Skeena Sockeye Lakes Hydroacoustic Surveys 2013

Prepared for the Pacific Salmon Commission by:
Janvier Doire and Charmaine Carr-Harris

March 2014

Skeena Fisheries Commission
3135 Barnes Crescent
Kispiox, BC
V0J 1Y4

ABSTRACT

Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys of six (6) juvenile sockeye rearing lakes (Johanson, Kitsumkalum, McDonell, Motase, Nilkitkwa, and Sustut Lakes) in the Skeena Watershed in 2013. The main objectives of the surveys were to enumerate and sample the sockeye fry population and to estimate the species composition of each lake. The results of these surveys are contained in this report.

Hydroacoustic sampling was conducted using a DT-X echosounder with a downward-pointing split-beam 200 kHz transducer. Fish samples were captured with mid-water trawl and gillnet gear. The trawl and gillnet samples were used to determine the species composition of pelagic “small” size fish at each lake.

The juvenile sockeye population estimates calculated in 2013 for McDonell, Motase, Nilkitkwa, and Sustut lakes appear to be mostly similar to hydroacoustic estimates generated in previous surveys of the same lakes, and still well below the rearing capacity of each system. The significant decrease observed at Johanson Lake is of concern, and should not be over-looked. The access to Johanson Lake may be blocked, preventing sockeye from utilizing its habitat for spawning and rearing. The portion of the rearing capacity used in 2013 at Johanson Lake has fallen significantly. The significant increase in the juvenile sockeye population estimate observed in Kitsumkalum Lake in 2013 is certainly representative of the increase in the sockeye escapement to this system observed in the last few years. Even though the juvenile sockeye population appears to have increased at Kitsumkalum Lake, it is still well below the rearing capacity of this system.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The Skeena Fisheries Commission (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).

During the late summer of 2013, the Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys of six juvenile sockeye rearing lakes in the Skeena Watershed (Figure 1). The main objectives of these surveys were to estimate the sockeye population size and the relative proportions of juvenile sockeye and competitor limnetic species in each lake.

Sustut and Johansen lakes are in the Sustut Watershed. The Sustut River is a high interior tributary approximately 97 km in length that drains into the Upper Skeena River (Gottesfeld 2008). Hydroacoustic surveys at Sustut and Johanson lakes were conducted in 2004 by Fisheries and Oceans Canada, Cultus Lake division, and in 2010 by the SFC.

Sustut Lake is located at an elevation of 1,301 m at the headwaters of the Sustut River. It is a shallow, productive lake with a surface area of 257 hectares, maximum depth of 19.6 m, and average depth of 5.8 m (Table 1). Sustut Lake is located within the traditional territories of the Gitxsan First Nation.

Johanson Lake is located at the headwaters of Johanson Creek, tributary to the Sustut River. With an elevation of 1,444 m, Johanson Lake hosts the highest known elevation sockeye population in the Skeena watershed. Johanson is smaller and deeper than Sustut Lake, with a surface area of 143 hectares, maximum depth of 52.5 m, and average depth of 16m (Table 1). Johanson Lake is located within the traditional territories of the Gitxsan First Nation.

Kitsumkalum Lake is a glacially turbid lake located in the middle reaches of the Kitsumkalum River, a 5th order tributary of the lower Skeena River that drains an area of 2,255 km^2. Kitsumkalum Lake covers a surface area of approximately 1,850 hectares, with an average depth of 75 m and a maximum depth of over 140 m. Past hydroacoustic surveys at Kitsumkalum Lake were conducted by the Cultus Lake laboratory in 2005, and the SFC in 2007, 2009, and 2011. Kitsumkalum Lake is located within the traditional territories of the Kitsumkalum First Nation.

McDonell Lake is the lowest of a chain of three lakes at the headwaters of the Zymoetz River. The Zymoetz River, is a 6th order tributary of the Skeena River and drains an area of 3,028 km^2 (Hall and Harris 2007). McDonell Lake is a clear and productive lake located at an elevation of 830 m and covering approximately 215 ha, with a mean depth of approximately 8 m (Table 1), and a surface area of 215 ha. The Gitksan Watershed Authorities (GWA) and the SFC have conducted annual hydroacoustic surveys at

McDonell Lake every year since 2005 except for 2012. McDonell Lake is located within the traditional territories of the Gitxsan and Wet'suwet'en First Nations.

Motase Lake is a glacially turbid lake at the headwaters of the Squingula River, which is a tributary of the upper Skeena River. Motase Lake covers a surface area of 409 hectares, with an average depth of 13 m and a maximum depth of 32 m. The Department of Fisheries Cultus Lake research group and the SFC conducted hydroacoustic surveys at Motase Lake in 2003, and 2009, respectively. Motase Lake is located within the traditional territories of the Gitxsan First Nation.

Nilkitkwa Lake is located between the upper and lower sections of the Babine River, downstream from the North Arm of Babine Lake, and approximately 1 km upstream of the Babine River enumeration facility. The sockeye that rear in Nilkitkwa Lake and the North Arm are the progeny of spawners in the upper and lower Babine River, and tributaries to Nilkitkwa Lake and the North Arm, and are thought to be part of the late spawning contingent of the wild Babine sockeye run (Wood 1998). Nilkitkwa Lake is a clear, productive system, with a surface area of 459 hectares, and a maximum depth of 19 m (Table 1). The SFC conducted the first hydroacoustic survey on Nilkitkwa Lake in 2011. Nilkitkwa Lake is located within the traditional territories of the Lake Babine First Nation.

The species "*Oncorhynchus nerka*" may include both anadromous (sockeye) and non-anadromous forms (kokanee) in all 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*".

Table 1. Physical characteristics of lakes surveyed in 2012

Lake	Watershed	Elevation (m)	Average Depth (m)	Maximum Depth (m)	Surface Area (ha)	Clarity
Johanson	Sustut	1,444	16.0	53	143	Clear
Kitsumkalum	Kitsumkalum	122	75.0	140	1,850	Turbid
McDonell	Zymoetz	830	8.0	15	215	Clear
Motase	Squingula	1,021	13.4	32	409	Turbid
Nilkitkwa	Babine	714	4.0	19	459	Clear
Sustut	Sustut	1,301	5.8	20	257	Clear

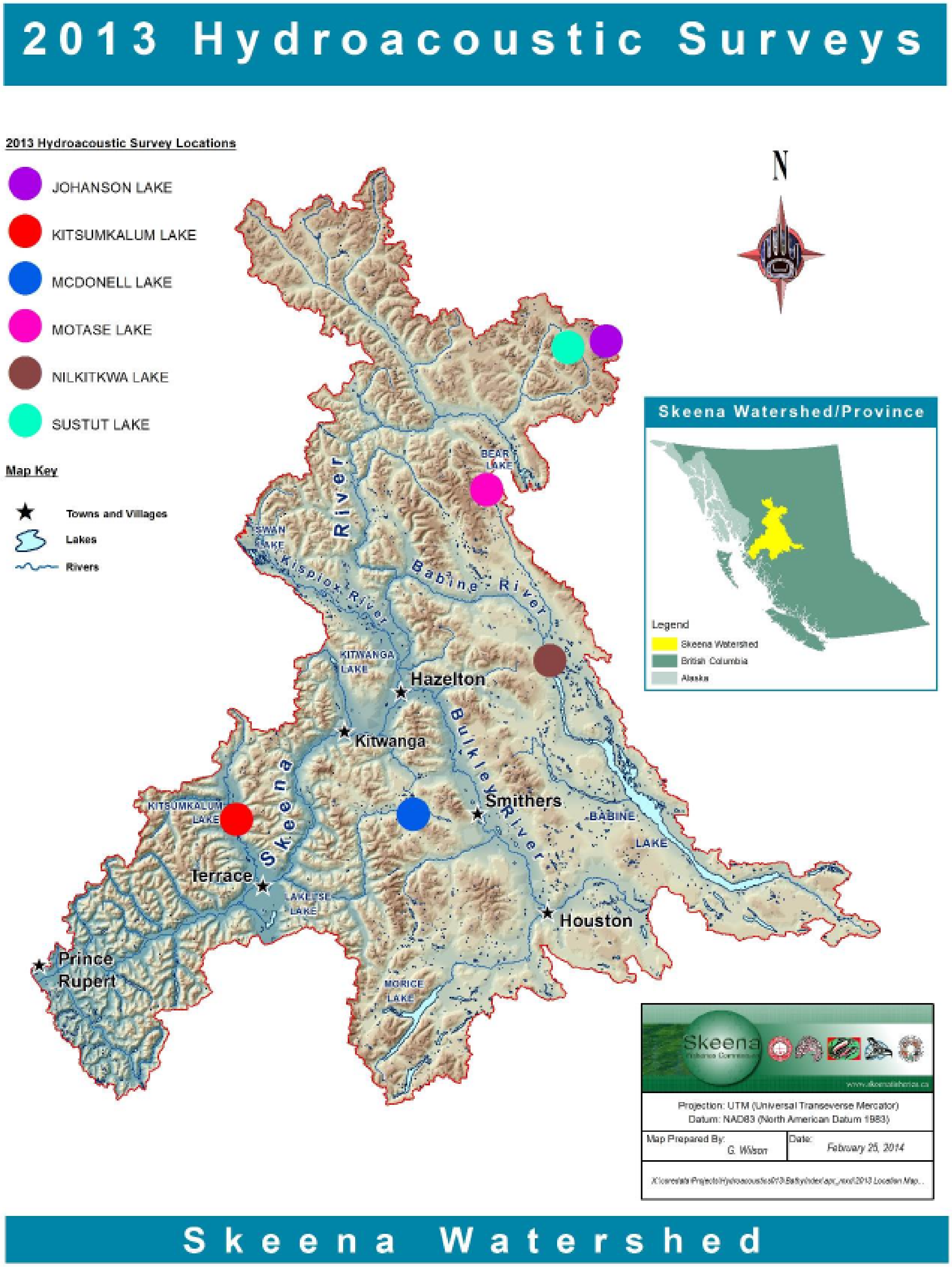


Figure 1. Location of the surveyed lakes in the Skeena watershed

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 200 kHz split-beam transducer producing a 6 degree beam. The single downward-pointing transducer was pole-mounted to our inflatable vessel, a Bombard Commando C-5 (Figure 2). During the hydroacoustic survey at Motase Lake, a second transducer was mounted horizontally, following the same method used by Carr-Harris (2010) in 2009 for Motase Lake and other shallow lakes of the Skeena Watershed. Hydroacoustic data were collected to an acoustic threshold of -100 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 survey designs used in 2013 at Johanson, Sustut, Motase, and Nilkitkwa were all created by the SFC (Figures 3, 4, 5, and 6). The surveys at McDonell, and Kitsumkalum lakes were conducted along transects established by the Department of Fisheries & Oceans Cultus Lake Research Laboratory (Figures 7 and 8).

Hydroacoustic estimates for Motase Lake are based on depth layer volumes that were calculated using bathymetric maps produced from lake depth data collected during the 2009 surveys using the DT-X system, combined with existing bathymetric data from the BC Ministry of Environment. The depth layer volumes for Nilkitkwa Lake were calculated using bathymetric data collected during a hydroacoustic survey conducted in 2011. The depth layer volumes for Sustut, and Johanson lakes were calculated using bathymetric data collected during a hydroacoustic survey conducted in 2010. Finally, bathymetric maps provided by the provincial Ministry of Environment were used to calculate depth layer volumes for Kitsumkalum, and McDonell lakes.

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.

Post-processing of hydroacoustic data was performed using Echoview software (v. 5.4.93). 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.

Fish densities were calculated using three different methods for down-looking acoustic data: integration, single target (ST), and tracked target (TT). The integration method integrates the average acoustic energy for each depth layer by the average target strength volumetric fish density for the stratum (n/m^3). In single target echo counting analysis (ST) the water column was sampled ping by ping (Simmonds and MacLennan 2005), and the number of single targets detected are summed by the post-processing software (Echoview v. 5.4.93). For each transect interval, the number of single target detections was divided by the sum of the individual ping sample volumes to produce an absolute fish density for the interval.

The tracked target estimate is produced by grouping single targets into individual fish tracks using the standard algorithms in Echoview. Tracked targets were then visually examined and, where necessary, edited to correct tracking errors using the editing tools in Echoview. The total number of fish tracks is then divided by the sampled wedge volume. The fish density for each depth layers was determined by dividing the number of tracked targets in each depth layer by the sampled volume of each depth layer.

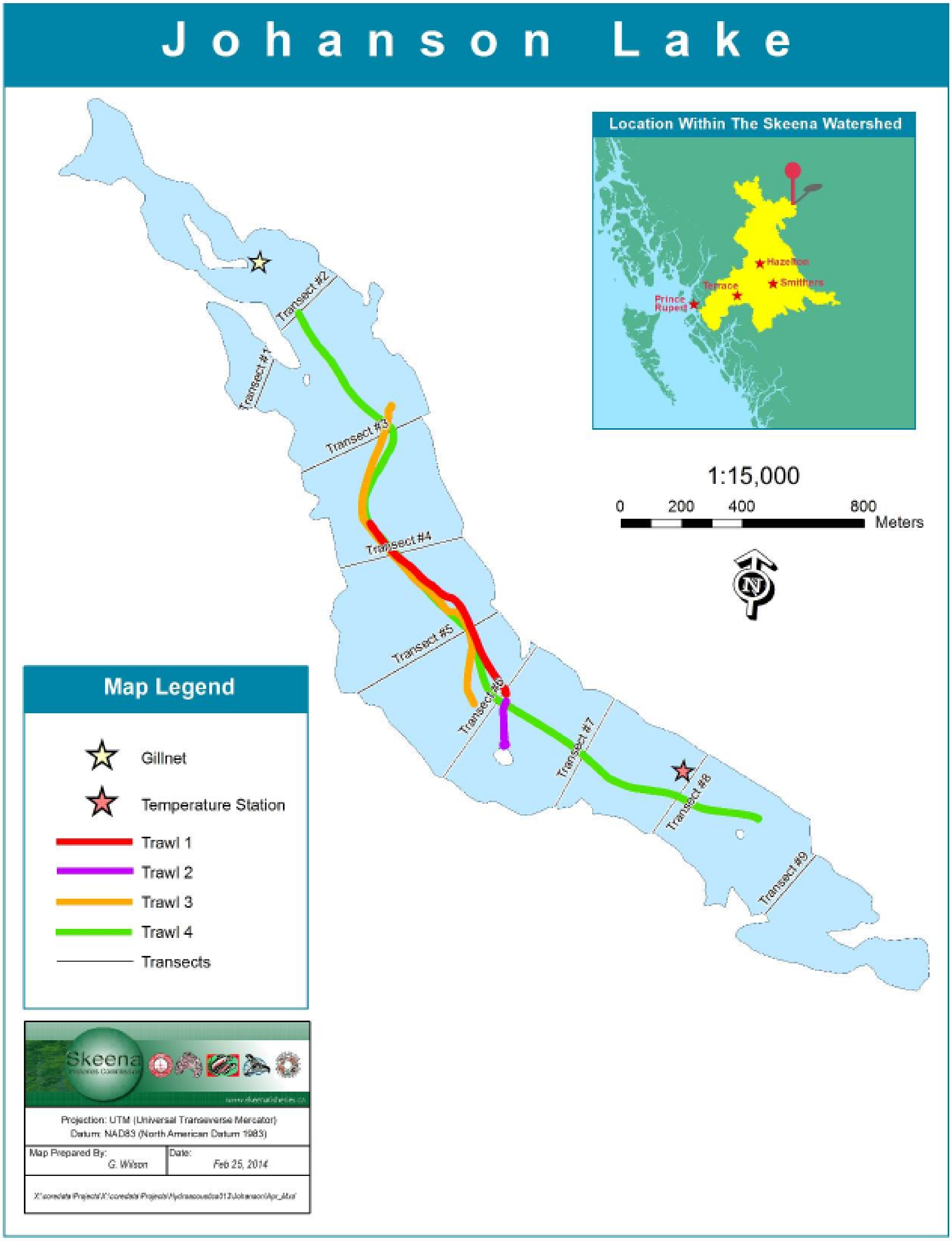


Figure 3. Johanson Lake survey map.

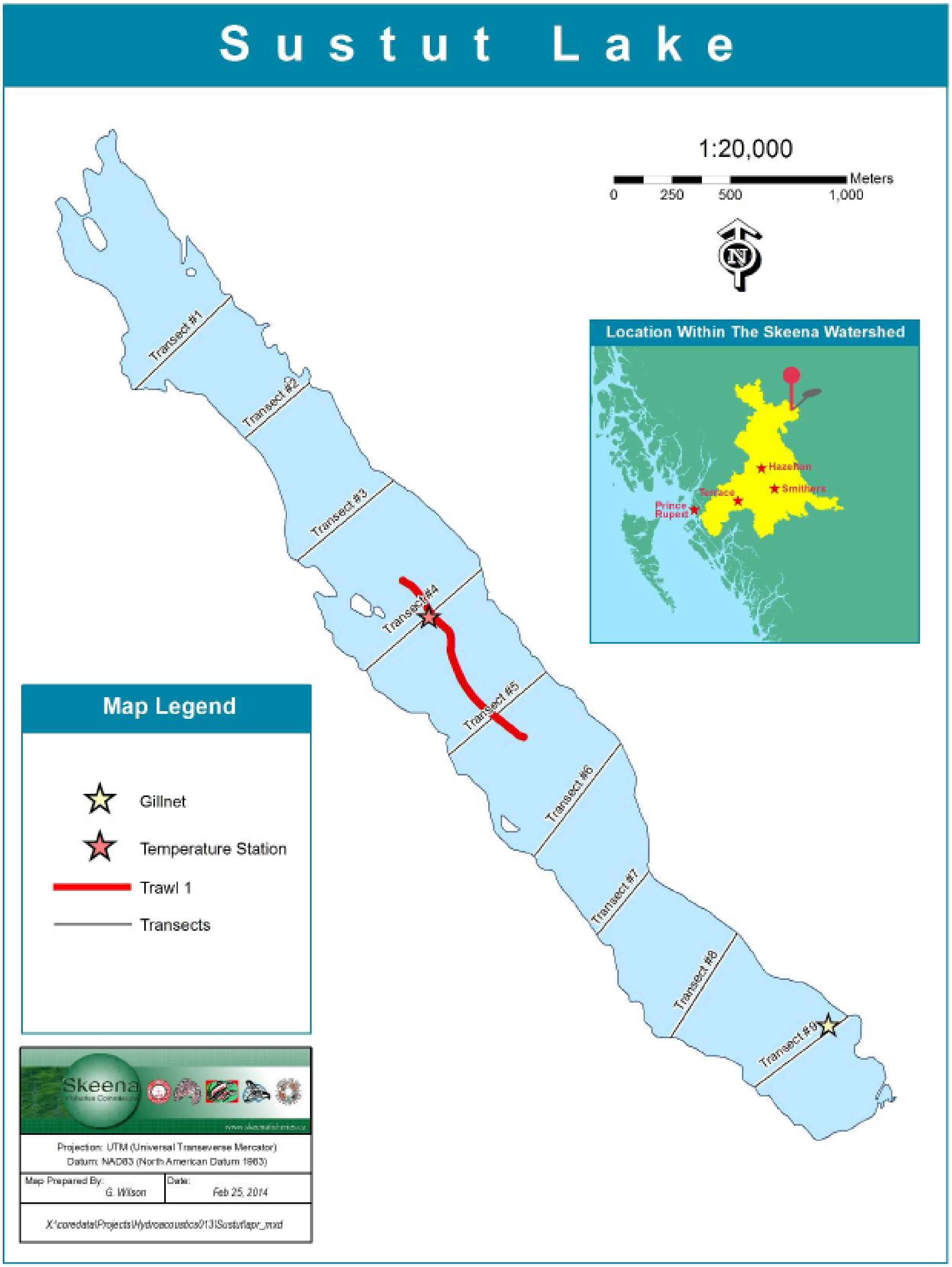


Figure 4. Sustut Lake survey map.

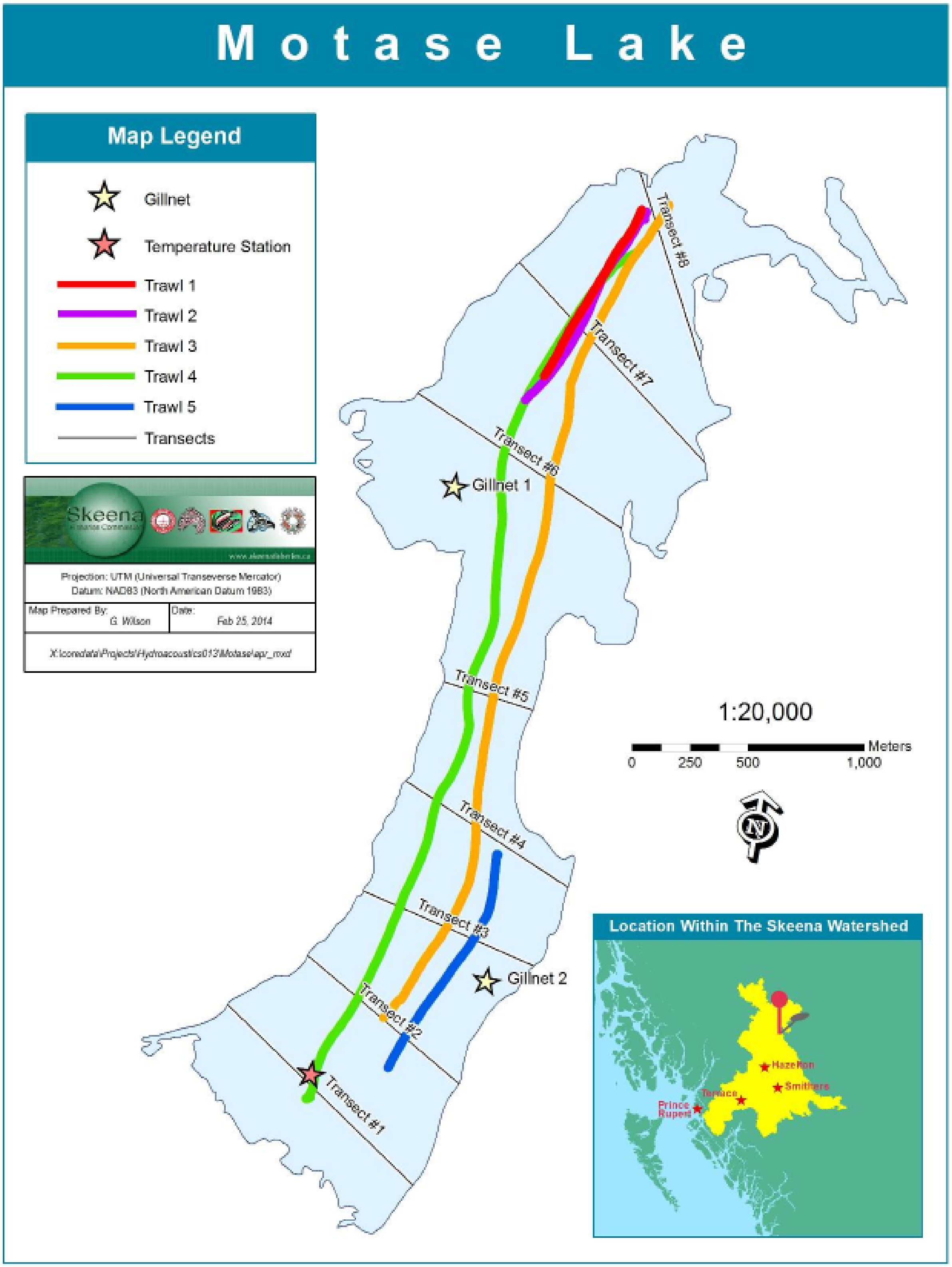


Figure 5. Motase Lake survey map

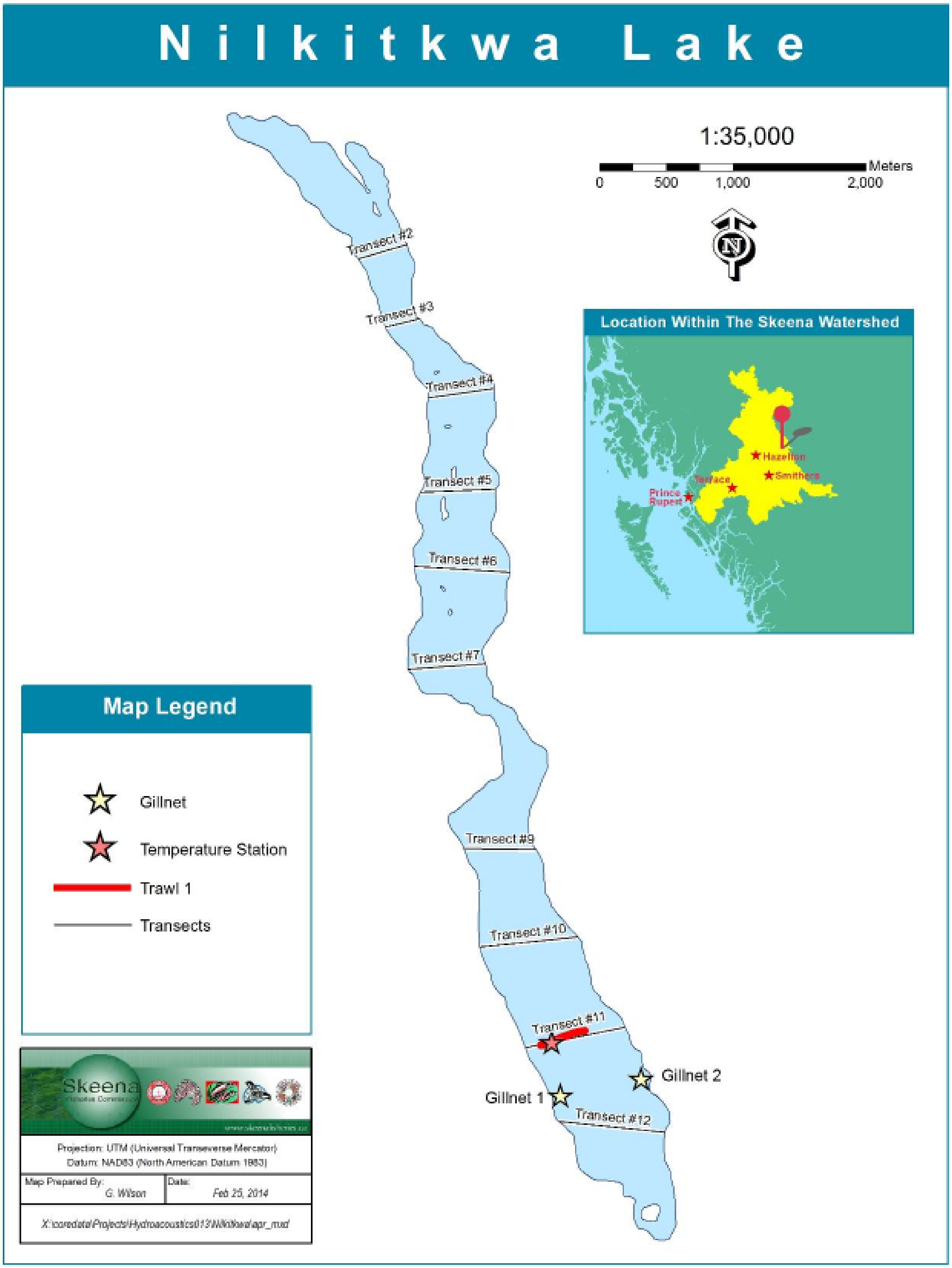
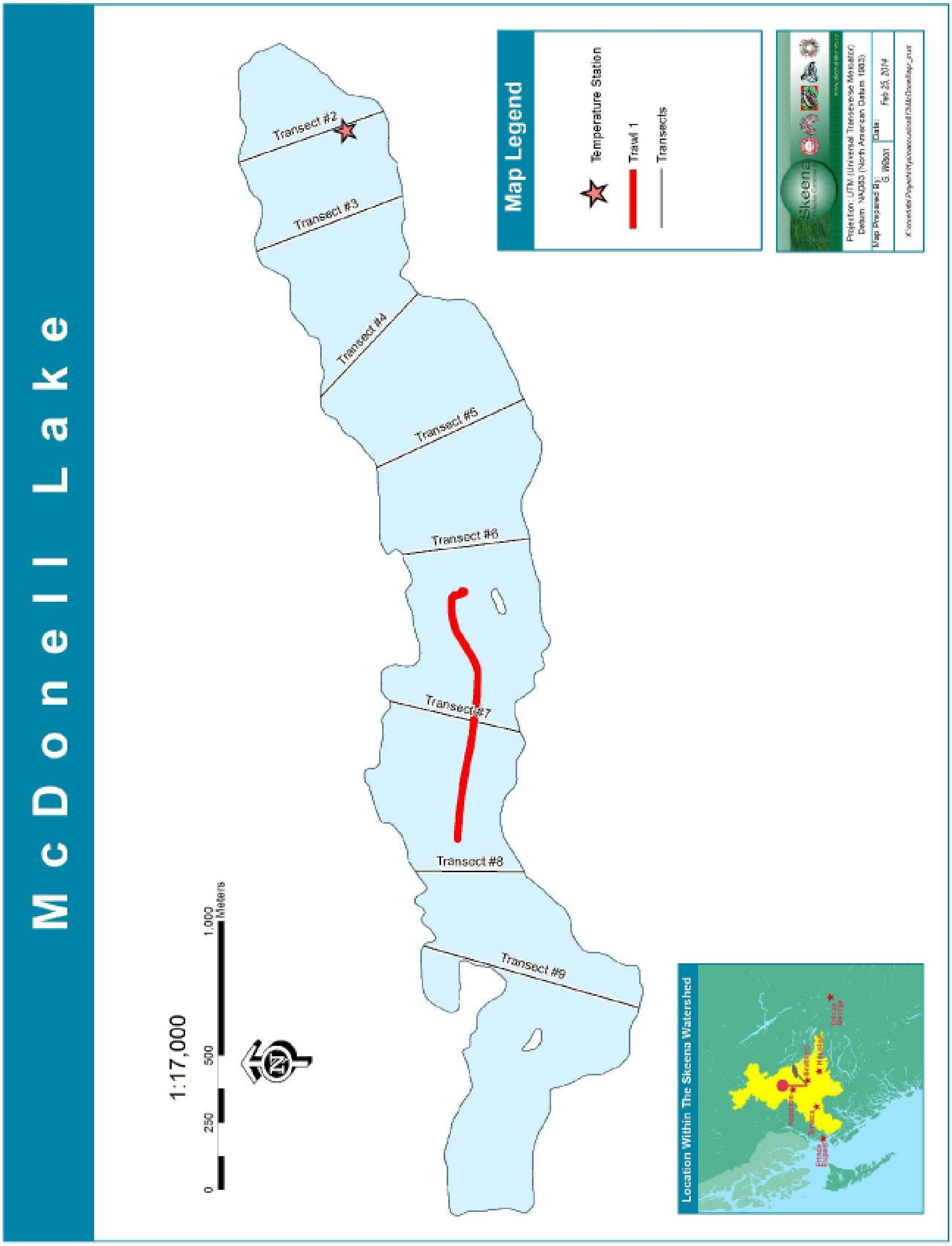


Figure 6. Nilkitkwa Lake survey map


McDonell Lake
Map Legend
Temperature Station
Trawl 1
Transects
Transect #2
Transect #3
Transect #4
Transect #5
Transect #6
Transect #7
Transect #8
Transect #9
1:17,000
0
250
500
1,000
Meters
Location Within The Skeena Watershed
Projection: UTM (Universal Transverse Mercator)
Datum: NAD83 (North American Datum 1983)
Map Prepared By: G. Wilson
Date: Feb 25, 2014

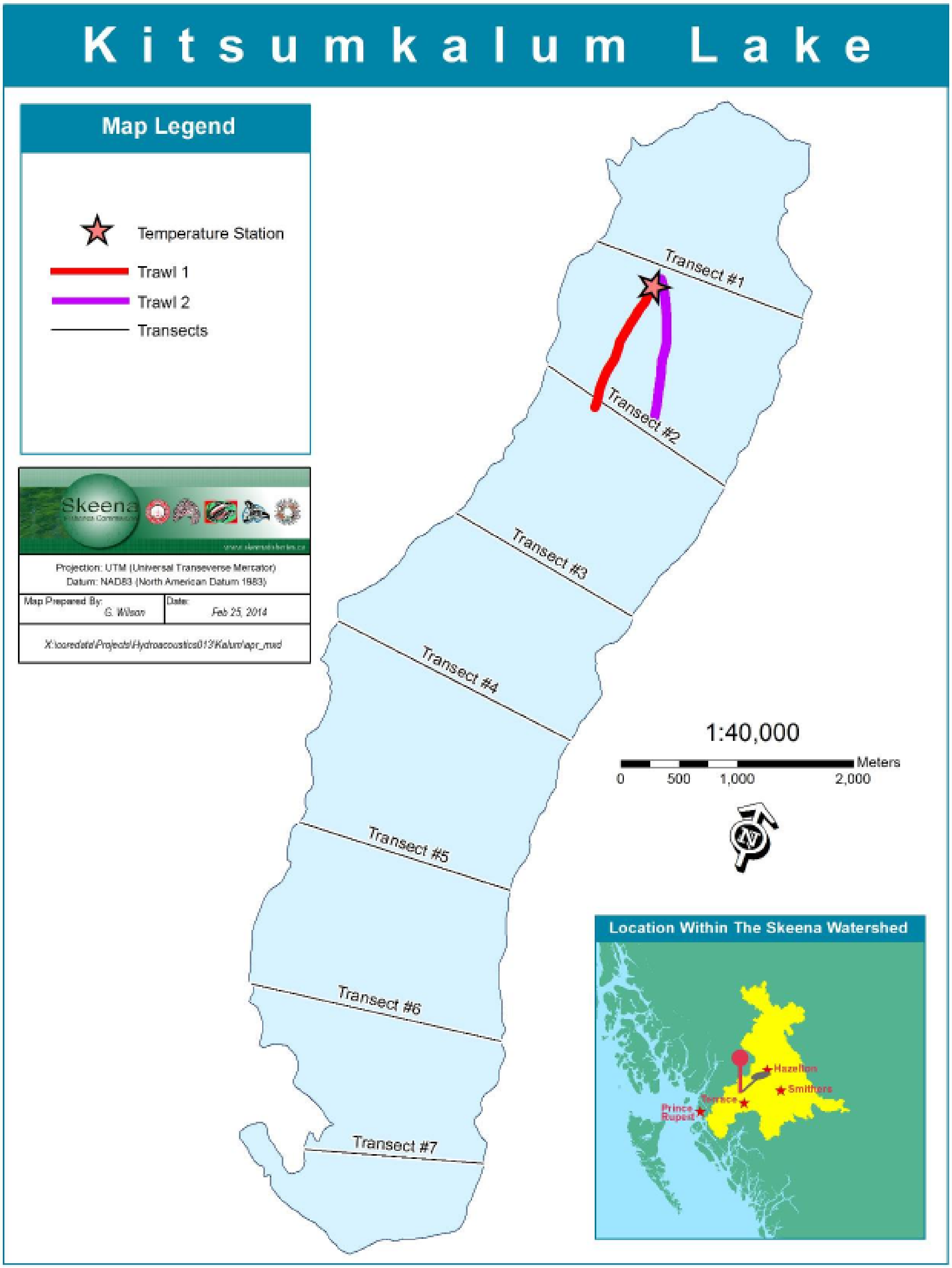


Figure 8. Kitsumkalum Lake survey map

Following the general guidelines of MacLellan and Hume 2010, population estimates for Sustut, Kitsumkalum, McDonell, and Nilkitkwa lakes were calculated using the integration method because their estimated fish densities were above 500 fish/ha. Estimates for Motase and Johanson lakes were calculated using the tracked target method. Results using the single target (ST) and tracked target (TT) methods are presented for comparison in Table 5.

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 all six 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 and gillnet 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.

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, which was calibrated and marked prior to sampling. In addition, Swedish gillnets were used to capture fish from 0-2m depths in the littoral zones at Johanson, Sustut, Motase, and Nilkitkwa lakes. These gillnets consisted of 4 variable mesh sizes between ½” and 1”. Gillnets were set at dusk and allowed to soak for the duration of the survey.

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 salmonids.

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen data were collected at all 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 data were recorded.

RESULTS AND DISCUSSION

Johanson Lake

Johanson Lake was surveyed on the night of August 6, 2013. The surface temperature was 16.7ºC degrees, with a gradual decline to 11.4 ºC at 8 m, and a small thermocline between 8 and 11 m with another gradual decline to a hypolimnion of 5.0 ºC below 14 m (Figure 12).

We captured 14 age-0 *O.nerka* during four trawl tows with a combined length of about 5.1 km (Figure 3, and Table 2). One gillnet was set twice at Johanson Lake for a total soak time of approximately 8 hours (Figure 3, and Table 3). One *O.nerka* measuring 74mm, and weighing 3.8g was captured in the gillnet (Table 4). The average length of *O.nerka* fry captured by trawl was 43.4 mm, with an average weight of 0.9 grams (Table 4). All of the *O.nerka* fry caught in the trawl were age-0, or young of the year fry. The *O.nerka* caught in the gillnet was age-1.

Hydroacoustic data were collected from nine transects across the long axis of the lake. Most fish targets were found between 4m and 7m depth in the water column (Figures 13 and 14). The hydroacoustic population estimate for age-0 *O.nerka* in Johanson Lake was 4.9×10^4 or 331/ha ± 47%, calculated with the tracked target method (Figure 9 and Table 5). The total age-0 *O.nerka* biomass was estimated at 43.6 kg (Table 6).

The PR capacity model (Cox-Rogers et. al 2004) provides a benchmark that can be used to compare an observed sockeye fry biomass with the rearing capacity of a given lake. According to the PR capacity model, the biomass of *O.nerka* fry observed during the 2013 hydroacoustic survey represents 6.2% of the rearing capacity, or R_{max}, at Johanson Lake (Table 6).

The 2013 Johanson Lake sockeye fry population density estimate (331/ha) and biomass estimate (44 kg) are significantly lower than the density and biomass estimates from hydroacoustic surveys undertaken in 2004 (1,195/ha, 337 kg), and 2010 (516/ha, 91 kg) (Table 7). There are no available recent sockeye escapement data specifically for Johanson Lake. The Ministry of Environment operates a fence on the Sustut River, tributary to both Johanson and Sustut lakes. In 2012 (brood year for 2013 age-0 *O.nerka*), 1,309 adult sockeye were enumerated at the Sustut fence (Ministry of Forests, Lands and Natural Resource Operations, 2013). This is similar to the average of 1,616 adult sockeye enumerated at the Sustut River fence since 1992, significantly smaller than the number of sockeye enumerated in 2003 (4,993) (brood year for 2004 age-0 *O.nerka*), and greater than the number of adult sockeye enumerated in 2009 (540) (brood year for 2010 age-0 *O.nerka*). The small number of age-0 *O.nerka* estimated in 2013 in Johanson Lake is surprising considering the number of adult sockeye enumerated at the Sustut fence in 2012 was close to the 20 year average, and the population of age-0 *O.nerka* estimated at Sustut Lake in 2013 was relatively abundant (see next page). A potential stream blockage on Johanson Creek between the Sustut River and Johanson Lake, may deter sockeye from accessing Johanson Lake, while allowing passage to Sustut Lake.

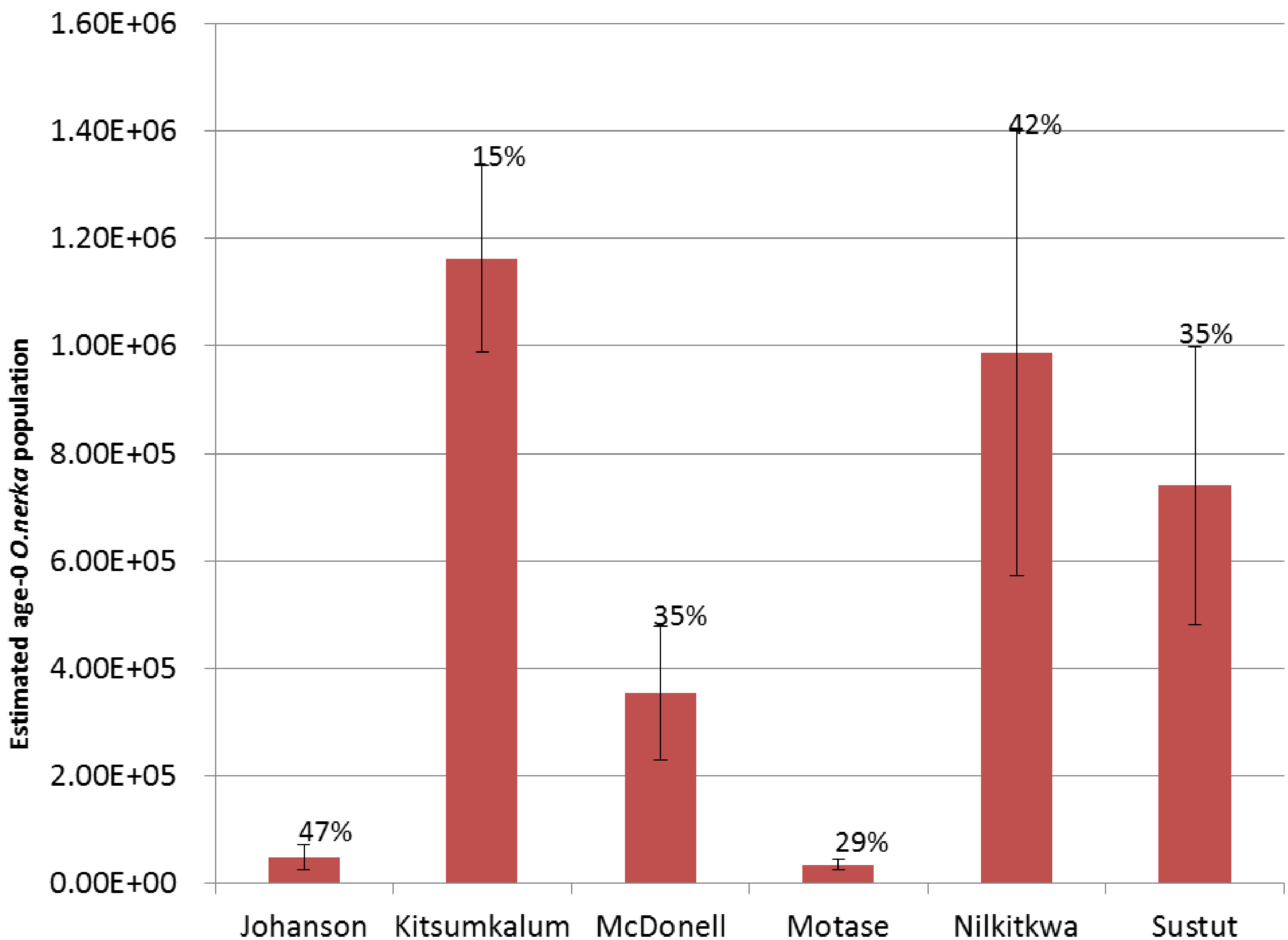


Figure 9. Graph showing the 2013 age-0 *O.nerka* population abundance estimates for Johanson, Kitsumkalum, McDonell, Motase, Nilkitkwa, and Sustut lakes. The error bars show the 95% confidence intervals.

Sustut Lake

Sustut Lake was surveyed on the night of August 6, 2013. The surface temperature was 18.0ºC degrees, with a gradual decline to 9.0 ºC at 15 m depth (Figure 12).

We captured 135 *O.nerka* during one trawl tow with a length of about 0.9 km (Figure 4, and Table 2). The average length of *O.nerka* fry captured by trawl was 40.3 mm, with an average weight of 0.7 grams (Table 4). All of the *O.nerka* caught by trawl were age-0, or young of the year fry. One gillnet was set at Sustut Lake for a soak time of approximately 5 hours (Figure 4, and Table 3). Three redside shiners (*Richardsonius balteatus*), and four *O.nerka* captured in the gillnet (Table 4) (Figure 11). The *O.nerka* caught in the gillnet were all age-1 or older with an average length of 83.5 mm and an average weight of 7.3 grams. The largest *O.nerka* caught in the gillnet was 107 mm in length, and weighed 15.4 g (Figure 11). It had developed gonads, and was most likely a kokanee.

Hydroacoustic data were collected from nine transects across the long axis of the lake. Most fish targets were found between 8 m and 12 m deep in the water column (Figures 13 and 20). The highest densities of fish targets were observed in the mid and southern sections of the lake. The hydroacoustic population for age-0 *O.nerka* in Sustut Lake was estimated at 7.40×10^5 or 2,893/ha ± 35%, calculated using the integration method (Figure 9 and Table 5). The total age-0 *O.nerka* biomass was estimated at 518 kg, or approximately 77% of Rmax for Sustut Lake (Table 6).

The relatively high age-0 *O.nerka* population estimate observed in 2013 in Sustut Lake is surprising considering the low estimate that was observed in Johanson Lake. Both lakes are part of the Sustut River Watershed. Previous surveys at both lakes estimated that 20% (in 2010) to 30% (in 2004) of the total age-0 *O.nerka* population estimated for Sustut and Johanson lakes were observed in Johanson Lake (Table 7). By 2013 this ratio has dropped to only 8%. The number of targets on the echograms from Johanson was clearly much lower than the number of targets on the Sustut Lake echograms. To illustrate this, Figures 14 and 20 show the echograms with the highest target density for both lakes. This significant decrease in age-0 *O.nerka* in Johanson Lake compared to Sustut Lake may be the result of a partial blockage, such as a beaver dam, on Johanson Creek between the Sustut River and Johanson Lake, which may deter sockeye from migrating further upstream.

Previous hydroacoustic surveys at Sustut Lake have raised the question of whether there are significant numbers of kokanee in Sustut and Johanson lakes (Carr-Harris, 2011). The presence of an *O.nerka* with developed gonads in a gillnet in this system in 2013 proves that kokanee are present in the upper Sustut lakes, however the abundance of the kokanee population is still unknown. The relative abundance of kokanee and sockeye in Sustut Lake will be quantified using genetic analysis during future hydroacoustic surveys.

Figure 10. Photo of the redside shiner and *O.nerka* caught in the gillnet set at Sustut Lake, on August 6, 2013.

Kitsumkalum Lake

Kitsumkalum Lake was surveyed on the night of September 7, 2013. The surface temperature was 14.3ºC degrees, with a gradual decline to 7.6 ºC at 30 m, the maximum cable length of the YSI meter used to measure temperature. No thermocline was observed at Kitsumkalum Lake (Figure 12).

We conducted two trawl tows with a total length of about 2.2 km at Kitsumkalum Lake (Figure 8 and Table 2). The total trawl catch was 44 *O.nerka* (Figure 10). Trawl depths ranged from approximately 18m to 28m (Table 2). The average length of *O.nerka* fry captured in the trawl was 49.2 mm, with an average weight of 1.3 grams (Table 4). All were age-0. Gillnets were not deployed at Kitsumkalum Lake.

Hydroacoustic data were collected from seven transects across the long axis of the lake. The fish targets at Kitsumkalum Lake were evenly distributed vertically between 4m and 35m in the water column, with a small peak in densities occurring at depths ranging from 18m to 32m (Figures 13 and 17). The horizontal distribution of fish targets was very uneven, with high densities of fish targets observed in the northern part of the lake, and low densities observed in the middle and southern sections of the lake.

The Kitsumkalum Lake age-0 sockeye population estimate was 1.16 x 10^6 or 629 age-0 *O.nerka*/ha ± 15%, calculated with the integration method (Figure 9 and Table 5). The total age-0 *O.nerka* biomass was estimated at 1,512 kg (Table 6). This estimated biomass is equivalent to 30% of the rearing capacity for Kitsumkalum Lake (Table 6).

Prior to 2013, the most recent hydroacoustic surveys of Kitsumkalum Lake were completed in 2005 by the Cultus Lake Salmon Research Laboratory, and again in 2007, 2009, and 2011 by the SFC (Table 7). The 2013 age-0 *O.nerka* density and biomass estimates are significantly larger than the past estimates of Kitsumkalum Lake. The increase in age-0 *O.nerka* is probably the result of the relatively strong 2012 sockeye escapement to Kitsumkalum Lake of 10,800, compared to the escapements of 5,500 in 2008 (brood year for 2009 age-0 *O.nerka*), 3,400 in 2006 (brood year for 2007 age-0 *O.nerka*), and 5,000 in 2004 (brood year for 2005 age-0 *O.nerka*) (Fisheries and Oceans Canada, 2013). The lower age-0 *O.nerka* estimate observed in 2011 was an exception to this trend, as the 2010 sockeye escapement to Kitsumkalum Lake (brood year for 2011 age-0 *O.nerka*) was similar to the 2012 escapement (10,900 versus 10,800) (Fisheries and Oceans Canada, 2013).

Figure 11. Photo of juvenile sockeye caught in one trawl tow at Kitsumkalum Lake. September 7, 2013.

McDonell Lake

McDonell Lake was surveyed on September 10, 2013. The surface temperature was 16.8 ºC with stable temperatures down to 5 metres depth, and a gradual decline to 10.9 ºC at 12 meters depth (Figure 12).

SFC captured 65 age-0 *O.nerka* during one trawl tow with an approximate length of 1.0 km (Figure 7, Tables 2, and 4). No gillnets were set at McDonell Lake. The average length of trawl captured *O.nerka* was 56.3 mm, with an average weight of 1.8 grams (Table 4). All of the *O.nerka* fry captured at McDonell Lake were age-0. Most of the fish targets were found between 9 m and 14 m depths (Figures 13 and 16). The highest densities of fish targets were found in the middle and eastern sections of the lake.

The age-0 *O.nerka* population estimate for McDonell Lake in 2013 was 3.54 x 10^5 or 1,651/ha ± 35%, calculated with the integration method (Figure 9 and Table 5). Given the average weight from the trawl sample, the estimated biomass was 637 kg, or approximately 64% of Rmax (Table 6). The 2012 age-0 *O.nerka* biomass estimate for McDonell Lake is significantly higher than the estimates obtained in previous surveys (Table 7). This observation is difficult to explain given that the 2012 sockeye escapement to McDonell Lake (1,970) was below the average (2,470) since 2002 (Fisheries and Oceans Canada, 2013).

Motase Lake

Motase Lake was surveyed on the nights of August 3 and 4, 2013. The surface temperature was 17.5ºC degrees, with a sharp decline to 8.8 ºC at 5 m depth, and a slow decline to 6.9 ºC at 25m depth (Figure 12).

We captured 65 *O.nerka* during five trawl tows with a combined length of about 10.3 km (Figure 5, and Table 2). Six prickly sculpins (*Cottus asper*), and 17 pygmy whitefish (*Prosopium coulterii*) were also caught in the trawl. Most of the *O. nerka* were captured at the surface, where three of the five trawl tows were conducted. Other species were captured lower in the water column (Table 2). Two gillnets were each set twice at Motase Lake for a total soak time of approximately 16.75 hours (Figure 5, and Table 3). A total of 51 *O.nerka* measuring 70.9mm, and weighing 4.1g on average were captured in the gillnets (Table 4). Two rainbow trout (*Oncorhynchus mykiss*) were also caught in the gillnets. The average length of *O.nerka* captured by trawl was 49.0 mm, with an average weight of 1.6 grams (Table 4). Fifty of the juvenile *O.nerka* that were caught by both gears were age-0, and 66 were older.

Hydroacoustic data were collected from eight transects across the long axis of the lake. Data from a horizontal transducer and vertical transducer were collected, and analyzed. Most fish targets were observed between the surface and 4m depth in the water column, from data collected by the horizontal transducer (Figure 13). Very few targets were observed from data collected by the vertical transducer (Figure 18). The hydroacoustic population estimate for age-0 *O.nerka* in Motase Lake calculated with the tracked target method was 3.4 x 10^4 or 84/ha ± 29%(Figure 9 and Table 5). The total age-0 *O.nerka* biomass was estimated at 42.9 kg (Table 6), representing 9.9% of the rearing capacity, or R_{max}, at Motase Lake.

The 2013 Motase Lake sockeye fry population density estimate (84/ha) and biomass estimate (34.2 kg) are comparable to density observed in 2009 (93/ha), and slightly larger than that observed in 2003 (Table 7). The Cultus Lake Salmon Research Laboratory used a single vertical transducer and did not collect horizontal data during the 2003 survey, which may explain why the age-0 *O.nerka* estimate for that year was smaller than the 2009 and 2013 estimates.

Nilkitkwa Lake

Nilkitkwa Lake was surveyed on the night of September 4, 2013. The surface temperature was 17.1ºC degrees, with a gradual decline to 16.7 ºC at 3 m, and a thermocline between 3 and 8 m with another gradual decline to a hypolimnion of 7.5 ºC below 11 m (Figure 12).

We conducted one trawl tow with a total length of only approximately 0.4 km at Nilkitkwa Lake (Figure 6 and Table 2). The total trawl catch was 444 *O.nerka*, which were caught at depths ranging from approximately 6m to 9m. The average length of *O.nerka* fry captured in the trawl was 49.3 mm, with an average weight of 1.2 grams (Table 4). All were age-0 *O.nerka*. Two gillnets were set at Nilkitkwa Lake, and two rainbow trout, one redside shiner, and two longnose sucker (*Catostomus catostomus*) were caught.

Hydroacoustic data were collected from ten transects across the long axis of the lake. Most of the fish targets were found between 5 m and 10 m (Figures 13 and 19). The highest densities of fish targets were found in the southern section of the lake.

The Nilkitkwa Lake age-0 sockeye population was estimated at 9.87×10^5 or 2,151 age-0 *O.nerka*/ha ± 42%, calculated with the integration method (Figure 9 and Table 5). The total age-0 *O.nerka* biomass was estimated at 1,184 kg (Table 6). No PR capacity model is available for Nilkitkwa Lake.

The most recent hydroacoustic survey of Nilkitkwa Lake prior to this one was completed in 2011 by the SFC (Table 7). The 2013 age-0 *O.nerka* density is similar to the density observed in 2011, however the estimated age-0 *O.nerka* biomass in 2011 (2,526 kg ± 55%) is more than twice the biomass estimated in 2013 (1,184 kg ± 42%), though this difference is not statistically significant.

CONCLUSION

Hydroacoustic surveys allow trends in juvenile sockeye populations in lakes that represent ongoing or potential conservation concerns to be ascertained. Regular hydroacoustic surveys provide a baseline that can be used to compare estimates across years. Where escapement is known, hydroacoustic data provides an indicator of freshwater survival.

The juvenile sockeye population estimates calculated in 2013 for McDonell, Motase, Nilkitkwa, and Sustut lakes appear to be mostly similar to hydroacoustic estimates generated in previous surveys of the same lakes (Table 7), and well below the rearing capacity of each system. The significant decrease observed at Johanson Lake is of concern, and should not be over-looked. The access to Johanson Lake may be blocked, preventing sockeye from utilizing its habitat for spawning and rearing. The portion of the rearing capacity used in 2013 at Johanson Lake has fallen to 6%. The significant increase in the juvenile sockeye population estimate observed in Kitsumkalum Lake in 2013 is certainly representative of the increase in the sockeye escapement to this system observed over the last few years. Even though the juvenile sockeye population appears to have increased at Kitsumkalum Lake, it is still well below the rearing capacity of this system (30%).

ACKNOWLEDGEMENTS

Funding for this project was provided by the Northern Fund of the Pacific Salmon Commission (PSC). The field work was carried out by Gordon Ridley, Jonathan Williams, and Yvonne Wesley, under the supervision of Janvier Doire. Thanks to Fisheries and Oceans Canada's Cultus Lake Group for sharing their data and transect designs. Allen Gottesfeld provided advice and technical support throughout the field season and during analysis. Analysis of the data and report preparation were by the authors, with mapping by Gordon Wilson, and editing by Davide Latremouille.

REFERENCES

Brett, J.R 1952. Temperature tolerance in young Pacific salmon, Genus Oncorhynchus. J. Fish. Res. Bd. Can. 9:265-323.

Carr-Harris, C. 2009 (1). McDonell Lake Hydroacoustic Surveys 2006 & 2007. Skeena Fisheries Commission, prepared for Gitksan Watershed Authorities.

Carr-Harris, C. 2009 (2). McDonell Lake Hydroacoustic Surveys 2008. Skeena Fisheries Commission, Prepared for Gitksan Watershed Authorities.

Carr-Harris, C. 2009. Skeena and Nass Sockeye Lakes Hydroacoustic Surveys 2008. Skeena Fisheries Commission, prepared for the Pacific Salmon Commission.

Carr-Harris, C. 2010. 2009 Skeena Sockeye Lakes Hydroacoustic Surveys. Skeena Fisheries Commission, prepared for the Skeena Watershed Initiative.

Carr-Harris, C. 2011. Skeena Sockeye Lakes Hydroacoustic Surveys 2010. Skeena Fisheries Commission, prepared for the Pacific Salmon Commission.

Carr-Harris, C. 2012 (1). 2011 Skeena and Nass Sockeye Lakes Hydroacoustic Surveys. Skeena Fisheries Commission. Unpublished report.

Carr-Harris, C. 2012 (2). 2011 Morrison and Nilkitkwa Lakes Hydroacoustic Surveys. Skeena Fisheries Commission, prepared for the Pacific Salmon Commission.

Cox-Rogers, S., Hume, J.M.B, and Shortreed, K.S. 2004. Stock Status and Lake-Based Production Relationships for Wild Skeena River Sockeye Salmon. Canadian Science Advisory Secretariat Research Document 2004/010.

Fisheries and Oceans Canada. 2013. NuSEDs database.

Gottesfeld, A. and Rabnett, K. 2008. Skeena River Fish and Their Habitat. Skeena Fisheries Commission. Hazelton, B.C.

Hall, P. and Carr-Harris C. 2008. Skeena & Nass Sockeye Lakes Hydroacoustic Surveys Report 2007. Skeena Fisheries Commission. Hazelton, B.C. Report to the Pacific Salmon Commission.

Hall, P. 2007. Skeena Sockeye Lakes Hydroacoustic Surveys Report 2006. Skeena Fisheries Commission. Prepared for Pacific Salmon Commission.

Hume, J. and MacLellan, S. 2008. Pelagic Fish Surveys of 23 Sockeye Rearing Lakes in the Skeena River System and in Northern British Columbia Coastal Watersheds from 1997 to 2005. Fisheries and Oceans Canada. Salmon and Freshwater Ecosystems Division, Science Branch. Cultus Lake Salmon Research Laboratory. Canadian Technical Report of Fisheries and Aquatic Sciences 2812.

Hume, J. and K. Shortreed. 2006. Limnological and limnetic fish surveys of North Coast Area lakes in 2005. Fisheries and Oceans Canada. Marine and Environmental Habitat Science Division. Cultus Lake Laboratory. Unpublished report.

Love 1977. Target strength of an individual fish at any aspect. J. Acoust. Soc. Am. 62:6.

MacLellan, S.G. and Hume, J.M.B. 2010. An evaluation of methods used by the freshwater ecosystems section for pelagic fish surveys of sockeye rearing lakes in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2886: v + 67 p.

Parker-Stetter, S.L., Rudstam, L.G., Sullivan, P.J. and Warner, D.M. 2009. Standard operating procedures for fishery acoustics in the Great Lakes. Great Lakes Fisheries Commission Special Publication 09-01. 180 pp. Available at: http://www.glfc.org/pubs/SpecialPubs/Sp09_1.pdf. Accessed April 22, 2009.

Shortreed, K.S., Hume, J.M., and Stockner, J.G. 2000. Using Photosynthetic Rates to Estimate the Juvenile Sockeye Salmon Rearing Capacity of British Columbia Lakes. *In* Sustainable fisheries management: Pacific Salmon. Edited by E. E. Knudsen, C. R. Steward, D. D. MacDonald, J. E. Williams, and D. W. Reiser. CRC Press. pp. 505-521.

Shortreed, K, Hume, J., and Morton, K. 2002. Trip report and preliminary analysis from limnological and fish surveys of eight North Coast Area lakes in September, 2001. Cultus Lake Laboratory. Fisheries and Oceans Canada, Marine and Environmental Habitat Science Division.

Shortreed, K. and Hume, J. 2004. Report on limnological and limnetic fish surveys of North Coast Area lakes in 2002 and 2003. Cultus Lake Salmon Research Laboratory. Fisheries and Oceans Canada.

Shortreed, K., Hume, J., and Malange, K. 2007. Preliminary Categorization of the Productivity of 37 Coastal and Skeena River System Lakes in British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences 2718. Fisheries and Oceans Canada. Science Branch, Pacific Region, Cultus Lake Salmon Research Laboratory.

Simmonds, J. and MacLennan, J. Fisheries Acoustics: Theory and Practices. 2005. Blackwell Publishing.

Table 2. 2013 Hydroacoustic surveys trawl summary by lake

Lake	Date	Trawl #	Time Start	Time End	Easting Start	Northing Start	Easting End	Northing End	Depth (m)	ON	PWF	Sc
Johanson	7-Aug-13	1	0047	0103	672943	6275172	673436	6274661	9-14	1	0	0
Johanson	7-Aug-13	2	0108	0113	673441	6274628	673442	6274485	12-15	0	0	0
Johanson	7-Aug-13	3	0124	0146	673337	6274611	672979	6275559	9-16	0	0	0
Johanson	7-Aug-13	4	0248	0336	672648	6275840	674295	6274316	6.5	13	0	0
Kitsumkalum	7-Sept-13	1	0243	0303	513823	6072411	513708	6071297	19-27	31	0	0
Kitsumkalum	7-Sept-13	2	0337	0400	514218	6071382	513866	6072531	18-28	13	0	0
McDonell	10-Sept-13	1	0100	0117	589161	6071306	590079	6071290	10	66	0	1
Motase	4-Aug-13	1	0246	0302	621831	6213280	621542	6212503	3-8	0	0	0
Motase	4-Aug-13	2	0313	0333	621480	6212387	621850	6213239	0-2	3	0	0
Motase	4-Aug-13	3	1700	1800	621340	6209665	621937	6213303	0-2	45	0	0
Motase	4-Aug-13	4	2110	2210	621834	6213089	621088	6209275	3-8	7	17	6
Motase	4-Aug-13	5	2238	2258	621396	6209457	621699	6210435	0-2	10	0	0
Nilkitkwa	4-Sept-13	1	0208	0215	648916	6136337	649247	6136447	6-9	444	0	0
Sustut	6-Aug-13	1	0009	0025	648916	6136337	649247	6136447	8.5	135	0	0

ON: *O.nerka*; PWF: Pygmy whitefish; Sc: prickly sculpin

Table 3. 2013 Gillnet location, effort, and catch by lake

Lake	Date	Gillnet #	Time Start	Time End	Easting	Northing	ON	RB	RSS	LNS
Johanson	7-Aug-13	2	0235	1045	672504	6275997	1	0	0	0
Motase	4-Aug-13	2	1445	2330	621244	6211971	31	0	0	0
Motase	4-Aug-13	2	1500	2305	621747	6209901	20	2	0	0
Nilkitkwa	3-Sept-13	2	1930	0335	649061	6135963	0	0	0	0
Nilkitkwa	3-Sept-13	2	1945	0320	649669	6136093	0	2	1	2
Sustut	5-Aug-13	1	2115	0220	658242	6270816	4		3	

ON: *O.nerka*; RB: rainbow trout; RSS: redside shiner; longnose sucker

Table 4. 2013 trawl and gillnet fish catch sample summary

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)
Johanson	Trawl	*O.nerka*	14	43.4	50	37	3.4	0.9	1.3	0.5	0.2
Johanson	Gillnet	*O.nerka*	1	74	74	74	0	3.8	3.8	3.8	0
Kitsumkalum	Trawl	*O.nerka*	44	49.2	63	35	7.1	1.3	2.5	0.5	0.5
McDonell	Trawl	*O.nerka*	65	56.3	73	41	6.9	1.8	4.3	0.7	0.8
Motase	Trawl	*O.nerka*	65	49	72	32	10.8	1.6	4.6	.3	1.2
Motase	Gillnet	*O.nerka*	51	70.9	83	66	3.3	4.1	6.9	2.9	0.6
Nilkitkwa	Trawl	*O.nerka*	444	49.3	67	32	6.1	1.2	3.3	0.2	0.5
Sustut	Trawl	*O.nerka*	135	40.3	55	27	7.2	0.7	1.8	0.1	0.4
Sustut	Gillnet	*O.nerka*	4	83.5	107	74	15.8	7.3	15.4	4.4	5.4

Table 5. 2013 lakes hydroacoustic estimates by method

Lake	Estimate Method	Size Class	Density		Population	
			n/ha	95% C.I.	n	95% C.I.
Johanson	Single Target	Age-0 nerka	358	43%	52,480	43%
		Other Small	27	43%	3,950	43%
		Large	2	143%	366	143%
	Tracked	**Age-0 nerka**	**331**	**47%**	**48,491**	**47%**
		Other Small	**29**	**41%**	**4,235**	**41%**
		Large	**5**	**137%**	**728**	**137%**
	Integration	Age-0 nerka	223	40%	32,696	40%
		Other Small	17	40%	2,461	40%
		Large	1	138%	173	138%
Kitsumkalum	Single Target	Age-0 nerka	900	23%	1,664,214	23%
		Other Small	0	0	0	0
		Large	11	80%	21,195	80%
	Tracked Target	Age-0 nerka	790	24%	1,461,137	24%
		Other Small	0	0	0	0
		Large	10	72%	17,666	72%
	Integration	**Age-0 nerka**	**629**	**15%**	**1,162,898**	**15%**
		Other Small	**0**	**0**	**0**	**0**
		Large	**7**	**94%**	**12,307**	**94%**
McDonell	Single Target	Age-0 nerka	2,764	34%	592,708	34%
		Other Small	0	0	0	0
		Large	204	52%	43,776	52%
	Tracked Target	Age-0 nerka	2,605	33%	558,698	33%
		Other Small	0	0	0	0
		Large	203	48%	43,532	48%
	Integration	**Age-0 nerka**	**1,651**	**35%**	**354,073**	**35%**
		Other Small	**0**	**0**	**0**	**0**
		Large	**124**	**49%**	**26,604**	**49%**
Motase	**Tracked Target**	**Age-0 nerka**	**84**	**29%**	**34,171**	**29%**
		Other Small	**105**	**40%**	**42,986**	**40%**
		Large	**12**	**n/a**	**4,783**	**n/a**
Nilkitkwa	Single Target	Age-0 nerka	3,385	27%	1,553,186	27%
		Other Small	219	132%	100,610	132%
		Large	201	41%	92,334	41%
	Tracked Target	Age-0 nerka	3,213	n/a	1,474,156	n/a
		Other Small	115	n/a	52,646	n/a

		Large	232	n/a	106,563	n/a
	Integration	**Age-0 nerka**	**2,151**	**42%**	**986,891**	**42%**
		Other Small	**92**	**155%**	**42,045**	**155%**
		Large	**154**	**58%**	**70,620**	**58%**
Sustut	Single Target	Age-0 nerka	4,454	27%	1,139,900	27%
		Other Small	975	80%	249,397	80%
		Large	165	23%	42,139	23%
	Tracked Target	Age-0 nerka	4,149	n/a	1,061,849	n/a
		Other Small	671	n/a	171,681	n/a
		Large	182	n/a	46,461	n/a
	Integration	**Age-0 nerka**	**2,893**	**35%**	**740,335**	**35%**
		Other Small	**504**	**170%**	**128,889**	**170%**
		Large	**120**	**33%**	**30,782**	**33%**

Table 6. PR Capacity comparison chart

Lake	**Adjusted Rmax**	**Acoustic survey date**	**Estimation Method**	**Observed *O.nerka* fall fry**	**Avg. Weight**	**Observed biomass (kg)**	**% Rmax**
Johanson	704*	6-Aug-13	Tracked target	48,491	0.9	43.6	6.2%
Kitsumkalum	5000*	7-Sep-13	Integration	1,162,898	1.3	1512	30.2%
McDonell	992*	10-Sept-13	Integration	354,073	1.8	637	64%
Motase	430*	4-Aug-13	Tracked target	42,986	1.0	42.9	9.9%
Nilkitkwa	n/a	3-Sept-13	Integration	986,891	1.2	1,184	n/a
Sustut	676*	6-Aug-13	Integration	740,335	0.7	518	77%

*- From Cox-Rogers *et al.* 2004

** - From Shortreed *et al.* 2000

***- Adjusted $_{\text{Rmax f}}$rom Shortreed *et al.* 2007

Table 7. Past hydroacoustic estimates for lakes surveyed in 2013

Lake	Year	Date	Age-0 sockeye		Method	Source
			n/ha	Biomass (kg)		
Johanson	2004	11 Sept	1,195	337	Integration	Hume and MacLellan (2008)
	2010	3-4 Sept	516	91	Integration	Carr-Harris (2011)
	2013	6 Aug	331	43.6	Tracked Target	
Kitsumkalum	2005	4 Sept	254	955	Integration	Hume and Shortreed (2006)
	2007	19 Oct	217	885	Integration	Hall and Carr-Harris (2008)
	2009	1 Sept	316	995	Tracked Target	Carr-Harris (2010)
	2011	4 Aug	291	438	Integration	Carr-Harris (2012)
	2013	7 Sept	629	1,512	Integration	
McDonell	2001	10 Sept	352	216	Tracked Target	Shortreed *et al.* 2002
	2002	13 Sept	595	216	Integration	Shortreed and Hume (2004)
	2005	22 Sept	880	487	Integration	Hall and Harris (2007)
	2006	9 Aug	371	104	Integration	Carr-Harris (2009) (1)
	2007	26 Sept	949	285	Integration	Carr-Harris (2009) (1)
	2008	18 Aug	1,486	464	Integration	Carr-Harris (2009) (2)
	2009	17 Aug	846	464	Tracked Target	Carr-Harris (2010)
	2010	6-Aug	1,607	285	Integration	Carr-Harris (2011)
	2011	22 Aug	1,535	464	Integration	Carr-Harris (2012) (1)
	2013	10 Sept	1,651	637	Integration	
Motase	2003	29 Aug	52	23.8	Tracked	Hume and MacLellan (2008)

					Target	
	2009	23 Sept	93	n/a	Tracked Target	Carr-Harris (2010)
	2013	3-4 Aug	84	34.2	Tracked Target	
Nilkitkwa	2011	28 Sept	2,162	2,526	Integration	Carr-Harris (2012) (2)
	2013	4 Sept	2,151	1,184	Integration	
Sustut	2004	10 Sept	2,652	862	Integration	Hume and MacLellan (2008)
	2010	1-Sept	1,000	325	Integration	Carr-Harris (2011)
	2013	6 Aug	2,893	518	Integration	

- Total small fish population. Not apportioned for age-0 *O.nerka

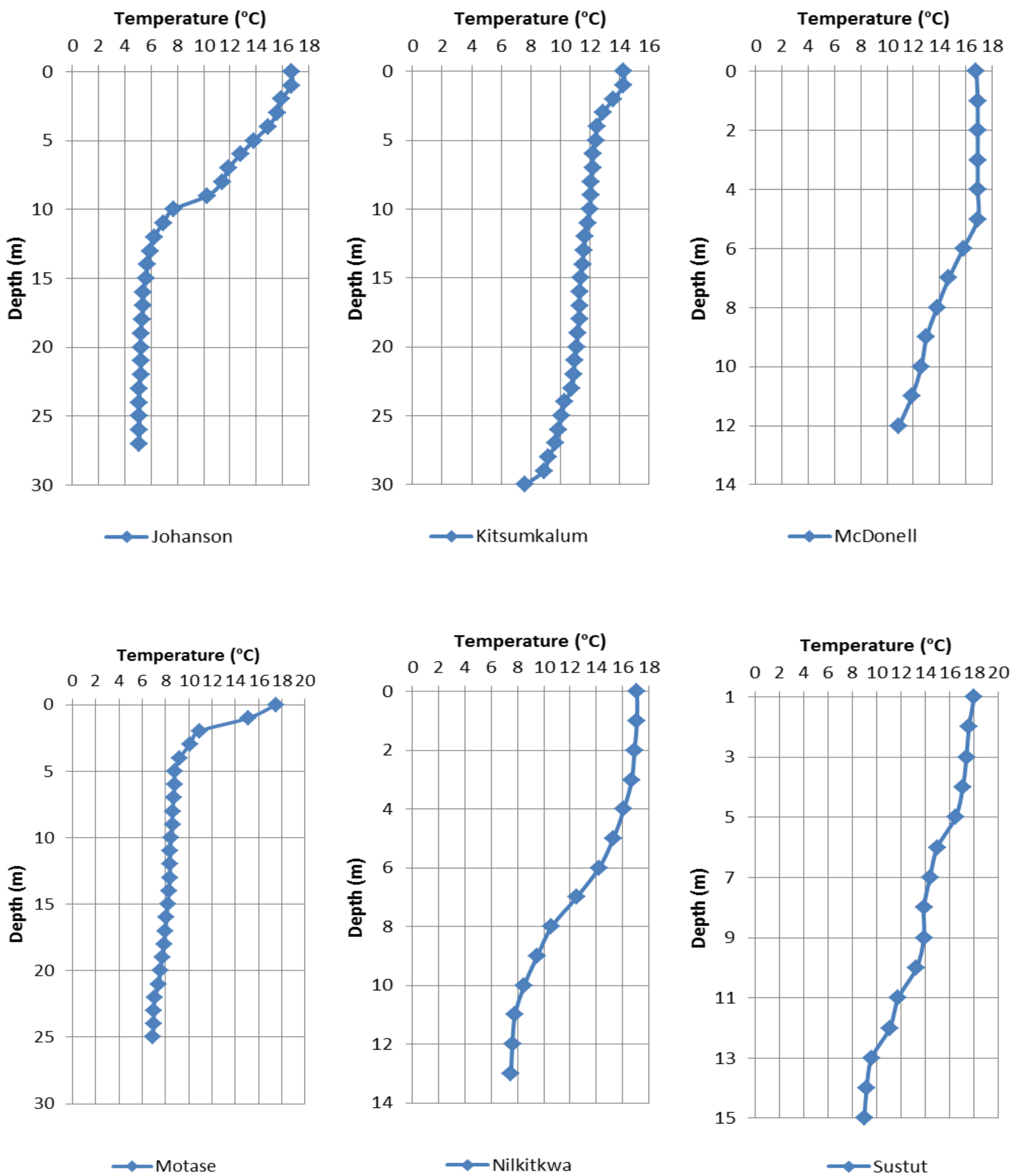


Figure 12. Temperature profiles for lakes surveyed in 2013. Note different scales.

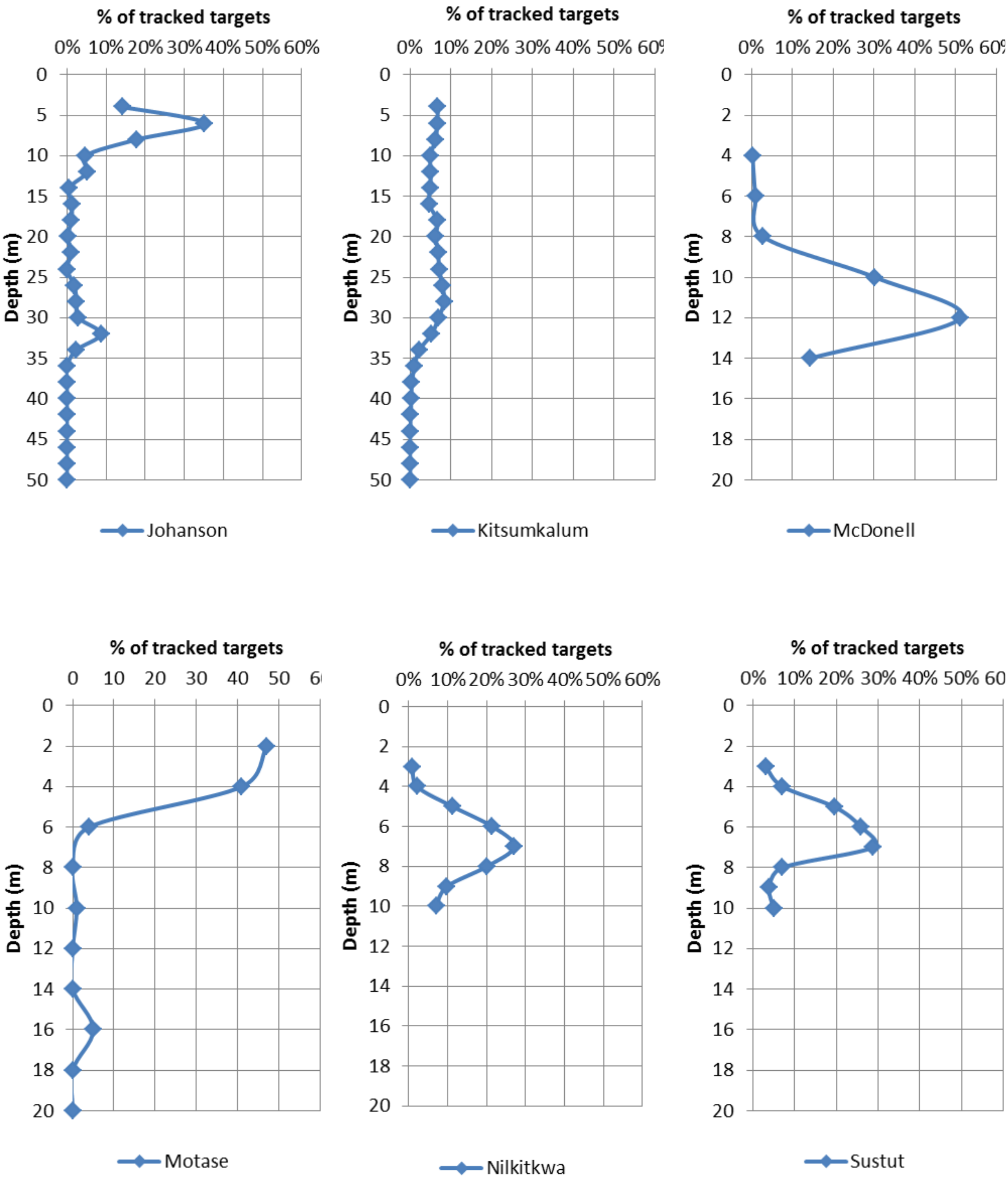


Figure 13. Vertical distribution of target density for 2013 lake surveys. Note different scales

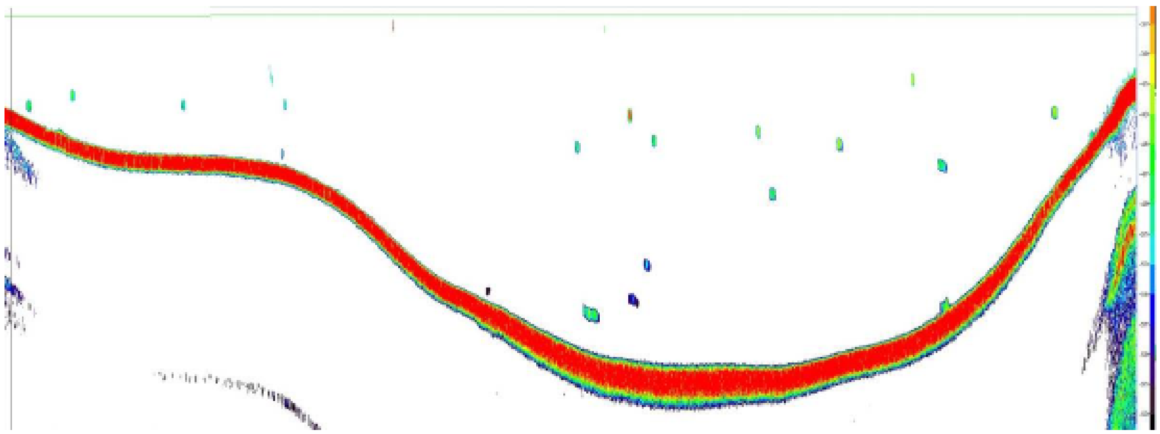
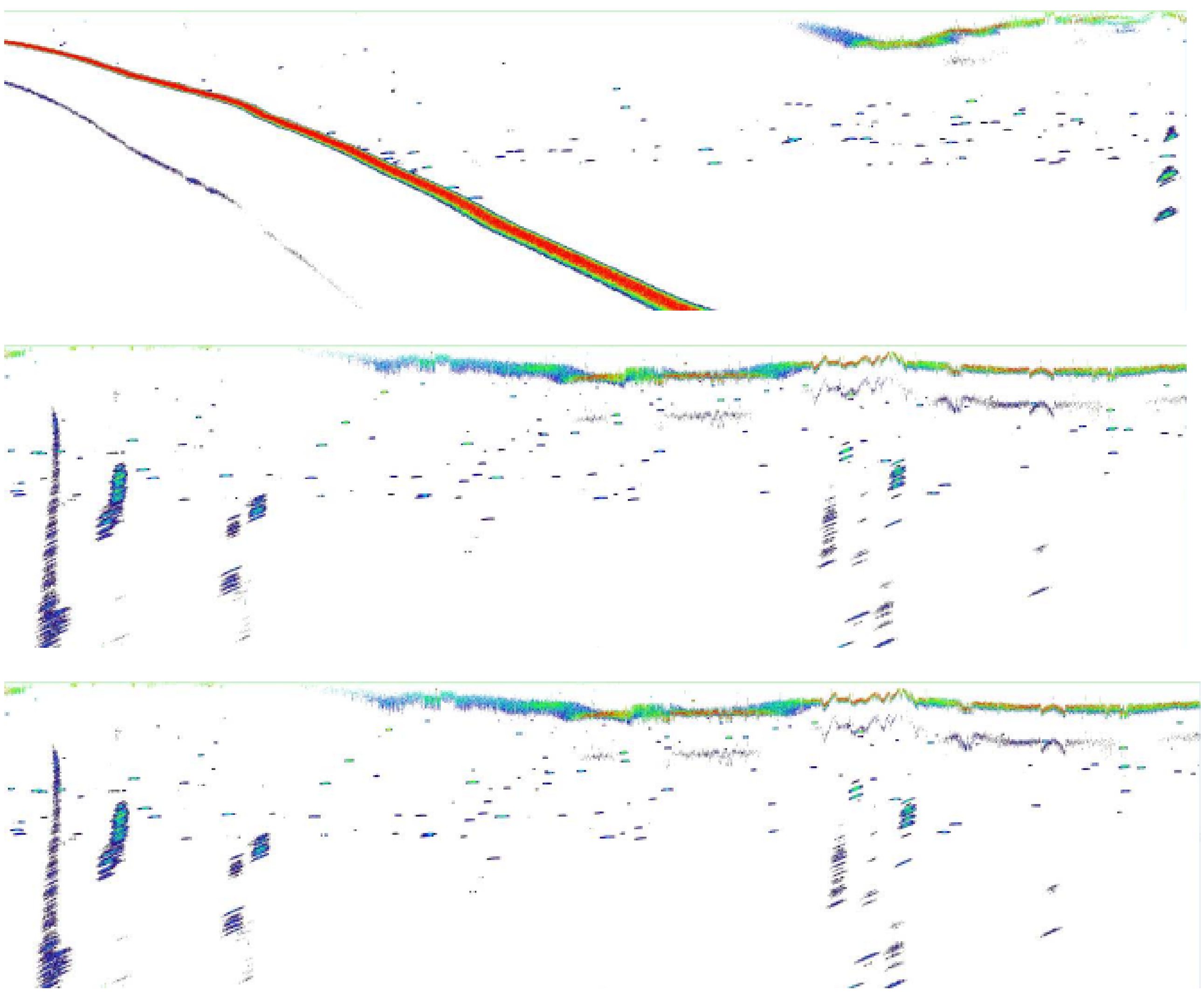


Figure 14. Johanson Lake transect 1 echogram



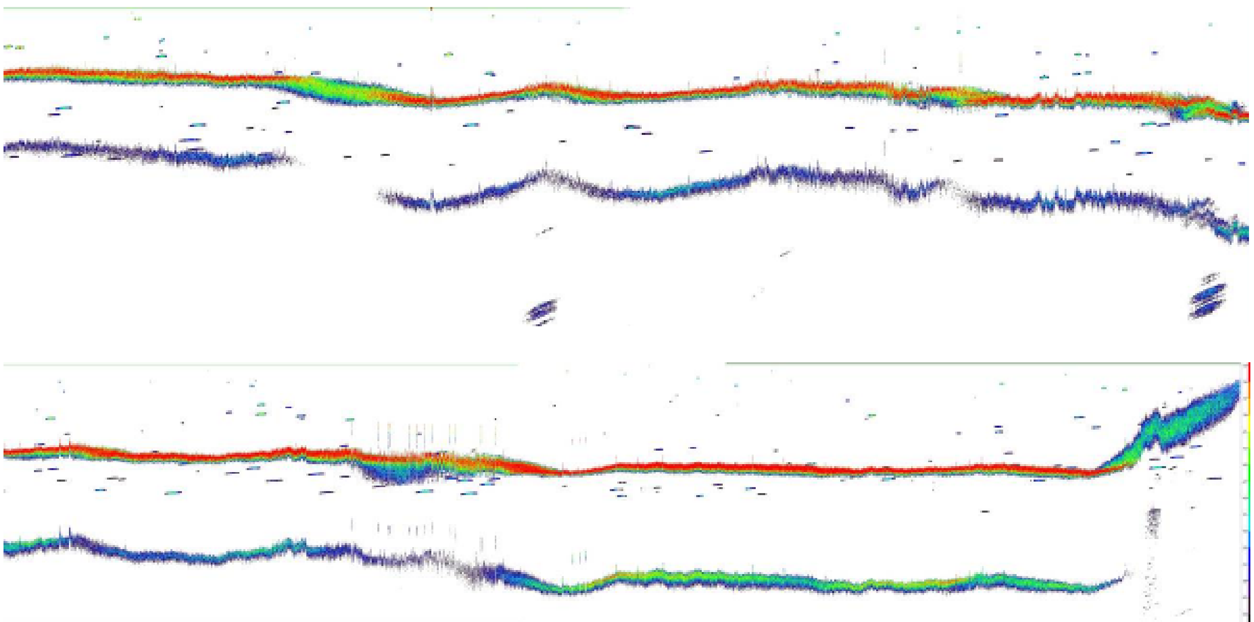


Figure 15. Kitsumkalum Lake transect 2 echogram

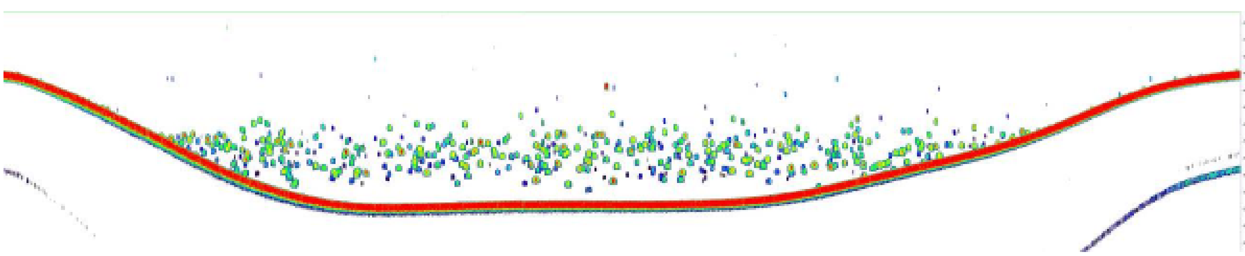


Figure 16. McDonell Lake transect 3 echogram

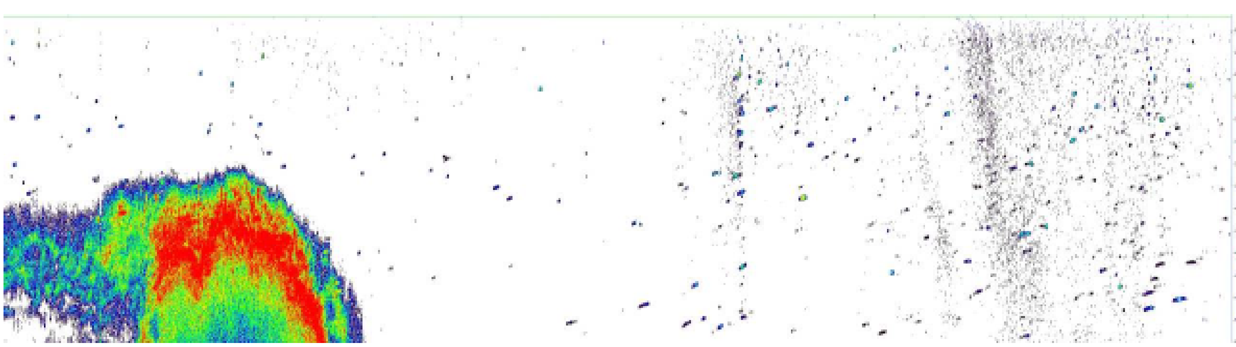


Figure 17. Motase Lake transect 8 echogram from horizontal transducer

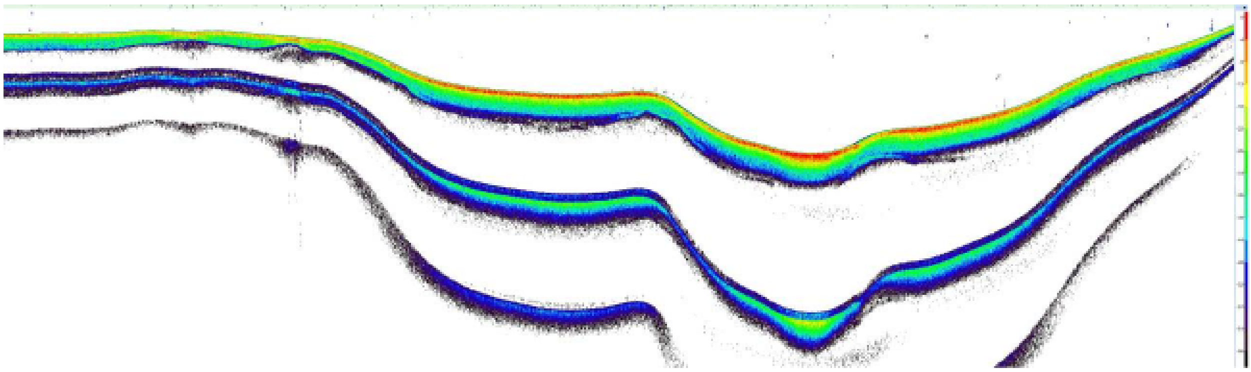


Figure 18. Motase Lake transect 8 echogram from vertical transducer

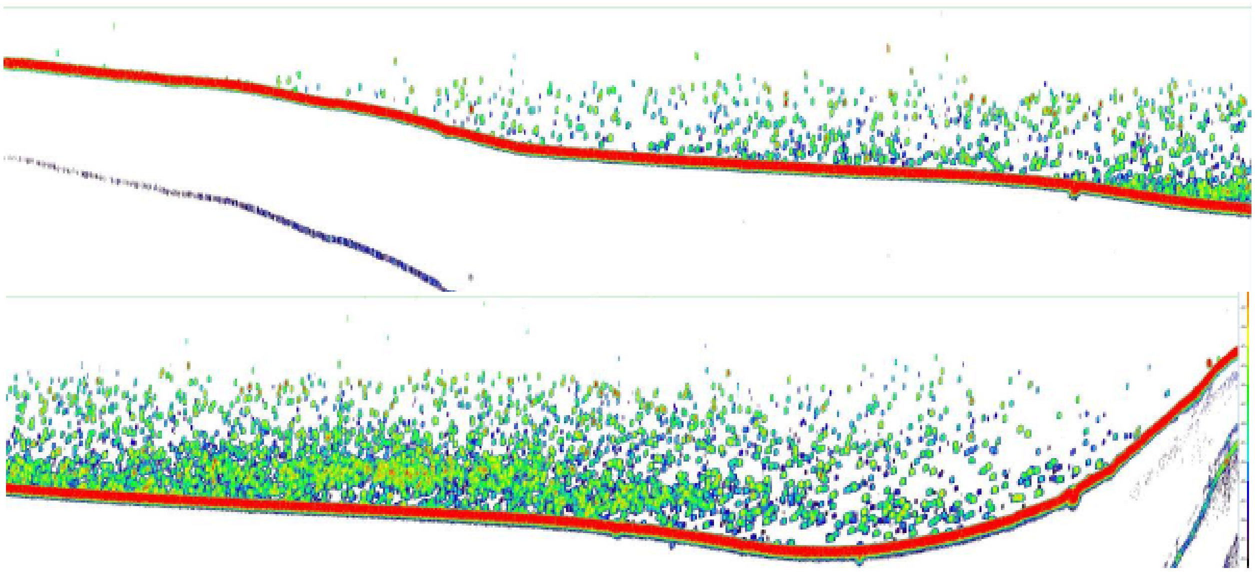


Figure 19. Nilkitkwa Lake transect 11 echogram

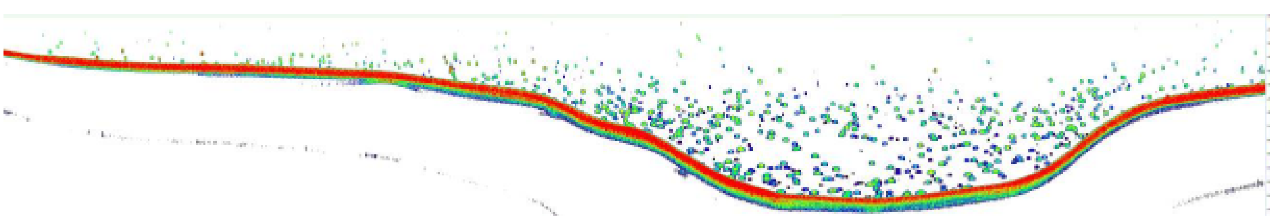


Figure 20. Sustut Lake transect 5 echogram