2015 Hydroacoustic surveys of Nilkitkwa Lake and the North Arm of Babine Lake

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ABSTRACT

Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys in two sockeye salmon rearing lakes in the Babine watershed in 2015. Nilkitkwa Lake and the North Arm of Babine Lake are considered to be the primary rearing areas for the progeny of sockeye salmon which spawn in the lower and upper Babine River, respectively. The main objectives of the surveys were to estimate the total abundance and biomass for the sockeye fry populations and the fish species composition of each lake. Skeena Fisheries Commission previously carried out sockeye fry assessments at Nilkitkwa Lake in 2011 and 2013. Two hydroacoustic surveys were also carried out in the summer and fall of 2013 in the North Arm of Babine Lake by the Department of Fisheries and Oceans in partnership with Skeena Fisheries Commission as part of a larger trophic assessment of Babine Lake. Results from the 2015 hydroacoustic survey were also compared to results from tow net surveys in 1955, 1956, and 1957.

The 2015 sockeye fry estimate for the North Arm of Babine Lake was approximately 4.2×10^6, which was similar to preliminary estimates generated during the summer and fall of 2013, which were approximately 5.4×10^6 and 4.2×10^6 respectively. The resulting fry per spawner ratios in the Upper Babine River calculated for brood years 2012 and 2014 were also very similar. The 2015 sockeye fry abundance estimate for Nilkitkwa Lake of approximately 5.5×10^5 was much lower than estimates for 2011 and 2013, of 9.7×10^5 and 9.8×10^5 respectively despite a significantly larger sockeye escapement to the Lower Babine River in 2014 compared to 2010 and 2012. The poor sockeye fry per spawner ratio observed for brood year 2014 in the Lower Babine River/Nilkitkwa Lake system is concerning. Further investigations into the factors influencing the survival of sockeye fry in the Lower Babine River/Nilkitkwa Lake system are warranted. We present a hypothesis which may explain the poor fry per spawner ratio for Nilkitkwa Lake in 2015 and suggestions for potential remediation measures.

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INTRODUCTION

Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys in two sockeye salmon rearing lakes in the Babine watershed in 2015, including Nilkitkwa Lake and the North Arm of Babine Lake (Figure 1), which are considered to be the primary rearing areas for the progeny of sockeye salmon which spawn in the lower and upper Babine River, respectively. The main objectives of the surveys were to estimate the total abundance and biomass for the sockeye fry populations, and to estimate the fish species composition and biomass of competitor limnetic species in each system.

SFC has conducted mobile hydroacoustic surveys in small lakes throughout the Skeena Watershed since 2005. Data of fall fry abundance obtained by hydroacoustic techniques for sockeye in their critical rearing habitat can be directly compared to lake productivity potential to provide an unbiased estimate of the status of the sampled conservation unit (Cox-Rogers *et. al*, 2004). SFC previously carried out hydroacoustic surveys at Nilkitkwa Lake in 2011 and 2013. Two hydroacoustic surveys were also carried out in the summer and fall of 2013 in the North Arm of Babine Lake by the Department of Fisheries and Oceans (DFO) in partnership with SFC as part of a larger trophic assessment of Babine Lake (Selbie and Pon, 2014). Johnson (1958) also estimated the abundance of sockeye fry in both Nilkitkwa Lake and the North Arm of Babine Lake based on catch per unit of effort with tow nets.

The late-wild Babine sockeye population uses Nilkitkwa Lake and the North Arm of Babine Lake as juvenile rearing habitat (Wood, 1998). Both water bodies are part of the Babine Lake system, which production has increased from 75% to about 90% of the Skeena River sockeye since the construction of spawning channels on the Fulton and Pinkut Rivers as part of the Babine Lake Development Project (BLDP) in the 1960s. The different Babine sockeye salmon sub-populations have distinct run timing, which break into early, mid- and late-timed spawners. Enhanced Babine sockeye salmon populations are mid-timed, and many wild Babine sockeye populations have early or late timing (Hume and Maclellan 2000). Babine Lake sockeye productivity has declined significantly while increasing in variability during the past two decades. Late-wild Babine sockeye returns have declined three-fold since the 1960s, while the other wild Babine sockeye populations (early-wild, and mid-wild) returns have been somewhat more stable. The late-wild Babine population, with distinctive run timing, is also behaviorally distinct from all other Babine sockeye populations. Upon emergence, fry migrate upstream to rear in Nilkitkwa Lake and the North Arm of Babine Lake (McCart, 1967). Other Babine populations migrate downstream upon emergence as fry. This behavioral difference is most likely genetically determined (McCart, 1967). The decline of the genetically distinct late-wild Babine River sockeye population is of concern to many First Nations groups, including Lake Babine Nation (LBN) and SFC.

The North Arm of Babine Lake is located at the northwest end of Babine Lake, extending between the communities of Old Fort to the south and Fort Babine to the north. The North Arm basin covers approximately 5,279 hectares and has a maximum depth of 99 m. Nilkitkwa and the North Arm of Babine lake are separated by a 2 km reach of the Upper Babine river, known locally as “Rainbow Alley”.

Nilkitkwa Lake is located downstream from the North Arm of Babine Lake and approximately 1 km upstream of the Babine River enumeration facility. Nilkitkwa is a clear and relatively productive lake with a surface area of 459 hectares, and a maximum depth of 19m.

Both of Nilkitkwa Lake and the North Arm of Babine Lake are located in the traditional territory of the Lake Babine First Nation.

Table 1. Physical characteristics of Nilkitkwa Lake and the North Arm of Babine Lake

Lake	Watershed	Elevation (m)	Average Depth (m)	Maximum Depth (m)	Surface Area (ha)	Clarity
Nilkitkwa	Babine Lake	710	4	19	459	Clear
North Arm	Babine Lake	712	21	99	5,279	Clear

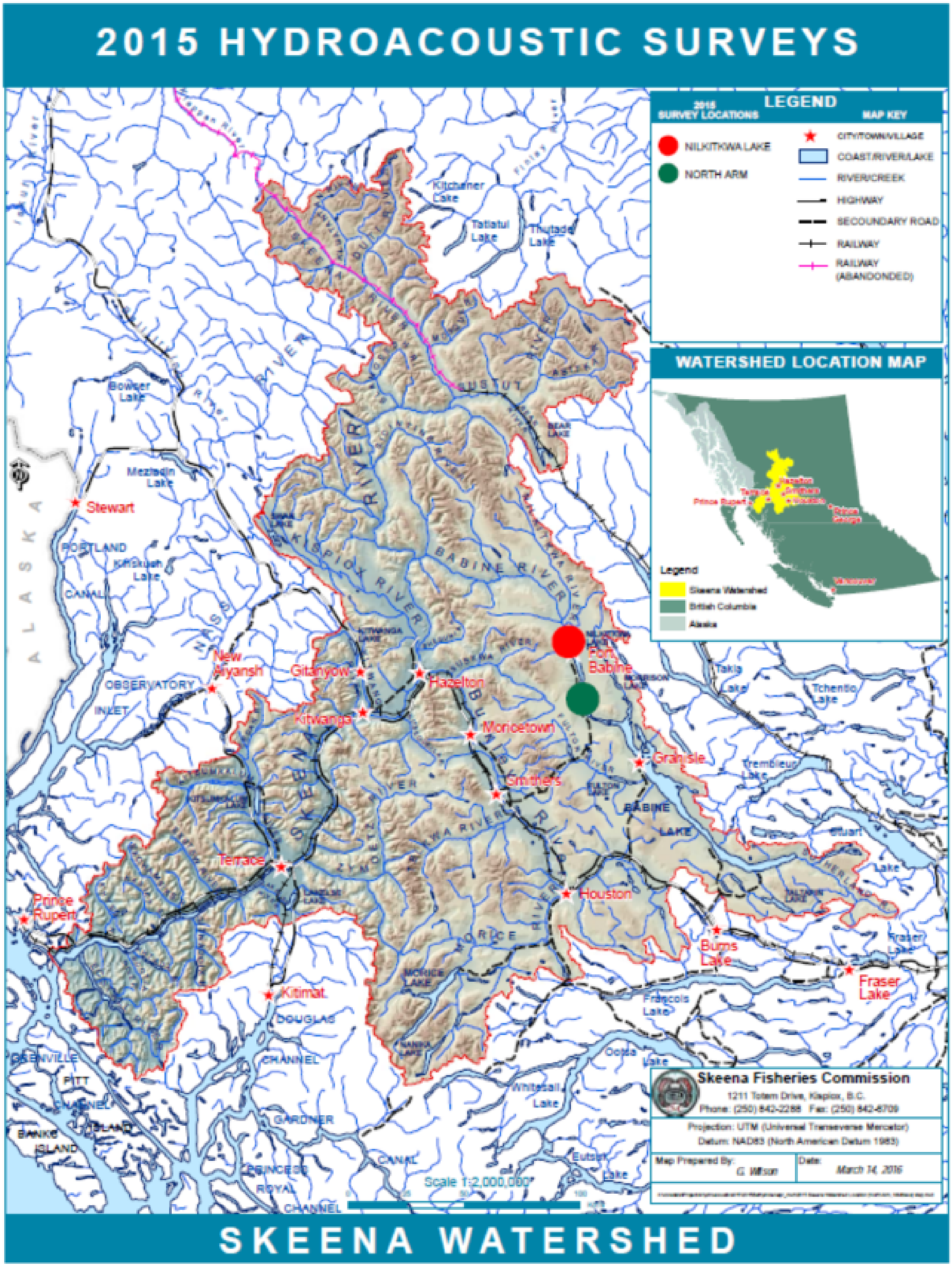

Figure 1. Location of surveyed lakes in the Skeena Watershed.

METHODS

Hydroacoustic Survey

Hydroacoustic surveys were conducted using similar methods and technology as in previous years (Hall, 2007, Hall and Carr-Harris, 2008) and as described in MacLellan and Hume (2010) and Parker-Stetter *et al.,* 2009. Transects were sampled using a Biosonics DT-X echosounder with a down-looking 200 kHz split-beam transducer producing a 6 degree beam, which was pole-mounted to an inflatable vessel, a Bombard Commando C-5 (Figure 2). Hydroacoustic data were collected to an acoustic threshold of -140 dB using Biosonics Visual Acquisition software as the vessel proceeded along transects at a constant speed of 1.0 m/sec.

Figure 2. Photo of the inflatable vessel with the hydroacoustic gear.

The North Arm of Babine Lake survey was conducted along transects established by the Department of Fisheries & Oceans Cultus Lake Research Laboratory (Figure 3). The Nilkitkwa Lake surveys were conducted along fixed transects that were established during SFC's initial survey of that lake in 2011 (Figure 4). The hydroacoustic estimates for Nilkitkwa Lake was based on depth layer volumes that were calculated using bathymetric maps produced from lake depth data collected during the 2011 and 2013 surveys using the DT-X system, combined with existing bathymetric data from the BC Ministry of Environment

Post-processing of hydroacoustic data was performed using Echoview software (v. 6.1.66). Data analysis was conducted using the same methodology as in previous years (Hall & Carr-Harris, 2008, Hall, 2007). Acoustic targets below -65 decibels were eliminated from analysis using the Parker-Stetter (2009) method of linking the Sv threshold to a TS threshold of -71 decibels, in order to include off-axis sub-threshold targets that would exceed the -65 threshold once compensation for their position is applied by the ST, or single target detection algorithm. The hydroacoustic system was calibrated prior to each survey by suspending a standard tungsten carbide sphere (36 mm diameter) in the acoustic beam. The observed target strength was compared to the predicted target strength at that temperature for the standard target. The difference between the observed and predicted target strength produced a calibration offset, which would be applied prior to post-processing of the data.

Following the general guidelines of MacLellan and Hume 2010, only population estimates calculated using the integration method are presented in this report because the total estimated fish densities are significantly above 500 fish/ha for both Nilkitkwa Lake and the North Arm of Babine Lake. The integration method scales the average volume backscattering coefficient (Sv) for each depth layer using the average target strength for the respective depth layer to calculate the volumetric fish density for the stratum (n/m^3).

Primary analysis outputs from Echoview were processed in Excel to calculate estimates of total age-0 *O.nerka* for each lake. Population estimation procedures were consistent with a stratified random transects sampling technique described by MacLennan and Simmonds (2005), and used by MacLennan and Hume (2010), and by SFC (ex. Carr-Harris 2012). Data from each transect were analyzed in 2m depth layers for both lakes. The volumetric densities calculated for each transect layer are multiplied by the layer volume of the lake area represented by that transect to produce a transect layer population estimate. Transect estimates are produced from the sum of layer population estimates. Transect densities are averaged and multiplied by the whole surface area of the lake to produce the total fish estimate for the entire lake or lake section.

The fish estimates were divided into "small" and "large" fish based on the distribution of target strengths from each transect and each layer. "Small" fish were classified as fish with target strengths between –64 and –46 dB. This target strength is approximately equivalent to salmoniform fish <135 mm in length, based on the Love (1977) 45^{o} aspect formula. Small fish were apportioned into "*O. nerka*" and "other small fish" based on the relative proportion of species in the trawl catch. Temperature profiles were also used to assist in determining where juvenile sockeye were likely to be at night based on their apparent preference for temperatures between 6 and 13 °C (Brett 1952).

Confidence intervals (95%) for fish densities and population estimates are determined by using each transect as a separate sample. The variability between transects within a lake or lake basin determines the error estimate around the average density or population estimate.

The variance calculated using the stratified random transects technique reflects the statistical confidence in the precision of the population estimate and is largely driven by the horizontal fish distribution throughout the lake. During data analysis, we observed that most of the fish targets, likely age-0 *O.nerka*, were constrained within specific depth layers, close to the thermocline. The age-0 *O. nerka* density varied greatly from depth layer to depth layer, which contributed to an increase in the variance calculated using the stratified random transects technique. In order to reduce the overall variance, we also used an alternative stratified random population estimation procedure that exploited this vertical distribution characteristic of age-0 *O. nerka,* which was tested by Doire and Carr-Harris, 2013. The area surveyed was stratified by depth layers instead of transect, and each transect provided one replicate for each depth stratum. The mean volumetric fish density was calculated for each depth stratum, and multiplied by the total layer volume to obtain an estimate of abundance for each depth stratum. All the abundance estimates were then summed to a total population for the lake. Variance was calculated for each depth stratum then summed, and the 95% confidence interval was calculated for the whole lake.

Fish Sampling

Pelagic fish were sampled using a 2 m x 2 m midwater trawl, which was deployed to a maximum depth of 35 m. The net was towed behind the boat at a constant speed of approximately 1m/s, and retrieved with a portable winch. The depth of each tow varied according to the length of the line that was deployed; depending on the depth of the lake, which was calibrated and marked prior to sampling. Large fish were counted and released. Small fish were sorted by species and stored in 10% formaldehyde, and weighed and measured after at least 30 days of preservation. Scales were removed and inspected under a compound microscope to determine the age of the salmonids.

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen data were collected at both lakes using a hand held YSI meter (model 85) with a maximum cable length of 30 m. The YSI meter was calibrated to the nearest 100' elevation, and allowed to stabilize for at least 15 minutes before the data was recorded. Temperature and dissolved oxygen were recorded at 1 meter intervals from the surface to a maximum depth of 29 m at both lakes.

Note: The species "*Oncorhynchus nerka*" may include both anadromous (sockeye salmon) and non-anadromous form (kokanee salmon) in both lakes surveyed. Separation of the two forms was not conducted as part of this study. In this report, they will be referred to as "*O. nerka*".

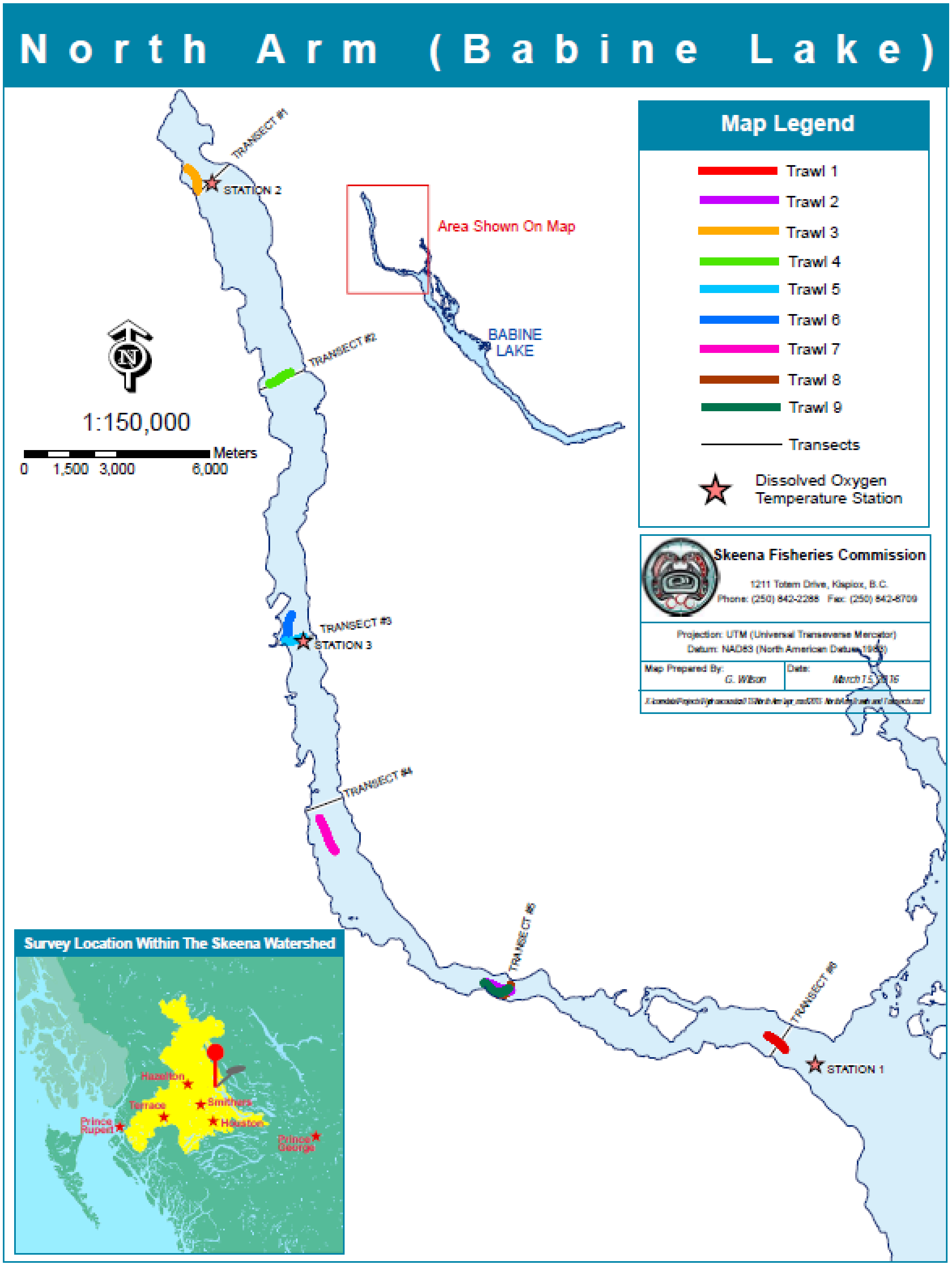

Figure 3. North Arm of Babine Lake survey map.

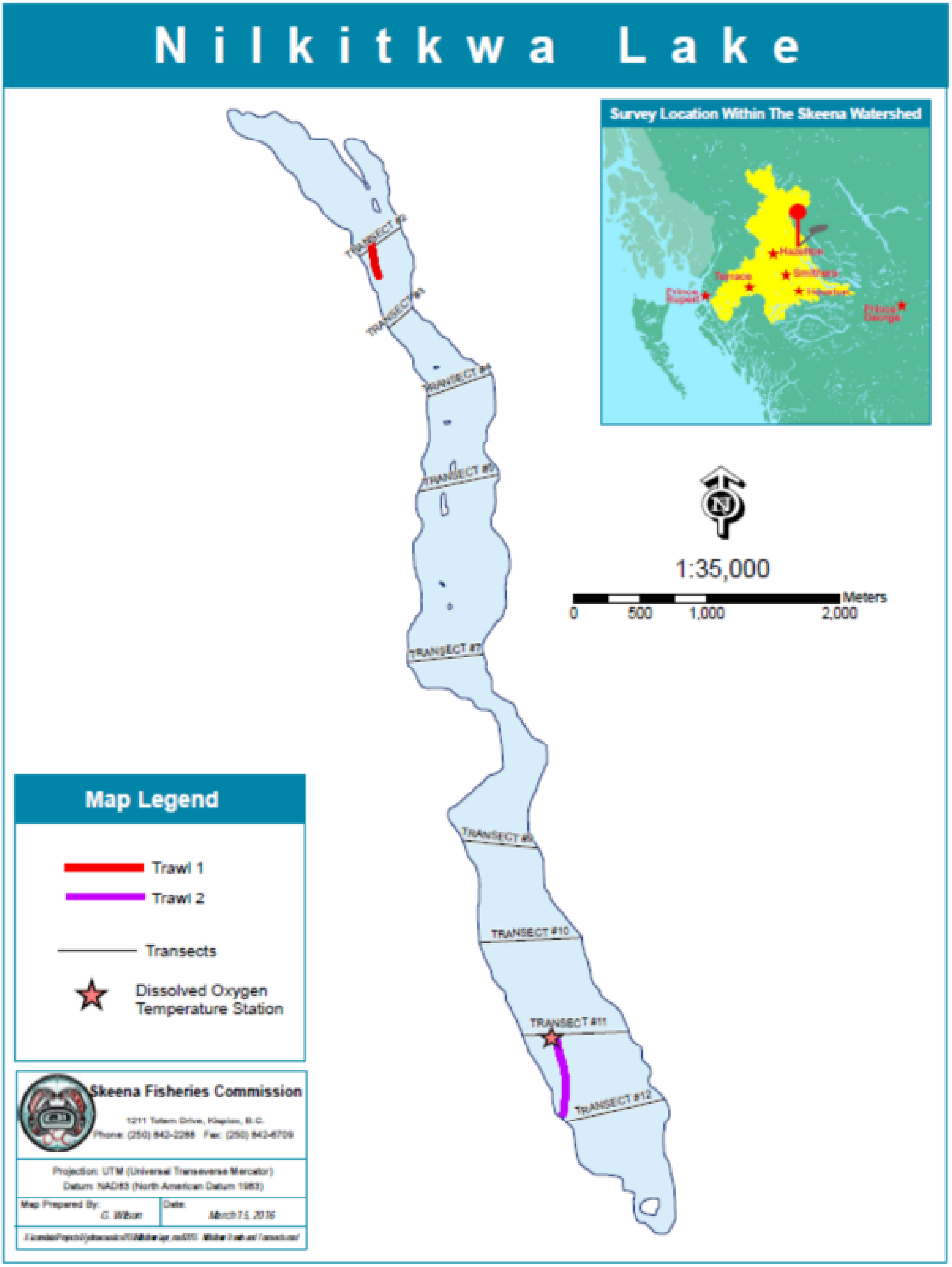

Figure 4. Nilkitkwa Lake survey map.

RESULTS AND DISCUSSION

North Arm of Babine Lake

The North Arm of Babine Lake was surveyed on the nights of September 9,10, and 11, 2015. Temperature and dissolved oxygen profiles were recorded at three different locations along the lake, here referred to as stations 1, and 2, and 3 (Figure 3). The temperature profiles varied at each of the three stations, with surface temperatures ranging from 17.1 ^{o}C at Station 3 to 20.9 ^{o}C at Station 2. There was an epilimnion of 16-18^{o}C at Station 1 to a depth of 17 meters, a thermocline between approximately 17 and 22 m depth, then a gradual thermal decline to 7.5 ^{o}C at 29 m depth (Figure 5a). Water temperatures at stations 2 and 3 declined steadily from the surface to thermoclines between 10 and 15 m (Figure 5a).

The concentration of dissolved oxygen (DO) at the surface ranged from 7.96mg/L at Station 2 to 8.86mg/L at Station 3. At Station 1, dissolved oxygen decreased to <7.5 mg/L at 5 m, then increased gradually to >7.5 mg/L at 20m, then increased rapidly to >9 mg/L at 29m. At Station 2, DO fluctuated between 8.0 and 9.0 mg/L throughout the water column to a depth of 25m, then decreased to 7.5 mg/L at 29 m. At Station 3, DO fluctuated between 8.0 and 9.0 mg/L throughout the water column (Figure 5b).

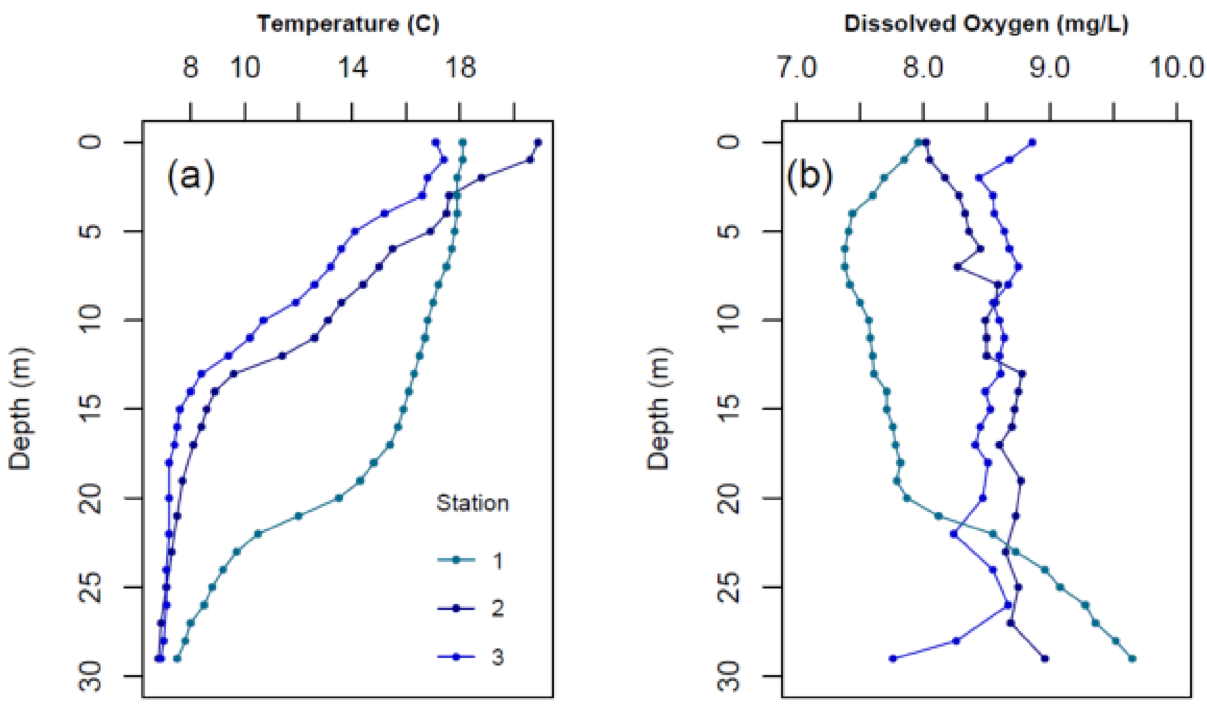

Figure 5. (a) Temperature and (b) dissolved oxygen profiles recorded at North Arm of Babine Lake, on September 9, 2015 (Station 1), September 10 (Station 2), and September 11 (Station 3)

Fish sampling
We conducted a total of nine trawl tows in the North Arm of Babine Lake, with a total trawl catch of 167 *O.nerka* fry, two char (*Salvelinus sp.*), and two Pygmy whitefish (*Prosopium coulteri*) (which were caught at depths ranging from approximately 7.5m to 15m, with the highest abundances captured in the 9m-11m range (Table 3). The average length of *O.nerka* fry captured in all the trawls was 65mm, with an average weight of 2.8 grams (Table 4, Figure 6). All of the *O. nerka* captured in the North Arm of Babine Lake were age-0, or young of the year fry.

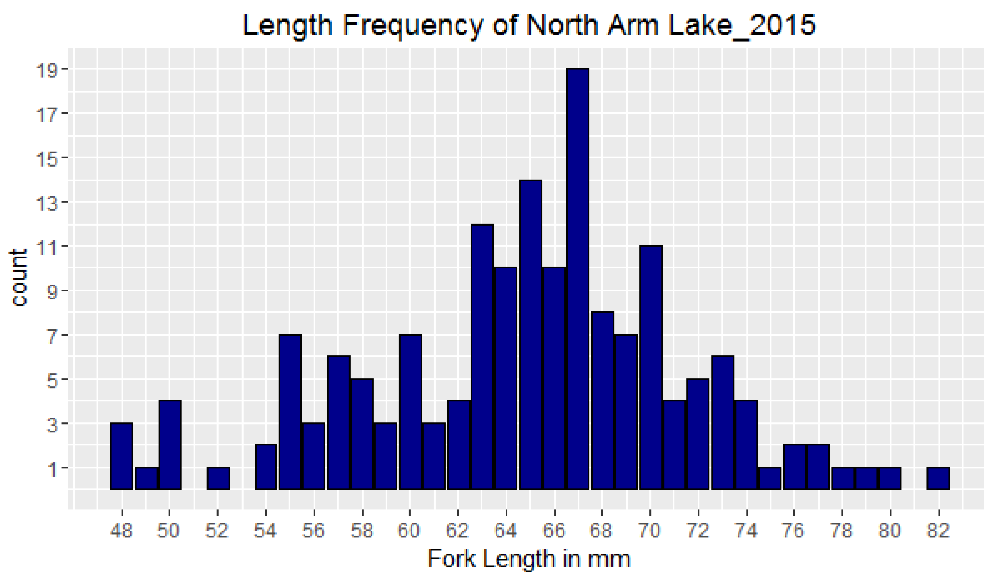

Figure 6. Length frequency histogram for age-0 *O. nerka* captured by trawl in the North Arm of Babine Lake, Sept. 9-11 2015

Acoustic survey
Hydroacoustic data were collected from six transects across the North Arm of Babine Lake. Most fish targets were recorded at depths between depths of 5 and 30 meters, with peak abundances between 5 and 15 meters (Figure 7). The highest abundances of fish targets were observed in the north and south ends of the basin, with intermediate abundances in the middle sections of the lake (Figure 8). The estimated density of age-0 *O. nerka* fry in the North Arm of Babine Lake in 2015 was 988/hectare, for an overall population estimate of $4.5 \times 10^6 \pm 27.4\%$ (Table 5). Based on the mean mass of 2.8 grams for *O. nerka* fry captured by trawl, the total age-0 *O.nerka* biomass was estimated at 12,474 kg.

The 2015 sockeye fry estimate for the North Arm of Babine Lake is similar to preliminary results from a previous sockeye fry assessment that was carried out on the North Arm in 2013. Hydroacoustic surveys carried out in the late summer and fall 2013 estimated the population of age-0 *O.nerka* in the North Arm of Babine Lake to be 5.4×10^6 in August 2013 and 4.2×10^6 in October 2013 (Selbie and Pon, 2014). The late summer fry per spawner ratio calculated for brood year 2014 was also very similar to the ratios calculated for brood year 2012 (Table 2).

Table 2. 2012 and 2014 brood year escapement estimates and associated late summer fry per spawner ratios for the Upper Babine River. Escapement data from Department of Fisheries and Oceans, NuSEDS database.

Brood years	Spawners escapement to Upper Babine River	Late summer fry per spawner	
2012	84,570	August	64
		October	50
2014	82,544	54	

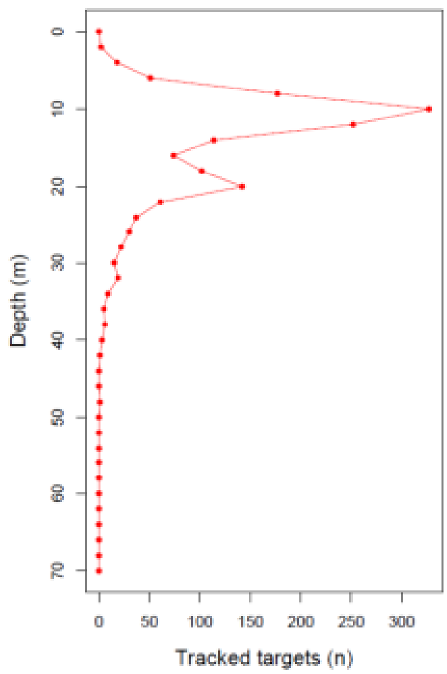

Figure 7. Vertical distribution of tracked targets in North Arm of Babine Lake, September 2015.

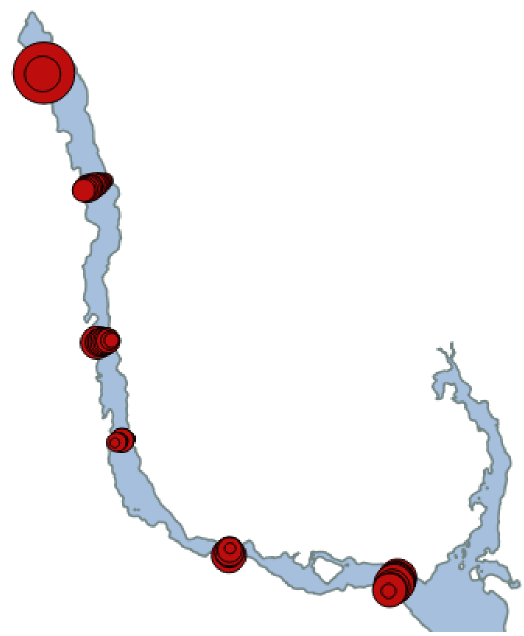

Figure 8. Horizontal distribution of tracked targets in the North Arm of Babine Lake.

Nilkitkwa Lake

Nilkitkwa Lake was surveyed on the night of September 12, 2015. A temperature and dissolved oxygen profile was recorded at one station (Figure 9) to a maximum depth of 12 m. The temperature ranged from 10.7°C-14.6°C, with an epilimnion of ~14°C to a depth of 5 m, an abrupt thermocline between 5 and 6 m depth, and a gradual decline to 10.7°C at 12 m (Figure 9a). The concentration of dissolved oxygen remained at 9 mg/L from the surface to 5m depth, then declined steadily to 5 mg/L at a depth of 12 m (Figure 9b).

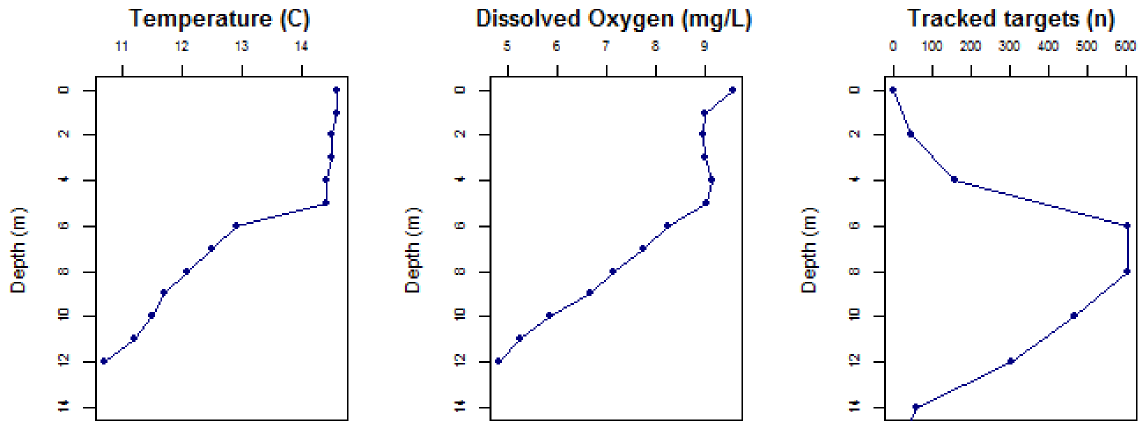

Figure 9. (a) Temperature and (b) dissolved oxygen profiles, and (c) vertical distribution of tracked targets from hydroacoustic survey at Nilkitkwa Lake, September 12, 2015.

Fish sampling

We conducted two trawl tows in Nilkitkwa Lake (Figure 4, Table 3), and captured 221 *O. nerka* fry and one prickly sculpin, including 11 *O. nerka* that were captured in a tow at the north end of the lake, and 210 which were captured in a tow in the south end of the lake. *O. nerka* fry were captured at depths ranging from approximately 5 – 8 m. All of the *O. nerka* captured in Nilkitkwa Lake in 2015 were age-0, with a mean length 56 mm, and a mean weight of 1.8 grams (Figure 10, Table 4).

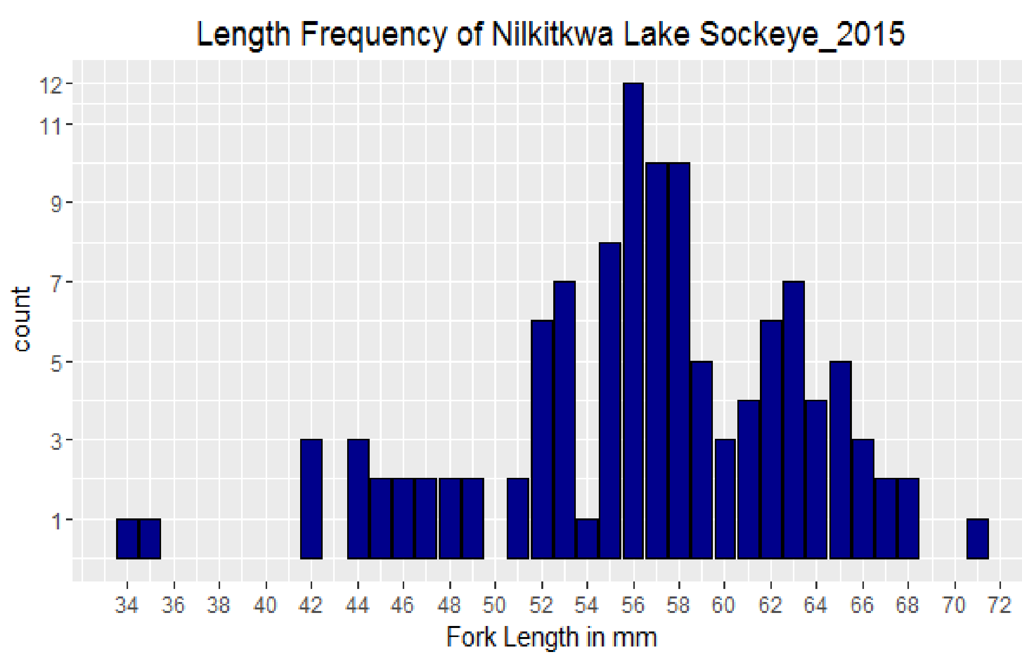

Figure 10. Length frequency of age-0 *O. nerka* fry captured by trawl in Nilkitkwa Lake.

Acoustic survey
Hydroacoustic data were collected from nine transects across the long axis of the lake. Most of the fish targets were found between 5 m and 12 m, below the thermocline (Figure 9c). The highest densities of fish targets were found in the southern basin of the lake, similar to observations made in 2011 (Figure 11).

The age-0 *O. nerka* fry population abundance in Nilkitkwa Lake in 2015 was estimated at 5.46 x 10^5 ± 63% (1,191/ha) using the stratification by transect procedure, or 5.40 x 10^5 ± 40% (1,178/ha) using the stratification by layer procedure (Figure 12 and Table 5). Based on the mean weight of 1.8 grams for trawl-captured age-0 *O. nerka* fry, the estimated total biomass for 2015 Nilkitkwa Lake age-0 *O. nerka* was approximately 980 kg.

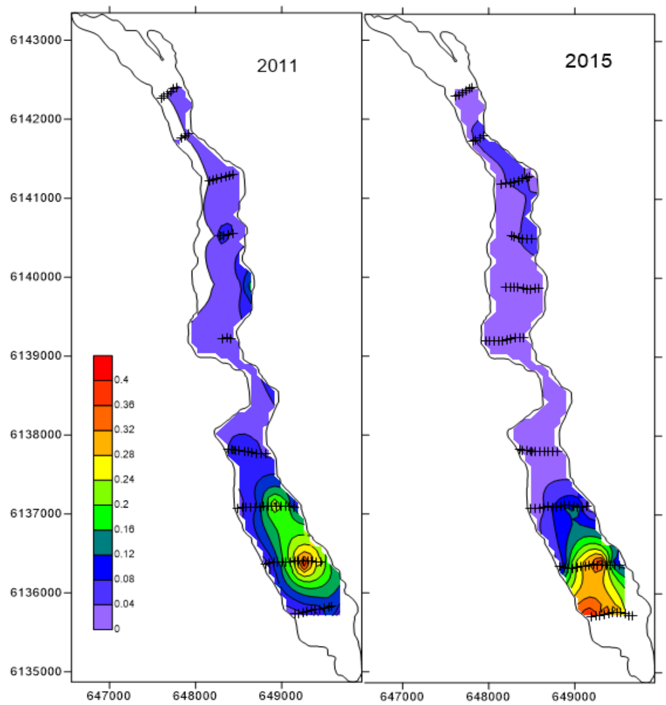

Figure 11. Contour maps showing horizontal distribution of tracked target density at Nilkiktkwa Lake in 2011 and 2015.

These results suggest that the age-0 *O.nerka* fry population in Nilkitkwa Lake was substantially smaller in 2015 (brood year 2014) than in 2011 (brood year 2010), and 2013 (brood year 2012) (Figure 12 and Table 5). However, slightly overlapping 95% confidence intervals around the hydroacoustic estimates presented here make it difficult to draw a firm conclusion regarding the relative abundances of *O.nerka* fry in Nilkitkwa Lake for the three years surveyed (Figure 12 and Table 5). Wide confidence intervals around hydroacoustic estimates are typical for lakes such as Nilkitkwa with non-uniform distribution of fish targets (i.e., most fish targets in one end of the lake) (Figure 11). A different method of statistical analysis, such as geostatistical analysis (REF) is likely to improve the precision of the hydroacoustic estimates. The difference between the 2011, 2013, and 2015 *O.nerka* fry population size can be observed when visually comparing the 2011, 2013, and 2015 echograms from Nilkitkwa Lake (Figures 15 to 24). For most transects, the

2011, and 2013 echograms show significantly more fish targets than the 2015 echograms (Figures 15 to 24). Age-0 *O.nerka* fry population estimates calculated from net surveys conducted in 1955 and 1957 by Johnson (1958), representing the progeny of brood years 1954 and 1956 respectively, were also much higher than the 2015 estimate (Figure 13), albeit calculated with different methodology. The estimates for brood years 1954 and 1956 were more than ten times larger than the 2015 estimate (Figure 13). Figure 13 also shows that the estimated Nilkitkwa Lake fall fry per Lower Babine River spawner ratio was the lowest for brood year 2014 (23 fry/spawner). The average Nilkiktka fall fry per Lower Babine River spawner ratio for brood years 1954 to 1956, calculated using tow net surveys estimates was 95 fry/spawner. For brood years 2010, and 2012 the average is 353 fry/spawner using hydroacoustic estimates, greater than the fall fry per spawner ratio estimated for brood year 2014 (Figure 13). By contrast, the fry per spawner ratio observed in the Upper Babine River/North Arm system for brood year 2014 was similar to the fry per spawner ratio estimated for brood year 2012, which suggests that the factors controlling low fry recruitment in Nilkitkwa Lake in 2014-2015 are unique to that system. The situation in the Lower Babine River/Nilkitkwa Lake system is concerning as the Lower Babine River wild sockeye population has already been declining significantly for many decades.

McCart (1967), Clarke and Smith (1972), and Lake Babine Nation Fisheries (2016) observed that following their emergence from gravel in the Upper and Lower Babine River, sockeye fry drift downstream with the current, while swimming perpendicularly to the current to reach calmer water close to shore. The sockeye fry continue to develop in low velocity areas along the stream margins until attaining a developmental stage and size to allow them to swim upstream in low water velocity areas along the stream margins, and into their nursery lake, either the North Arm of Babine Lake for Upper Babine River fry, or Nilkitkwa Lake for Lower Babine River fry.

Clarke and Smith (1972), and Lake Babine Nation Fisheries (2016) reported a significant number of fry in the Lower Babine River drifting downstream of the Babine River adult salmon counting fence. Clarke and Smith (1972) reported that at least 7.5 million fry, or more than 18% of the estimated sockeye fry emerging in the Lower Babine River in 1966 drifted past the Babine counting fence. Clarke and Smith (1972) assumed those fry could not swim back upstream through the fence to reach Nilkitkwa Lake, and were lost to the population. In 2015 a significant number of sockeye fry were also observed immediately downstream of the Babine counting fence (Lake Babine Nation Fisheries, 2016 and Doire *et al.*, 2016). They appeared to not be able to migrate upstream through the fence because of a water velocity barrier. The fence structure and debris (logs and pieces of wooden docks, and boats) accumulating upstream backed up the water, and created a significant difference between the water elevation upstream and downstream of the fence, which resulted in an increase in water velocities through the fence. Water velocities over 1.5m/s, which are much greater than the maximum burst swimming speed of sockeye fry, were measured at the counting fence (Lake Babine Nation Fisheries, 2016 and Doire *et al*., 2016) in early and mid-June 2015.

Water discharge data for the lower Babine River is not available before 1972, however data available for spring 2011, 2013, and 2015 from Environment Canada's Water Office's website, show that discharge in the lower Babine River was significantly greater in 2011 and 2015 compared to 2013. In fact, the 2011 and 2015 nival flood discharges were near the maximum discharge (260 m^3/s) recorded in the lower Babine River since 1972 (Figure 14). The Lower Babine River, upstream of the Babine counting fence, is mostly confined to its channel, increasing water velocity as discharge increases, hence emerging sockeye fry would be carried further downstream before reaching suitable rearing habitat close to shore, and a greater proportion of them would drift downstream of the Babine counting fence during years of high discharge such as in 2011 and 2015. Figure 14 also shows that compared with 2011 and 2013, water discharge in the Lower Babine River increased much earlier in the spring of 2015. For example, in 2015 the discharge reached 100 m^3/s almost two weeks earlier than in 2011, and two and a half weeks earlier than in 2013 (Figure 14). The earlier increase in discharge, and water velocity may have coincided with the peak of sockeye fry emergence, causing an even higher proportion of newly emerged sockeye fry in the Lower Babine River to drift downstream of the Babine counting fence compared to 2011 and 2013.

Earlier peak nival floods resulting from shorter winters related to increasing global temperatures are already being observed, and will most likely increase in frequency and intensity (Loukas *et al.*, 2002). If earlier, higher discharges from the Nilkitkwa River coincide with peak fry emergence and interact with the barrier to upstream migration created by the Babine counting fence to contribute to poor fry recruitment for the Lower Babine River sockeye population such as observed in 2015, it is likely to occur more often in the future. It is thus imperative to design and implement a solution to improve upstream sockeye fry passage through the Babine counting fence during a wide range of discharge to prevent the loss of significant proportions of sockeye fry emerging in the Lower Babine River in future years.

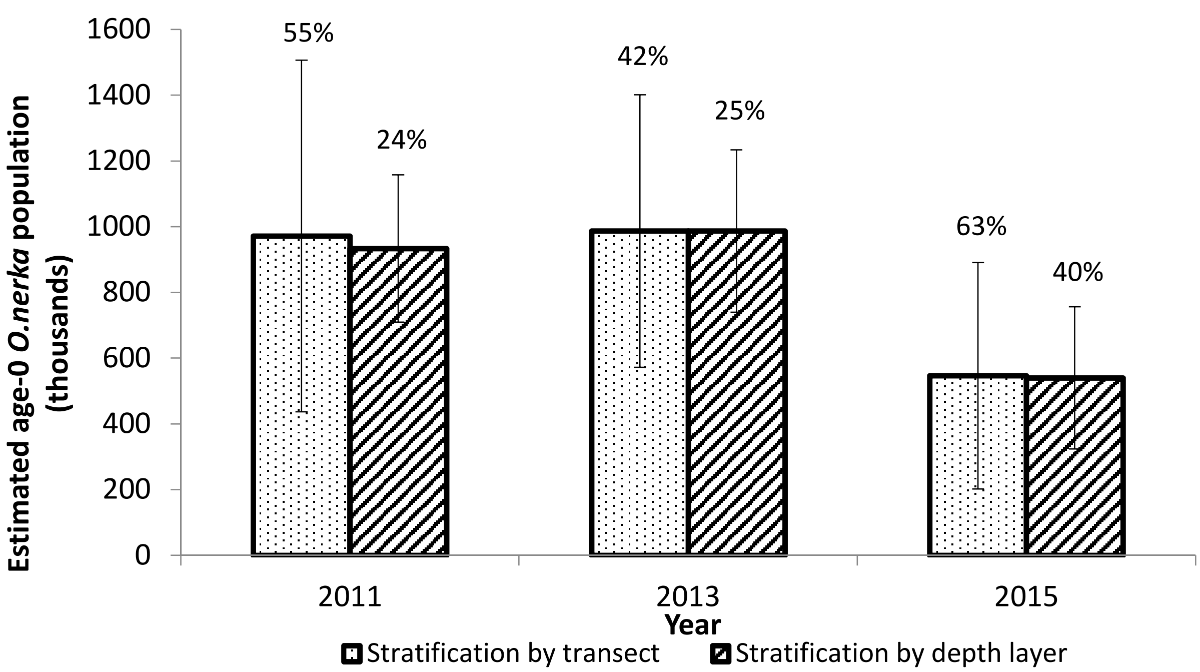

Figure 12. Graph showing the 2011, 2013, and 2015 age-0 *O.nerka* population abundance estimates for Nilkitkwa Lake, using the stratification by transects and the stratification by depth layers population estimation procedures. The error bars show the 95% confidence intervals.

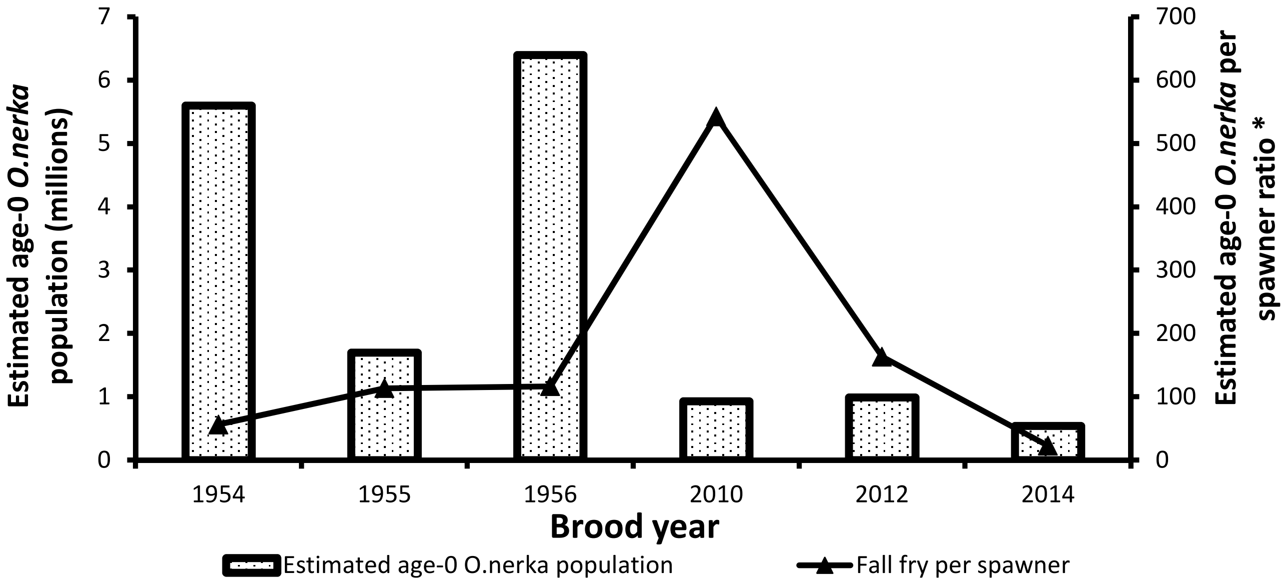

Figure 13. Age-0 *O.nerka* population estimate for Nilkitkwa Lake, and estimated age-0 *O.nerka* per spawner in the Lower Babine River for Brood years 1954, 1955, 1956, 2010, 2012, and 2014.

*- Calculated using escapement data from Department of Fisheries and Oceans, NuSEDS database.

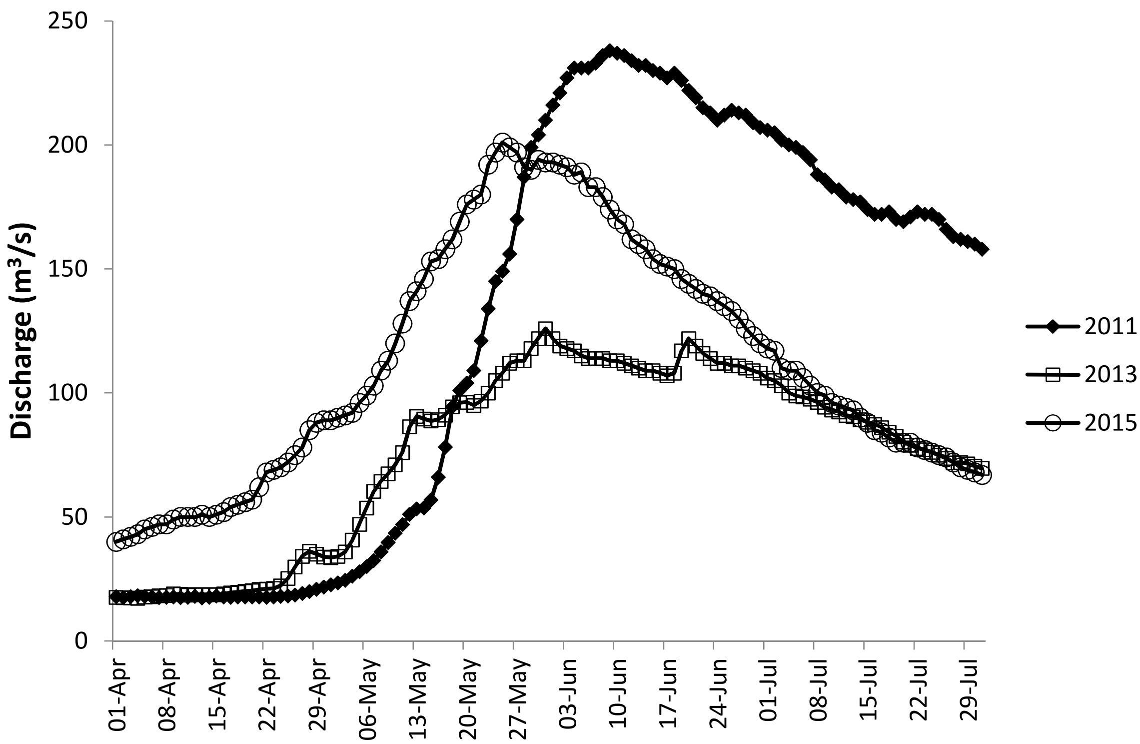

Figure 14. Discharge in the Lower Babine River in the springs of 2011, 2013, and 2015. Data from Environment Canada's Water Office's website.

CONCLUSION

Regular hydroacoustic surveys provide unbiased estimates which allow us to assess trends in juvenile sockeye populations for a given rearing lake. Data from acoustic surveys provide baseline data that can be used to compare with future hydroacoustic estimates. If spawner escapement estimates are available, hydroacoustic estimates provide an indicator of freshwater survival and productivity. Fry abundance estimates may also be used to compare sockeye fry populations with lake productivity. At this time, there has been no recent trophic capacity estimate conducted for Nilkitkwa Lake, however a 2013 assessment of Babine Lake will provide rearing capacity information for the North Arm of Babine Lake when results are published.

While the sockeye fry population estimates calculated in 2015 for the North Arm of Babine Lake appear similar to hydroacoustic estimates generated in a previous survey carried out in 2013, this is not true for Nilkitkwa Lake. The 2015 sockeye fry population estimate for Nilkitkwa Lake was less than 60% of population estimates for 2011 and 2013. This is despite a relatively strong sockeye salmon spawner escapement to the Lower Babine River in 2014, which produced the age-0 *O. nerka* fry that reared in Nilkitkwa Lake in 2015. By comparison, brood year escapement for sockeye salmon spawners in the Upper Babine River, which are thought to produce the fry that rear in the North Arm of Babine Lake, was similar in 2012 and 2014, the brood years for the 2013 and 2015 *O. nerka* fry populations, for which hydroacoustic estimates were very similar. These results suggest variation in freshwater survival between sockeye salmon that spawn in the Upper and Lower Babine rivers. The Babine River adult salmon counting fence located on the Lower Babine River may impede sockeye fry that drifted downstream of it from migrating back to Nilkitkwa Lake, their nursery lake. This scenario may be amplified during years of early nival flood such as 2015.

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Table 3. 2015 Babine Lake North Arm and Nilkitkwa Lake hydroacoustic surveys trawl summary

Lake	Date (2015)	Trawl #	Time Start	Time End	Easting Start	Northing Start	Depth (m)	ON	Ch	Sc	PW
North Arm	9-Sept	1	2306	2317	670002	61018700	15	22	0	0	0
North Arm	10-Sept	2	0240	0255	661184	6103796	10.5	6	1	0	0
North Arm	10-Sept	3	2217	2230	651045	6129578	9	97	0	0	0
North Arm	11-Sept	4	0111	0125	653400	6123378	9.5	13	0	0	0
North Arm	11-Sept	5	2208	2218	653917	6115065	7.5	3	0	0	0
North Arm	11-Sept	6	2230	2244	653889	6115121	9	10	0	0	0
North Arm	12-Sept	7	0024	0041	655508	6108284	9	4	0	0	0
North Arm	12-Sept	8	0156	0206	660704	6103755	11	5	0	0	1
North Arm	12-Sept	9	0211	0226	660302	6104031	11	7	0	0	1
Nilkitkwa	12-Sept	1	2132	2136	647800	6142110	8	11	0	1	0
Nilkitkwa	12-Sept	2	2347	2355	649186	6135796	5	210	0	0	0

ON: *O.nerka*; Ch: Char sp; Sc: prickly sculpin; PW: Pygmy whitefish

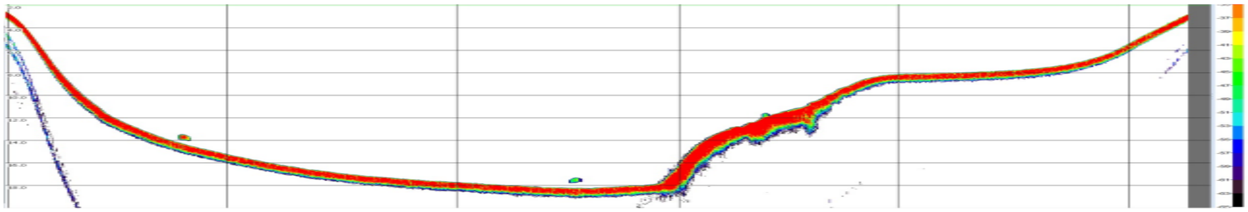
Table 4. Fish sample data for age-0 *O. nerka* fry captured by trawl in the North Arm of Babine Lake and Nilkitkwa Lake.

Lake	Gear	Species	n	Mean Length (mm)	Max. Length (mm)	Min. Length (mm)	Std. Dev. Length (mm)	Mean Weight (g)	Max. Weight (g)	Min. Weight (g)	Std. Dev. Weight (g)
Nilkitkwa	Trawl	Age 0 *O.nerka*	116	56	71	34	6.91	1.83	3.79	0.39	0.63
North Arm	Trawl	Age 0 *O.nerka*	168	65	82	48	6.73	2.81	5.74	1.06	0.92

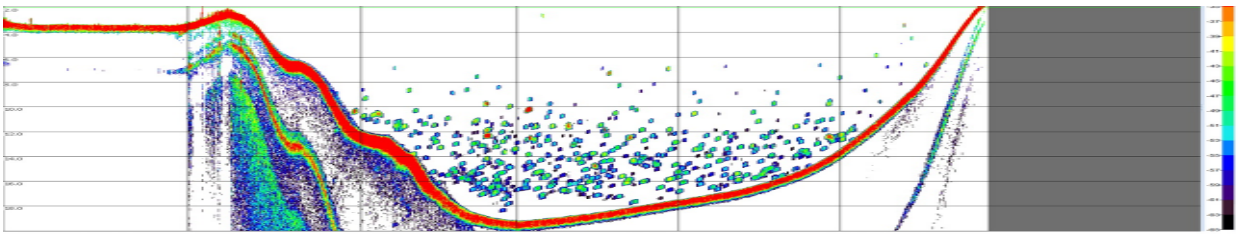
Table 5. 2015 Hydroacoutic estimates of population and density for age-0 *O. nerka* in Nilkitkwa and the North Arm of Babine Lake

Lake/Basin	Year/Date	Estimate method	Size class	Density n/ha	Population n	95% CI %
Nilkitkwa Lake	2015 *(11 Sept)*	Integration (Stratification by transect)	Age-0 *O. nerka*	1,191	546,469	63%
			Other "small" fish	172	78,854	55%
			Large fish	153	70,362	59%
		Integration (Stratification by layer)	Age-0 *O. nerka*	1,178	540,400	40%
			Other "small" fish	173	79,300	90%
			Large fish	158	72,597	61%
	2013 *(4 Sept)*	Integration (Stratification by transect)	Age-0 *O. nerka*	2,151	986,891	42%
			Other "small" fish	92	42,045	155%
			Large fish	154	70,620	58%
		Integration (Stratification by layer)	Age-0 *O. nerka*	2,151	986,891	25%
			Other "small" fish	115	42,045	73%
			Large fish	154	70,585	50%
	2011 *(28 Sept)*	Integration (Stratification by transect)	Age-0 *O. nerka*	2,162	971,672	55%
			Other "small" fish	-	-	-
			Large fish	127	58,293	60%
		Integration (Stratification by layer)	Age-0 *O. nerka*	2,035	933,833	24%
			Other "small" fish	-	-	-
			Large fish	127	58,294	38%
Babine (North Arm)	2015	Integration	Age-0 *O. nerka*	864	4,563,950	30%
			Other "small" fish	10	51,367	200%
			Large fish	224	1,180,621	63%

2011



2013



2015

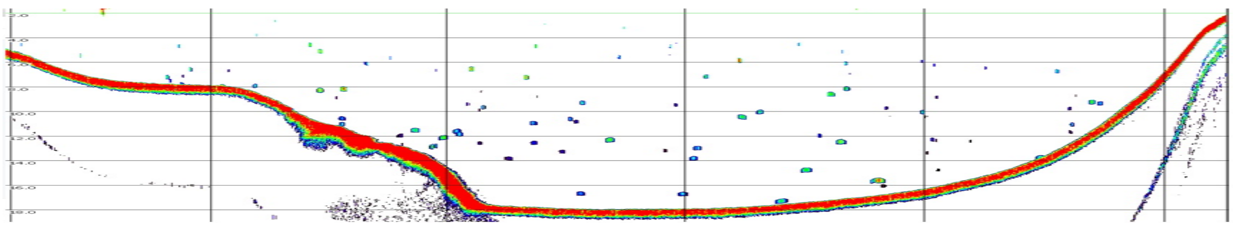
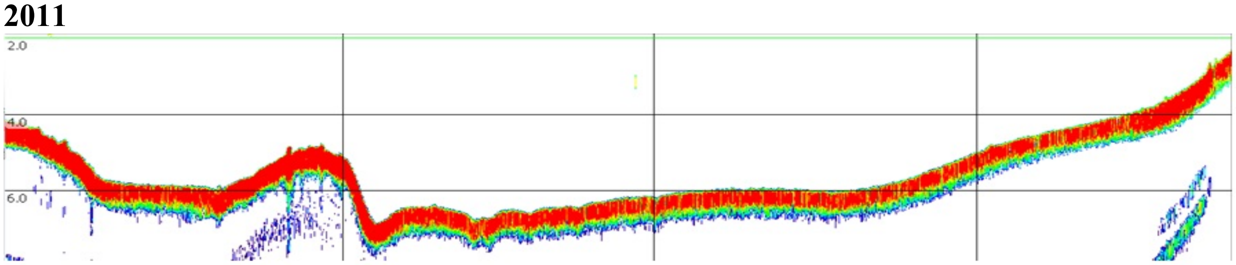
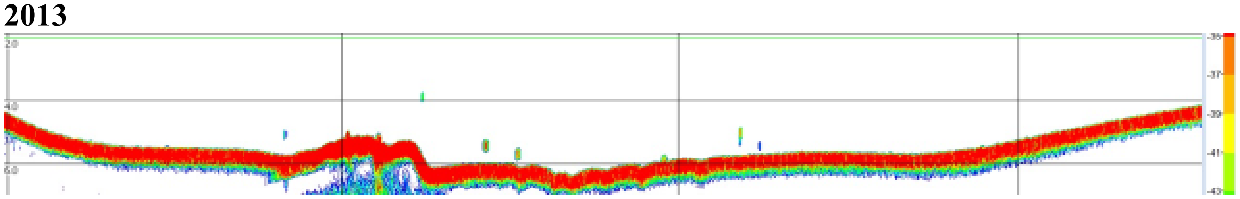


Figure 15. 2011, 2013, and 2015 Nilkitkwa Lake transect 2 echograms.

2011



2013



2015

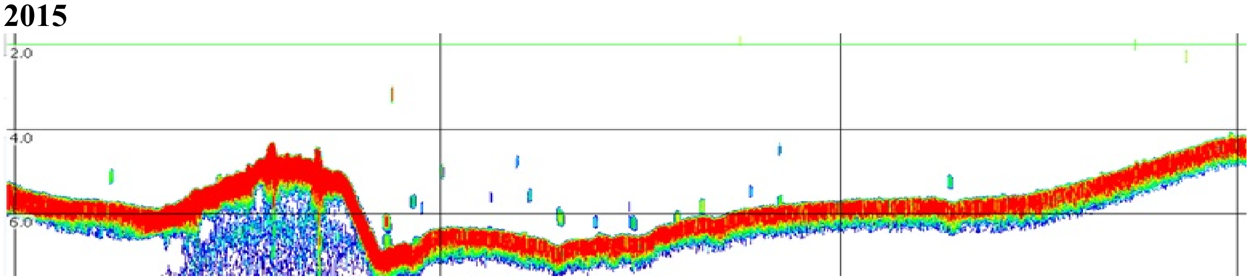
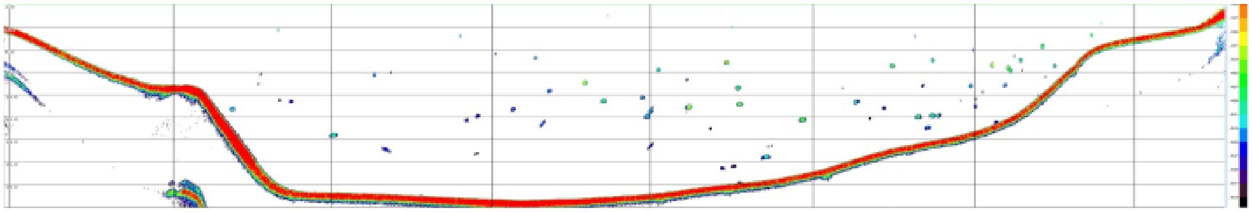
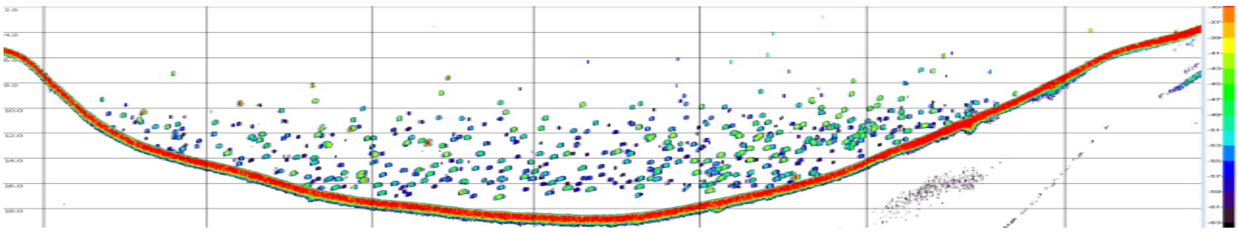


Figure 16. 2011, 2013, and 2015 Nilkitkwa Lake transect 3 echograms.

2011



2013



2015

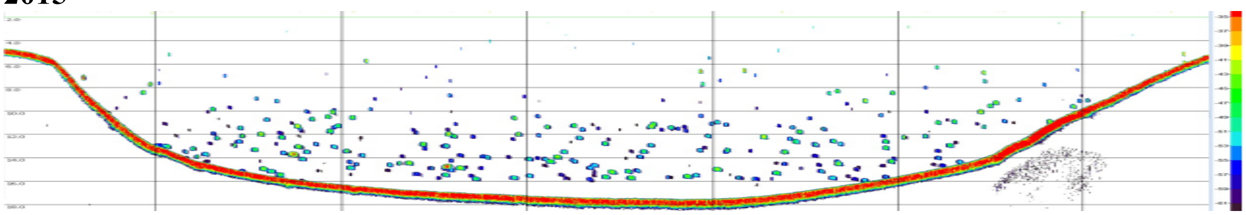
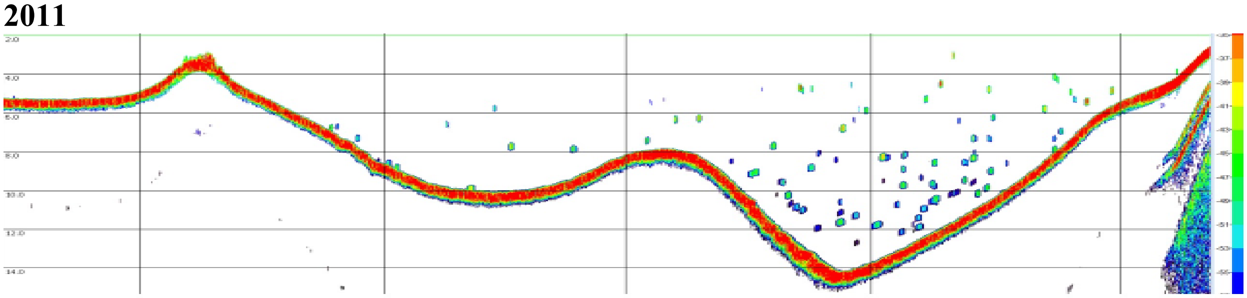
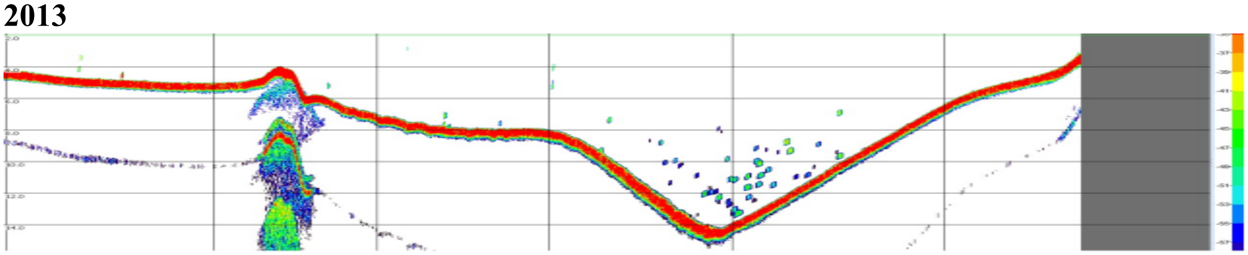


Figure 17. 2011, 2013, and 2015 Nilkitkwa Lake transect 4 echograms.

2011



2013



2015

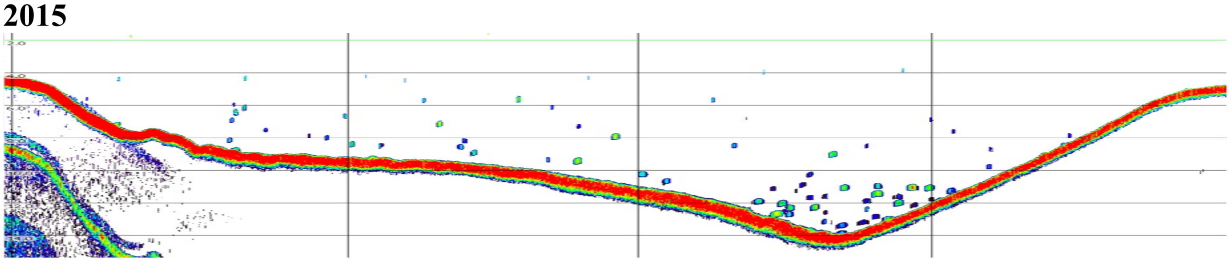


Figure 18. 2011, 2013, and 2015 Nilkitkwa Lake transect 5 echograms.

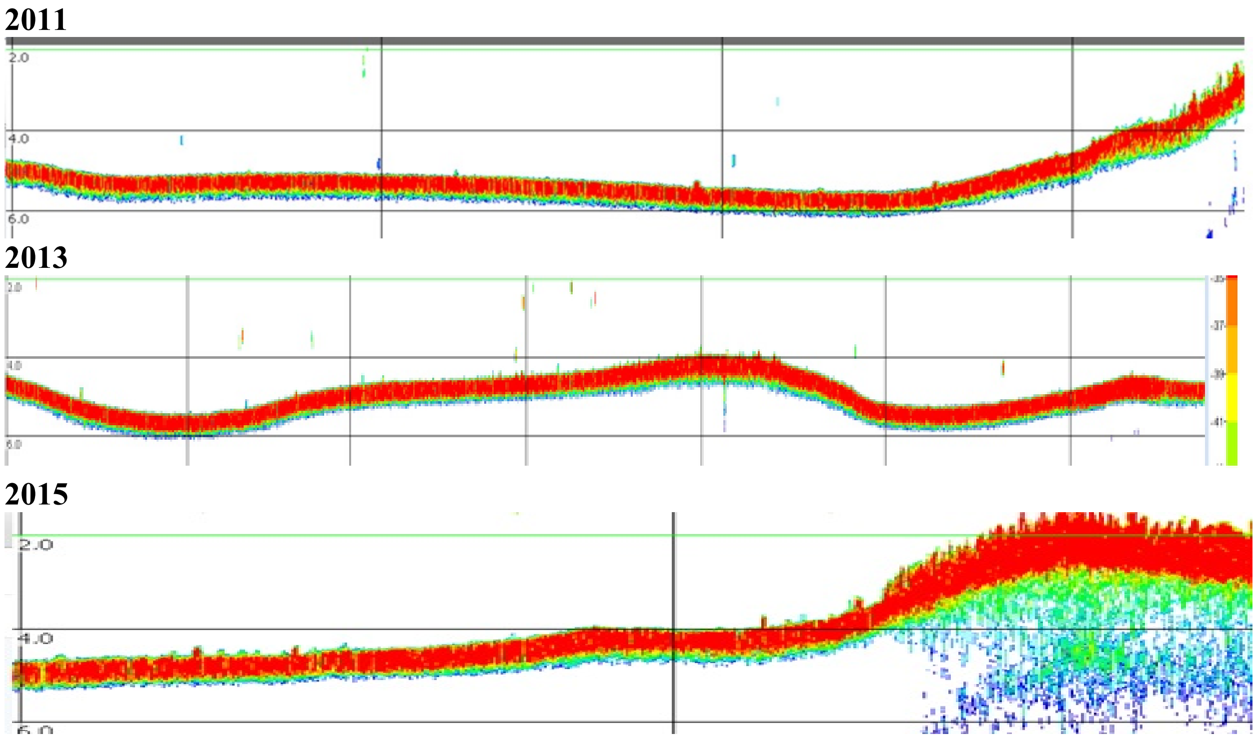


Figure 19. 2011, 2013, and 2015 Nilkitkwa Lake transect 6 echograms.

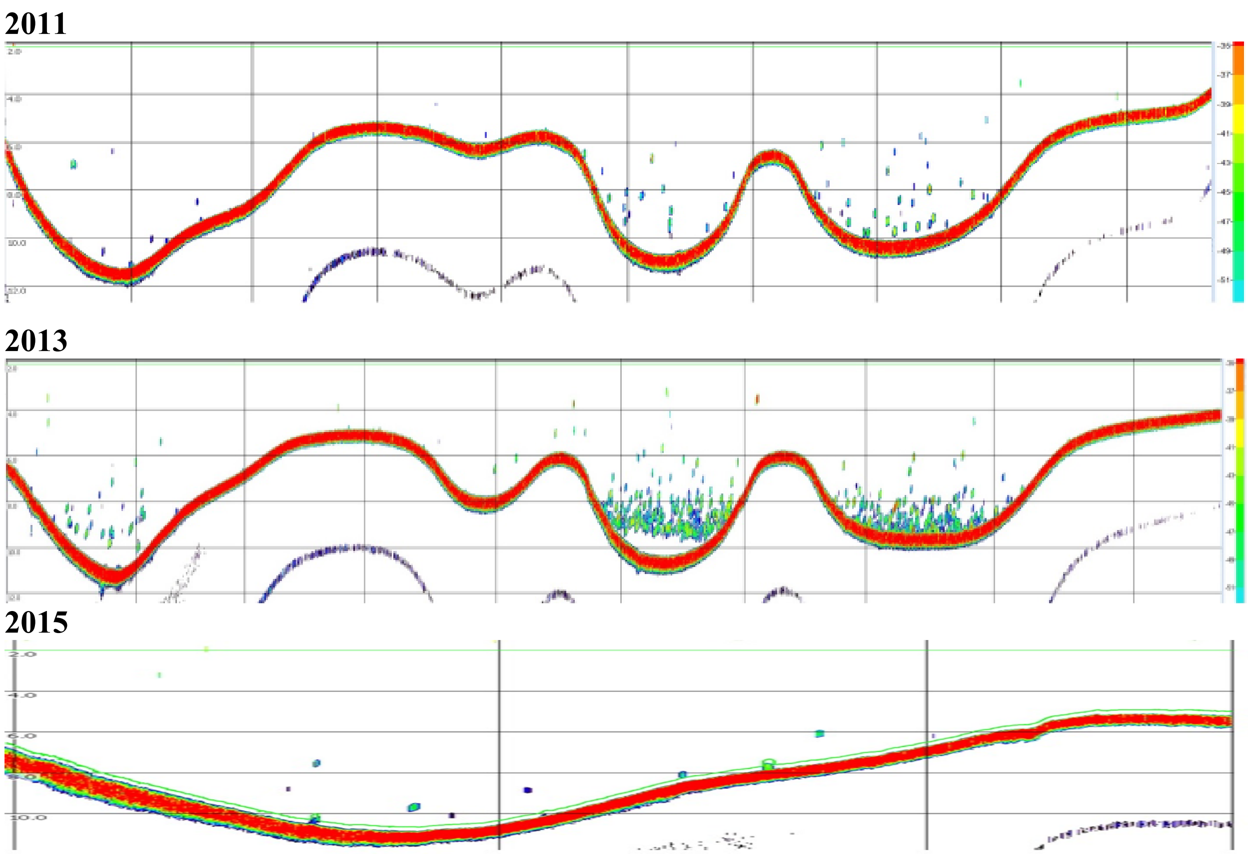


Figure 20. 2011, 2013, and 2015 Nilkitkwa Lake transect 7 echograms.

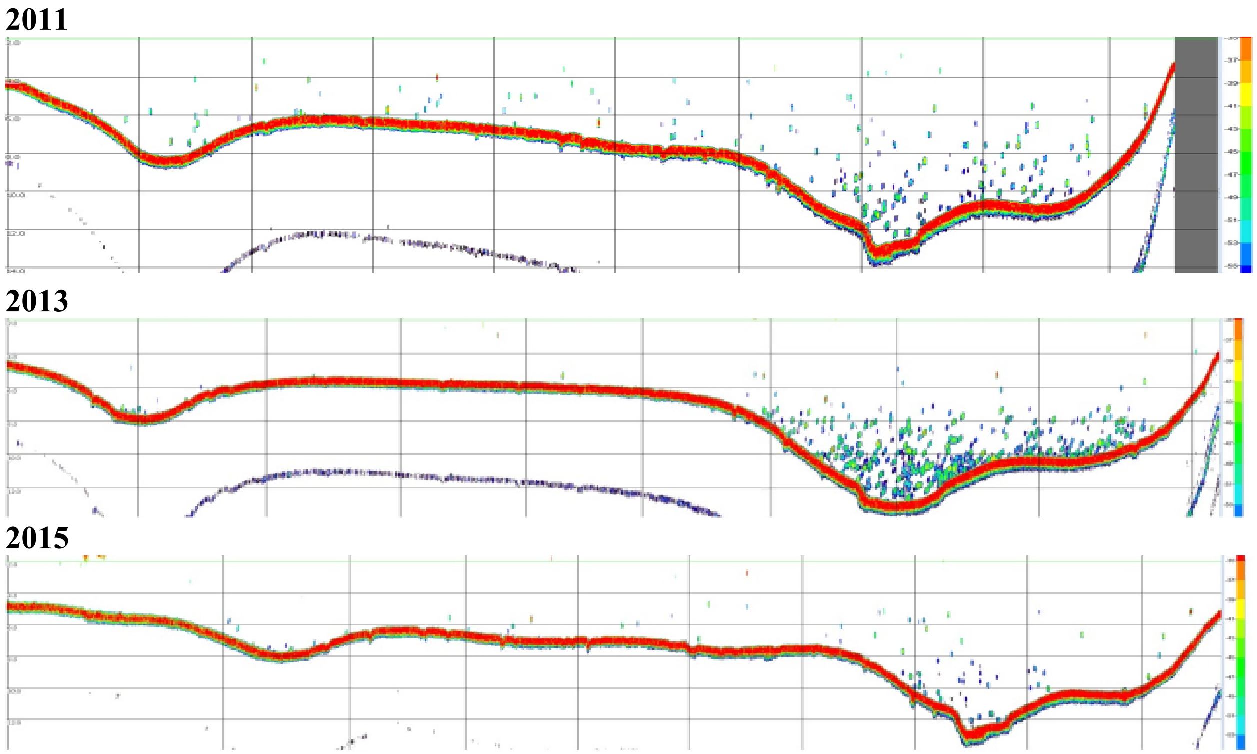


Figure 21. 2011, 2013, and 2015 Nilkitkwa Lake transect 9 echograms.

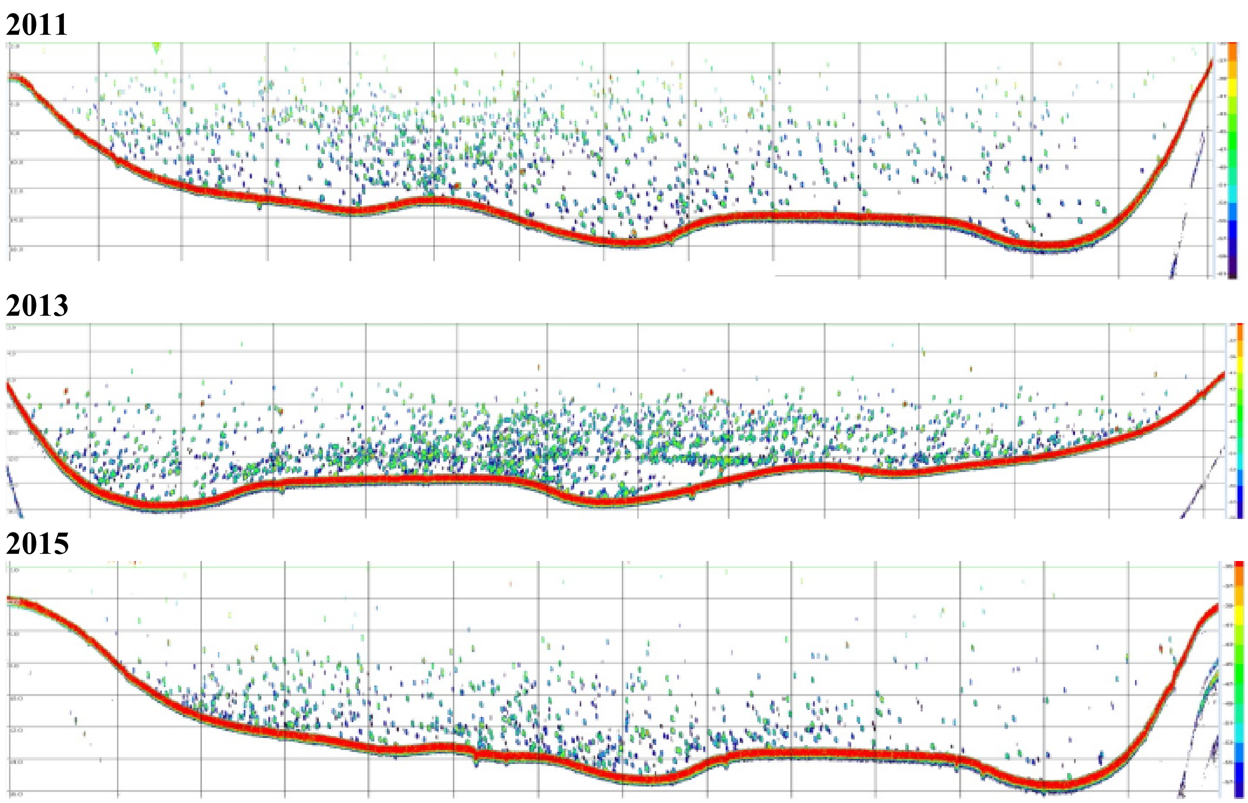
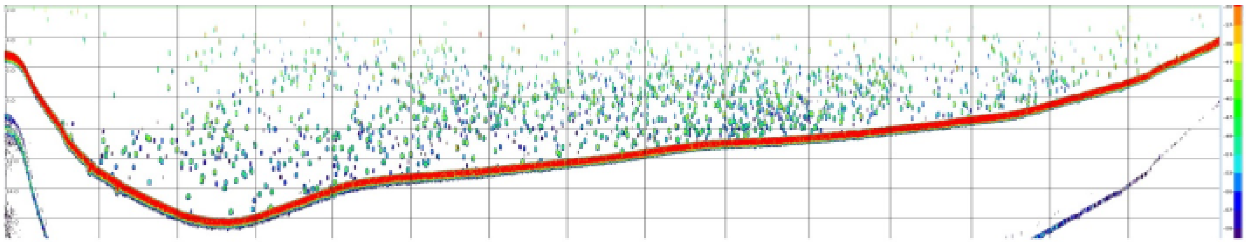
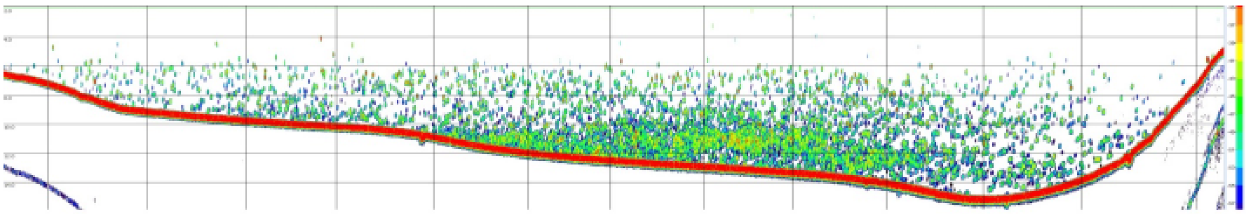


Figure 22. 2011, 2013, and 2015 Nilkitkwa Lake transect 10 echograms.

2011



2013



2015

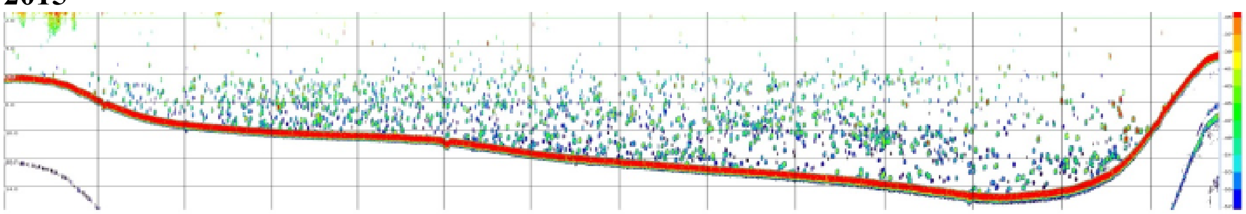
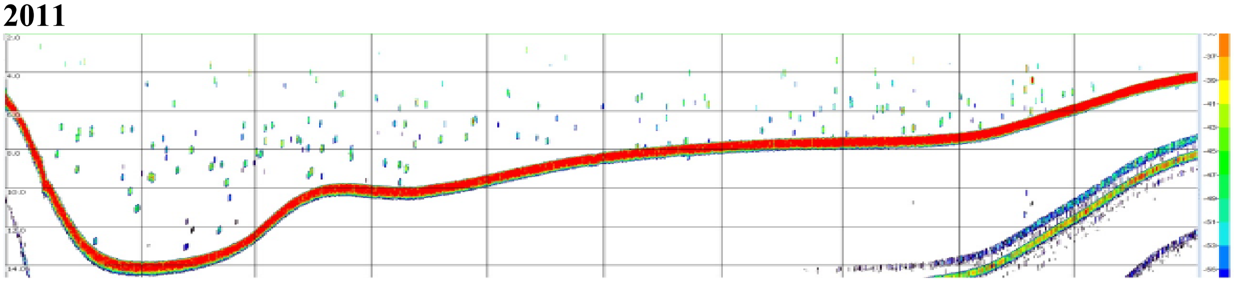
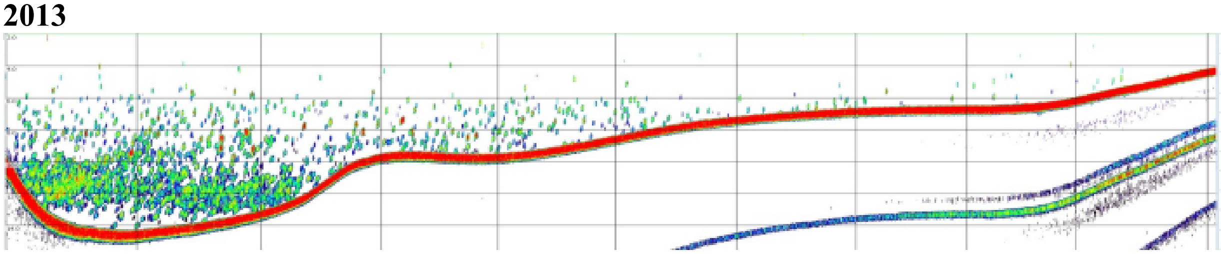


Figure 23. 2011, 2013, and 2015 Nilkitkwa Lake transect 11 echograms.

2011



2013



2015

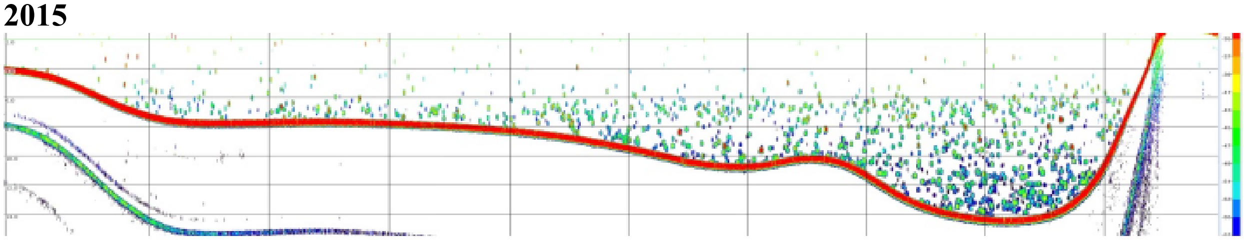


Figure 24. 2011, 2013, and 2015 Nilkitkwa Lake transect 12 echograms.