



2015 Babine Lake Watershed Sockeye Smolt Population Estimation Project – Mark-Recapture

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Abstract

2015 Babine Lake Watershed Sockeye Smolt Population Estimation Project – Mark-Recapture

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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. Following 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, the Lake Babine Nation (LBN), in collaboration with the Skeena Fisheries Commission (SFC), successfully resumed the Babine Lake Watershed Sockeye Smolt Enumeration Project, and continued it again in 2014, and 2015 using the mark-recapture protocol employed by the Department of Fisheries and Oceans with some improvements. As in 2014, the marked smolt recovery efficiency during catch examinations was improved with the use of a coded-wire tag detector. Also in 2015, the number of color codes to identify the day a smolt was released was increased to improve accuracy.

The 2015 Babine Lake Smolt Enumeration Project was once again a great success, and an example of a fruitful collaboration between two First Nations organizations, LBN and SFC. Daily out-migrating Babine Lake Watershed sockeye smolt population estimates were calculated for the whole 2015 smolt migration season.

The estimate of the total sockeye smolt population that migrated out of the Babine Lake Watershed in the spring of 2015 was calculated to be 21,715,205 ± 2,784,335.

Introduction

Babine Lake is the largest natural lake in British Columbia, and 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 (Wood *et al.* 1998, McKinnell and Rutherford 1994). This important watershed supports an average annual harvest of up to 1.5 million sockeye in the commercial (Canada and United States), recreational, and First Nations fisheries and an average escapement to spawning of one million.

There is a long history of intensive science and careful monitoring of salmon populations in the Babine Lake Watershed. The Department of Fisheries and Oceans (DFO) has counted adult sockeye returning to the Babine Lake Watershed at the Babine adult counting fence since 1946, and estimated the number of out-migrating sockeye smolts between 1959 and 2002 at a trap located at the outlet of Nilkitkwa Lake, as shown in Figure 3. The data from both the adult and smolt counting fences, and from the Fulton and Pinkut spawning channel fry counts, have historically allowed fisheries managers to estimate sockeye recruitment, and fry to smolt survival in the Babine Lake Watershed. The Babine sockeye smolt enumeration facility was closed in 2002 due to government budget constraints. Available pre-2002 data shows a significant decline in some of the Babine sockeye population fry to smolt survival starting in the mid-1980s (Figure 1). Patterns of freshwater survival (fry to smolt survival) and marine survival (smolt to returning adult) of the Babine sockeye stocks have been unknown since 2002 due to the discontinuation of the program.

Babine sockeye returns have also declined significantly in numbers in the past two decades (Figure 2). As the Babine Lake Watershed sockeye smolt productions of the past ten years are unknown, it is impossible to determine the extent to which the decreasing returns are due to freshwater versus ocean limitations.

Reliable estimates of the sockeye smolt populations leaving the Babine Lake Watershed are required for sound management of the stock. For that reason the Lake Babine Nation (LBN), in collaboration with the Skeena Fisheries Commission (SFC), with funding from the Pacific Salmon Commission (PSC), resumed the Babine Lake Watershed sockeye smolt population estimation project in the spring of 2013 (Doire and Macintyre, 2014), and continued the effort in 2014, and 2015. The objective of the project is to estimate the daily and total number of sockeye smolts migrating out of the Babine Lake Watershed in the spring of 2015 while maintaining consistency with the methodology used by DFO from 1959 to 2002 in order to permit historical comparisons.

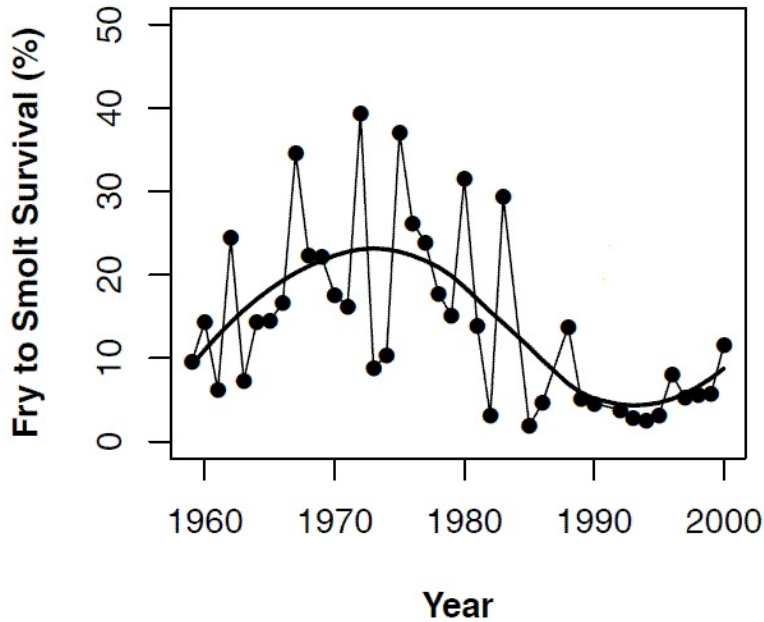


Figure 1. Changes in North Arm of Babine Lake/Nilkitkwa Lake sockeye populations survival during the freshwater component of their life-cycle. Fry numbers were estimated based on spawner counts and smolt numbers were estimated by mark and recapture experiments at the Babine Smolt Fence. The number of eggs per female and the egg to fry survival are based on experience at the Babine spawning channels. Data from Cox-Rogers and Spilsted 2012. Data after the 2000 brood year is not available due to the discontinuation of the program.

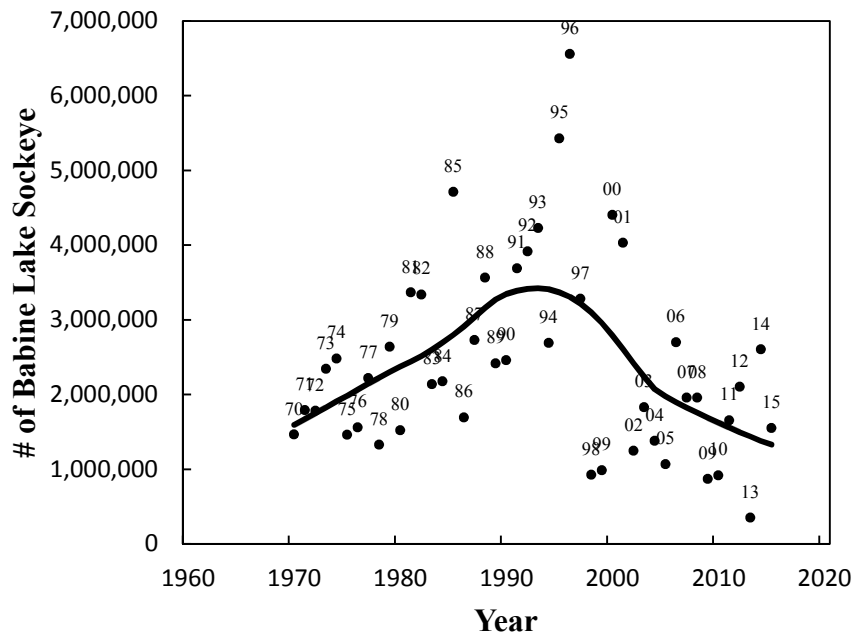


Figure 2. Trends in annual Babine Lake sockeye returns (catch plus escapement), 1970-2015. The trend line is fitted by LOWESS (F=0.5). Updated data from Cox-Rogers and Spilsted 2012. The 2013, 2014, and 2015 data points are interim values.



Figure 3. Map showing the Babine Lake Watershed, and the location of the Babine Sockeye Smolt Enumeration Facility. Map by Gordon Wilson - Gitksan Watershed Authorities.

Methods

2.1 Study Area

The Babine Lake Watershed is located in the Eastern part of the Skeena River Watershed, approximately 70 km northeast of Smithers, BC (Figure 3). During their migration to the ocean, all of the juvenile sockeye rearing within the Babine Lake Watershed travel through the outlet of Nilkitkwa Lake before entering the Babine River. From 1959 to 2002, the DFO operated a smolt enumeration facility (including a trap, associated leads, and a working platform with sheds) at the outlet of Nilkitkwa Lake. The facility was used for the 2015 study, after some basic maintenance work.

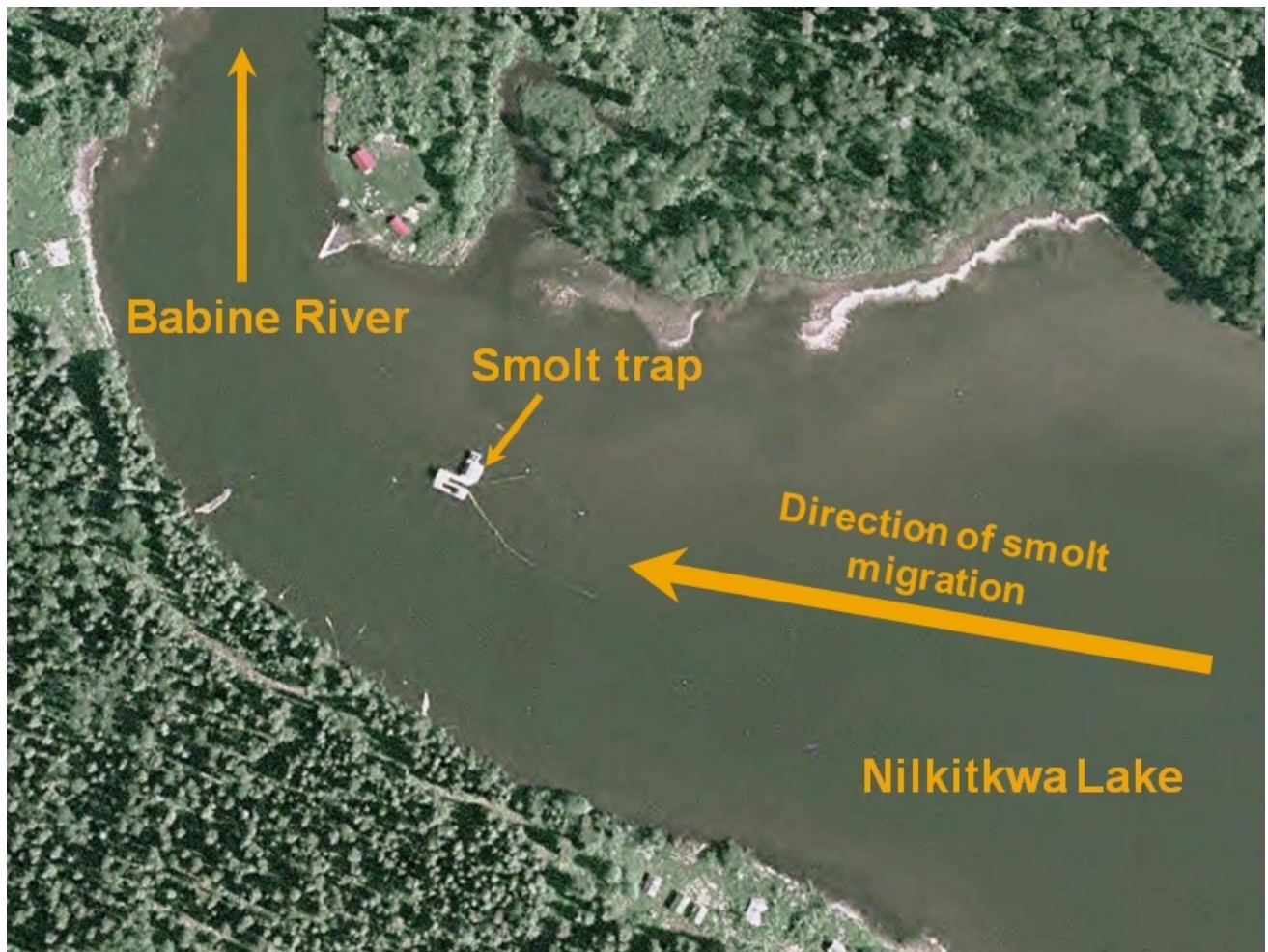


Figure 4. Satellite view of the Babine sockeye smolt enumeration facility, with the associated leads.



Figure 5. Front view of the Babine smolt enumeration facility, with the wire mesh leads, and the entrance to the smolt trap in the middle of the two leads.

2.2 Study Protocol

The mark-recapture sampling techniques and protocol used during this project were those that were extensively developed, documented, and standardized by the DFO and others (Jordan and Smith, 1968, MacDonald and Smith, 1980, and MacDonald et al. 1987).

From April 25th to June 10th 2015, a portion of the daily sockeye smolt run was captured in the fish trap, part of the Babine smolt enumeration facility, located at the north end of Nilkitkwa Lake. The 2015 project started earlier than in 2013 and 2014 because of concerns that sockeye smolts would start migrating earlier than usual, due to earlier timing of ice-off at Nilkitkwa Lake, which was ice-free before April 23rd 2015, when the site was accessed. Despite the early ice-off, the timing of the onset of smolt migration was similar to 2013 and 2014. We began to capture sufficient numbers of sockeye smolt to start tagging on May 3rd. A total of 79,604 captured smolts were tagged from May 4th to May 31st (Table 1). 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 6). New for 2015, twelve (instead 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) describe the tags, and the process of tagging in more detail. The tagged smolts were transferred into a tank filled with approximately 500 liters of aerated lake water, installed on an inflatable boat (Figure 7), and transported to the southern part of Nilkitkwa Lake to be released. Daily numbers of tagged smolts released are presented in Table 1.

Table 1. Daily number of sockeye smolts tagged and released between May 4th and May 31st 2015.

| Date | Number of tagged smolts released | Date | Number of tagged smolts released |
|---------------|---|---------------|---|
| May 4 | 1,005 | May 18 | 2,829 |
| May 5 | 2,512 | May 19 | 3,087 |
| May 6 | 2,968 | May 20 | 2,983 |
| May 7 | 2,992 | May 21 | 3,013 |
| May 8 | 2,926 | May 22 | 3,029 |
| May 9 | 3,063 | May 23 | 3,029 |
| May 10 | 2,982 | May 24 | 3,036 |
| May 11 | 3,012 | May 25 | 2,976 |
| May 12 | 3,043 | May 26 | 3,051 |
| May 13 | 2,996 | May 27 | 3,028 |
| May 14 | 2,932 | May 28 | 3,060 |
| May 15 | 3,067 | May 29 | 3,055 |
| May 16 | 2,868 | May 30 | 3,071 |
| May 17 | 1,009 | May 31 | 2,982 |
| | | Total | 79,604 |

Tagged smolt releases were dispersed over a large area extending 6 to 8 km from the smolt enumeration facility so that they randomly mix with the smolt population migrating through Nilkitkwa Lake. This created a flow of marked smolts mixed with the unmarked smolts migrating through the outlet of Nilkitkwa Lake. Daily count and examination of the smolts captured at the enumeration facility were conducted from May 4th until June 10th (Figure 8), and provided tagged/untagged smolt ratios from which daily run estimates and related standard errors were calculated using the parsimonious model developed by MacDonald and Smith (1980). Daily estimates and standard errors were summed to provide the total estimate for the whole out-migration season, and the related standard error was multiplied by 1.96 to provide the 95% confidence interval.

Again in 2015, a coded-wire tag detector was used as a metal detector to help detect tagged smolt (Figure 8), and minimise human error during smolt examination. There were concerns that an unknown number of tagged smolts may have been missed during the smolt examinations in 2013, resulting in an over-estimation of the migrating smolt population estimate. The use of the coded-wire tag detector is believed to have eliminated the chance of missing tagged smolts during smolt examinations.

Finally, 50 smolts were sampled daily for length and weight measurements, and to record the prevalence of *Eubothrium salvelini*, a parasite affecting the digestive tract of sockeye smolts in the Babine Lake Watershed.



Figure 6. A tagged sockeye smolt before release.



Figure 7. View of the inflatable boat used to release tagged sockeye smolts at the south end of Nilkitkwa Lake. The metal tank was filled with water and held over 3,000 tagged sockeye smolts for transportation.

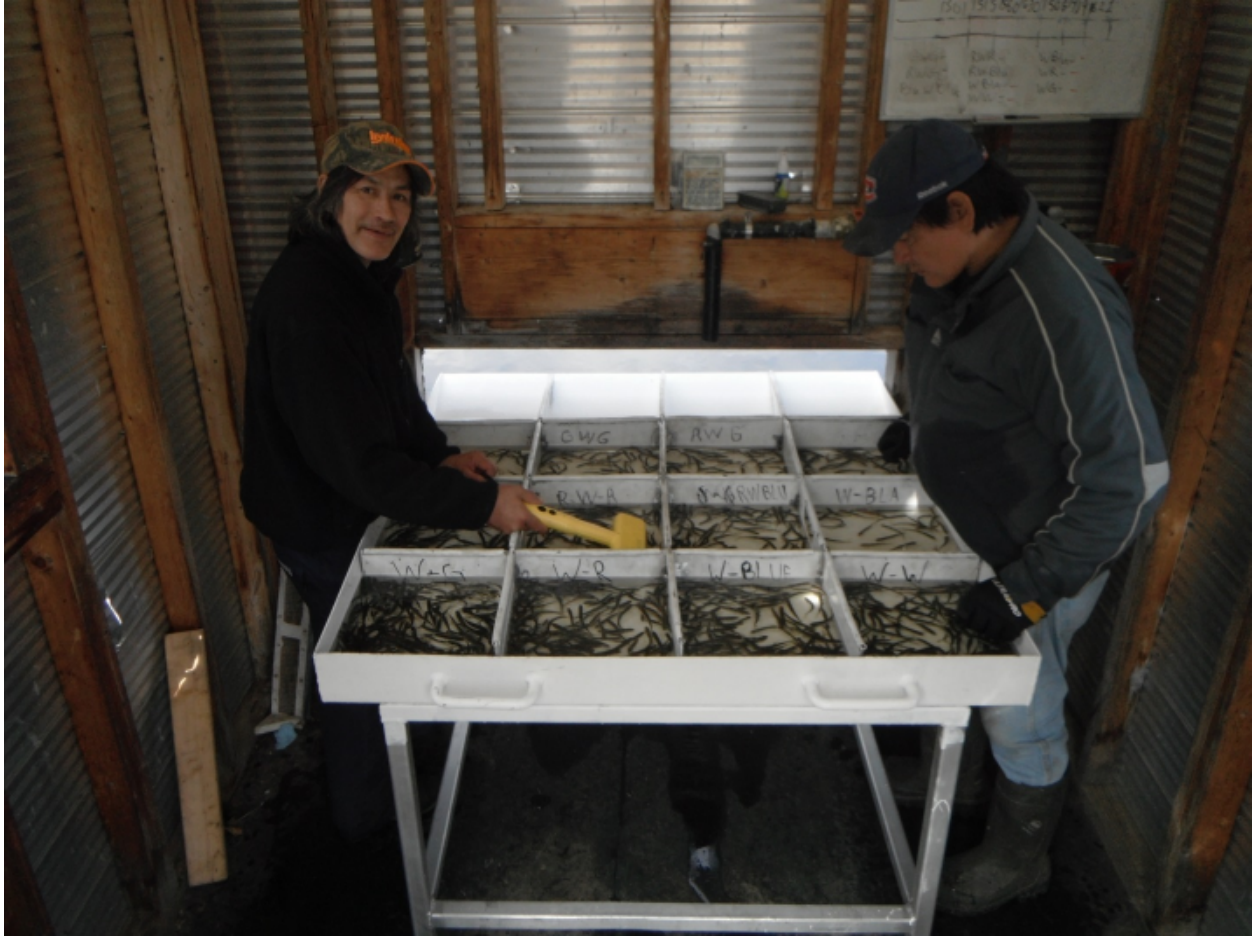


Figure 8. View of two technicians examining sockeye smolt for tags using a coded-wire tag detector as a metal detector.

Results and Discussions

Between April 25th and June 10th, 2015, a total of 675,782 sockeye smolts were captured; of these, 4,665 were recaptured tagged smolts (Table 2).

Table 2. Daily number of tagged sockeye smolts recaptured, and total sockeye smolts captured at the Babine smolt enumeration facility between April 25th and June 10th, 2015.

| Date | Tagged smolts | Total smolts | Date | Tagged smolts | Total smolts | Date | Tagged smolts | Total smolts |
|----------|---------------|--------------|--------|---------------|--------------|--------------|---------------|----------------|
| April 25 | 0 | 2 | May 11 | 305 | 8,356 | May 27 | 21 | 38,532 |
| April 26 | 0 | 4 | May 12 | 347 | 6,485 | May 28 | 106 | 36,236 |
| April 27 | 0 | 1 | May 13 | 287 | 4,285 | May 29 | 124 | 8,236 |
| April 28 | 0 | 6 | May 14 | 146 | 1,686 | May 30 | 158 | 17,788 |
| April 29 | 0 | 5 | May 15 | 212 | 2,413 | May 31 | 128 | 21,872 |
| April 30 | 0 | 4 | May 16 | 116 | 1,053 | June 1 | 30 | 2,765 |
| May 1 | 0 | 430 | May 17 | 288 | 3,379 | June 2 | 6 | 1,827 |
| May 2 | 0 | 106 | May 18 | 505 | 29,684 | June 3 | 4 | 853 |
| May 3 | 0 | 694 | May 19 | 317 | 59,780 | June 4 | 2 | 2,343 |
| May 4 | 0 | 5,853 | May 20 | 325 | 76,330 | June 5 | 1 | 2,619 |
| May 5 | 0 | 5,326 | May 21 | 128 | 70,915 | June 6 | 1 | 1,374 |
| May 6 | 2 | 7,093 | May 22 | 85 | 27,326 | June 7 | 0 | 1,159 |
| May 7 | 18 | 12,388 | May 23 | 235 | 37,693 | June 8 | 1 | 1,954 |
| May 8 | 112 | 23,426 | May 24 | 182 | 59,322 | June 9 | 1 | 1,308 |
| May 9 | 168 | 16,982 | May 25 | 97 | 29,659 | June 10 | 0 | 795 |
| May 10 | 141 | 5,041 | May 26 | 66 | 40,394 | Total | 4,665 | 675,782 |

Figure 9 shows the daily migrating sockeye smolt population estimates between May 4th and June 10th 2015, calculated using the parsimonious model. It shows a clear separation on May 17-18 between the “early” migrating smolt run from the North Arm of Babine Lake and Nilkitkwa Lake, and the “late” migrating smolt run, from the main basin of Babine Lake, Hagan Arm, Morrison Arm, and Morrison Lake. The “early” migrating smolt run population was estimated at $1,831,665 \pm 1,010,639$ (95%CI), and the “late” migrating smolt run population was estimated at $19,883,540 \pm 2,594,442$ (95%CI), for a total smolt population of $21,715,205 \pm 2,784,335$ (95%CI) migrating out of the Babine Lake Watershed in the spring of 2015.

“Early” migrating smolts had an average length of 83.2mm, and an average weight of 4.8g (Table 3). “Late” migrating smolts were of similar size, with an average length of 84.5mm, and an average weight of 5.0g (Table 3). The parasite *Eubothrium salvelini* affected 31.4% of the “early” migrating smolts, and 36.7% of the “late” migrating smolts (Table 3).

2015 Daily Migration Parsimonious

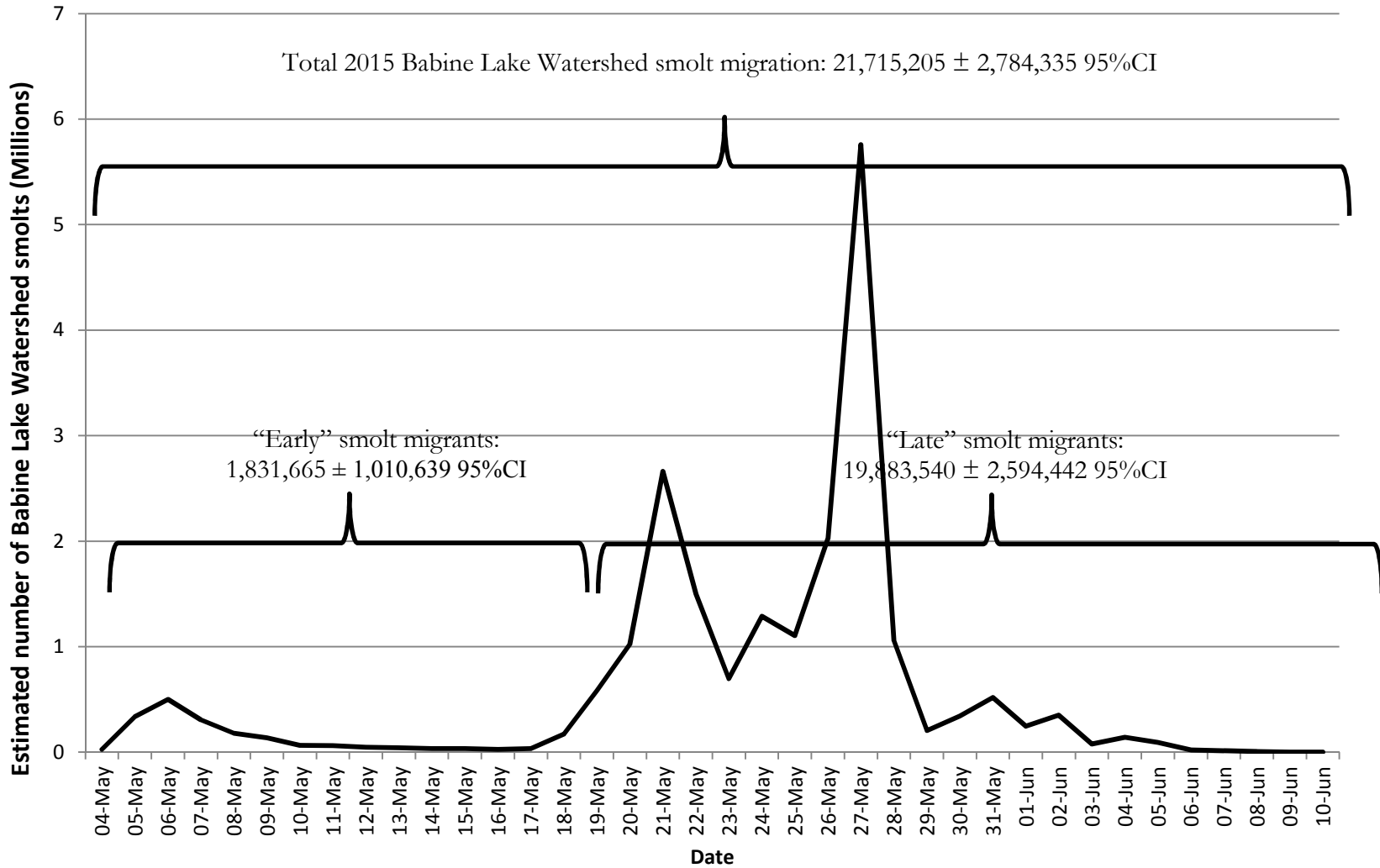


Figure 9. Daily estimated number of smolts migrating out of the Babine Lake Watershed in 2015.



Figure 10. Example of the parasite *Eubothrium salvelini*.

Table 3. 2015 Babine smolt enumeration project smolt sample summary

| | n | Mean Length (mm) | Std. Dev Length (mm) | Mean Weight (g) | Std. Dev Weight (g) | Presence of <i>Eubothrium</i> (%) |
|------------------|----------|-------------------------|-----------------------------|------------------------|----------------------------|--|
| “Early” migrants | 700 | 83.2 | 6.9 | 4.8 | 1.2 | 31.4 |
| “Late” migrants | 1150 | 84.5 | 5.7 | 5.0 | 1.1 | 36.7 |

Figures 10 and 11 compare data from the 2015 Babine sockeye smolt project with historical data. The two figures show the trends in estimated number of smolts, and fry to smolt survival for the “late” (Figure 10), and “early” (Figure 11) smolt migrants for brood years 1959 to 2000, 2011, 2012, and 2013.

The estimated “late” smolt number for brood year 2013 (19.9 million) is significantly lower than historical numbers (Figure 10). It is similar to the low smolt numbers estimated in the early days of the Fulton and Pinkut rivers enhancement facilities, and also similar to numbers observed in the 1990’s (Figure 10). Figure 10 also shows that the fry to smolt survival for brood year 2013 (31.8%) appears to be within historical average, and was certainly higher than the poor survival rates observed in the 1990’s.

Similar observations are made for the “early” smolt migrants. Figure 11 shows that the “late” smolt number estimate for brood year 2013 (1.8 million) is low compared to historical data, but the estimated fry to smolt survival for brood year 2013 (18.2%) was within the historical range

of variation, and well above the very low fry to smolt survival observed in the 1980's and 1990's.

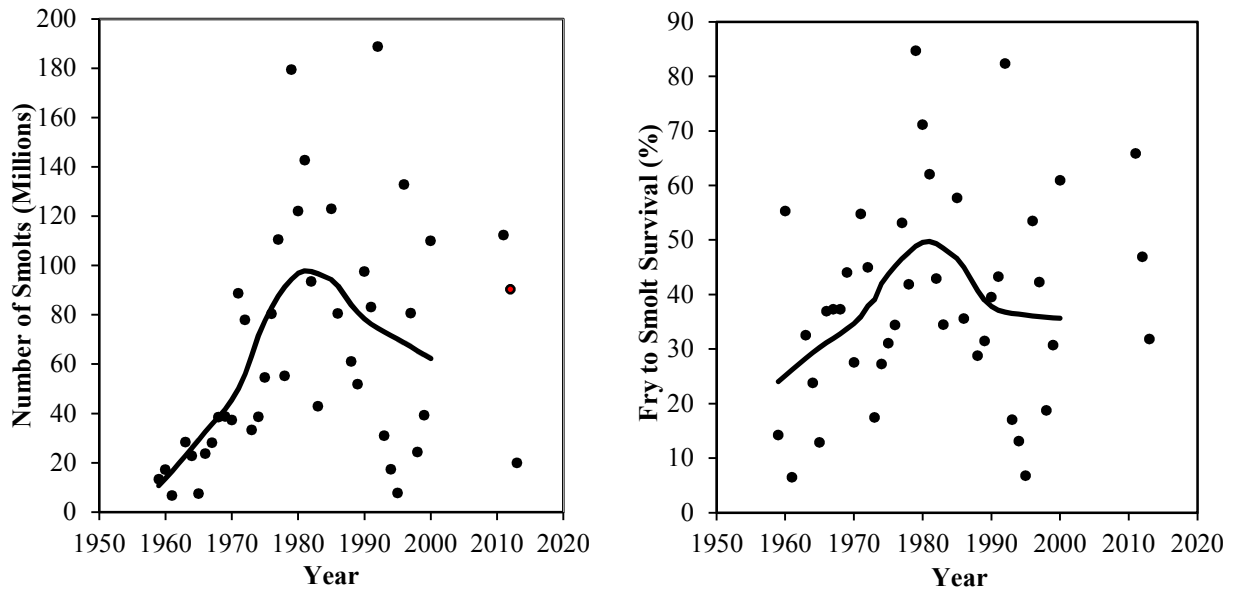


Figure 11. Trends in estimated number of smolt and fry to smolt survival for “late” smolt migrants. Brood years 1959 to 2000, 2011, 2012, and 2013. The trend lines are fitted by LOESS (F=0.5). 1959-2000 data from Cox-Rogers and Spilsted (2012).

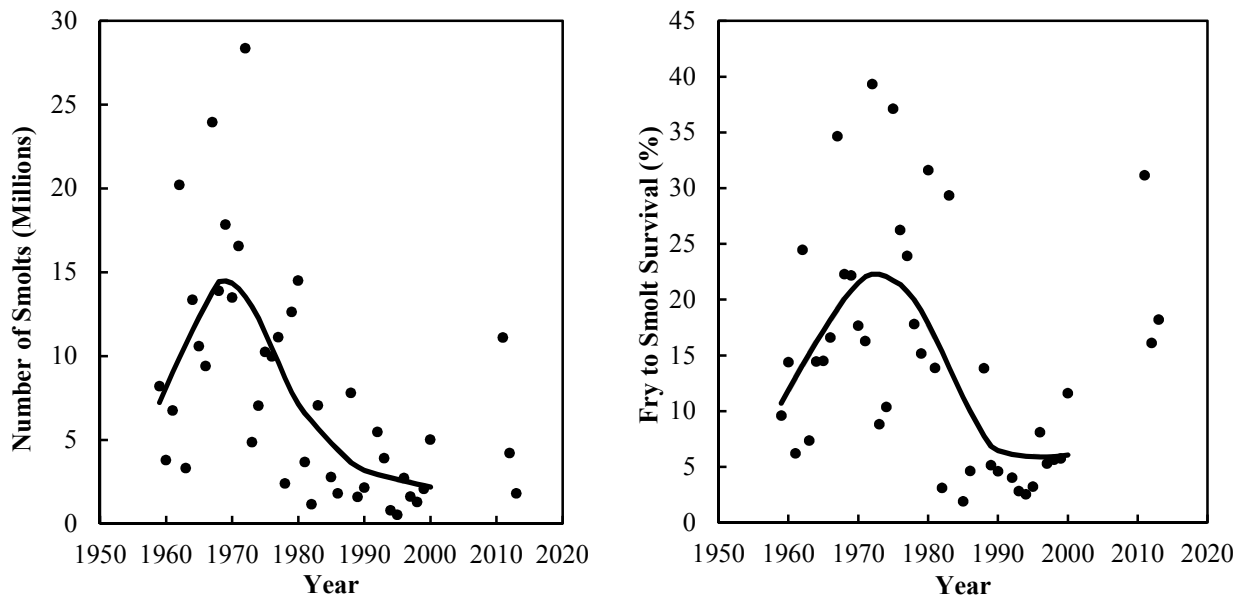


Figure 12. Trends in estimated number of smolt and fry to smolt survival for “early” smolt migrants. Brood years 1959 to 2000, 2011, 2012, and 2013. The trend lines are fitted by LOESS (F=0.5). 1959-2000 data from Cox-Rogers and Spilsted (2012).

Figures 10 and 11 suggest that the brood year 2013 sockeye smolt production from the Main Arm of Babine Lake and the North Arm/Nilkitkwa Lake was not significantly limited by reduced fry to smolt survival. Smolt numbers were mostly limited by the brood year 2013 fry recruitment. Indeed, the brood year 2013 sockeye escapement to the Babine Lake Watershed was the poorest since 1960 (Figure 12), and the extremely low escapement was compounded by pre-spawn mortality problems at the Fulton and Pinkut artificial spawning channels, which resulted in very low fry recruitment estimates to the Main Arm of Babine Lake (Figure 13-a). The brood year 2013 fry recruitment to the Main Arm of Babine Lake was approximately three times lower than the 1970-2010 average (Figure 13-a). Such low fry numbers had not been observed since the mid-1960's, before the first measurable return resulting from the Babine Lake Development Project (BLDP) occurred in 1970 (Figure 13-a). Although less obvious because the late-wild Babine River population has been declining significantly over the last few decades, the brood year 2013 fry recruitment to the North Arm/Nilkitkwa Lake was also very poor compared to historical numbers (Figure 13-b).

Considering the low brood year 2013 fry recruitment to the Main Arm of Babine Lake, a greater fry to smolt survival may have been expected because of reduced competition for food, however depensatory mortality may have prevented an increase in the brood year 2013 fry to smolt survival. Similarly an increase in the mean weight of ‘late’ smolts may have been expected, however Figure 14 shows that the brood year 2013 mean smolt weight was within, not greater, than the historical average.

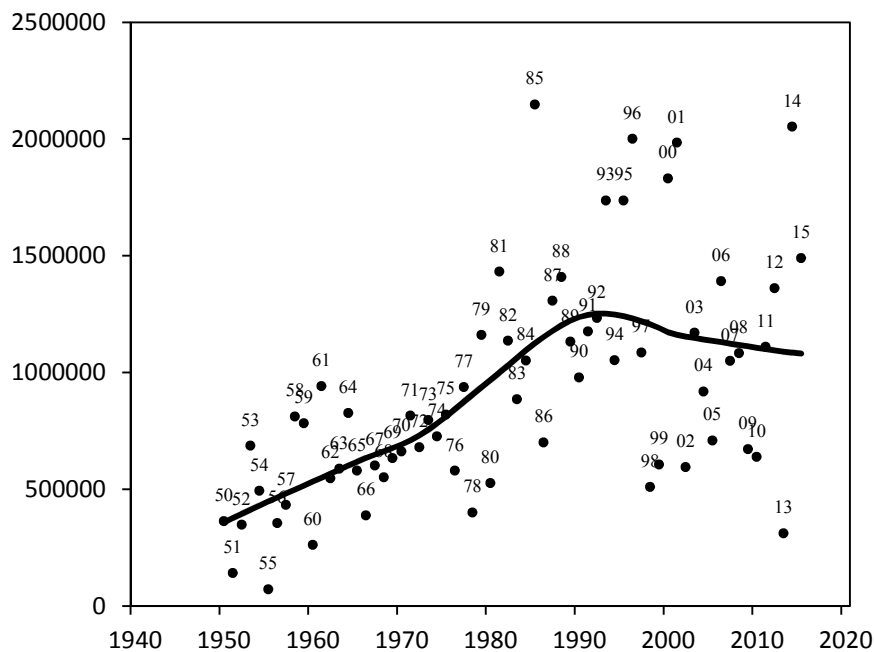
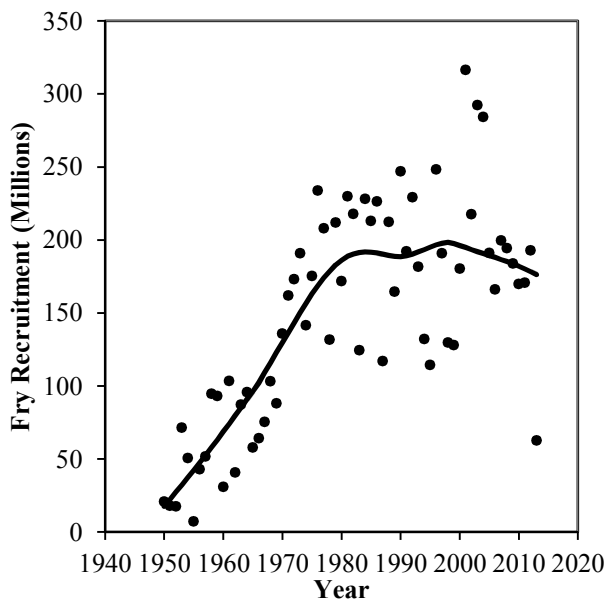
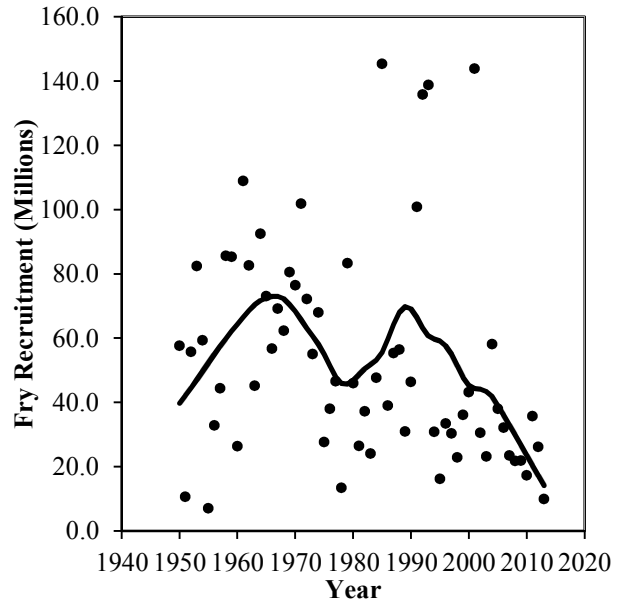


Figure 13. Sockeye escapement to the Babine Lake Watershed (Babine River adult fence counts) 1950-2015. Updated data from Cox-Roger and Spilsted 2012.



a – Main Basin



b – North Arm/Nilkitkwa Lake

Figure 14. Trends in fry recruitment for the Main Basin (a) and for the North Arm/Nilkitkwa Lake (b). Brood year 1950-2013. The trend line is fitted by LOESS ($F=0.5$). Updated data from Cox-Roger and Spilsted 2012.

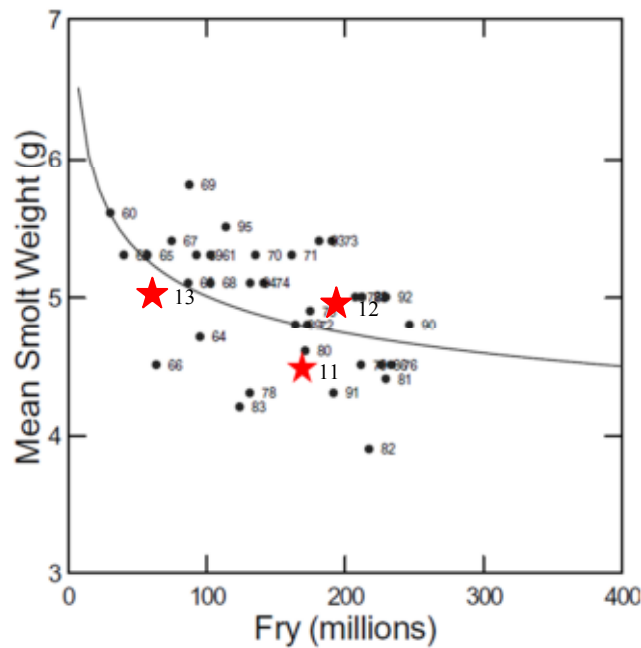


Figure 15. Graph showing the relationship between mean “late” migrant smolt weight and fry recruitment to the Main Arm of Babine Lake from 1960 to 1995, 2011, 2012, and 2013. Line fitted as an exponential function. 1960 to 1995 data from Wood *et al.* (1998).

Conclusions

The 2015 Babine Lake Smolt Enumeration Project was again a success and an example of a fruitful collaboration between two First Nations organizations: LBN and SFC. Daily out-migrating Babine Lake Watershed sockeye smolt population estimates were successfully calculated for the entirety of the 2015 smolt migration season.

The estimate of the total sockeye smolt population that migrated out of the Babine Lake Watershed in the spring of 2015 was calculated to be 21,715,205. It appears that the low 2013 sockeye escapement to the Babine Lake system, pre-spawn mortality problems at the BLDP, and resulting poor brood year 2013 fry recruitment to the Babine Lake Watershed greatly limited the number of sockeye smolts that migrated to the ocean in the spring of 2015. Similar to observations made for brood years 2011 and 2012, freshwater survival for brood year 2013 was within the historical average, and well above the very low fry to smolt survival observed in the 1990's.

The value of the information provided by the 2015 Babine Lake Smolt Enumeration Project will increase when brood year 2013 adults migrate back to the Babine Lake Watershed in 2016 (three years old jacks), 2017 (four years old adult), and 2018 (five years old adults). It will again be possible to calculate smolt to adult ocean survival, and to evaluate the extent to which the decreasing Babine Lake Watershed sockeye returns are due to freshwater versus ocean limitations.

Finally, the Babine Lake Watershed Sockeye Smolt Enumeration Project will continue in the spring of 2016. The same mark-recapture technique will be used including the use of the coded-wire tag detector, which greatly improved the recovery efficiency of tagged fish during catch inspection, and the increased number of color codes to identify marked smolts.

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References

- Cox-Rogers, S., and B. Spilsted. 2012. Updated assessment of sockeye salmon production from Babine Lake, British Columbia. *Can. Tech. Rep. Fish. Aquat. Sci.* 2956, viii, 65p.
- Doire, J., and Macintyre, D. 2014. The Resumption of the Babine Lake Watershed Sockeye Smolt Population Estimation Project. Skeena Fisheries Commission, prepared for the Pacific Salmon Commission.
- Doire, J., and Macintyre, D. 2015. 2014 Babine Lake Watershed Sockeye Smolt Population Estimation Project – Mark-Recapture. Skeena Fisheries Commission, prepared for the Pacific Salmon Commission.
- Jordan, F.P., and Smith, H.D. 1968. An aluminum staple tag for population estimates of salmon smolts. *The Progressive Fish Culturist* **30**, 230-234.
- MacDonald, P.D.M., and Smith, H.D. 1980. Mark-recapture estimation of salmon smolt runs. *Biometrics*. **36**, 401-417.
- MacDonald, P.D.M., Smith, H.D., and Jantz, L. 1987. The utility of Babine smolt enumerations in management of Babine and other Skeena River sockeye salmon (*Oncorhynchus nerka*) stocks. *In: Sockeye Salmon Population Biology and Future Management* H.D. Smith, L. Margolis, and C.C. Wood Eds. *Can Spec. pub. Fish. Aquat. Sci.* **96**. pp. 280-295.
- McKinnell S. and D. Rutherford. 1994. Some sockeye salmon are reported to spawn outside the Babine Lake Watershed in the Skeena drainage. PSARC Working Paper S94-11:52p.
- Wood, C.C., Rutherford, D.T., Bailey, D., and Jakubowski, M. 1998. Assessment of sockeye salmon production in Babine Lake, British Columbia with forecast for 1998. *Can. Tech. Rep. Fish. Aquat. Sci.* 2241: 50p.