Skeena Sockeye Lakes Hydroacoustic Surveys 2014

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ABSTRACT

Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys of five (5) juvenile sockeye rearing lakes (Stephens, Swan, McDonell, Alastair, and Johnston Lakes) in the Skeena Watershed in 2014. 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.

In general, the juvenile sockeye population hydroacoustic estimates calculated in 2014 did not reflect the record low 2013 sockeye return to the Skeena Watershed. Estimates for Alastair, Johnston, Stephens, and McDonell lakes were lower than most estimates from previous years, but even lower estimates were expected. The 2014 age-0 *O.nerka* population hydroacoustic estimate at Swan Lake was even the greatest of all previous hydroacoustic estimates for this lake despite the very low sockeye return to the Swan Lake Watershed in 2013. The presence of kokanee, and/or sockeye lake spawners may partly explain the high age-0 *O.nerka* population estimate at Swan Lake. More research should focus on techniques to accurately identify juvenile kokanee from juvenile sockeye. The accuracy of age-0 sockeye population hydroacoustic estimates at Swan Lake, and other Skeena lakes would be greatly improved if the age-0 *O.nerka* could be apportioned between kokanee and sockeye.

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INTRODUCTION

The Skeena Fisheries Commission (SFC) has conducted mobile hydroacoustic surveys in small lakes throughout the Skeena Watershed since 2005. Fall fry abundance data for juvenile sockeye in their critical rearing habitat obtained by hydroacoustic techniques can be directly compared to lake productivity potential to provide an unbiased estimate of the status of each conservation unit (Cox-Rogers et. al 2004).

We conducted hydroacoustic surveys at five (5) juvenile sockeye rearing lakes in the Skeena Watershed (Figure 1) during the late summer of 2014. 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. We expected that 2014 sockeye fry populations in Skeena sockeye rearing lakes would be low compared with previous surveys as a result of very poor sockeye returns to the Skeena River in 2013.

Swan and Stephens lakes are the two major sockeye rearing lakes of the upper Kispiox River, a 5th order tributary that drains into the middle Skeena River downstream of the Skeena-Babine confluence. The Kispiox river is approximately 140 km long and drains an area of 2,088 km^2 (Gottesfeld and Rabnett 2008).

Swan Lake is the larger of the two lakes at the head of the Kispiox drainage, with a surface area of 1,760 Ha, maximum depth of 69 m and average depth of 19 m (Table 1). Swan Lake has a complicated bathymetry, with at least three well-defined basins punctuated by over 30 islands and a number of shoals. The last hydroacoustic survey at Swan Lake was conducted in 2010 by the SFC, and by the Department of Fisheries & Oceans Cultus Lake Research Laboratory in 2002.

Stephens Lake is smaller and more productive than Swan Lake, with a surface area of 197 ha, maximum depth of about 25 m, and average depth of 11 m (Table 1). Stephens Lake was surveyed by the Department of Fisheries & Oceans Cultus Lake Research Laboratory in 2002, and by the SFC in 2005, 2009, and 2010. Swan and Stephens lakes are located within the traditional territories of the Gitxsan First Nation.

Alastair Lake is located at the headwaters of the Gitnadoix River, a third order tributary of the Skeena River, west of Terrace. Alastair is a clear, productive lake which contains a large known population of threespined stickleback, which may compete for food resources with juvenile sockeye fry (MacLellan and Hume 2010). Visual escapement estimates at the Alastair Lake tributaries are complicated by a known population of lakeshore spawners. Previous hydroacoustic surveys were conducted at Alastair Lake was conducted in 2011 by the SFC and by the Department of Fisheries & Oceans Cultus Lake Research Laboratory in 2009. Alastair Lake is within the traditional territories of the Allied Tribes of Lax Kw'alaams.

Johnston Lake is located on the coastal end of the Skeena River, at approximately 100m elevation on a tributary to the Ecstall River, a fourth-order tributary to the lower Skeena River. Johnston is one of two known sockeye rearing lakes in the Ecstall system, which drains an area of 1,485 km^2 (Gottesfeld and Rabnett 2008). Johnston Lake is moderately turbid due to glacial runoff from the surrounding mountains. Johnston is a small deep lake with a surface area of only 192 ha, maximum depth of 77 m, and average depth of 45 m (Table 1). Johnston Lake was surveyed by the Department of Fisheries & Oceans Cultus Lake Research Laboratory in 2005, and by the SFC in 2010. Johnston Lake is also located within the traditional territories of the Allied Tribes of Lax Kw'alaams.

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. Every year, the Gitksan Watershed Authorities (GWA), in collaboration with Wet'suwet'en Fisheries Program conducts sockeye spawner enumeration upstream of McDonell Lake in the upper Zymoetz River.

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 2014

Lake	Watershed	Elevation (m)	Average Depth (m)	Maximum Depth (m)	Surface Area (ha)	Clarity
Alastair	Alastair	45	21.0	79	686	Clear
Johnston	Ecstall	24	45.0	77	193	Clear
McDonell	Zymoetz	830	8.0	15	215	Clear
Stephens	Kispiox	519	11.0	25	197	Clear
Swan	Kispiox	526	19.0	69	1,760	Clear

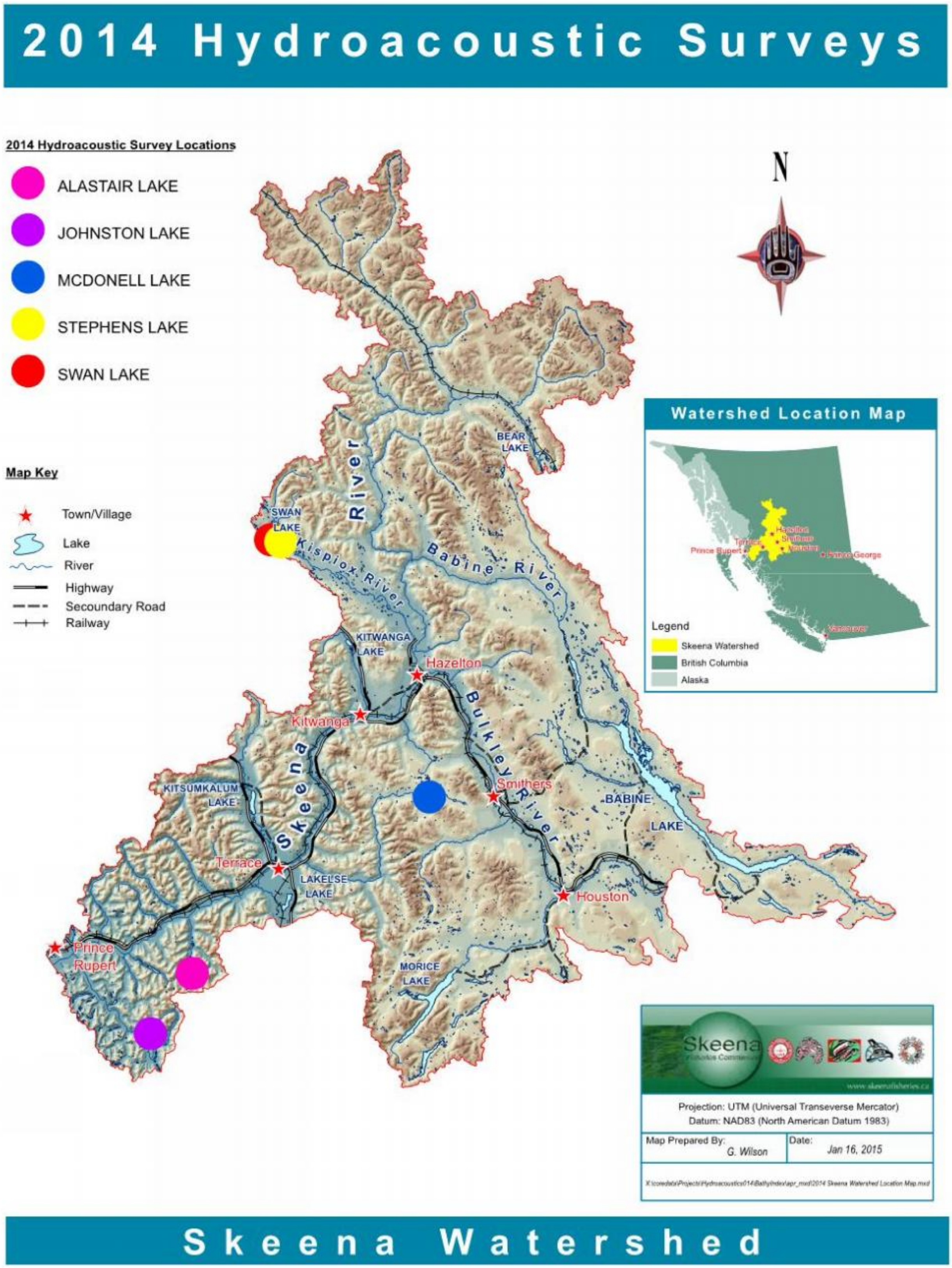

Figure 1. Location of the surveyed lakes in the Skeena watershed

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). 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 2014 at Alastair, Johnston, and Swan were all created by the SFC (Figures 3, 4, and 5). The surveys at McDonell, and Stephens lakes were conducted along transects established by the Department of Fisheries & Oceans Cultus Lake Research Laboratory (Figures 6 and 7). Three transects were added to the Stephens Lake survey design to improve the precision of the sockeye fry population estimate.

Hydroacoustic estimates for Alastair, Johnston, Stephens and Swan lakes are based on depth layer volumes that were calculated using bathymetric maps produced from lake depth data collected during past SFC surveys using the DT-X system, combined with existing bathymetric data from the BC Ministry of Environment, or the Department of Fisheries & Oceans Cultus Lake Research Laboratory. Bathymetric maps provided by the provincial Ministry of Environment were used to calculate depth layer volumes for McDonell Lake.

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 was applied prior to post-processing of the data.

Post-processing of hydroacoustic data was performed using Echoview software (v. 6.0.94). 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. 6.0.94). 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.

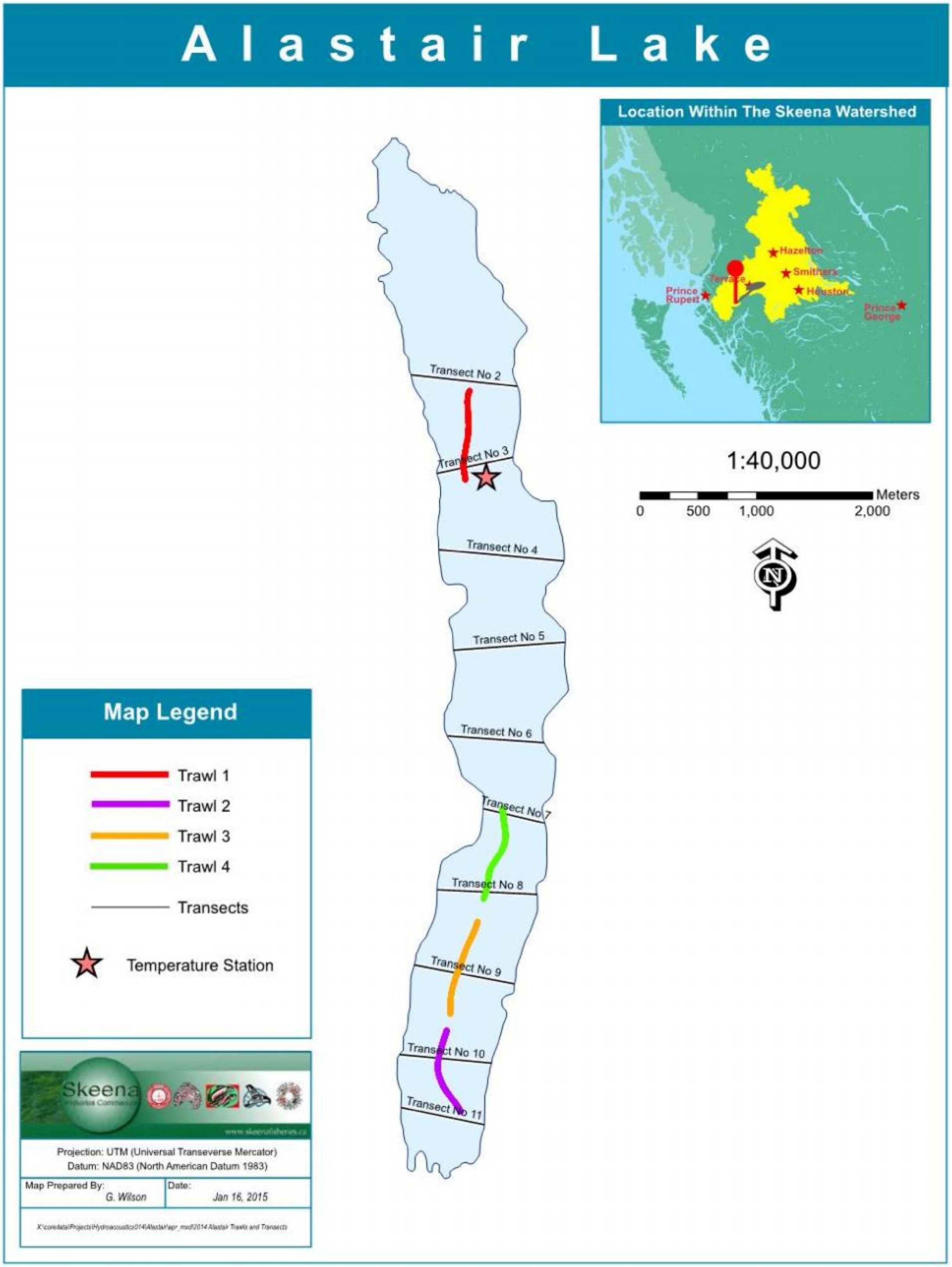

Figure 3. Alastair Lake survey map.

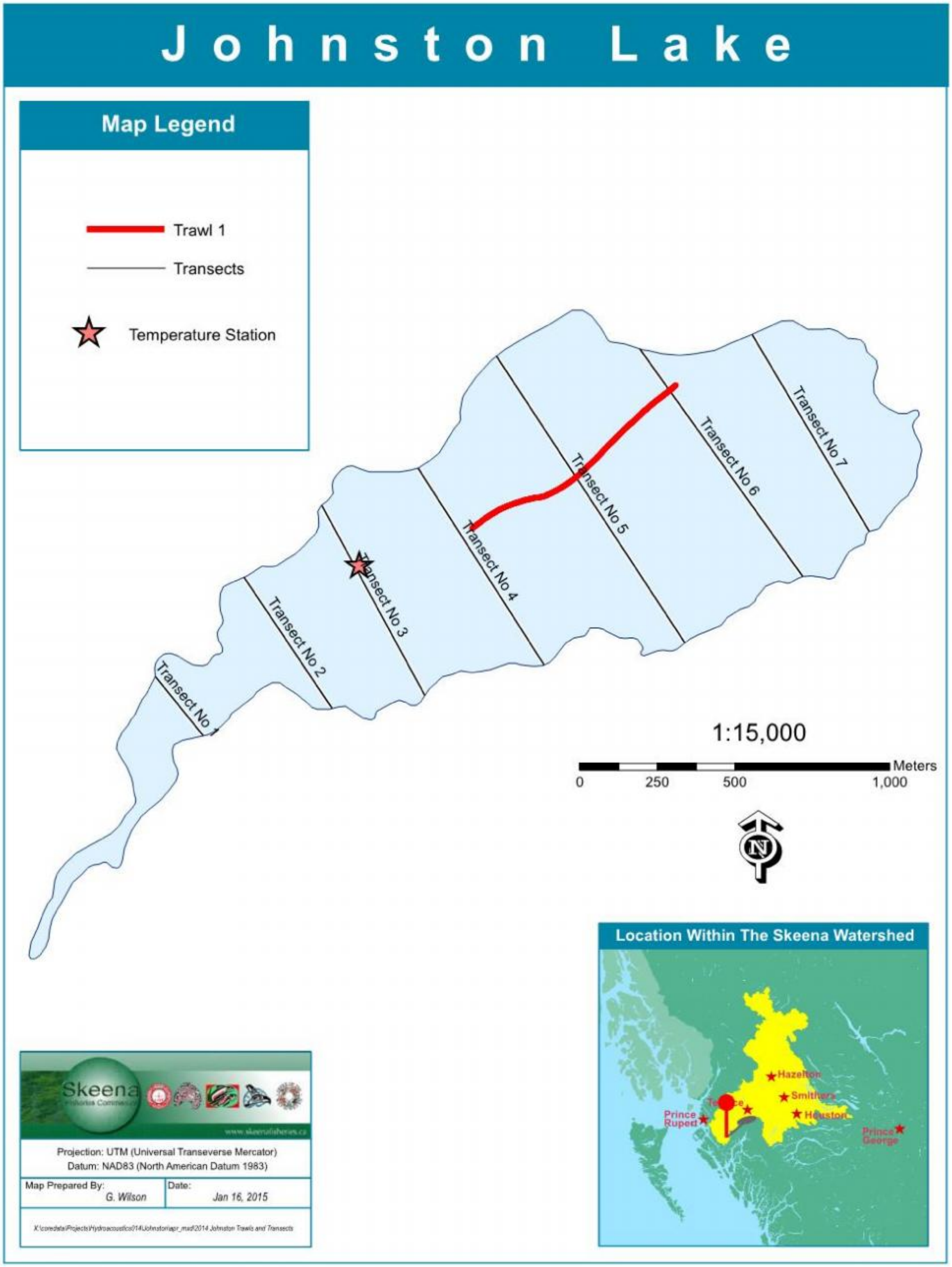

Figure 4. Johnston Lake survey map.

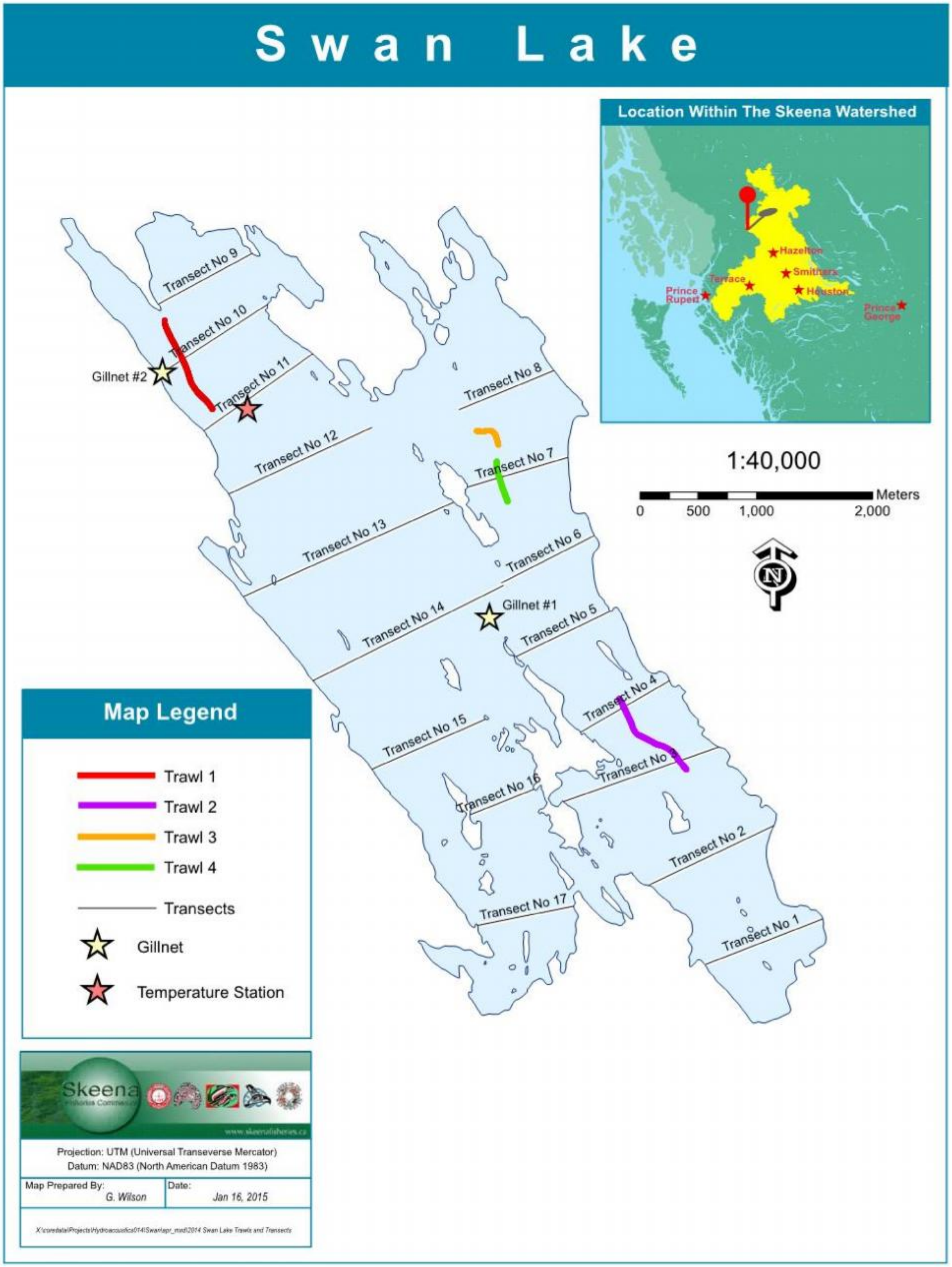

Figure 5. Swan Lake survey map

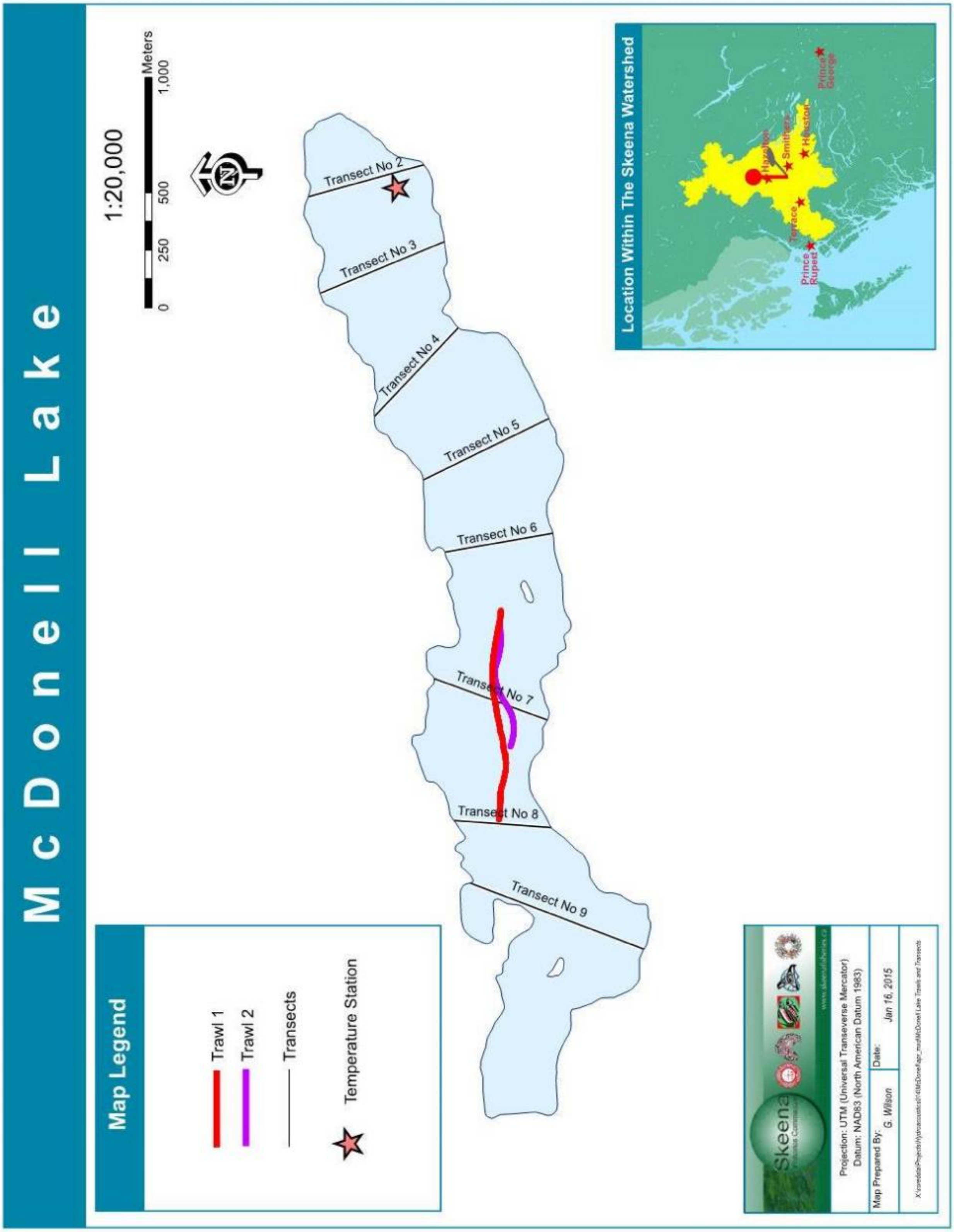

Figure 6. McDonell Lake survey map

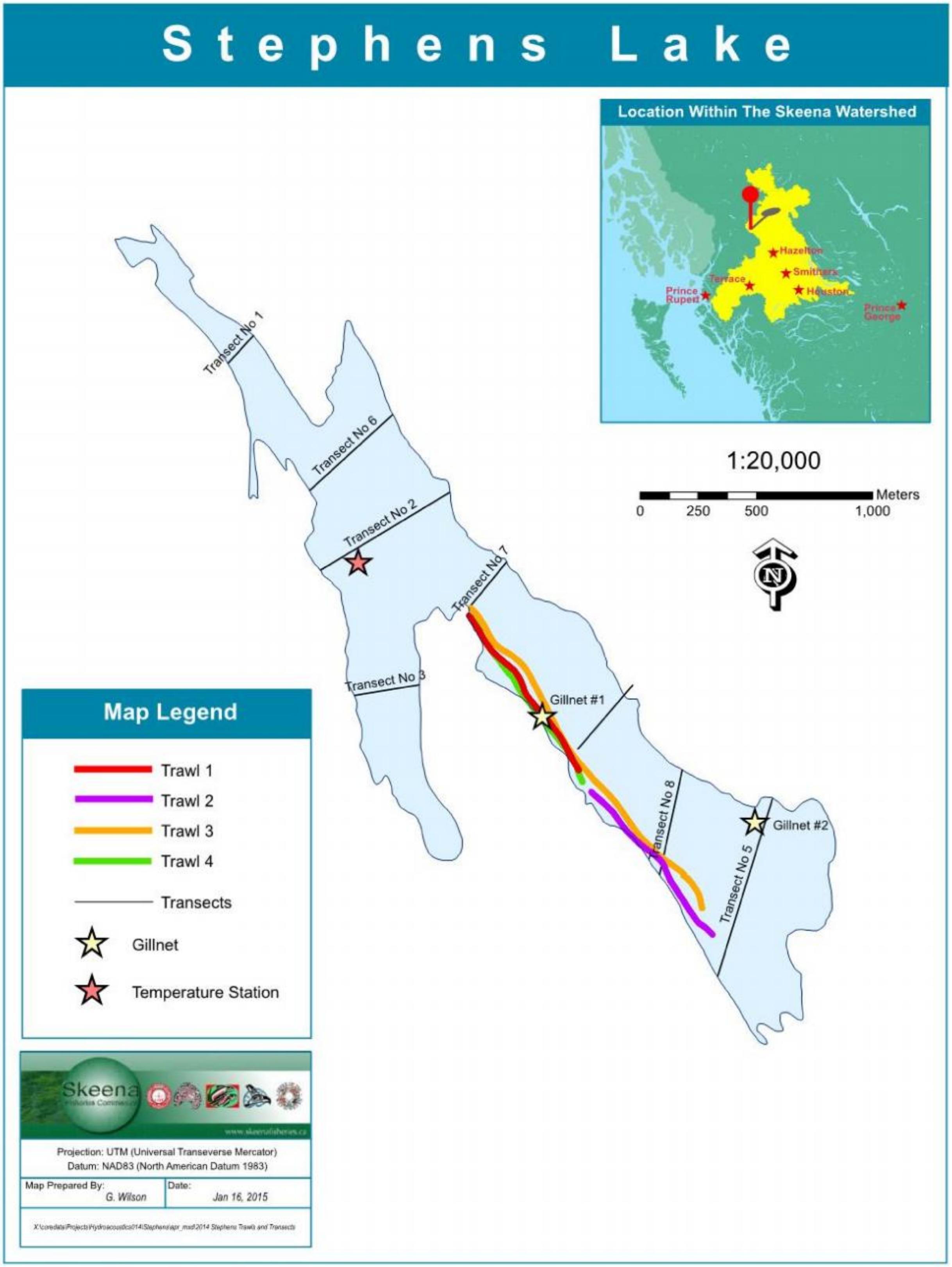

Figure 7. Stephens Lake survey map

Following the general guidelines of MacLellan and Hume (2010), population estimates for Alastair, Johnston, and McDonell lakes were calculated using the integration method because their estimated fish densities were well above 500 fish/ha. Estimates for Swan and Stephens lakes were calculated using the tracked target method. We present results using all three estimation methods for each lake 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 (i.e., Carr-Harris 2012). Data from each transect were analyzed in 2m depth layers for all five 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 zone at Stephens, and Swan lakes. These gillnets consisted of 4 variable mesh sizes between ½" and 1". Gillnets were set at dusk and allowed to soak overnight.

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 dissecting 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

Alastair Lake

Alastair Lake was surveyed on the night of September 21, 2014. The surface temperature was 17.3ºC degrees, with a gradual decline to 15.4 ºC at 8 m, and a thermocline between 8 and 14 m with another gradual decline to a hypolimnion of approximately 7.0 ºC below 20 m (Figure 10).

We captured 53 *O.nerka* and 259 threespine stickleback during four trawl tows with a combined length of about 3.6 km (Figure 3, and Table 2). Most (230) of the threespine stickleback were caught in trawl tow #1 at a depth of approximately 6 meters. No *O.*nerka were caught in trawl tow #1. All of the *O.nerka* were caught in trawl tow #2, 3, and 4, which were between 12.5 to 15m deep. Only 29 threespine stickleback were caught in trawl tow #2, 3, and 4. *O.nerka* scales readings revealed that 17 were age-0, and 36 were age-1. The average length of the age-0 *O.nerka* fry was 61.6 mm, with an average weight of 2.4 grams, and the average length and weight of the age-1 *O.nerka* fry was 73.2 mm, and 4.2 grams, respectively (Table 4).

Hydroacoustic data were collected from ten transects across the long axis of the lake (Figure 3). Most fish targets were found between 3m and 15m depth in the water column (Figures 11 and 12). The vertical distribution of fish targets was bimodal, with distinct peaks at 7m and 10m depth. This, combined with the trawl catch observations may indicate that threespine stickleback and the *O.nerka* were mostly segregated in the water column, with threespine stickleback schooling above the thermocline (8m) and juvenile *O. nerka* schooling below the thermocline. This is consistent with the temperature preference of juvenile sockeye reported by Brett (1952). We therefore apportioned 100% of the “small fish” estimate from 2m to 8m depth as threespine stickleback, and 65% of the “small fish” estimate below 8m depth was apportioned as *O.nerka* to account for the variation in vertical distribution in fish targets and trawl catches between these two species. The *O.nerka* estimate was also apportioned between age-0 and age-1 classes according to the proportion of each in the total trawl catch. Age-0 *O. nerka* represented 32% of the total *O.nerka* population estimate as observed in the trawl catches. The 2014 hydroacoustic population estimate for age-0 *O.nerka* at Alastair Lake was $3.7 \times 10^5 \pm 123{,}466$, equivalent to a density of 511/ha, calculated with the integration method (Figure 8 and Table 5). The total age-0 *O.nerka* biomass was estimated at 878 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 age-0 *O.nerka* fry observed during the 2014 hydroacoustic survey represents 15.4% of the rearing capacity, or R_{max}, at Alastair Lake (Table 6).

2013 sockeye returns to Alastair Lake and Southend Creek, the major spawing tributary, which produced the age-0 *O.nerka* population estimated in 2014 were 8,900 spawners, below the decadal (2003-2012) average return of 9,600 to Alastair Lake and Southend Creek, and also lower than the returns Alastair Lake and Southend Creek observed during the 2010 (16,850 spawners) (Fisheries and Oceans Canada, 2014), which produced the fall fry population estimated during the 2011 Alastair Lake hydroacoustic surveys (Carr-Harris, 2012). Very few adult sockeye spawners were recorded in Alastair Lake (adults present, presumably in low numbers) and Southend Creek (400 spawners) in 2008 (Fisheries and Oceans Canada, 2014), the brood year which produced the fall fry that were enumerated in a 2009 hydroacoustic estimate.

The 2014 Alastair Lake sockeye fry population density estimate (511/ha) is significantly lower than the density of age-0 *O.nerka* estimated in 2011 (1,830/ha), however the fry biomass estimated in 2014 (878kg) is only slightly lower than the 2011 (1,311kg) biomass because the average weight of the *O.nerka* fry captured in 2014 (2.4g) was more than twice the average weight of the fry captured in 2011 (1.0g). No age-1 *O.nerka* were captured by trawl in 2011, and therefore none of the estimated *O.nerka* population was apportioned as age-1, whereas age-1 *O. nerka* comprised 68% of the trawl samples, and species composition estimate, in 2014. Hume *et. al* (2010) observed a high relative proportion of age-1 (51%) and age-0 (49%) *O.nerka* in 2009. The age-0 *O. nerka* population at Alastair Lake is affected both by intraspecific competition with the large stickleback population in Alastair Lake, and interspecific competition from age-1 *O. nerka* in the second year following a strong return to this system.

Johnston Lake

Johnston Lake was surveyed on the night of September 22, 2014. The surface temperature was 16.8ºC degrees, with a gradual decline to 12.4 ºC at 12 m, and a weak thermocline between 12 and 20 m with another gradual decline to a hypolimnion of approximately 6.5 ºC below 28 m (Figure 10).

We captured 215 *O.nerka*, and 14 threespine stickleback (*Gasterosteus aculeatus*) during one trawl tow with a length of about 0.9 km (Figure 4, and Table 2). *O.nerka* scales readings revealed that 80% were age-0, and 20% were age-1. The average length of the age-0 *O.nerka* fry was 47.7 mm, with an average weight of 0.8 grams, and the average length and weight of the age-1 *O.nerka* fry was 62.9 mm, and 2.0 grams, respectively (Table 4). The threespine stickleback had an average weight of 0.9g.

Hydroacoustic data were collected from seven transects across the long axis of the lake. Most fish targets were found between 6 m and 16 m deep in the water column (Figures 11 and 13), with some fish found deeper. The highest densities of fish targets were observed in the mid-section of the lake (transects 4, 5, and 6). 94% of the “small fish” population estimate was apportioned to *O.nerka* based on the proportion of *O.nerka* caught in the trawl tow. The *O.nerka* estimate was further apportioned between age-0, and age-1 classes, according to the scales readings results. The hydroacoustic population for age-0 *O.nerka* in Johnston Lake was estimated at $5.94 \times 10^5 \pm 128,045$, equivalent to a density of 3,085/ha, calculated using the integration method (Figure 9 and Table 5). The total biomass of age-0 *O.nerka* was estimated at 475 kg, or approximately 47% of R_{max} for Johnston Lake (Table 6).

Previous hydroacoustic surveys at Johnston Lake have resulted in significantly greater age-0 *O.nerka* population density estimates. Hume and MacLellan (2008), and Carr-Harris (2011) estimated respectively that age-0 *O.nerka* densities in Johnston Lake were 6,084/ha in 2005, and 7,535/ha in 2010 (Table 7). Spawner surveys have not been conducted at Johnston Lake since 2003, which makes it impossible to know if the 2013 sockeye escapement to Johnston Lake was significantly lower than in 2004 (brood year for the 2005 survey), and 2009 (brood year for the 2010 survey).

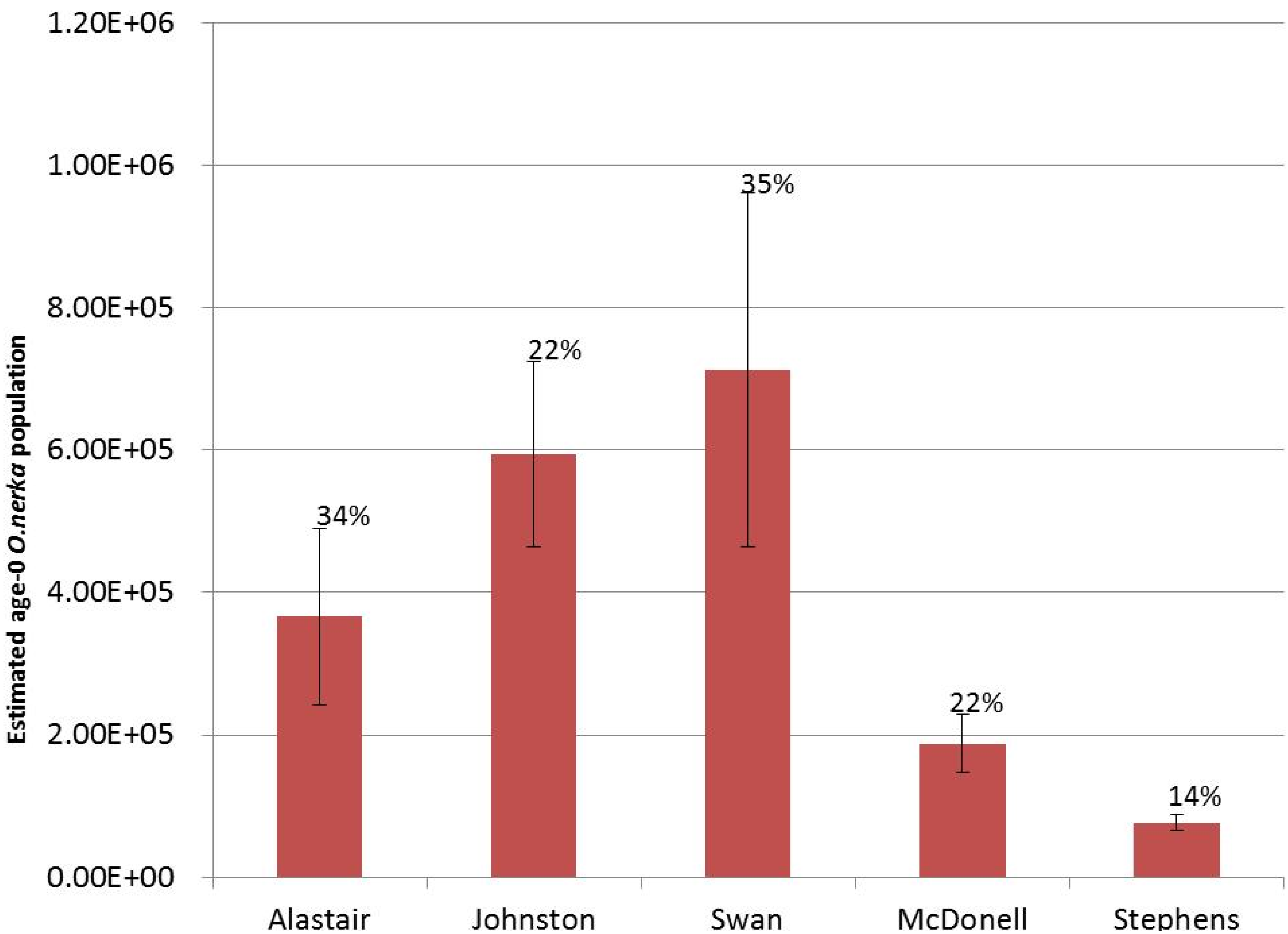

Figure 8. Graph showing the 2014 age-0 *O.nerka* population abundance estimates for Alastair, Johnston, Swan, McDonell, and Stephens lakes.

The error bars show the 95% confidence intervals.

Swan Lake

Swan Lake was surveyed on the nights of August 21-22, 2014. The surface temperature was 19.3ºC degrees, with a gradual decline to 18.6 ºC at 7 m, and a strong thermocline between 7 and 9m with another gradual decline to a hypolimnion of approximately 5 ºC below 25 m (Figure 10).

We conducted four trawls with a combined length of approximately 2.4 km at Swan Lake (Figure 10 and Table 2). Trawl depths ranged from approximately 7m to 13m (Table 2). The total trawl catch was 72 *O.nerka* (Figure 10), of which 68 were age-0, and 4 were age-1 as indicated by scale ageing. The average length for age-0 *O.nerka* fry was 41.8 mm, with an average weight of 0.8 grams, and the average length and weight of the age-1 *O.nerka* fry was 71.0 mm, and 3.6 grams, respectively (Table 4). Four gillnets were deployed for a total of approximately 50 gillnet-hours at Swan Lake. No fish were captured by gillnet at Swan Lake.

Hydroacoustic data were collected from seventeen transects across the long axis of the lake. Almost 80% of the fish targets at Swan Lake were observed between 7m and 12m in the water column, with a peak in densities (20%) observed at 9m depth (Figures 12 and 14). The horizontal distribution of fish targets at Swan Lake was fairly uniform. The water temperature above 4m depth at Swan Lake during our survey was significantly higher than the thermal preference of juvenile sockeye (Brett 1952), we apportioned 100% of the "small fish" estimate above 4m depth to "other fish". We apportioned 100% of the "small fish" estimate below 4m depth to *O*.nerka, and 94% of the *O.nerka* estimate was apportioned to age-0 *O.nerka* based on the age composition of the sample. The Swan Lake age-0 *O.nerka* population estimate was $7.13 \times 10^5 \pm 246{,}744$, equivalent to a density of 404/ha, calculated with the tracked target method (Figure 8 and Table 5). The total age-0 *O.nerka* biomass was estimated at 570 kg (Table 6). This estimated biomass is equivalent to 11% of the rearing capacity for Swan Lake (Table 6).

The most recent hydroacoustic surveys of Swan Lake prior to 2014 were completed by the Cultus Lake Salmon Research Laboratory in 2002, and by the SFC in 2010 (Table 7). The 2014 age-0 *O.nerka* density and biomass estimates are significantly higher than the 2010 estimates, and similar to the 2002 estimates. The density and biomass of age-0 *O.nerka* estimated in 2014 at Swan Lake are surprisingly large considering that in 2013, no spawning sockeye were observed in any of the Swan Lake tributaries, or in upper Club Creek, and only 1,883 were observed in Lower Club Creek (Fisheries and Oceans Canada, 2014), which drains into Stephens Lake. By comparison, 10,109, and 8,904 sockeye spawners were enumerated on the spawning grounds associated with Swan Lake in 2001, and 2009 respectively (Fisheries and Oceans Canada, 2014). The greater age-0 *O.nerka* trawl catch per unit of effort (CPUE) observed during the 2014 survey of 25.5/15min tow (Figure 10), compared to the 2002 (7.25/15min), and 2010 (10.8/15min) age-0 *O.nerka* trawl CPUE supports the relatively large 2014 hydroacoustic estimate of the age-0 *O.nerka* population at Swan Lake.

A sockeye lake spawner population is thought to be present at Swan Lake, and approximately 20 lake spawners were observed in 2013. Lake spawners are extremely difficult to observe and count. There may have been a significant number of sockeye that spawned in Swan Lake in 2013 without being observed, resulting in the large 2014 age-0 *O.nerka* population. There are numerous shallow gravel shoals at Swan Lake that may provide adequate spawning habitat for sockeye. Hume and MacLellan (2008) also reported that Swan Lake most likely supported an important population of resident kokanee, however spawning kokanee have never been observed in the Swan and Stephens Lakes watershed. The relatively large age-0 *O.nerka* population estimated in 2014 at Swan Lake may include a significant number of kokanee. The kokanee may have benefitted from the low 2013 sockeye return, and the resulting reduced competition for spawning habitat, but again no spawning kokanee were observed in 2013. It is unlikely that most of the 712,770 age-0 *O.nerka* estimated at Swan Lake in 2014 were age-0 kokanee. Mature kokanee are much smaller with lower fecundity than mature sockeye. Female kokanee produce an average of 450 eggs (Scott and Crossman, 1973), whereas female sockeye from Babine Lake, and Lakelse Lake produce between 3,000 and 4,000 eggs (Foerster, 1968). More research is necessary to accurately identify age-0 sockeye from age-0 kokanee so the age-0 *O.nerka* population can be properly apportioned between anadromous and nonanadromous forms.

Figure 9. Photo of 51 juvenile sockeye caught in trawl tow # 2 at Swan Lake. August 22, 2014.

McDonell Lake

McDonell Lake was surveyed on August 23, 2014. The surface temperature was 17.3 ºC with an epilimnion to 7 metres depth, and a gradual decline to 10.8 ºC at 13 meters depth (Figure 10).

A total of 66 *O.nerka*, and two prickly sculpin (*Cottus asper*) were captured at McDonell Lake, during two trawl tows with an approximate length of 1.6 km (Figure 6, Tables 2, and 4). No gillnets were set at McDonell Lake. The average length of trawl captured *O.nerka* was 55.8 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 8 m and 13 m depths (Figures 12 and 15). The highest densities of fish targets were found in the eastern section of the lake.

Considering that the water temperatures measured between the surface and 8m were well above the range of temperature preferred by juvenile sockeye, 0% of the “small fish” population estimate above 8m was apportioned to age-0 *O.nerka* during the analysis. We apportioned 100% of the “small fish” population estimate below 8m was apportioned to age-0 *O.nerka* although we captured two prickly sculpin during trawl tows. Prickly sculpin, which lack a swim bladder are invisible to acoustic gear, making their contribution to the “small fish” acoustic population estimate insignificant.

The age-0 *O.nerka* population estimate for McDonell Lake in 2014 was $1.88 \times 10^5 \pm$ 41,386, equivalent to a density of 877/ha, calculated with the integration method (Figure 8 and Table 5). Given the average weight from the trawl sample, the estimated biomass was 338 kg, or approximately 34% of R_{max} (Table 6).

The 2014 age-0 *O.nerka* density estimate for McDonell Lake is significantly lower than the densities estimated in previous recent surveys (Table 7). However the *O. nerka* density observed in 2014 is higher than expected given a very low sockeye return to the Upper Zymoetz of 454 spawners observed in 2013, compared to the average (2,302) since 2002 (Fisheries and Oceans Canada, 2014). When considering the time of the year when surveys were conducted, the age-0 *O.nerka* captured by trawl in 2014 had a relatively higher mean weight compared to previous surveys. This is most likely a result of lower competition for food resulting from the lower density. The higher mean weight resulted in an observed biomass that is only somewhat lower than the biomasses estimated in recent surveys at McDonell Lake.

Stephens Lake

Stephens Lake was surveyed on the night of August 20, 2014. The surface temperature was 19.5ºC degrees, with a slow decline to 18.8 ºC at 5 m, and a strong thermocline between 5 and 10 m with a gradual decline to a hypolimnion of approximately 5 ºC below 25 m (Figure 10).

We conducted four trawl tow with a total length of approximately 4.5 km at Stephens Lake (Figure 7 and Table 2). The total trawl catch was 37 *O.nerka*, and one coho salmon

(*Oncorhynchus kisutch*), which were caught at depths ranging from approximately 8m to 13m. The average length of *O.nerka* fry captured in the trawl was 59.3 mm, with an average weight of 2.3 grams (Table 4). All were age-0 *O.nerka*. Two gillnets were set at Stephens Lake, capturing one rainbow trout (*Oncorhyncus mykiss*), and four coho were caught.

Hydroacoustic data were collected from eight transects across the long axis of the lake. Most of the fish targets were found between 6 m and 8 m (Figures 12 and 16). The highest densities of fish targets were found in the mid-section of the lake.

Because of the warm water temperatures observed above 6m depth, and the fact that no juvenile *O.nerka* were caught in the gillnets fishing between 0 and 2m depth, 0% of the "small fish" population estimated in the layers above 6m depth was apportioned to age-0 *O.nerka*. Age-0 *O.nerka* represented 97% of the trawl catch, 97% of the "small fish" population estimated below 6m was apportioned to age-0 *O.nerka*. Finally, the Stephens Lake age-0 sockeye population was estimated at $7.69 \times 10^4 \pm 10{,}518$, equivalent to a density of 391/ha, calculated with the tracked target method (Figure 8 and Table 5). The total age-0 *O.nerka* biomass was estimated at 177 kg (Table 6), equivalent to 10% of the rearing capacity at Stephens Lake.

The 2014 age-0 *O.nerka* density and biomass estimates at Stephens Lake are the second lowest of all density and biomass estimates from past hydroacoustic surveys (Table 7). The 2013 sockeye return of 1,883 (Fisheries and Oceans Canada, 2014) to the lower Club Creek was significantly lower than the 2001 (7,953), 2004 (5,487), and 2009 (8,000) returns, brood years for the 2002, 2005, and 2010 hydroacoustic surveys. As expected, the 2014 age-0 *O.nerka* density estimate at Stephens Lake was relatively low, following the very low the 2013 adult sockeye return to lower Club Creek.

CONCLUSION

Hydroacoustic surveys allow us to ascertain trends in juvenile sockeye populations in lakes that represent ongoing or potential conservation concerns. 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.

While estimates for Alastair, Johnston, Stephens, and McDonell lakes were lower than past estimates for these systems, the juvenile sockeye population hydroacoustic estimates calculated in 2014 generally did not reflect the record low 2013 sockeye return to the Skeena Watershed. The 2014 age-0 *O.nerka* population hydroacoustic estimate at Swan Lake was higher than all previous hydroacoustic estimates despite the very low sockeye return to the Swan Lake Watershed in 2013. The presence of kokanee, and/or sockeye lake spawners may partly explain the high age-0 *O.nerka* population estimate at Swan Lake. Future research should focus on developing techniques to accurately identify juvenile kokanee from juvenile sockeye. The accuracy of age-0 sockeye population hydroacoustic estimates at Swan Lake, and other Skeena lakes would be greatly improved if the age-0 *O.nerka* could be separated between kokanee and sockeye.

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Table 2. 2014 Hydroacoustic surveys trawl summary by lake

Lake	Date	Trawl #	Time Start	Time End	Easting Start	Northing Start	Easting End	Northing End	Depth (m)	ON	TS	Sc	Co
Alastair	21-Sep-14	1	2128	2143	487984	5997943	487938	5997168	6.5	0	230	0	0
Alastair	21-Sep-14	2	0107	0121	487897	5991739	487781	599242	12.5	36	21	0	0
Alastair	21-Sep-14	3	0138	0153	487810	5992581	488046	5993369	14.5	13	0	0	0
Alastair	21-Sep-14	4	0206	0221	488096	5993563	488253	5994351	15	4	8	0	0
Johnston	22-Sept-14	1	2339	2354	470483	5970243	469826	5969783	10	215	14	0	0
Swan	22-Aug-14	1	0015	0030	519355	6184724	519778	6183950	10	20	0	0	0
Swan	22-Aug-14	2	2326	2341	523859	6180854	523284	6181463	7	51	0	0	0
Swan	23-Aug-14	3	0150	0155	522322	6183155	522225	6183508	13	0	0	0	0
Swan	23-Aug-14	4	0200	0206	522243	6183644	522053	6183757	11	1	0	0	0
McDonell	23-Aug-14	1	2312	2328	589159	6071304	590066	6071296	10	35	0	1	0
McDonell	23-Aug-14	2	2340	2350	589475	6071260	590018	6071302	10.5	31	0	1	0
Stephens	20-Aug-14	1	0240	0255	526055	6181325	526528	6180661	8	12	0	0	1
Stephens	20-Aug-14	2	0307	0322	526599	6180576	527123	6179953	10-13	3	0	0	0
Stephens	20-Aug-14	3	0336	0406	527080	6180066	526086	6181359	9	13	0	0	0
Stephens	20-Aug-14	4	0416	0431	526077	6181299	526537	6180592	9-10	9	0	0	0

ON: *O.nerka*; TS: Threespine stickleback; Sc: prickly sculpin; Co: Coho

Table 3. 2014 Gillnet location, effort, and catch by lake

Lake	Date	Gillnet #	Time Start	Time End	Easting	Northing	ON	RB	Co
Swan	22-Aug-14	2	0005	2015	519245	6184254	0	0	0
Swan	22-Aug-14	2	2145	0230	522060	6182143	0	0	0
Stephens	20-Aug-14	2	2230	1330	526287	6180874	0	0	0
Stephens	20-Aug-14	1	2245	1320	527203	6180419	0	1	4

ON: *O.nerka*; RB: rainbow trout; Co: Coho

Table 4. 2014 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)
Alastair	Trawl	Age-0 *O.nerka*	17	62	71	48	6.1	2.4	3.4	1.0	0.8
Alastair	Trawl	Age-1 *O.nerka*	36	73.2	79	65	3.2	4.2	5.22	2.86	0.6
Alastair	Trawl	Threespine stickleback	259	n/a	n/a	n/a	n/a	0.4	2.1	0.1	0.4
Johnston	Trawl	Age-0 *O.nerka*	172	47.7	58	40	3.2	0.8	2	0.4	0.2
Johnston	Trawl	Age-1 *O.nerka*	43	62.9	68	58	2.6	2.0	2.9	1.3	0.4
Johnston	Trawl	Threespine stickleback	14	n/a	n/a	n/a	n/a	0.9	2.1	0.5	0.4
Swan	Trawl	Age-0 *O.nerka*	68	41.8	53	25	4.7	0.8	1.35	0.1	0.2
Swan	Trawl	Age-1 *O.nerka*	4	71	75	67	3.7	3.6	4.5	3.1	0.6
McDonell	Trawl	*O.nerka*	66	55.8	67	48	4.3	1.8	3.8	0.9	0.6
Stephens	Trawl	Age-0 *O.nerka*	37	59.3	76	43	8.0	2.3	4.6	0.7	0.9
Stephens	Trawl	Coho	1	75.0	--	--	--	5.82	--	--	--
Stephens	Gillnet	Coho	4	85.25	103	69	14.8	8.2	13.68	3.48	4.2
Stephens	Gillnet	Rainbow	1	180.0	--	--	--	n/a	--	--	--

Table 5. 2014 lakes hydroacoustic estimates by method

Lake	Estimate Method	Size Class	Density (n/ha)	Population	95% C.I.
Alastair	Single Target	Age-0 nerka	747	535,062	173,255
		Age-1 nerka	1,587	1,137,006	368,167
		Stickleback	5,896	4,225,617	1,103,368
		Large	405	290,482	111,921
	Tracked Target	Age-0 nerka	716	512,841	165,465
		Age-1 nerka	1,521	1,089,787	351,613
		Stickleback	4,938	3,539,026	1,063,605
		Large	379	271,320	109,247
	Integration	**Age-0 nerka**	**511**	**365,941**	**123,466**
		Age-1 nerka	**1,085**	**777,624**	**262,364**
		Stickleback	**3,655**	**2,619,114**	**773,822**
		Large	**265**	**189,732**	**79,859**
Johnston	Single Target	Age-0 nerka	4,727	910,238	178,470
		Age-1 nerka	1,158	222,917	65,812
		Stickleback	377	72,625	14,240
		Large	417	80,262	35,796
	Tracked Target	Age-0 nerka	4,282	824,542	182,220
		Age-1 nerka	1,055	203,234	59,130
		Stickleback	342	65,788	14,539
		Large	355	68,286	28,758
	Integration	**Age-0 nerka**	**3,085**	**594,172**	**128,045**
		Age-1 nerka	**760**	**146,433**	**41,921**
		Stickleback	**246**	**47,407**	**10,216**
		Large	**247**	**47,559**	**18,554**
Swan	Single Target	Age-0 nerka	411	725,783	248,806
		Age-1 nerka	27	47,278	17,350
		Other Small	19	33,235	40,782
		Large	94	165,189	74,901
	Tracked Target	**Age-0 nerka**	**404**	**712,770**	**246,744**
		Age-1 nerka	**26**	**46,568**	**17,477**
		Other Small	**18**	**30,938**	**34,350**
		Large	**98**	**172,302**	**67,485**
	Integration	Age-0 nerka	262	462,032	172,977
		Age-1 nerka	17	29,491	11,041
		Other Small	11	19,280	27,405
		Large	68	119,339	52,711

McDonell	Single Target	Age-0 nerka	1,501	321,766	67,061
		Other Small	78	16,816	12,225
		Large	720	154,473	76,075
	Tracked Target	Age-0 nerka	1,461	313,386	73,038
		Other Small	67	14,317	8,207
		Large	719	154,128	72,743
	Integration	**Age-0 nerka**	**877**	**188,049**	**41,386**
		Other Small	**50**	**10,827**	**8,414**
		Large	**439**	**94,217**	**44,933**
Stephens	Single Target	Age-0 nerka	407	79,927	21,822
		Other Small	24	4,631	4,258
		Large	115	22,559	7,380
	Tracked Target	**Age-0 nerka**	**391**	**76,905**	**10,518**
		Other Small	**21**	**4,224**	**3,712**
		Large	**117**	**22,927**	**10,027**
	Integration	Age-0 nerka	319	62,745	21,796
		Other Small	14	2,746	2,091
		Large	71	14,021	4,958

Bold type indicates preferred method of estimation

Table 6. PR Capacity comparison chart

Lake	**Adjusted Rmax (kg)**	**Acoustic survey date**	**Estimation Method**	**Observed *O.nerka* fall fry**	**Avg. Weight**	**Observed biomass (kg)**	**% Rmax**
Alastair	5,708*	21-Sep-14	Integration	365,941	2.4	878	15.4%
Johnston	1,005*	22-Sep-14	Integration	594,172	0.8	475	47%
Swan	5,336*	21/22-Aug-14	Tracked target	712,770	0.8	570	11%
McDonell	992*	23-Aug-14	Integration	188,049	1.8	338	34%
Stephens	1,721*	20-Aug-14	Tracked target	76,905	2.3	177	10%

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

Table 7. Past hydroacoustic estimates for lakes surveyed in 2014

Lake	Year	Date	Age-0 sockeye			Method	Source
			n/ha	Mean weight (g)	Biomass (kg)		
Alastair	1995	11 Oct	1,994	1.7	2,326	Tracked Target	Shortreed *et al.* (1998)
	2009	13 Sept	266	1.75	318	Integration	Hume *et al.* (2010)
	2011	29 Aug	1,830	1.0	1,311	Integration	Carr-Harris (2012)
	2014	21 Sept	511	2.4	878	Integration	
Johnston	2005	1 Sept	6,084	0.5	587	Integration	Hume and MacLellan (2008)
	2010	8 Sept	7,535	0.8	1,102	Integration	Carr-Harris (2011)
	2014	22 Sept	3,085	0.8	475	Integration	
Swan	2002	06 Sept	329*	1.0	523*	Tracked Target	Hume and MacLellan (2008)
	2010	11 Aug	184*	0.7	230*	Tracked Target	Carr-Harris (2011)
	2014	21-22 Aug	404	0.8	570	Tracked Target	
McDonell	2001	10 Sept	353**	n/a	n/a	Tracked Target	Shortreed *et al.* 2002
	2002	13 Sept	595	1.5	216	Integration	Shortreed and Hume (2004)
	2005	22 Sept	880	2.4	487	Integration	Hall and Harris (2007)
	2006	9 Aug	371	1.2	104	Integration	Carr-Harris (2009) (1)

	2007	26 Sept	949	1.3	285	Integration	Carr-Harris (2009) (1)
	2008	18 Aug	1,436	1.5	464	Integration	Carr-Harris (2009) (2)
	2009	17 Aug	846	n/a	n/a	Tracked Target	Unpublished data
	2010	6-Aug	1,607	0.9	285	Integration	Carr-Harris (2011)
	2011	22 Aug	1,535	1.4	464	Integration	Carr-Harris (2012)
	2013	10 Sept	1,651	1.8	637	Integration	Doire and Carr-Harris (2014)
	2014	21 Aug	877	1.8	338	Integration	
Stephens	2002	10 Sept	897	2.1	371	Integration	Hume and MacLellan (2008)
	2005	13 Oct	1,200	3.8	870	Integration	Hall and Harris (2007)
	2010	13 Aug	853	2.3	387	Integration	Carr-Harris (2011)
	2014	20 Aug	391	2.3	177	Tracked Target	

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

****- No *O.nerka* caught in trawl**

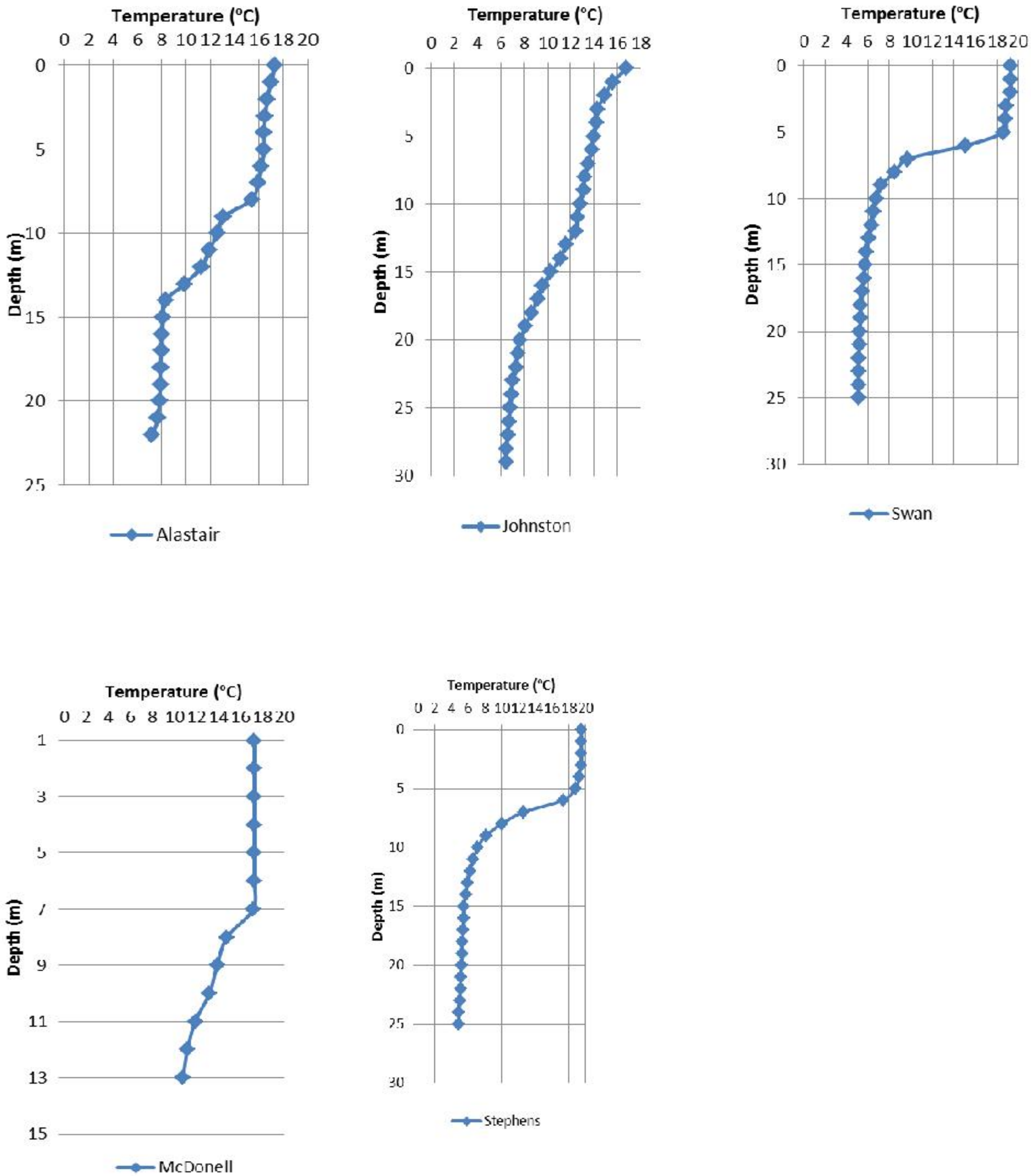

Figure 10. Temperature profiles for lakes surveyed in 2014.

Note different scales.

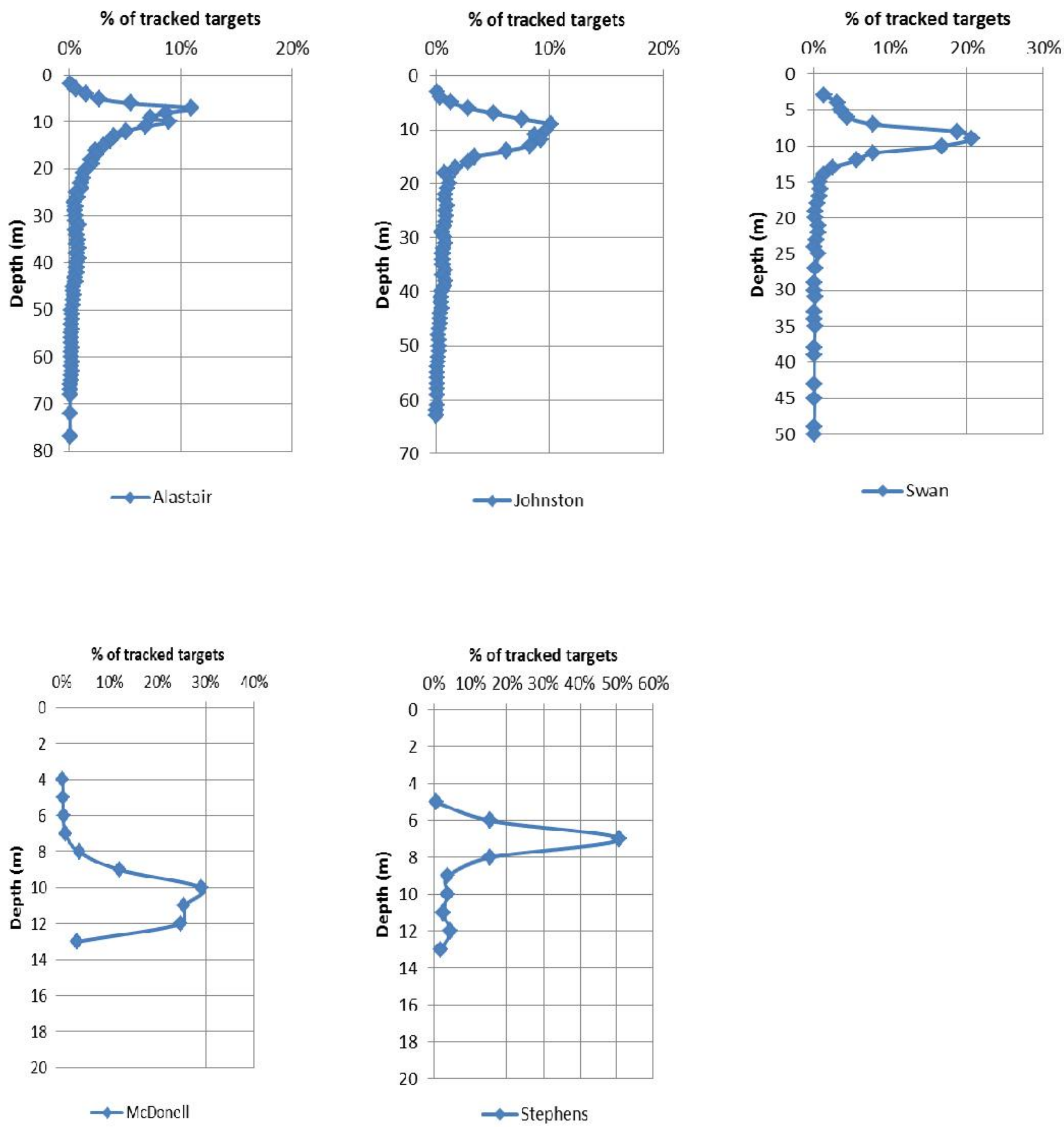

Figure 11. Vertical distribution of targets for lakes surveyed in 2014.

Note different scales

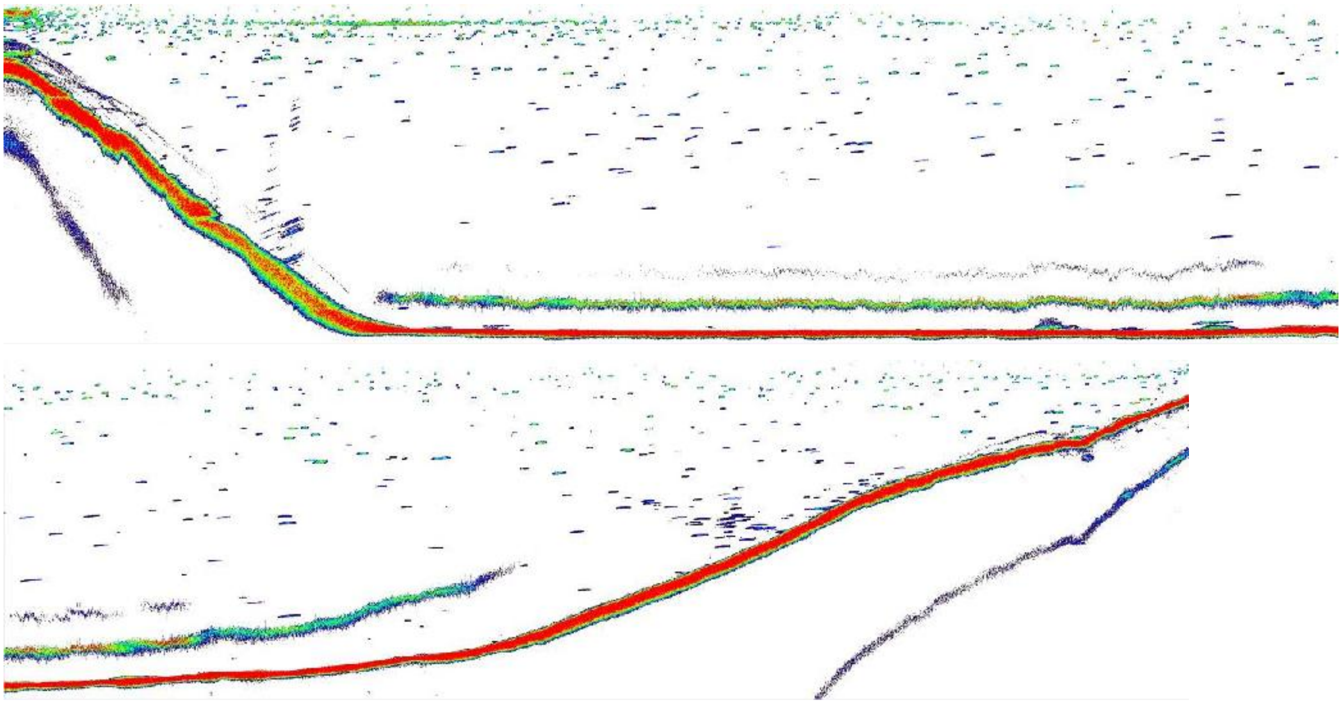

Figure 12. Alastair Lake transect 10 echogram

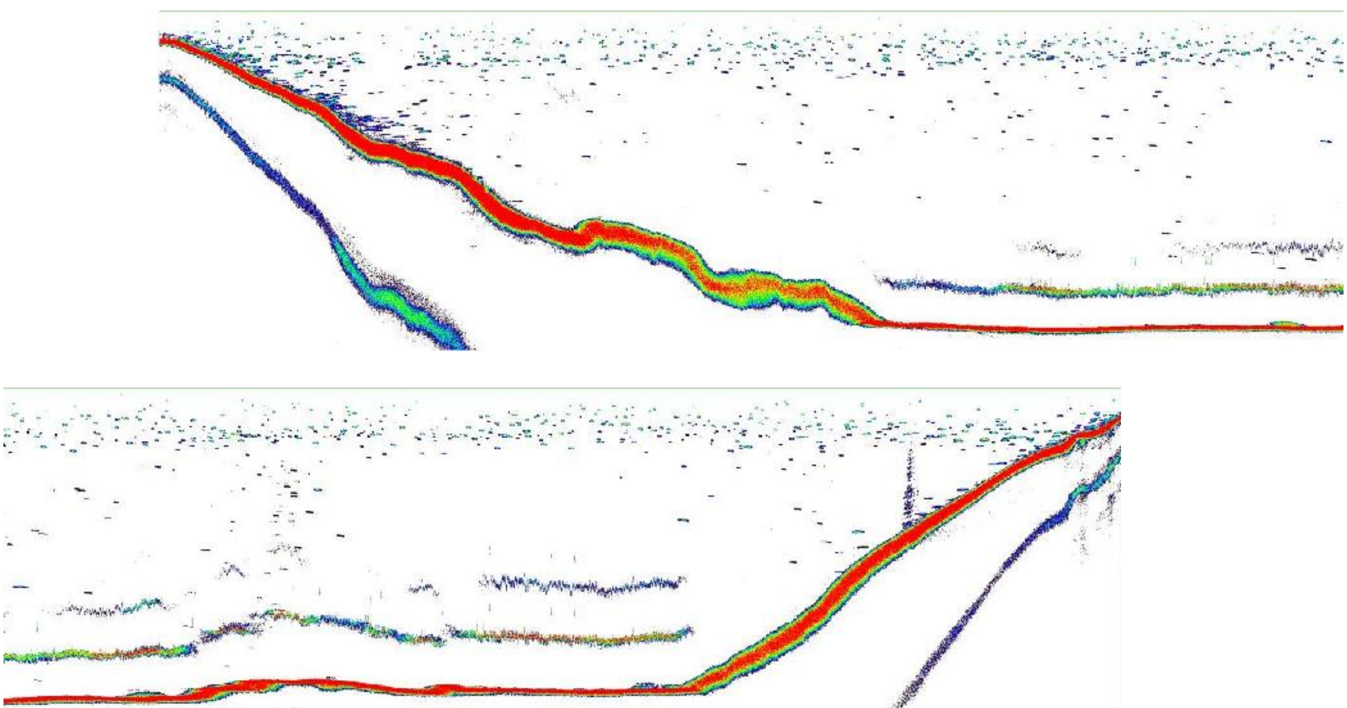

Figure 13. Johnston Lake transect 6 echogram

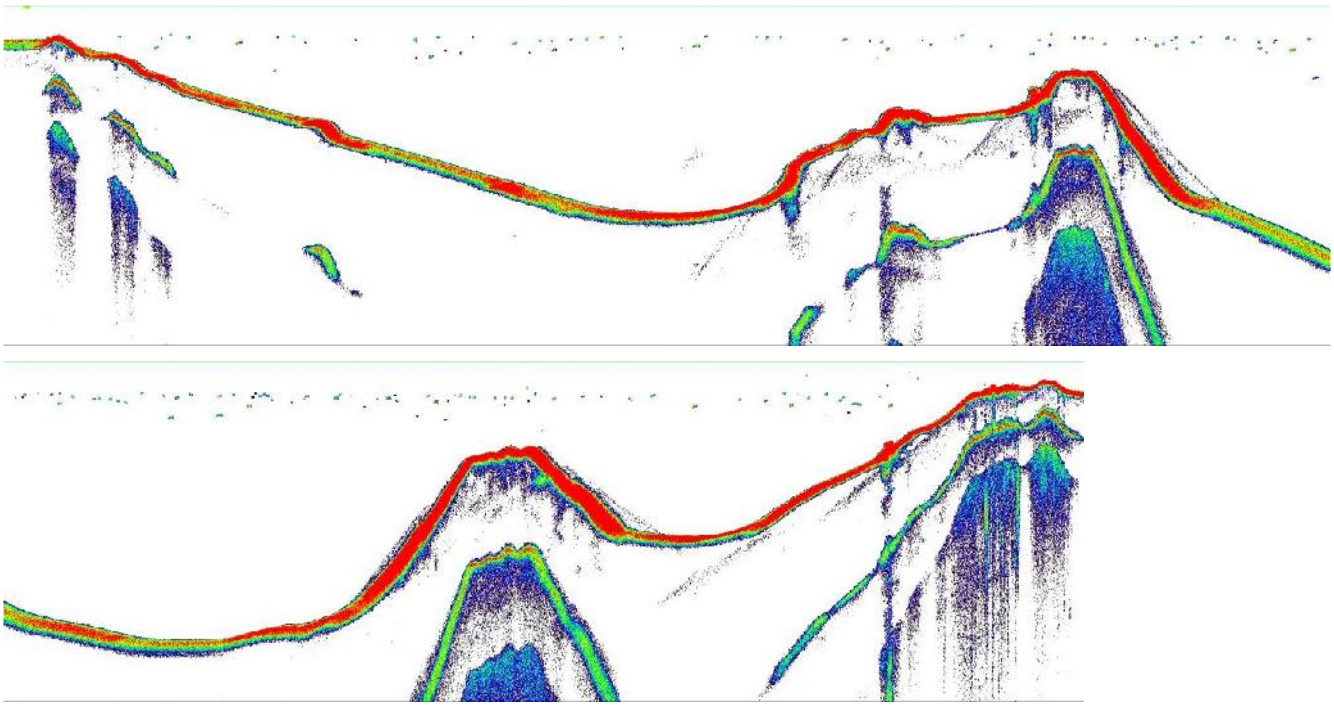

Figure 14. Swan Lake transect 8 echogram

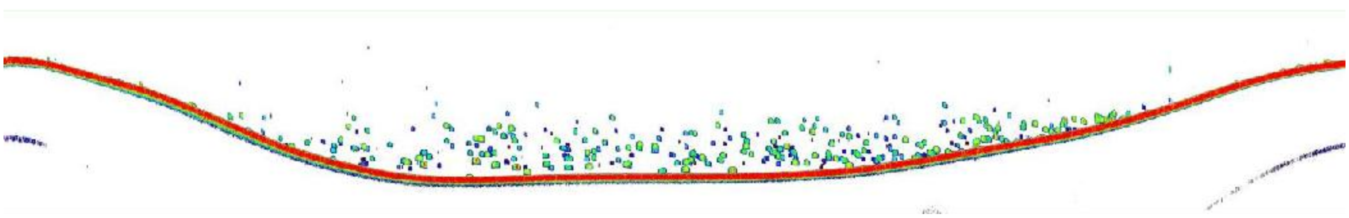

Figure 15. McDonell Lake transect 3 echogram

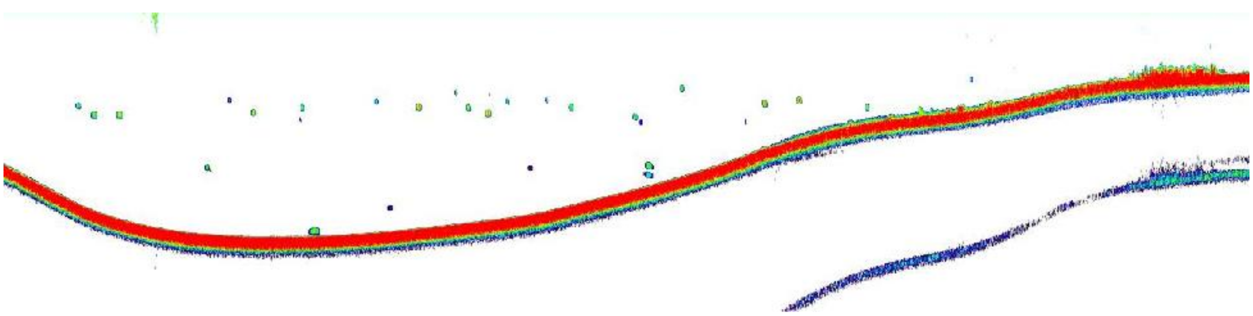

Figure 16. Stephens Lake transect 8 echogram