$ for both length and weight). Mean condition factor of Early Migrant smolts was also statistically lower than the mean condition factor of the Late Migrant smolts (**Table 5**) (Mann-Whitney U test, $p < 0.001$).

Table 5. Comparisons between Early Migrant smolt and Late Migrant smolt fork length, weight, Fulton Condition Factor and frequency of parasitism by *E. salvelini* (Eubo.) observed during the 2017 Babine Lake watershed smolt out-migration in 2017. Same-letter superscript letters indicate statistically significantly differences between means.

Smolt Migrant Group	n	Mean FL (mm)	Min FL (mm)	Max FL (mm)	FL Std Dev (mm)	Mean Weight (g)	Min Weight (g)	Max Weight (g)	Weight Std Dev (g)	Mean Daily Eubo. Freq. (%)	Mean Fulton Condition Factor
2017 Early Migrants	895	81^{a}	53	103	9	4.8^{b}	1.3	9.6	1.5	27	0.8141^{c}
2017 Late Migrants	1400	86^{a}	60	107	7	5.6^{b}	1.9	11.4	1.3	20	0.8743^{c}

In 2017 Early Migrant smolts, *E. salvelini* presence did not have a significant effect on the condition factor of the smolts (Mann-Whitney U Test, $p = 0.4408$). However, the mean length and weight of Early Migrants parasitized by *E. salvelini* were significantly larger than those that were not parasitized (Mann-Whitney U test, $p < 0.001$ for both length and weight, **Table 6**).

Table 6. A comparison of mean lengths, weights and Fulton Condition Factors for BY 2015 Early Migrant Babine Sockeye parasitized and not parasitized by *Eubothrium salvelini*. Same-letter superscript letters indicate statistically significantly differences between means.

Brood Year 2015 Early Migrant Group							
	n	Mean FL (mm)	FL Std. Dev. (mm)	Mean Weight (g)	Weight Std. Dev. (g)	Mean Fulton Condition Factor	Fulton Condition Factor Std. Dev.
Not Parasitized	652	80^{a}	9	4.6^{b}	1.5	0.8197	0.2245
Parasitized	243	84^{a}	8	5.2^{b}	1.5	0.7988	0.2283

No significant differences were found in mean weight or condition factor of parasitized versus non-parasitized Late Migrant smolts (Mann-Whitney U test, p = 0.06 and p = 0.14 respectively, **Table 7**). Mean length of Late Migrant smolts parasitized by *E. salvelini* was greater than non-parasitized Lame Migrant smolts (Mann-Whitney U test, p = 0.048), though the difference between mean fork lengths was small (1mm) and possibly biologically insignificant.

Table 7. A comparison of mean lengths, weights and Fulton Condition Factors for BY 2015 Late Migrant Babine Sockeye parasitized and not parasitized by *Eubothrium salvelini*. Same-letter superscript letters indicate statistically significantly differences between means.

Brood Year 2015 Late Migrant Group

	n	Mean FL (mm)	FL Std. Dev. (mm)	Mean Weight (g)	Weight Std. Dev. (g)	Mean Fulton Condition Factor	Fulton Condition Factor Std. Dev.
Not Parasitized	1119	86[a]	7	5.6	1.2	0.8738	0.0778
Parasitized	281	87[a]	7	5.8	1.3	0.8762	0.0765

The BY 2015 results were consistent with previous years' data in that the mean fork lengths for both Early and Late Migrant are similar to each other and to those in the previous four brood years, and that despite the lack of statistical significance, the Late Migrant group has a larger mean fork length than the Early Migrant group (LBNF 2017, **Figure 26**) The 2015 BY Late Migrant group had the longest average fork length (86mm) of any brood year from BY 2011-BY 2015, while the shortest was found in BY 2011 (81mm). The longest mean fork length for the Early Migrant Group was 83mm in 2013.

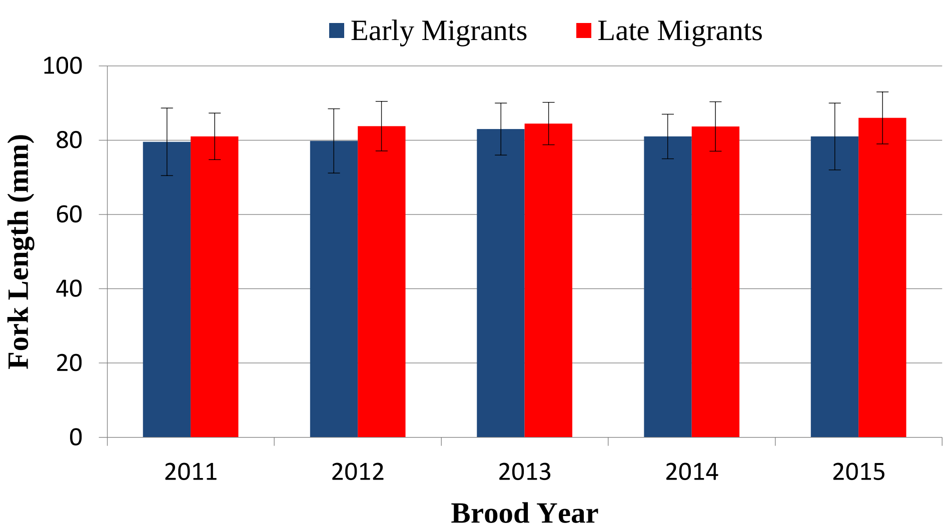


Figure 26. Early and Late Migrant Mean Fork Lengths for brood years 2011 to 2015. Error bars represent ± 1 standard deviation.

BY 2015 Early Migrant mean weights continued a declining trend from BY 2013, before which the mean weights of the Early Migrant group had been rising for two years. The 2015 BY Late Migrant mean weights continued the increasing trend from 2011 to 2014 (**Figure 27**). With the 2017 transition date between early and late migrants being later than usual, this could be due to longer residence in lake basins allowing for more biomass accumulation. There is a larger difference between early and late migrant weights in 2017 than previous years, which may be due to the early start and late end to sampling, which would increase the variation of foraging time in the Lakes before out-migration, and therefore possibly increase the range of weights of smolts migrating out of the Lake throughout the sampling period.

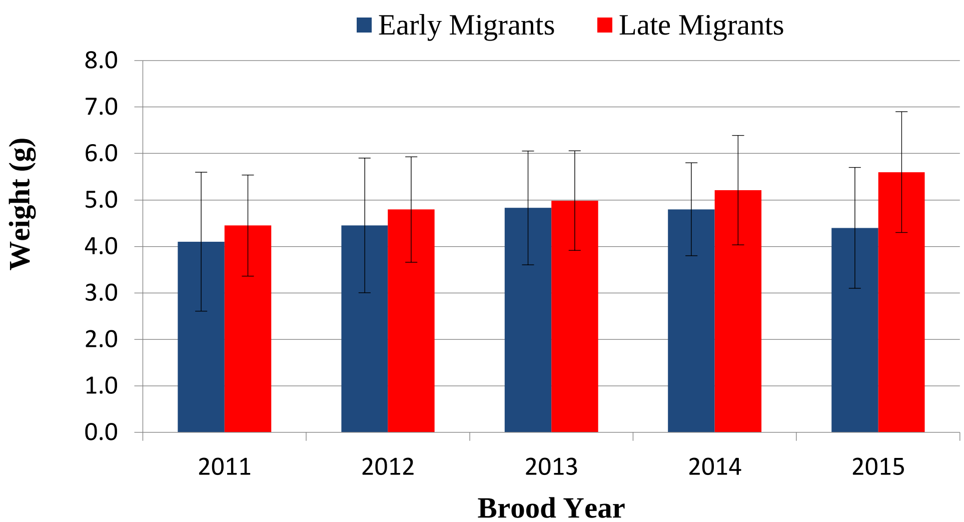


Figure 27. Early and Late Migrant Mean Weights for brood years 2011 to 2015. Error bars represent ± 1 standard deviation.

Mean condition factor for brood years 2011-2015 for both Early and Late Migrant smolts remains similar. The 2017 mean condition factors for Early and Late migrant smolts were higher than previous brood years since 2011, with the exception of the 2014 BY. There is very little difference in the Early and Late migrant condition factors for BY 2015 (**Figure 28**).

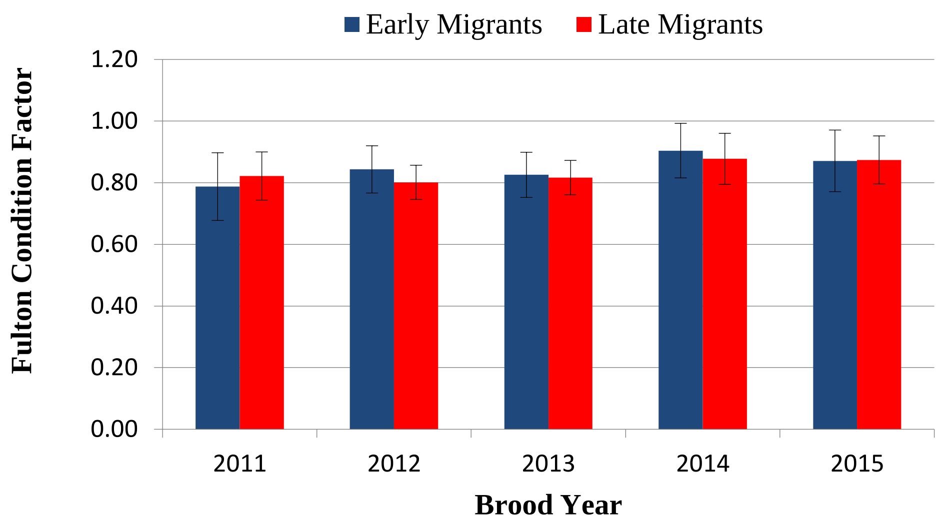


Figure 28. Early and Late Migrant Mean Fulton Condition Factor for brood years 2011 to 2015. Error bars represent ± 1 standard deviation.

The BY 2017 mean frequency of *E. salvelini* for early and late migrants is lower than those of BYs 2012-2014 (**Figure 29**). With BY 2015 frequencies for Early and Late Migrant of 27% and 20% respectively, the average annual *E. salvelini* frequencies for Early (29%) and Late (24%) Migrants remains within the historical ranges observed by Smith (1973) of 6-45% and 5-46% respectively. All BYs since 2011, with the exception of BY 2013, have had higher rates of parasitism in the Early Migrant group compared to the Late Migrant group, which is contrary to the findings of Smith (1973).

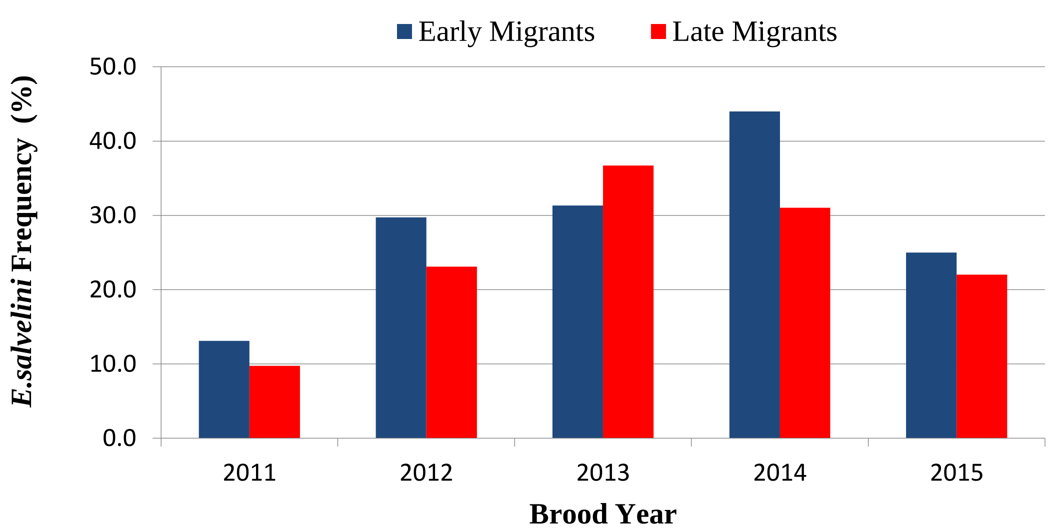


Figure 29. Frequency (%) of parasitization of the cestode parasite *Eubothrium salvelini* in Babine smolts for brood years 2011-2015.

In contrast to the trend of increasing frequency of *E. salvelini* parasitism from BY 2011-BY 2014, there was a sharp decline in *E. salvelini* parasitism in the BY 2015 Early Migrant group (**Figure 29**), however, there is no clear trend in weight, length, or condition factor between 2011 and 2015 brood years.

Between brood years 2011 and 2015 there is a strong positive correlation between *E. salvelini* frequency and Early Migrant mean weight and condition factor, however the correlation is only significant in the case of condition factor (r = 0.781, p > 0.05 and r = 0.870, p < 0.05 for mean weight and condition factor respectively, **Table 8**). There is a non-significant, weak positive correlation between Early Migrant mean fork length and *E. salvelini* frequency (r=0.442, p>0.05). The Late Migrant smolts have a non-significant positive correlation between *E. salvelini* frequency and mean weight, and condition factor, however the correlation between *E. salvelini* frequency and condition factor is very weak (r = 0.387, p > 0.05 and r = 0.087, p > 0.05 for mean length, weight, and condition factor respectively). There was a significant positive correlation between *E. salvelini* frequency and mean fork length of Late Migrant smolts (r = 0.518, p < 0.05, **Table 8**).

Table 8. Correlation between the frequency of *Eubothrium salvelini* and Babine Lake watershed sockeye smolt mean length, mean weight, mean CF for brood years 2011, 2012, 2013, 2014 and 2015.

Metric	Early Migrants				Late Migrants			
	r coefficient	r^2	t-value	Significance (DF= 3)	r coefficient	r^2	t-value	Significance (DF= 3)
Mean Length	0.442	0.20	0.698	p > 0.05	0.518	0.27	0.856	p < 0.05
Mean Weight	0.781	0.61	1.770	p > 0.05	0.387	0.15	0.593	p > 0.05
Mean Condition	0.870	0.76	2.497	p < 0.05	0.087	0.01	0.124	p > 0.05

Two-tail no a-priori critical t-value for n=5, DF=3, = 3.182. Critical t-value = 2.353 for one-tail a-priori

Smolt production for brood years 2011-2015 had an inverse correlation with smolt fitness factors (**Table 9**). As with the 2016 Early Migrant group, there was a significant inverse correlation in the 2017 Early Migrants between total smolt production and mean smolt weight (r = -0.864, p < 0.05, LBNF 2017). This indicates that competition amongst the early migrant smolts is likely, however, it is not evident in the Late Migrant group, where there is a weak non-significant inverse correlation between total smolt production and mean smolt weight (r = -0.154, p < 0.05).

The correlation between total Early Migrant smolt production and *E. salvelini* is strong and significant (r = -0.810, p < 0.05). The Late Migrant smolts also have a very strong inverse relationship between total Late Migrant production and *E. salvelini* parasitism (r = -0.944, p > 0.05, **Table 9**, **Figure 30**). As with the 2016 analysis, this may indicate that total smolt production may be inhibited by *E. salvelini* parasitism (LBNF 2017). Early migrant mean fork length and condition factor had negative correlations with total smolt production, however neither were significant (r = -0.274, p > 0.05 and r = -0.579, p > 0.05 for mean length and condition factor respectively, **Table 9**). The same is the case for Late Migrant smolts' mean fork length (r = -0.274, p > 0.05), however, mean condition factor has a very weak positive correlation with total production, which is not significant (r = 0.037, p > 0.05).

Table 9. Correlations between total smolt production for BY 2011, 2012, 2013, 2014 and 2015 Early Migrant and Late Migrant groups with smolt fitness and frequency of *Eubothrium salvelini* parasitism.

	Early Migrants				**Late Migrants**			
Metric	r coefficient	r^2	t-value	Significance (DF= 3)	r coefficient	r^2	t-value	Significance (DF= 3)
Mean Length	-0.732	0.54	1.863	p > 0.05	-0.274	0.07	0.493	p > 0.05
Mean Weight	-0.864	0.75	2.967	p < 0.05	-0.154	0.02	0.269	p > 0.05
Mean Condition	-0.579	0.34	1.231	p > 0.05	0.037	0.00	0.063	p > 0.05
***E. salvelini* frequency**	-0.810	0.66	2.389	p < 0.05	-0.944	0.89	4.975	p < 0.05

Two-tail no a-priori critical t-value for n=5, DF=3, = 3.182. Critical t-value = 2.353 for one-tail a-priori

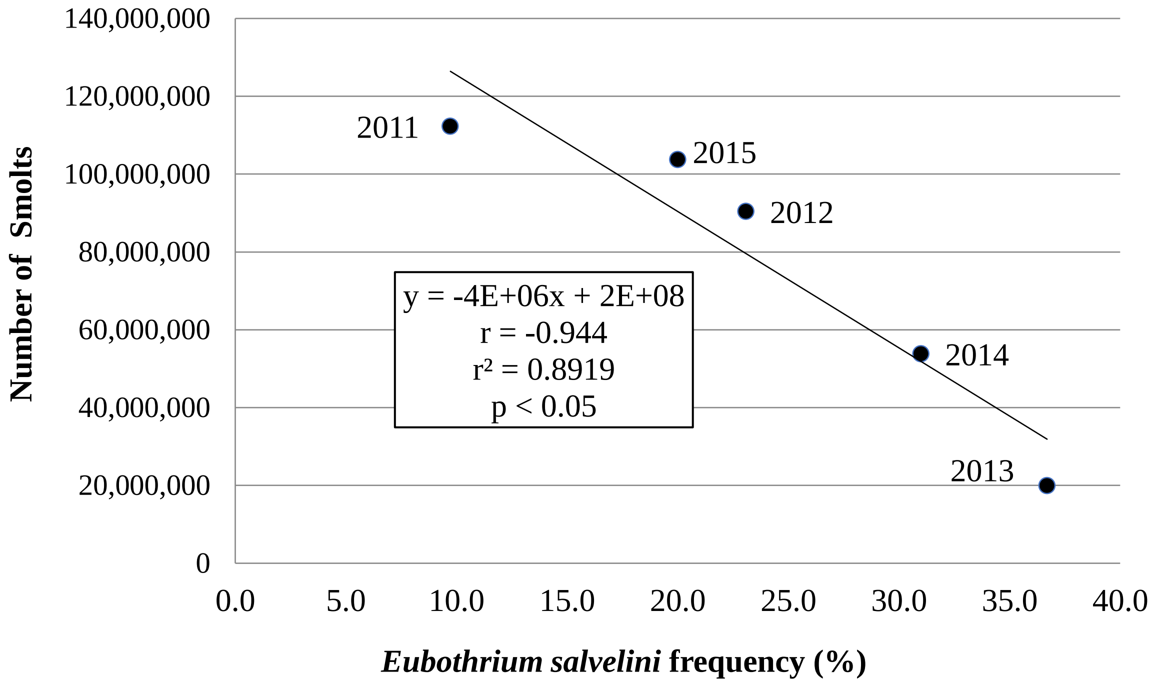


Figure 30: BY 2011 to BY 2015 Late Migrant smolt production in relation to mean daily *Eubothrium salvelini* Parasitization Frequency (%).

As with the 2016 results, the effects of *E. salvelini* were not negative to smolt fitness as would be expected based on previous literature (Boyce 1979, LBNF 2017). Boyce (1979) looked at the parasitism rate of *E. salvelini* in sockeye smolts and found that higher rates of parasitism led to deleterious effects, while the results from lower rates of parasitism were inconclusive. No data on the number of *E. salvelini* worms found in individual sockeye smolts was taken in 2017, the relationship of number of *E. salvelini* individuals and smolt fitness could be explored in the future.

3.4.2 Late Migrant Smolt Weights, Pre-BLDP and Post-BLDP

The Babine Lake Development Project was established to address the concern of limited spawning habitat for sockeye. (Ginetz 1977). Three spawning channels were constructed by 1971 (Cox-Rogers and Spilsted, 2012). Since 1950, there has been a declining trend in mean Late Migrant smolt weight (**Figure 31**).

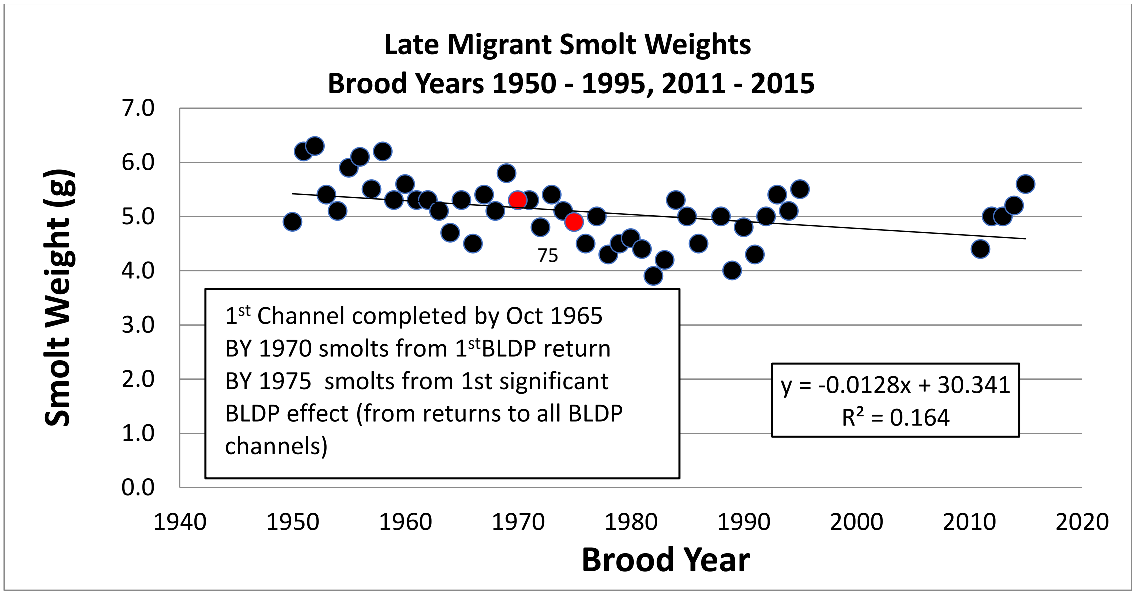


Figure 31. The Long-term trend in Babine Lake sockeye Late Migrant smolt weights for brood years 1950-2002 and brood years 2011 to 2015. 1970 = the first sockeye middle run return affected by the BLDP; 1975 = the first sockeye Babine Lake main basin return dominated by BLDP (BY 1950 to BY 2000). *Data courtesy of Cox-Rogers and Spilsted (2012)*.

Between 1950 – 1969, before the BLDP, smolt weight had a downward trend, with a weak correlation coefficient (r = -0.4032, **Figure 32**). Since 1970, almost no correlation between brood year and Late Migrant smolt weight was observed (**Figure 33**).

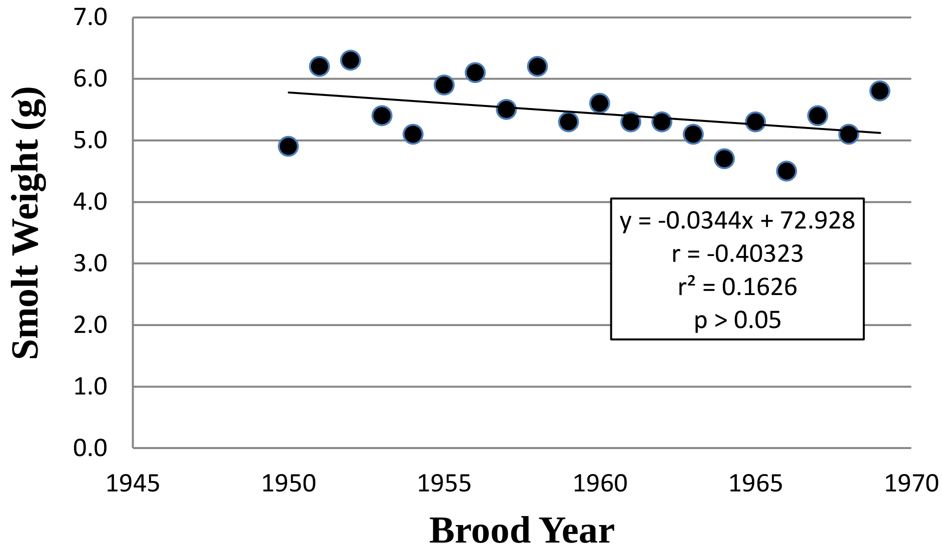


Figure 32. The declining trend in mean Late Migrant smolt weights from 1950 – 1969. *Data courtesy of Cox-Rogers and Spilsted (2012).*

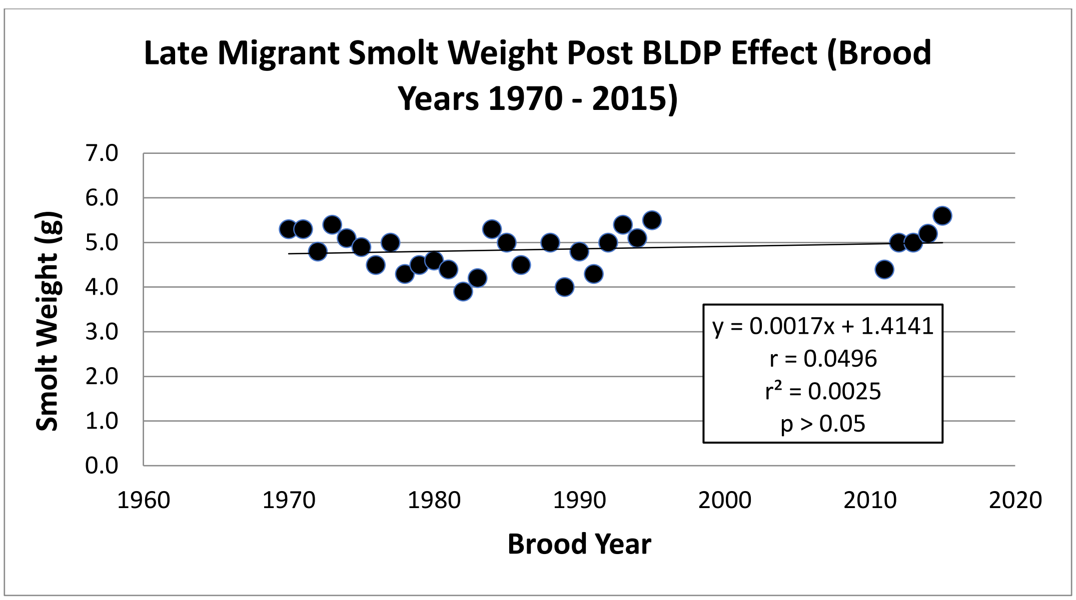


Figure 33. Babine Lake sockeye Late Migrant smolt mean weights Post-BLDP (BY 1970 -1995, BY 2011 – 2015).

The 2015 BY mean Late Migrant smolt weight of 5.6g is the largest weight observed since the BLDP began to have an effect on Babine Lake sockeye populations (**Figure 31**). The BY 2015 smolt weight appears to be an outlier from the modelled trendline of smolt weight versus fry recruitment in the Main Arm. In 2016 it was suggested that the possible increase of zooplankton prey availability due to the low abundance of BY 2013 smolts may have continued into BY 2015 (LBNF 2017). The slightly longer freshwater residence time and later timing of out-migration may have also contributed to the relatively large BY 2015 Late Migrant smolt weight.

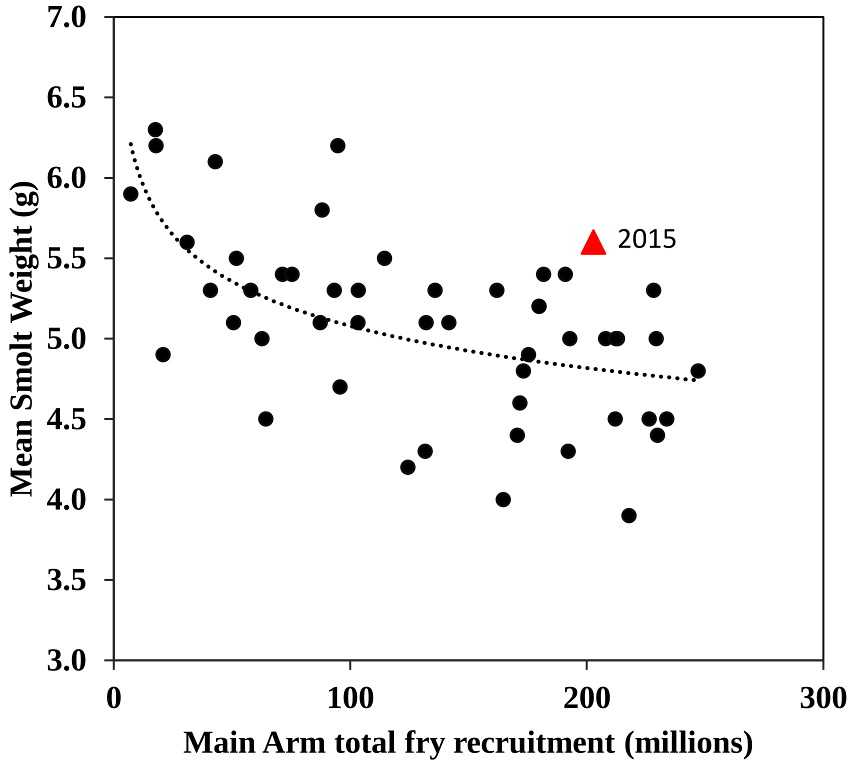


Figure 34. Mean BY 2015 Late Migrant smolt weight (g) in relation to fry recruitment for BY 1960 to BY 1995 and BY 2011 to BY 2015.

3.5 Fry and Smolt Production and Survival

BY 2015 Late Migrant smolt population estimate of 103,732,802 ± 4,056,270 is greater than both the mean estimate since BY 2011, which is approximately 76 million and the mean estimate across all years of the program since 1959 of approximately 66 million (**Figure 35**). The Late Migrant smolt population estimates saw an increasing trend from the beginning of the program in 1959 until 1980, after which time, the trend population estimates decreased rapidly until the late 1980's then stabilized. Since the early-1970's, the interannual variation has increased, indicating that the variation in population estimates from year to year may be cause by the smolts out-migrating from BLDP spawning channels.

Fry to smolt survival follows a similar trend, increasing from the beginning of the smolt program until 1979, followed by a sharp decline until 1991 and an upward trend since. At approximately 51%, the 2015 BY fry to smolt survival is greater the historical average of approximately 39%, and the recent average of ~45% since BY 2011.

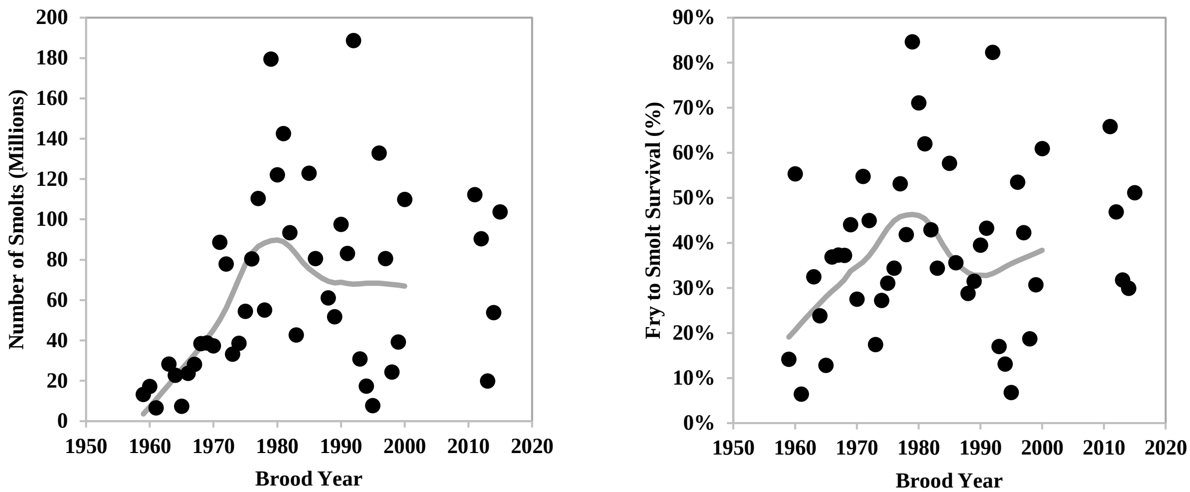


Figure 35. Trends in estimated number of smolts and fry-to-smolt survival for Late Migrant smolts for BYs 1959 to 2000 and 2011 through 2015. The dark grey trend lines are fitted by LOESS (n=20) in Excel. *BY 1959 to BY 2000 data from Cox-Rogers and Spilsted (2012)*.

The BY 2015 Early Migrant smolt group had an estimated population of 5,653,423 (**Figure 36**). This estimate is lower than the historical average population estimate for Early Migrant smolts of 7,714,909 but greater than the average population estimate for recent brood years since 2011, which is 5,201,997. Total smolt production of the Early Migrant group had an upward trend from 1959 to 1969, followed by a steep declining trend that began about a decade before that of the Late Migrant population but also continued until the early 1990's before gradually increasing again. This trend is similar to that of Early Migrant fry to smolt survival (**Figure 36**). The percent fry to smolt survival for BY 2015 of approximately 15% is about equal to the historical average, which is also approximately 15%, but lower than the average of the recent brood years since 2011 of approximately 19%.

Brood year 2015 had a higher than average total escapement through the Babine Fence of 1,511,689 (**Figure 37**). The effective escapement, which is the estimate of sockeye that spawn in the wild tributaries of Babine Lake or any of the Babine Lake Development Program spawning channels (Pinkut or Fulton), was the highest since BY 2007. This may have contributed to the higher than recent average total smolt estimate for BY 2015.

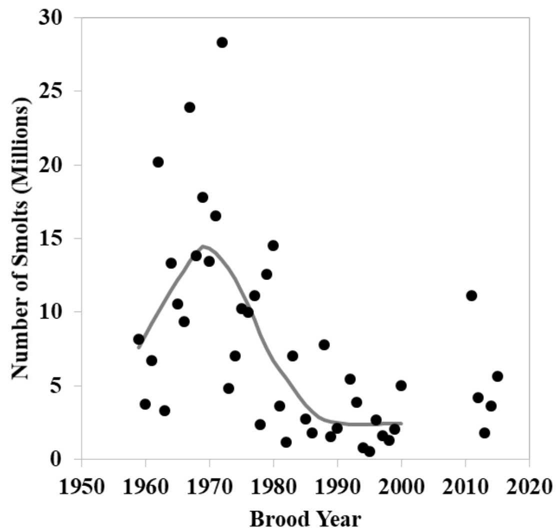


Figure 36. Trends in estimated number of smolts and fry-to-smolt survival for Early Migrant smolts. BYs 1959 to 2000 and 2011-2015. The trend lines are fitted by LOESS (n=20) in Excel. *BY 1959 to BY 2000 data from Cox-Rogers and Spilsted (2012)*.

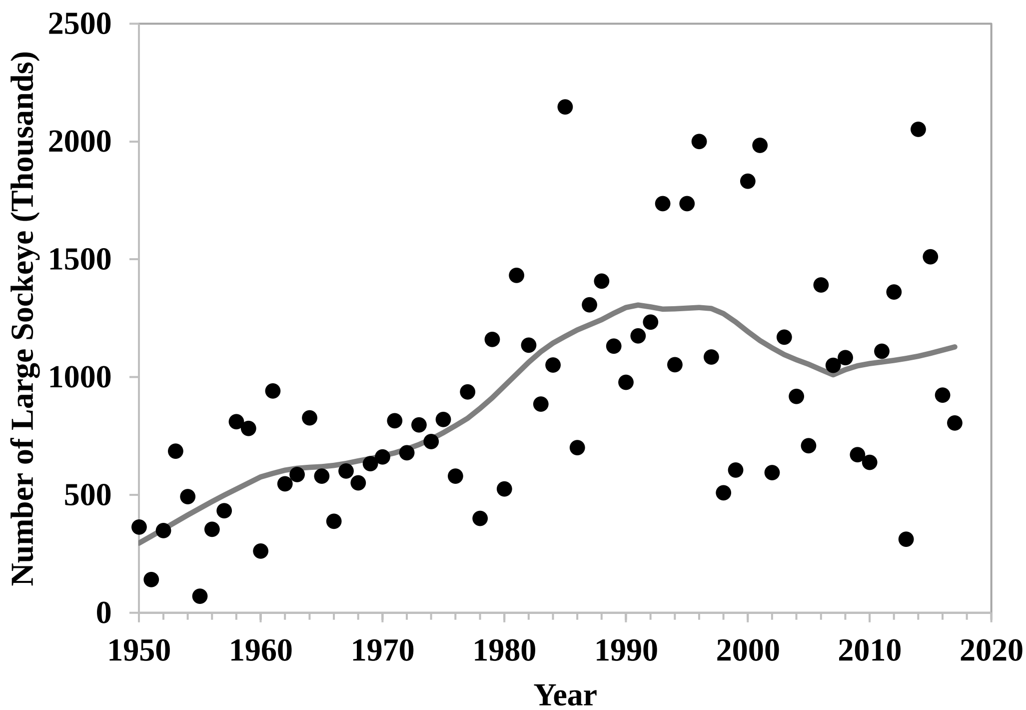
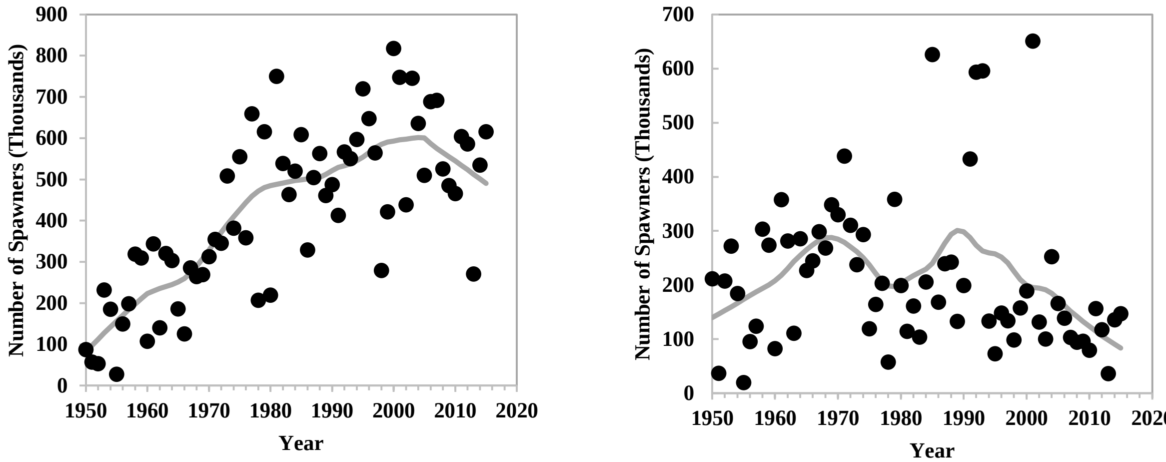


Figure 37. Total sockeye salmon escapement into the Babine Lake Watershed (Babine River adult fence counts) from 1950 to 2016. *Updated data from Cox-Roger and Spilsted 2012*.

The number of spawners that are included in spawner-to-fry or spawner-to-smolt estimates are illustrated in **Figure 38** for the Main Basin (panel (a)) and for the Babine Lake North Arm/Nilkitkwa Lake (panel (b)). There was an escapement of 615,164 sockeye spawners to the Main Basin of Babine Lake. The trend of escapement to the Main Basin increased from 1950 to 2004, and then began to decline. The escapement of BY 2015 sockeye spawners to Babine Lake North Arm/Nilkitkwa Lake (including Babine River) was 146,850, below the historical average, the trend of escapement in the North Arm and Nilkitkwa Lake continues to decline since 1989.



(a) – **Main Basin** (b) – **North Arm/Nilkitkwa Lake**

Figure 38. Trends in estimated spawners for BY 1950-2015 Main Basin (a) and North Arm/Nilkitkwa Lake (b).The dark grey trend lines were fitted by LOESS (n=20) in Excel. *Updated data from Cox-Rogers and Spilsted (2012).*

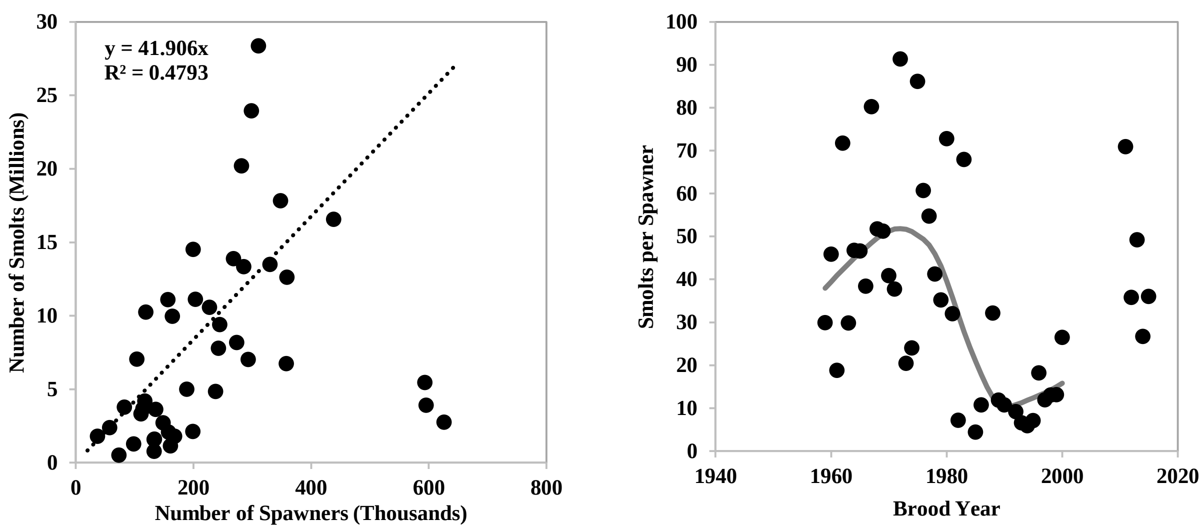


Figure 39. Early Migrant Smolt production in relation to number of spawners and the long-term trend in the number of smolts produced by brood year.

Early Migrant smolt production was significantly positively correlated to annual escapement (**Figure 39**, left panel) (r = 0.3398, p<0.05) indicating a general positive relationship between escapement and smolt production for a given brood year. The relationship is non-linear due to the very low smolt production relative to escapement for BY 1985, BY 1992 and BY 1993 suggesting density dependent embryo and alevin survival at high spawner densities. The low smolt production relative to the very high escapements of approximately 600,000 large adults observed for BY 1985, BY 1992 and BY 1993 Early Migrants may have been caused by redd superimposition which can cause high embryo and alevin mortality (Essington *et al*., 2003). Figure 35 suggests that spawners below 200,000 in the Early Migrant Smolt Group have a very low likelihood of producing high numbers of smolts, whereas escapements between 200-400,000 generally produce large numbers of smolts.

The Early Migrant smolts-per-spawner trend appears to be trending upward based on BY 1995 to BY 2000 and BY 2011 to BY 2014 data (**Figure 39**, right panel). However, this may be due to the very low post-1990 escapements that may result in increased juvenile sockeye fitness and survival in response to reduced intraspecific competition.

Late Migrant smolt production, similar to Early Migrant smolt production, was significantly positively correlated with escapement (r = 0.5180, p < 0.001) (**Figure 40**, left panel). However, escapement only explains 28% of the variation in Late Migrant smolt production about the trend line (r^2 = 0.2804) indicating that factors other than escapement can strongly affect smolt production for a given brood year for both Early Migrants and Late Migrants. Similarly, considerable variation in smolt production in relation to escapement was also apparent for the Early Migrant group.

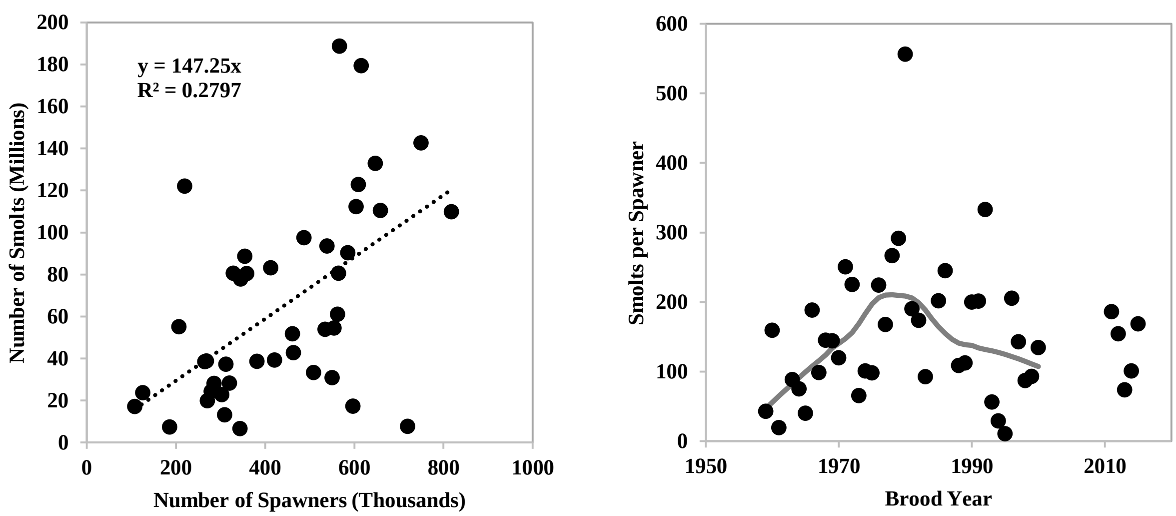
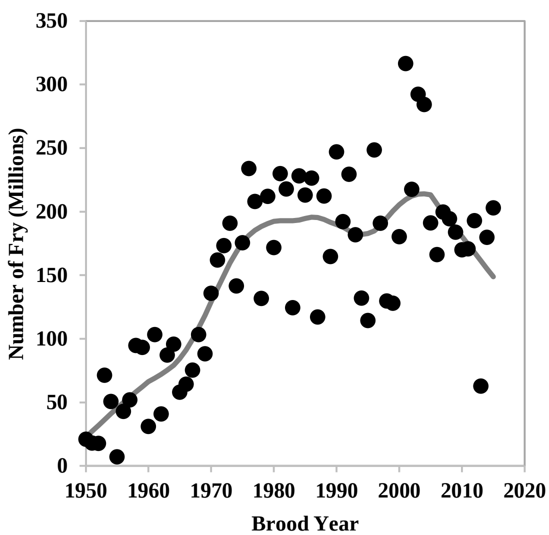
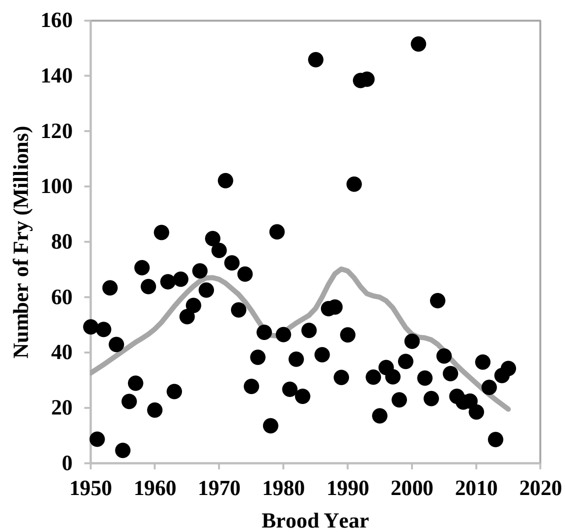


Figure 40. Late Migrant Smolt production in relation to number of spawners and trend in smolts-per spawner. The dark grey trend line in the right hand panel was fitted by LOESS (n=20) in Excel.

Total fry recruitment to the Main Basin (Late Migrant smolts) and to Babine Lake North Arm/Nilkitkwa Lake (Early Migrant smolts) is shown in panels (a) and (b) of **Figure 41** respectively. The BY 2015 fry recruitment to the Main Basin of Babine Lake was estimated to be approximately 203 million, which is higher than the average since 1950 of approximately 150 million fry and the average recruitment since the spawning channels were completed in 1971, of approximately 190 million. The general trend of estimated recruitment of fry to the Main Basin increased from 1950 to the early 1980's followed by smaller increases and decreases, however, the trend of recruitment has been declining since 2007.

The total fry recruitment to the North Arm of Babine Lake and Nilkitkwa Lake is estimated to by approximately 34 million for BY 2015, less than the average since 1950 of approximately 50 million fry (**Figure 41**). Early Migrant group fry recruitment has seen a steep decline since BY 1989 to BY 2015. The number of fry estimated per spawner for each year is 233, which was an estimate based on fry production in the Pinkut and Fulton spawning channel (MacDonald and Hume, 1984). These assumptions have not been tested in the wild tributaries and therefore are likely not representative of actual recruitment from wild tributaries.





(a) – **Main Basin** (b) – **North Arm/Nilkitkwa Lake**

Figure 41. Trends in BY 1950-2015 fry recruitment for the Main Basin (a) and for the North Arm/Nilkitkwa Lake (b).The dark grey trend lines were fitted by LOESS (n=20) in Excel. *Updated data from Cox-Rogers and Spilsted (2012).*

High smolt to spawner survival for BY 2015 may have been due to high flow conditions throughout the migration period and approximately average discharges for the remainder for the calendar year, which likely provided ample flow for egg incubation and overwinter pools for rearing fry (**Figure 19**).

Despite the increase in the trend of total escapement to the Babine Watershed in recent years, effective escapement to both the Main Basin and the North Arm/ Nilkitkwa Lake have seen recent declines (**Figure 37** and **Figure 38**). Fry to smolt survival for both Early and Late Migrant groups has seen a small increasing trend in recent years, however the trend of total smolts has remained about the same (**Figure 35** and **Figure 36**).

4.0 Conclusions and Recommendations

The 2017 sockeye smolt enumeration project was successful in obtaining a low confidence interval for the Late Migrant smolt group. Due to a delay in recaptures the Early Migrant estimate from the parsimonious model had estimated high numbers of out-migrating smolts in the first five days of the program and had an associated wide confidence interval. This led to investigation of previous estimates, which indicated this had happened previously when tag recaptures were delayed for several days. For this reason, it is recommended that the parsimonious model used to generate smolt out-migration estimates be reviewed, especially in cases where tag recoveries are delayed beyond the first day after tagging begins.

In addition, it is recommended that the tagging method be reviewed in regards to tag retention and mortality. It has been proposed that visual elastomer tags may provide a more accurate estimate as they are permanent, in addition to additional information being available once those smolts return as adults.

Further investigation into parasitism by *E. salvelini* is recommended, as there is a clear relationship between total smolt production and frequency of *E. salvelini* (**Figure 30**), however the effect on smolt fitness is not clear. Boyce (1979) found deleterious effects at high levels of parasitism, but unclear results at lower *E. salvelini* frequencies.

Early tagging work showed that the Early Migrant smolts are progeny from Lower and Upper Babine River and Nilkitkwa spawning populations (Wood et al. 1998). Previous genetic work on smolts has been done with microsatellites (Janvier Doire, personal communication) that supports this, however differentiation of Babine Lake populations through microsatellite methods is not highly effective. In 2017 and 2018, tissue samples from 25 smolts per day (taken from lethally sampled biosampled smolts) were collected. Future work with these samples could include the use of newer methodologies (e.g. Single Nucleotide Polymorphisms) that may resolve Babine Lake population structure with a higher degree of certainty.

In the summer and fall of 2017, a preliminary limnological survey was completed by LBNF at a number of stations in Nilkitkwa Lake to assess fry rearing conditions. It was found that key prey (e.g. cladoceran zooplankton such as *Daphnia* and large copepods) were not present in late summer and fall. Furthermore, dissolved oxygen in the lake was below guideline concentrations required for optimal fry rearing. Reduced sockeye fry survival may be a contributing cause to observed declines in Early Migrant smolt production. More intensive limnological monitoring of both Nilkitkwa Lake and the North Arm of Babine Lake throughout the year is needed to determine whether Early Migrant sockeye fry and smolt production is limited by habitat quality and prey availability.

Continuation of the Babine smolt enumeration program is highly recommended, as it provides important information regarding Babine sockeye recruitment. The information collected allows for inferences as to which stages of the life cycle are limiting to escapement. As suggested in 2016, review of the fry-per-spawner multiplier is another important component to understanding sockeye survival in the Babine Watershed. Future work includes the examination of smolt numbers as a factor in predictions for adult returns, given that we now have 5-years in the recent time series.

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