Skeena Sockeye Lakes Hydroacoustic Surveys 2015

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ABSTRACT

Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys of six (6) juvenile sockeye rearing lakes (Bear, Azuklotz, Johanson, Sustut, McDonell and Ecstall lakes) in the Skeena Watershed in 2015. 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.

2015 fall sockeye fry hydroacoustic population estimates ranged from 1.9×10^4 at Ecstall Lake to 1.3×10^6 at Bear Lake, with densities ranging from 179 fry/hectare at Ecstall Lake to 717 fry/hectare at Bear Lake. Bear Lake, which was the largest lake surveyed in 2015 had the highest fry density and abundances observed in 2015, while Ecstall Lake, which was the smallest lake surveyed in this year, had the lowest.

Regular rotational hydroacoustic surveys are a reliable and cost-effective means for assessing the stock status Skeena sockeye salmon populations. Where escapement information is unreliable or not available, hydroacoustic surveys provide an informative snapshot of the status of a given sockeye population. Reliable escapement estimates are available for few of the lakes that were surveyed in 2015. However, hydroacoustic estimates for previous years are available for all of the lakes that we surveyed in 2015, forming time-series of fry abundance data which can be compared with trophic capacity estimates at each lake.

Hydroacoustic surveys have been conducted in Mcdonell Lake for 13 of the last 15 years, providing a time series of fall fry abundance estimates that may be directly compared with spawner enumeration estimates for the Upper Zymoetz River in most of these years. In 2015, we carried out two separate hydroacoustic surveys at Mcdonell Lake on two nights in a row. The estimates for these two surveys were very similar, within 99% of one another, which confirms the repeatability of hydroacoustic methodology as an estimation technique for fall fry abundance.

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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 six (6) juvenile sockeye rearing lakes in the Skeena Watershed (Figure 1) during the late summer, early fall of 2015. 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.

Bear Lake (Figure 1) drains into the Bear River, a 5^{th} order tributary to the Sustut River, in the northeastern Skeena Watershed. The Bear River watershed drains an area of approximately 452 km^2 (Gottesfeld & Rabnett 2008). Bear Lake covers approximately 1961 hectares (Table 1). There are two distinct basins in the north and south ends of with maximum depths of 44 and over 70 m respectively. Tsaytut Bay is a large littoral area that covers 440 ha on the east side of Bear Lake. Sockeye escapement estimates are not available as stock assessment has never been conducted regularly at Bear Lake. Bear Lake is located within the traditional territories of the Gitxsan First Nation. Previous hydroacoustic surveys at Bear Lake were conducted in 2003 by Fisheries and Oceans Canada, Cultus Lake division, and by the SFC in 2008 and 2012.

Azuklotz Lake (Figure 1) is a clear, shallow lake located in the Northeast section of the Skeena watershed adjacent to Bear Lake, which empties into the Bear River which drains into the Sustut River, a tributary of the upper Skeena River. Azuklotz Lake has a surface area of 166 hectares, a maximum depth of 9.5 m and an average depth of 4 m (Table 1). Previous hydroacoustic surveys at Azuklotz Lake were conducted in 2003 by Fisheries and Oceans Canada, Cultus Lake division, 2009, and 2012 by the SFC. Azuklotz Lake is located within the traditional territories of the Gitxsan First Nation.

Johanson and Sustut lakes are in the Sustut Watershed (Figure 1). 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 and 2013 by the SFC.

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.

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.

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. Gitksan Watershed Authorities (GWA) and SFC have conducted annual hydroacoustic surveys at McDonell Lake every year since 2005 except for 2012. In 2015 McDonell Lake was surveyed two nights in a row to test the replicability of the hydroacoustic technique as a tool to estimate juvenile sockeye population abundance. 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.

Ecstall Lake is located on the coastal end of the Skeena River, at approximately 35m elevation, a fourth-order tributary to the lower Skeena River. Ecstall 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). Esctall Lake is moderately turbid due to glacial runoff from the surrounding mountains. It is a small, relatively shallow lake with a surface area of only 90 ha, a maximum depth of 20 m, and an average depth of 7 m (Table 1). The Department of Fisheries & Oceans Cultus Lake Research Laboratory previously conducted a hydroacoustic survey at Ecstall Lake in 2005. Ecstall Lake is located within the traditional territories of the Allied Tribes of Lax Kw'alaams.

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 2015

Lake	Watershed	Elevation (m)	Average Depth (m)	Maximum Depth (m)	Surface Area (ha)	Clarity
Azuklotz	Bear	789	4	10	166	Clear
Bear	Bear	789	13.5	70	1943	Clear
Ecstall	Ecstall	35	7	20	90	Stained
Johanson	Sustut	1,444	16.0	53	143	Clear
McDonell	Zymoetz	830	8.0	15	215	Clear
Sustut	Sustut	1,301	5.8	20	257	Clear

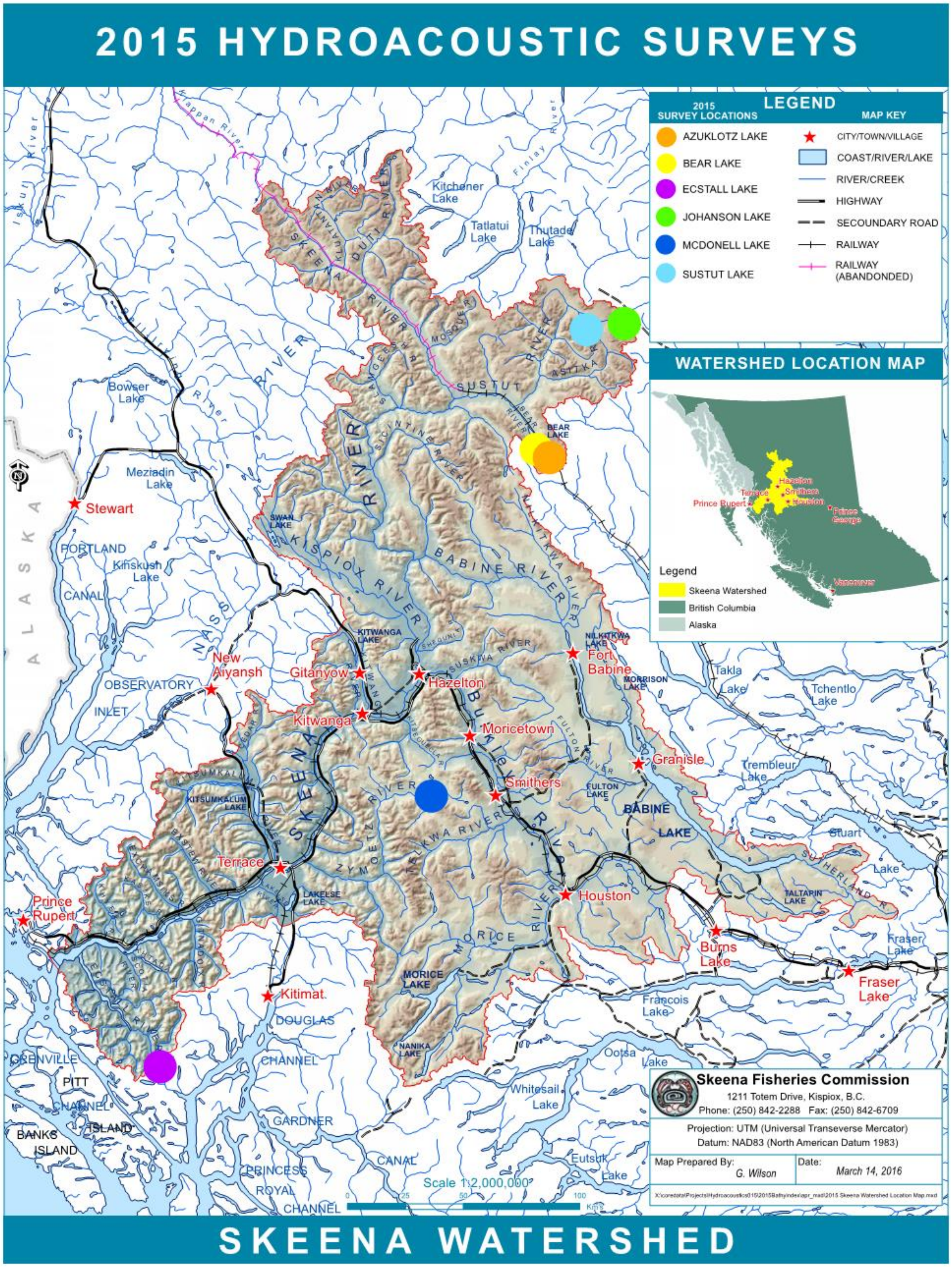

Figure 1. Location of the surveyed lakes in the Skeena watershed

METHODS

Hydroacoustic Survey

Hydroacoustic surveys were conducted using similar methods and technology as in previous years (Hall and Harris 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° 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 -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 survey designs used in 2015 at Johanson, Sustut, and Ecstall lakes (Figures 5, 6, and 8) were all created by the SFC for surveys in previous years, with the exception of Ecstall Lake for which the survey design was established in 2015. The surveys at Bear, Azuklotz, and McDonell lakes were conducted along transects established by the Department of Fisheries & Oceans Cultus Lake Research Laboratory (Figures 3, 4, and 7).

Hydroacoustic estimates for Johanson, Sustut, Bear, and Ecstall 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 Azuklotz, 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 was applied prior to post-processing of the data.

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.

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. 6.1.66). 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.

Following the general guidelines of MacLellan and Hume (2010), population estimates for Bear, Azuklotz, Sustut, and McDonell lakes were calculated using the integration method because their estimated fish densities were above 500 fish/ha. Estimates for Johanson and Ecstall lakes were calculated using the tracked target method. We present results using all three estimation methods for each lake for comparison in Table 6.

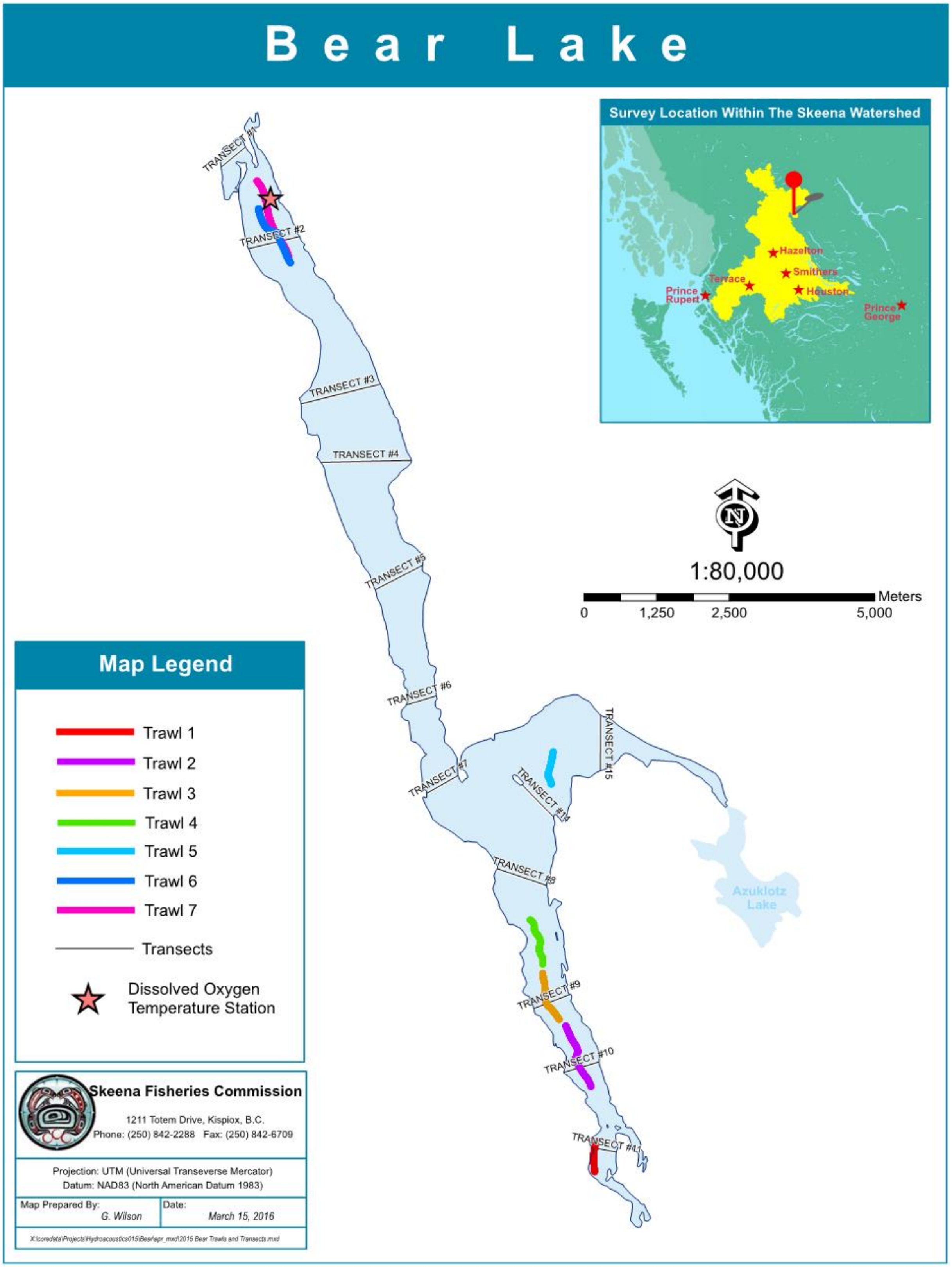

Figure 3. Bear Lake survey map.

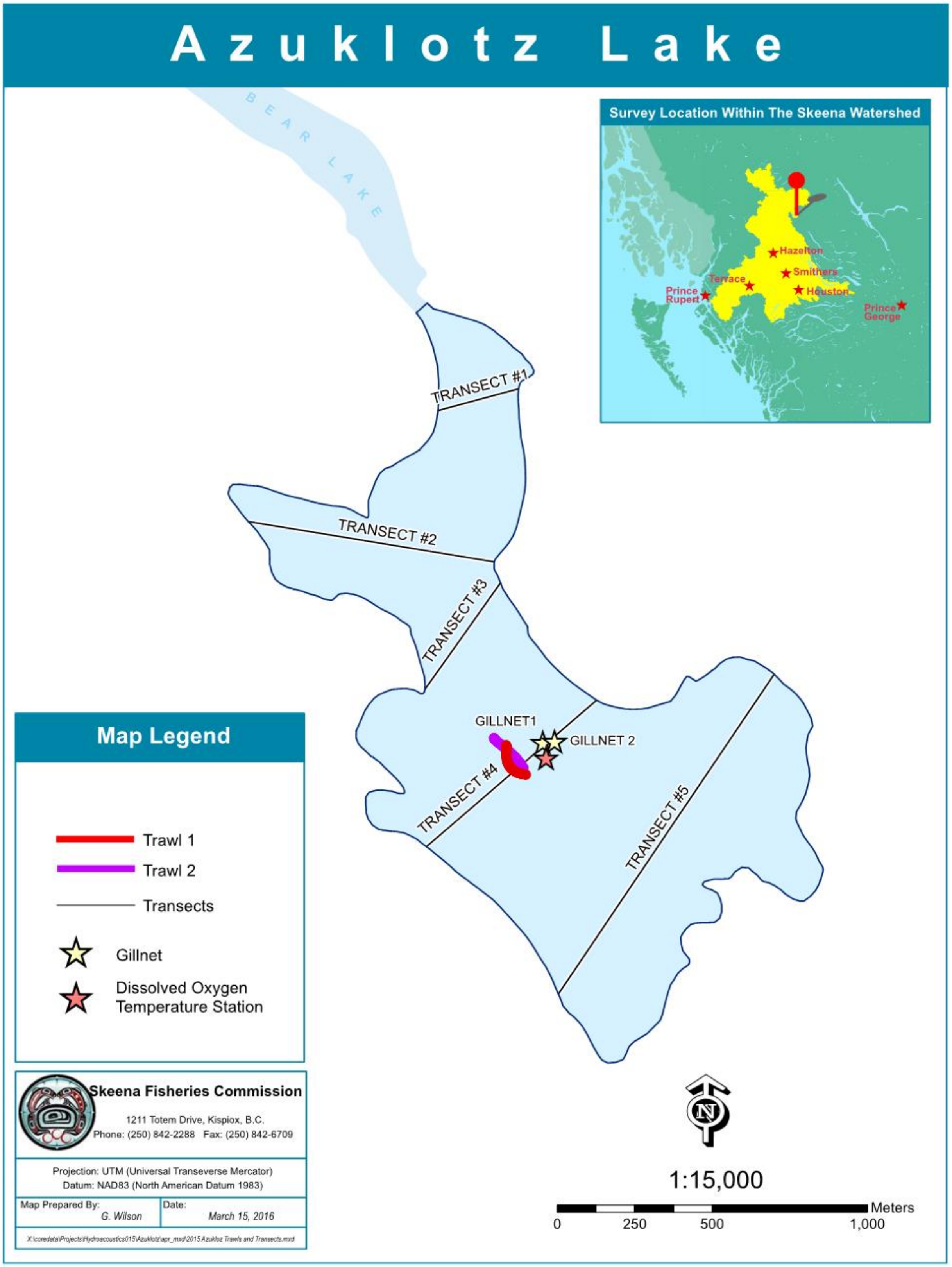

Figure 4. Azuklotz Lake survey map.

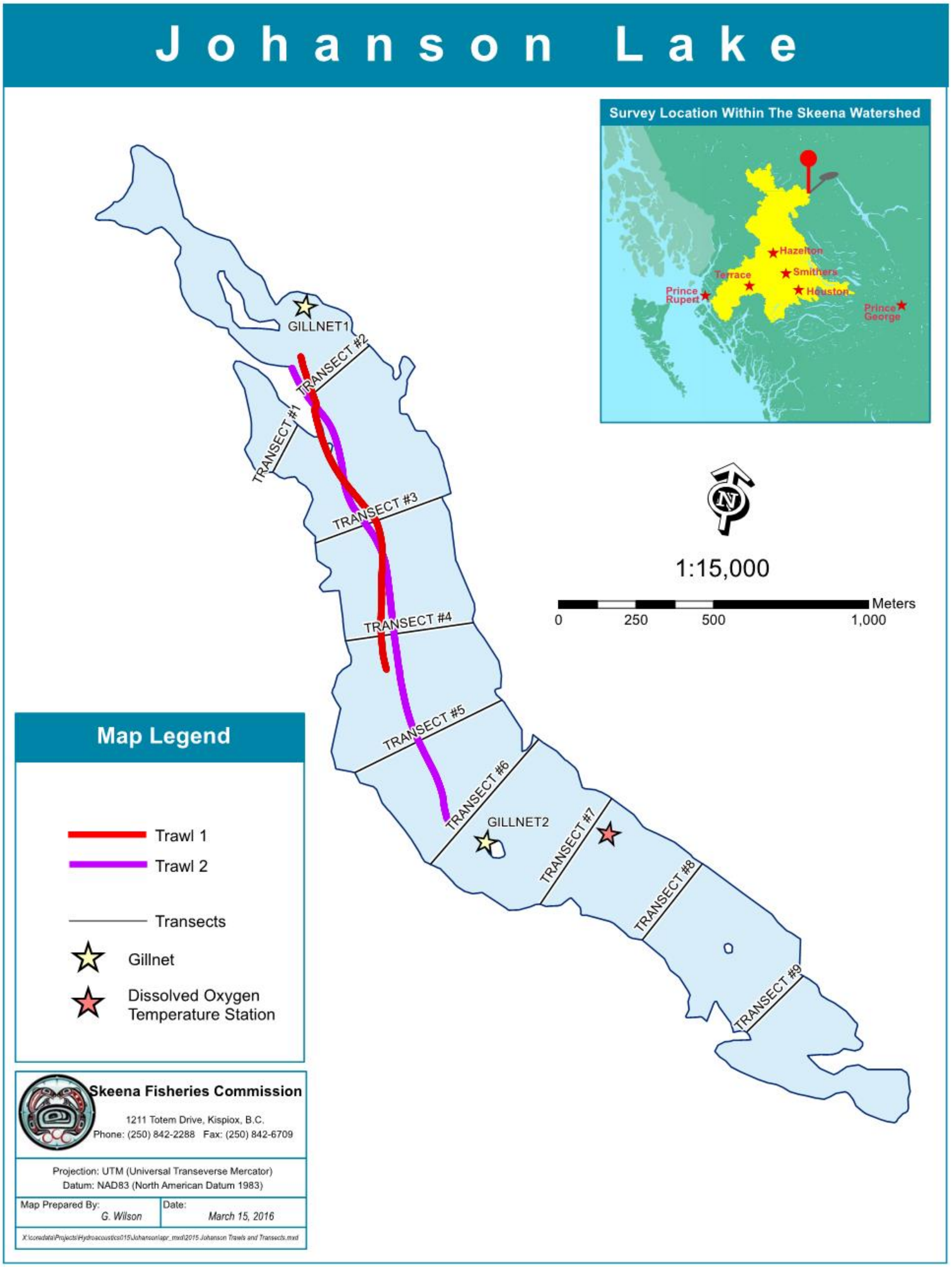

Figure 5. Johanson Lake survey map

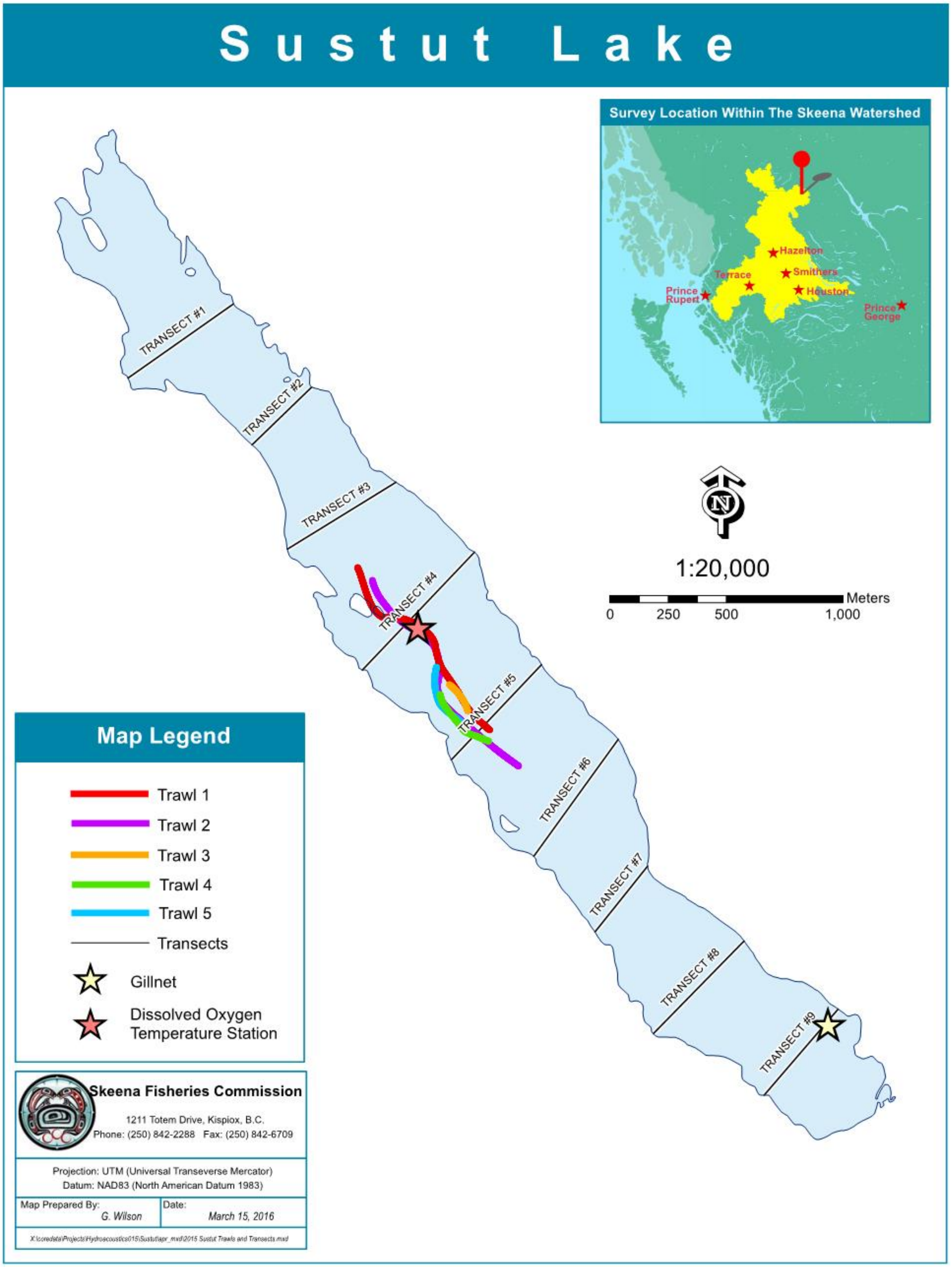

Figure 6. Sustut Lake survey map

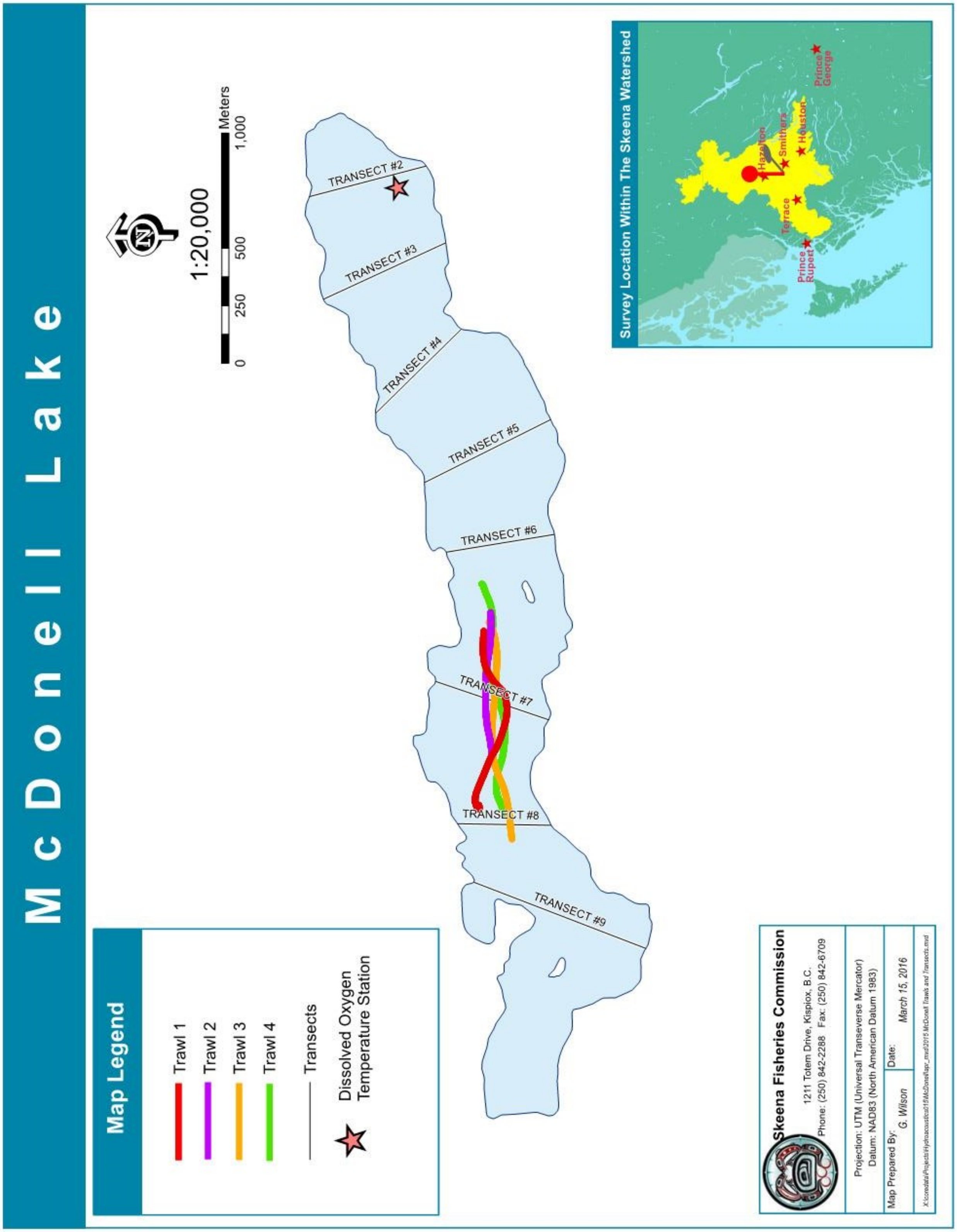

Figure 7. McDonell Lake survey map

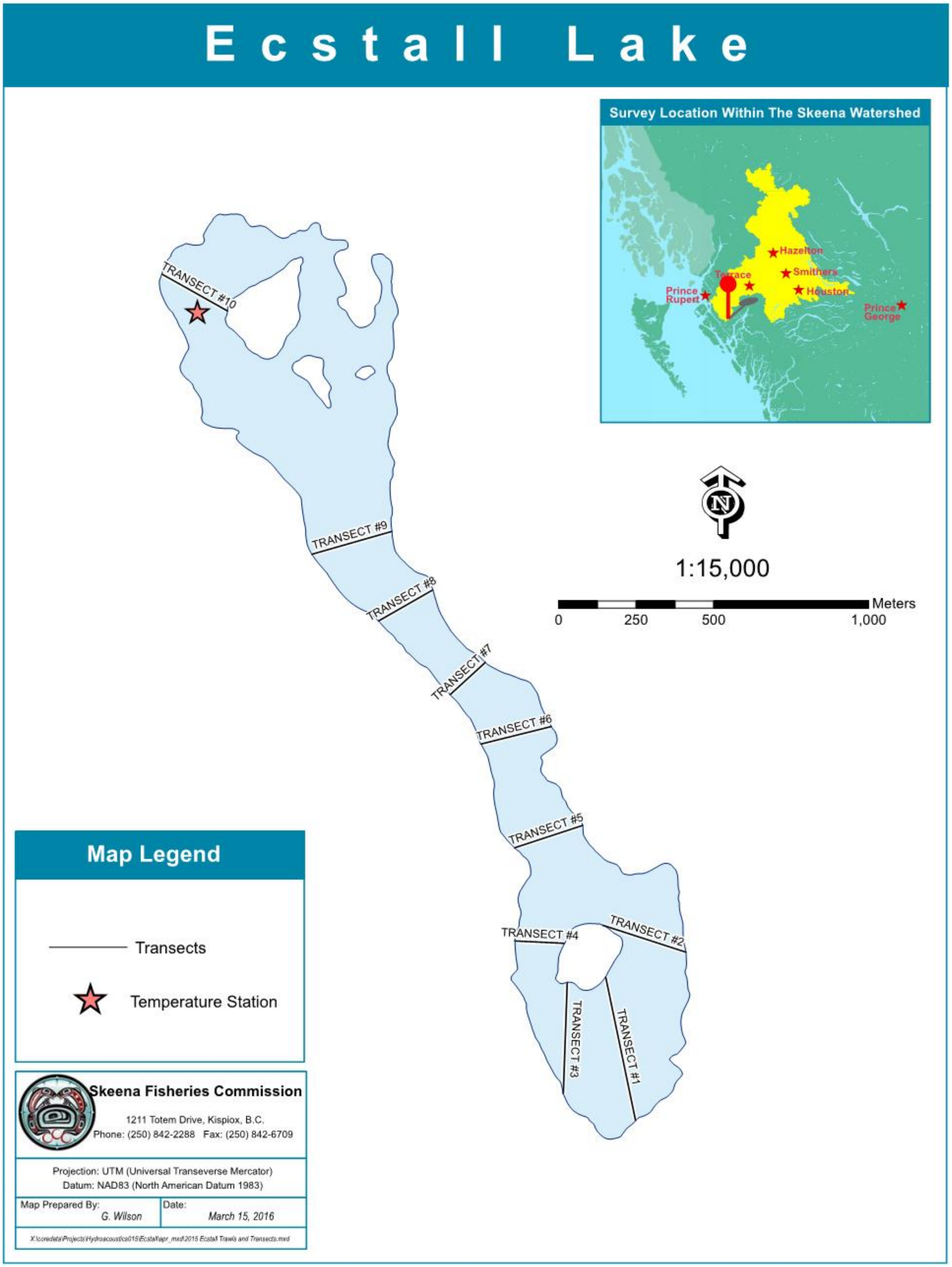

Figure 8. Ecstall Lake survey map

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 MacLellan and Hume (2010), and by SFC (i.e., Carr-Harris 2012). Data from each transect were analyzed in 2m depth layers for all lakes but Azuklotz Lake, for which data was analyzed in 1m depth layers . 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 1 m/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 Sustut, and Johanson lakes, and along the bottom at Azuklotz Lake. 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

Bear Lake

Bear Lake was surveyed on the nights of August 12, 13, and 15, 2015. The surface temperature was 19.9ºC degrees, with a gradual decline to 18.9 ºC at 8 m, and a thermocline between 8 and 12 m with another gradual decline to a hypolimnion of approximately 10.5 ºC below 29 m (Figure 11).

We captured 87 *O.nerka*, 2 Pygmy whitefish (*Prosopium coulterii*), and 1 redside shiners (*Richardsonius balteatus)* during seven trawl tows with a combined length of about 6.5 km (Figure 3, and Table 3). All of the juvenile sockeye and Pygmy whitefish were caught in the trawl tows # 1, 2, 3, 4, 6 and 7, which covered depth ranging from 7m to 20m. The redside shiner was caught during trawl #5, at a depth of only 1.5m. All *O. nerka* caught were age-0, or young of the year fry. The average length of *O. nerka* fry captured was 59.3 mm with an average weight of 2.8 grams (Table 5).

Hydroacoustic data were collected from thirteen transects across the long axis of the lake (Figure 3). We did not survey transects 12, 13 and 16 based on advice from previous surveys that they were shallow with few fish.

Most fish targets at Bear Lake were found above 30 m depth in the water column, with peak densities occurring at depths ranging from 5m to 15m (Figures 12 and 13). Considering that the water temperatures measured between the surface and 6m were well above the range of temperature preferred by juvenile sockeye Brett (1952), 0% of the "small fish" population estimate above 6m was apportioned to age-0 *O.nerka* during the analysis. According to the proportion of age-0 *O.nerka* caught during the trawl tows below 6m depth, we apportioned 98% of the "small fish" population estimate below 6m to age-0 *O.nerka* . The 2015 hydroacoustic population estimate for age-0 *O.nerka* at Bear Lake was $1.4 \times 10^6 \pm 2.6 \times 10^5$, equivalent to a density of 717/ha, calculated with the integration method (Figure 9 and Table 6). The total age-0 *O.nerka* biomass was estimated at 3,903 kg (Table 7).

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 2015 hydroacoustic survey represents 43% of the rearing capacity, or R_{max}, at Bear Lake (Table 6).

The previous hydroacoustic surveys of Bear Lake prior to this one were completed in 2003 by the Cultus Lake Salmon Research Laboratory, and by SFC in 2008, and 2012 (Table 8). The 2015 age-0 *O.nerka* density and biomass estimates are slightly smaller than the 2012 age-0 *O.nerka* estimates at Bear Lake (Table 8), however the difference is not statistically significant considering the relatively wide confidence intervals around the estimates. When compared to estimates from 2003 and 2008, the 2015 age-0 *O.nerka* density and biomass estimates at Bear Lake are significantly larger (Table 8).

There is little available recent sockeye escapement data for Bear Lake, where sockeye enumeration is complicated by the known presence of lakeshore spawners (Gottesfeld &

Rabnett, 2008). Stronger sockeye returns to the Bear Lake system in 2011, and 2014, compared to 2002, and 2007 may explain the significantly greater abundance of age-0 *O. nerka* observed during the late summers of 2012, and 2015.

Azuklotz Lake

Azuklotz Lake was surveyed on August 15, 2015. The water temperature was stable at 19.5 ºC from the surface to 3m depth. A small thermocline was observed between 3 and 7 meters, with a hypolimnion of 15.8 degrees ºC at 10 meters (Figure 11).

We captured 13 *O.nerka*, one Pygmy whitefish, and one prickly sculpin during three trawl tows with a length of about 0.4 km (Figure 4, and Table 3). One double gillnet, and one single gillnet were set along the bottom in the deepest (10 m) area of Azuklotz Lake, for a total soak time of approximately 7.5 hours (Figure 4 and Table 4). Sixty six (66) *O.nerka* were captured in the gillnets (Table 4).Scales readings revealed that all the *O.nerka* captured in the trawls were age-0. Two of the *O.nerka* captured in the gillnets were age-1, the others were all age-0. The average length of the age-0 *O.nerka* fry caught in the trawls and gillnets was 72.2 mm, with an average weight of 4.0 grams, and the average length and weight of the age-1 *O.nerka* fry was 121 mm, and 22.1 grams, respectively (Table 5). The prickly sculpin and the pygmy whitefish had a weight of 4.0g, and 2.0, respectively (Table 5).

Hydroacoustic data were collected from five transects across the long axis of the lake (Figure 4). Most of the fish targets were found close to the bottom, around 9-10 m (Figures 12 and 14). The highest densities of fish targets were found in the deepest section of the lake, along Transect 4. The water temperature between the surface and 4 m depth was well above the range of temperature preferred by juvenile sockeye Brett (1952), hence 0% of the “small fish” population estimate above 4m was apportioned to *O.nerka* during the analysis. Furthermore, 99% of the “small fish” population estimate below 4 m was apportioned to *O.nerka* based on the proportion of *O.nerka* caught in the trawl tows and gillnets. Finally, the *O.nerka* estimate was apportioned between age-0, and age-1 classes, according to the scale readings results. The hydroacoustic population for age-0 *O.nerka* in Azuklotz Lake was estimated at $7.13 \times 10^4 \pm 2.5 \times 10^4$, equivalent to a density of 430/ha, calculated using the integration method (Figure 9 and Table 5). The total biomass of age-0 *O.nerka* was estimated at 285 kg, or approximately 20% of R_{max} for Azuklotz Lake (Table 6).

The 2015 age-0 *O.nerka* population density estimate for Azuklotz Lake is significantly lower than the August 2012 age-0 *O.nerka* density estimate (Doire and Carr-Harris, 2013), similar to the August 2003 density estimate (Shortreed and Hume, 2004), and slightly higher than the estimate obtained in September 2009 (Carr-Harris 2010) (Table 8). The age-0 *O.*nerka biomass estimated in 2015 (285kg) is significantly greater than the age-0 *O.nerka* biomass estimated in 2009 (98 kg) by Carr-Harris (2010), but similar to the age-0 *O.nerka* biomass of 305 kg and 219 kg estimated respectively in 2003 by Shortreed and Hume (2004), and by Doire and Carr-Harris (2013) (Table 8). It should be noted that the 2012 age-0 *O.nerka* mean weight (1.1g) and biomass were calculated using only trawl caught fish, whereas the age-0 *O.nerka* mean weight and biomass were calculated using only gillnet caught fish in 2003 and 2009, and gillnet and trawl caught fish were used to calculate the 2015 age-0 *O.nerka* mean weight and biomass. This explains the significantly smaller 2012 age-0 *O.nerka* mean weight compared to 2003, 2009, and

2015. As MacLellan and Hume (2010) reported, gillnets catch considerably larger fish than 2x2m trawls partly because 2x2m trawls have a tendency to bias against catching larger fish, as larger fish can swim fast enough to avoid being caught in the trawl.

No escapement number for Azuklotz Lake is available for 2014 (Fisheries and Oceans Canada 2015 NuSEDS database). The database only mentions that adult sockeye were present on the spawning grounds in 2014, compared to 2,547 spawners enumerated in 2011, brood year for the 2012 survey.

Johanson and Sustut lakes

Johanson Lake was surveyed on the night of August 17, 2015. The surface temperature was 16.3ºC degrees, with a gradual decline to 14.4 ºC at 8 m, and a thermocline between 8 and 13 m with another gradual decline to a hypolimnion of 7.0 ºC below 14 m (Figure 11).

We captured nine *O.nerka* during two trawl tows with a combined length of about 3.0 km (Figure 5, and Table 3). One of the trawl tows was conducted at the surface, and the other tow was conducted at 8m depth. One double gillnet, and one single gillnet were set at Johanson Lake, for a total soak time of almost 10 hours (Figure 5, and Table 4). We captured ten (10) *O.nerka* with an average length of 77.8 mm, and an average weight of 4.5g by gillnet (Table 5). The average length of the *O.nerka* fry captured by trawl was 54.8 mm, with an average weight of 1.4 grams (Table 5). All of the *O.nerka* fry caught in the trawl and gillnets were age-0, or young of the year fry.

Hydroacoustic data were collected from nine transects across the long axis of the lake (Figure 5). Most fish targets were found between 3m and 12m depth in the water column (Figures 12 and 15). Because only age-0 *O.nerka* were caught in the trawl and gillnets, 100% of the "small fish" population estimate was apportioned to age-0 *O.nerka.* The hydroacoustic population estimate for age-0 *O.nerka* in Johanson Lake was $6.7 \times 10^4 \pm 1.3 \times 10^4$ or 457/ha, calculated with the tracked target method (Figure 9 and Table 6). The total age-0 *O.nerka* biomass was estimated at 201 kg (Table 7).

According to the PR capacity model, the biomass of age-0 *O.nerka* fry observed during the 2015 hydroacoustic survey at Johanson Lake represents 29% of the rearing capacity, or R_{max} (Table 7).

The 2015 Johanson Lake sockeye fry population density estimate (457/ha) and biomass estimate (201 kg) are significantly higher than the density and biomass estimates observed during the last hydroacoustic survey at Johanson Lake which was carried out in 2013 (Table 8). Compared to older surveys, the 2015 population density estimate is similar to the 2010 density estimate, but lower than the 2004 estimate (Table 8). In 2015 the age-0 *O.nerka* mean weight was calculated using trawl and gillnet caught fish, whereas only trawl caught fish were used in the calculation of the 2004, 2010, and 2013 age-0 *O.nerka* mean weight. This significantly increased the average fry weight observed in 2015 compared to previous surveys (Table 8). This resulted in the 2015 age-0 *O.nerka* biomass estimate being significantly greater than the 2010 biomass estimate, and similar to the 2004 biomass estimate. If only fry caught during the trawl tows were included to calculate the average fry weight, the 2015 estimated age-0 *O.nerka* biomass would be similar to the 2010 biomass estimate, but lower than the 2004 estimate.

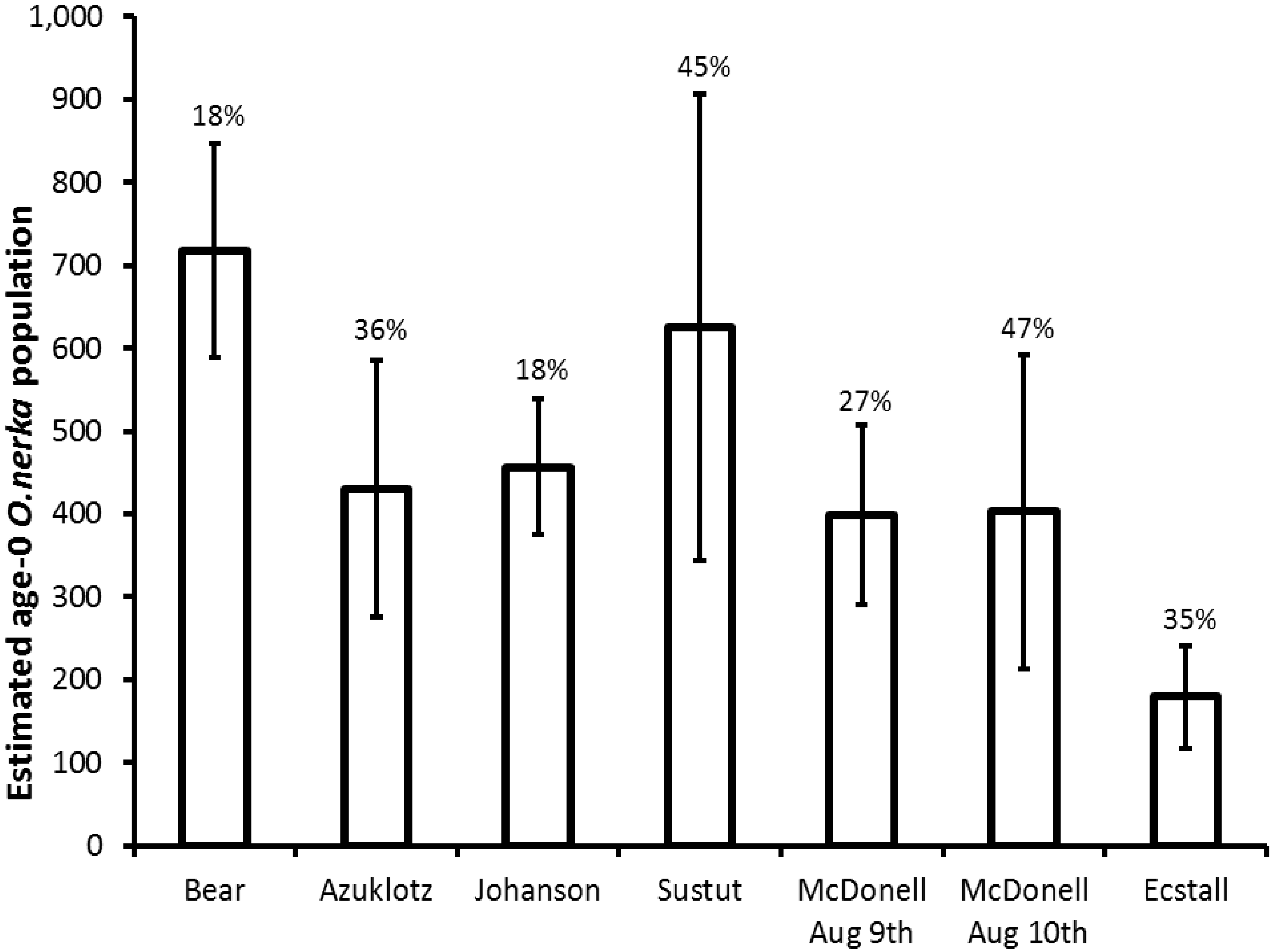

Figure 9. Graph showing the 2015 age-0 *O.nerka* population density estimates for Bear, Azuklotz, Johanson, Sustut, McDonell - August 9th, McDonell - August 10th, and Ecstall lakes.

The error bars show the 95% confidence intervals.

Sustut Lake was surveyed on the nights of August 16, 2015. The surface temperature was 14.7ºC degrees, with a gradual decline to 14.0 ºC at 7 m, and a thermocline between 7 and 13m with another gradual decline to a hypolimnion of approximately 8.7 ºC at 15 m (Figure 11).

We conducted five trawl tows with a combined length of approximately 3.0 km at Sustut Lake (Figure 6 and Table 3). Trawl depths ranged from approximately 7m to 14.5m (Table 3). The total trawl catch was 54 *O.nerka*, and 2 peamouth chub (*Mylocheilus caurinus*). All of the *O.nerka* were age-0, and had an average weight and length of 1.2 grams, and 48.4 mm, respectively (Table 5). One double gillnet was deployed for just over three hours at Sustut Lake (Figure 6 and Table 4). Three peamouth chub, and 24 *O.nerka* were captured in the gillnet (Figure 10 and Table 5). The *O.nerka* captured in Sustut Lake were not aged because of problems with preservation in ethanol. Fry weights are also not available from Sustut Lake because of the use of ethanol to preserve them. Considering the length frequency distribution of the other 23 *O.nerka* caught in the gillnet, and data from Hume and MacLellan (2008) 11 were assumed to be age-0 (mean length of 70.1 mm), and 12 were assumed age-1 (mean length of 92.8 mm) (Table 5). The largest *O.nerka* caught in the gillnet was 142 mm in length (Figure 10 and Table 5). This fish was male with developed gonads, and was most likely a kokanee older than age-1.

Figure 10. Photo of 24 *O.nerka*, and three peamouth chub caught in the gillnet at Sustut Lake. August 16, 2015.

Hydroacoustic data were collected from eight transects across the long axis of Sustut lake (Figure 6). Fish were mostly uniformly distributed throughout the water column, with higher densities between 15 m and the bottom (20 m) (Figure 12). Fish were also mostly uniformly distributed throughout the lake. Age-0 *O.nerka* and age-1 *O.nerka* accounted for 79%, and 15% of the catches in the trawl tows and the gillnets, respectively. The "small fish" population was apportioned accordingly. Considering the kokanee caught in the gillnet was larger than 135 mm, it was not included in the "small fish" proportion calculation. The age-0 *O.nerka* population in Sustut Lake was estimated at $1.59 \times 10^5 \pm 7.1 \times 10^4$ or 625/ha, calculated using the integration method (Figure 9 and Table 6). The total age-0 *O.nerka* biomass was estimated at 192 kg, or approximately 28% of Rmax for Sustut Lake (Table 7).

There are no available recent sockeye escapement data specifically for Johanson Lake or Sustut Lake, however the Ministry of Environment operates a fence on the Sustut River downstream of the tributaries to both Johanson and Sustut lakes. In 2014 (the brood year for 2015 age-0 *O.nerka*), 1,062 adult sockeye were enumerated at the Sustut fence, which is significantly smaller than the 2003 escapement of 4,993 (brood year for 2004 age-0 *O.nerka*), greater than the 2009 escapement of 540 (brood year for 2010 age-0 *O.nerka*), and only slightly lower than the 2012 escapement (brood year for 2013 age-0 *O.nerka*) (Ministry of Forests, Lands and Natural Resource Operations, 2015).

When compared with results from previous surveys (2004, 2010, and 2013) at Sustut and Johanson lakes, and their respective brood year escapements enumerated at the Sustut River fence, the relatively low total age-0 *O.nerka* population estimate observed in 2015 in Sustut and Johanson lakes is surprising (Figure 10). The very low trawl CPUE (catch per unit of effort) obtained in 2015 in Sustut (1.1 *O.nerka*/min) compared to the greater 2004 (8.2 *O.nerka*/min), and 2013 (8.4 *O.nerka*/min) trawl CPUE in the same lake supports the significant difference between the 2010, 2013 and 2015 hydroacoustic estimates.

The presence of kokanee in Sustut Lake was suggested by Hume and MacLellan (2008), observed by Doire and Carr-Harris (2014), and observed again in 2015 when a sexually mature 142mm kokanee was caught in a gillnet. The differences in the age-0 *O.nerka* 2004, 2010, 2013, and 2015 hydroacoustic population estimates may be driven by significant fluctuations in the kokanee population in Sustut Lake, and the high fry per spawner ratio observed for brood year 2009 and 2012 are most likely due to a high age-0 and/or age-1 kokanee population in 2010 and 2013. The relative abundance of kokanee and sockeye in Sustut Lake may be quantified using genetic analysis during future hydroacoustic surveys.

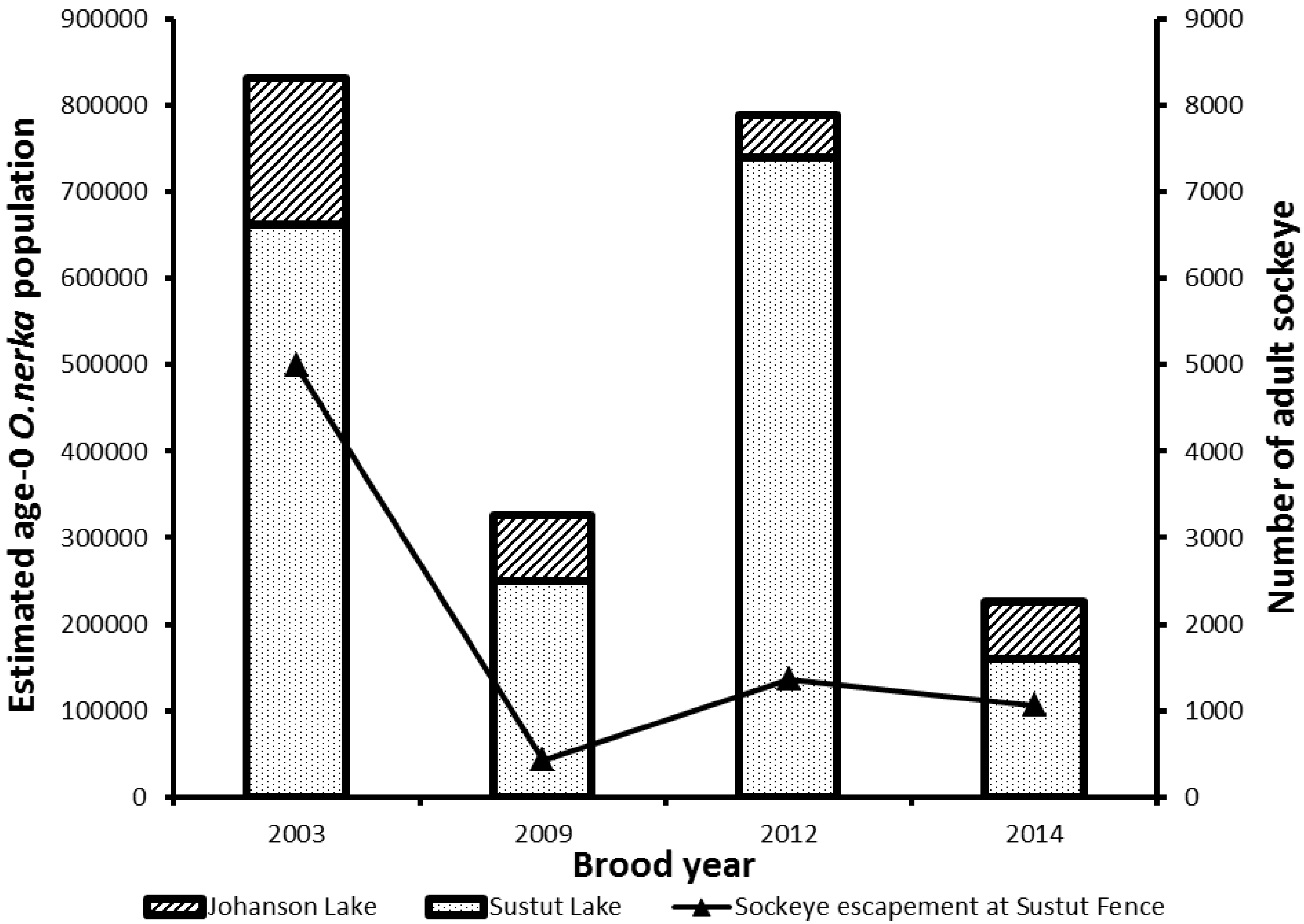

Figure 11. Age-0 *O.nerka* population estimate for Sustut and Johanson Lake, and sockeye escapement at the Sustut fence for Brood year 2003, 2009, 2012, and 2014.

McDonell Lake

McDonell Lake was surveyed on August 9, 2015, and the exact same survey design was replicated on August 10, 2015 to test the replicability of the hydroacoustic technique. On August 10th, the surface temperature was 17.9 ºC with an epilimnion to 5 metres depth, and a gradual decline to 9.0 ºC at 14 meters depth (Figure 11).

A total of 50 *O.nerka*, and one prickly sculpin were captured at McDonell Lake, during four trawl tows with an approximate length of 3.6 km (Figure 8, Tables 2, and 4). No gillnets were set at McDonell Lake. The average length of trawl captured *O.nerka* was 50.1 mm, with an average weight of 1.4 grams (Table 4). All of the *O.nerka* fry captured at McDonell Lake were age-0. Most of the fish were observed between 7 m and 13 m depth (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 8 m were well above the range of temperature preferred by juvenile sockeye (Figure 11), 0% of the "small fish" population estimate above 6m was apportioned to age-0 *O.nerka* during the analysis. We apportioned 100% of the "small fish" population estimate below 6m to age-0 *O.nerka* although we captured one 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 2015 age-0 *O.nerka* population for McDonell Lake was estimated at $8.55 \times 10^4 \pm 2.13 \times 10^4$ during the August 9th survey, and $8.64 \times 10^4 \pm 4.04 \times 10^4$ during the August 10th survey, using the integration method (Table 6). These abundances are equivalent to densities of 399/ha estimated on August 9th, and 403/ha estimated on August 10th (Figure 9). Given the average weight from the trawl sample, the estimated biomass was 120 kg on August 9th, or approximately 12% of R_{max}, and 121 kg on August 10th, also approximately 12% of R_{max} (Table 6).

The results obtained during the two consecutive hydroacoustic surveys conducted at McDonell Lake in 2015 are relatively similar, and show that the hydroacoustic technique is replicable, at least for McDonell Lake.

The 2015 age-0 *O.nerka* population density, and biomass estimates for McDonell Lake are significantly lower than the densities, and biomasses estimated in all but two (2001, and 2006) previous surveys at McDonell Lake (Table 7). The 2015 age-0 *O.nerka* population density and biomass estimates are over four times lower than the estimates from the 2008, 2010, 2011, and 2013 surveys. The low trawl CPUE (Table 2), and the low number of fish observed on the echograms (Figures 17, and 18) in 2015 confirm the low age-0 *O.nerka* population estimates calculated at McDonell in 2015. The *O. nerka* population estimated in 2015 is much lower than expected considering the 2014 escapement of 1,814 spawners counted and reported by DFO (Fisheries and Oceans Canada 2015 NuSEDS database) in the Upper Zymoetz. It is equivalent to only approximately 47 fry per spawner, which is significantly lower than the average fry per female observed for brood year 2004 to 2013 of 129, not including brood year 2008

(Table 2). GWA staff also conducted sockeye escapement survey in the Upper Zymoetz River in 2014, during which they enumerated only 210 spawners. The disparity between the DFO and GWA sockeye spawner counts in the Upper Zymoetz in 2014 is significant, and should be resolved.

Table 2. Number of sockeye fry per spawner calculated from hydroacoustic estimates at McDonell Lake.

Brood Year	Fry/Spawner
2004	60
2005	23
2006	167
2007	162
2008	1,299
2009	203
2010	221
2012	180
2013	114
Average*	**258**

*- Average does not include brood year 2008.

Ecstall Lake

Ecstall Lake was surveyed on the night of October 25, 2015. The surface temperature was 15.7ºC degrees, with a slow decline to 13.8 ºC at 10 m, and a thermocline between 10 and 13 m with a gradual decline to a hypolimnion of approximately 9 ºC at 17 m (Figure 11).

We conducted three trawl tows with a total length of approximately 0.5 km at Ecstall Lake (Table 3). The total trawl catch was 17 *O.nerka*, and two threespine stickleback. The average length of *O.nerka* fry captured in the trawl was 57.4 mm, with an average weight of 2.2 grams (Table 5). All were age-0 *O.nerka*.

Hydroacoustic data were collected from ten transects across the long axis of the lake. Most of the fish targets were found between 12 m and the bottom (Figures 12 and 19). The highest densities of fish targets were found in the mid-section of the lake.

Considering that age-0 *O.nerka* represented 90% of the trawl catch at Ecstall Lake, 90% of the "small fish" population estimated was apportioned to age-0 *O.nerka*. The Ecstall Lake age-0 *O.nerka* population was estimated at $1.94 \times 10^4 \pm 6.81 \times 103$, equivalent to a density of 179/ha, calculated with the tracked target method (Figure 9 and Table 6). The total age-0 *O.nerka* biomass was estimated at 43 kg (Table 7), equivalent to 7% of the rearing capacity at Ecstall Lake.

The 2015 age-0 *O.nerka* density and biomass estimates at Ecstall Lake are significantly larger than the *O.nerka* density and biomass estimated by Hume and MacLellan (2008) in August 2005, the only previous hydroacoustic survey at Ecstall Lake (Table 8). In 2005, only 4% of the 1.39×10^5 "small fish" population was apportioned to age-0 *O.nerka*, and

96% was apportioned to threespine stickleback because of the high proportion of threespine stickleback in the trawl catches. It appears that the threespine stickleback population in Ecstall Lake has decreased considerably between 2005 and 2015, potentially decreasing competition for food available to age-0 *O.nerka*.

There is no available recent sockeye escapement data for the Ecstall River system (Fisheries and Oceans Canada 2015 NuSEDS database).

CONCLUSION

Hydroacoustic surveys are an efficient method for producing estimates of fall fry abundance for juvenile sockeye in a given rearing lake. For systems where spawner abundance is available, fall fry estimates may be used to estimate spawner-to-fry survival, which informs our understanding of trends in lake productivity status. Regular rotational hydroacoustic surveys are a cost-effective means of generating a time series data for Skeena sockeye salmon rearing lakes.

Many Skeena sockeye salmon rearing lakes are remote, and spawner enumeration is challenging for a number of reasons. Most spawner enumerations are carried out by visual estimation, and for most systems, abundance trends are provided by indices from one or a few spawning areas rather than absolute abundances for the whole system. For example, Bear Lake sockeye salmon includes salmon that spawn in Bear River, Azuklotz Creek, and Bear Lake. The Bear Lake component of lake spawning sockeye, which are challenging to enumerate visually, are rarely estimated. For systems such as Ecstall Lake, for which spawner enumeration is not carried out at all, the data from hydroacoustic surveys may be the available estimates by which to assess the status of a sockeye population. For these systems, hydroacoustic surveys may provide the most reliable available estimates by which to gauge trends in sockeye salmon abundance.

An exception to infrequent and/or unreliable sockeye spawner estimates in remote Skeena streams is an enumeration weir operated by the Ministry of Environment in the Sustut River which records sockeye salmon escapement, however the fence count at Sustut River does not separate sockeye salmon destined for Johansen and Sustut lakes. Skeena Fisheries Commission has conducted three hydroacoustic surveys at Sustut and Johansen Lakes since 2009, and noted little correlation between the abundance of fall fry and the abundance of brood year spawners recorded at the enumeration weir, which for the 2009 and 2012 brood years appeared to be insufficient to produce the number of fry observed in the two lakes combined (Figure 11). It is likely that the fall fry population estimate is confounded by an unknown proportion of resident kokanee in Sustut Lake, and further investigation would be necessary to establish the relative proportion of anadromous and resident *O. nerka* fry.

Of the systems that we surveyed in 2015, regular visual estimates have only been reliably conducted in the Upper Zymoetz, the principle spawning area for McDonell Lake sockeye salmon, since 2000. Hydroacoustic surveys have been conducted in McDonell Lake for 13 of the last 15 years, providing a time series of fall fry abundance estimates that may be directly compared with spawner enumeration estimates for the Upper Zymoetz River in most of these years. Assuming that the spawner estimate accounts for most of the sockeye salmon returning to the Upper Zymoetz River, spawner-to-fry survival has ranged by nearly two orders of magnitude from about 22 to more than 1200 McDonell Lake fry produced per Upper Zymoetz sockeye spawner. There is likely considerable variability in the Upper Zymoetz sockeye spawner estimate resulting from variable conditions during stream walks, such as water level and run timing. We note that in 2014, the brood year for the 2015 fall fry abundance estimate, that the spawner escapement estimate reported by the Department of Fisheries and Oceans of 1,814 spawners was substantially higher than that reported by Gitksan Watershed Authorities. In 2015, we carried out two separate hydroacoustic surveys at Mcdonell Lake on two nights in a row, to test the repeatability of hydroacoustic estimation techniques. The estimates for these two surveys were very similar, within 99% of one another, which indicates that the hydroacoustic methodology used to estimate fry abundance in this system is indeed repeatable, perhaps more so than visual estimation techniques for spawner enumeration.

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Table 3. 2015 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	PW	RS	PC
Bear	13-Aug-15	1	2252	2305	638271	6212181	638300	6212704	12	25	0	0	0	0	0
Bear	13-Aug-15	2	2324	2344	638209	6213647	637779	6214699	16.5	8	0	0	1	0	0
Bear	14-Aug-15	3	0002	0017	637660	6214798	637378	6215604	20	15	0	0	0	0	0
Bear	14-Aug-15	4	0029	0044	637379	6215754	637161	6216514	13	28	0	0	0	0	0
Bear	14-Aug-15	5	0123	0133	637526	6218849	637558	6219407	1	0	0	0	0	1	0
Bear	15-Aug-15	6	2359	0019	632495	6228760	633041	622781	7	3	0	1	0	0	0
Bear	16-Aug-15	7	0026	0052	633003	6227919	632460	6229232	16	8	0	0	1	0	0
Azuklotz	15-Aug-15	1	0112	0115	640873	6216962	640809	6217057	7.5	7	0	0	1	0	0
Azuklotz	15-Aug-15	2	0129	0132	n/a	n/a	n/a	n/a	7.5	4	0	0	0	0	0
Azuklotz	15-Aug-15	3	0142	0145	640864	6216985	640768	6217081	8	2	0	1	0	0	0
Johanson	18-Aug-15	1	0049	0109	672654	6275920	673105	6274971	1	1	0	0	0	0	0
Johanson	18-Aug-15	2	0152	0222	673378	6274530	672627	6275892	8	8	0	0	0	0	0
Sustut	16-Aug-15	1	2347	0004	656890	6272089	656316	6272794	13	22	0	0	0	0	0
Sustut	17-Aug-15	2	0022	0041	656383	6272740	657011	6271937	7	4	0	0	0	0	2
Sustut	17-Aug-15	3	0053	0056	656793	6272178	656715	6272291	14.5	3	0	0	0	0	0
Sustut	17-Aug-15	4	0108	0113	656674	6272250	656885	6272046	14.5	14	0	0	0	0	0
Sustut	17-Aug-15	5	0126	0132	656777	6272124	656660	6272364	14.5	11	0	0	0	0	0
McDonell	11-Aug-15	1	0014	0027	589978	6071362	589215	6071383	7.5	1	0	0	0	0	0
McDonell	11-Aug-15	2	0038	0052	589446	6071333	590201	6071366	9.5	15	0	1	0	0	0
McDonell	11-Aug-15	3	0107	0123	590019	6071345	589076	6071238	10.5	22	0	0	0	0	0
McDonell	11-Aug-15	4	0151	0208	589182	6071272	590184	6071379	9	12	0	0	0	0	0
Ecstall	25-Oct-15	1	2235	2238	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0	0
Ecstall	25-Oct-15	2	2245	2248	n/a	n/a	n/a	n/a	n/a	6	0	0	0	0	0
Ecstall	25-Oct-15	3	2259	2302	n/a	n/a	n/a	n/a	n/a	11	2	0	0	0	0

ON: *O.nerka*; TS: Threespine stickleback; Sc: prickly sculpin; PW: Pygmy whitefish; RSS: redside shiner; PC: Peamouth chub

Table 4. 2015 Gillnet location, effort, and catch by lake

Lake	Date	Gillnet #	Time Start	Time End	Easting	Northing	ON	PC
Azuklotz	14-Aug-15	2	2225	0155	640826	6217052	37	0
Azuklotz	14-Aug-15	1	2230	0220	640863	6217055	29	0
Johanson	17-Aug-15	2	2115	0255	672538	6276067	9	0
Johanson	17-Aug-15	1	2125	0125	673412	6274467	1	0
Sustut	16-Aug-15	2	2120	0240	658242	6270816	24	3

ON: *O.nerka*; PC: Peamouth chub

Table 5. 2015 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)
Bear	Trawl	Age-0 *O.nerka*	87	59.3	82	31	11.8	2.8	7.9	0.39	1.7
Bear	Trawl	Pygmy Whitefish	2	88	94	82	8.5	6.1	8.1	4.2	2.7
Bear	Trawl	Redside shiner	1	84	--	--	--	7.74	--	--	--
Azuklotz	Trawl	Age-0 *O.nerka*	13	66.8	77	49	7.2	3.0	5.21	1.0	1.1
Azuklotz	Trawl	Pygmy Whitefish	1	64	--	--	--	1.96	--	--	--
Azuklotz	Trawl	Prickly sculpin	1	70	--	--	--	4.01	--	--	--
Azuklotz	Gillnet	Age-0 *O.nerka*	64	73.3	98	60	7.6	4.2	11.9	1.8	2.0
Azuklotz	Gillnet	Age-1 *O.nerka*	2	121	122	119	2.1	22.1	23.0	21.2	1.3
Johanson	Trawl	Age-0 *O.nerka*	9	54.8	61	45	4.5	1.4	2	0.7	0.4
Johanson	Gillnet	Age-0 *O.nerka*	10	77.8	82	74	2.5	4.5	5.1	3.7	0.3
Sustut	Trawl	Age-0 *O.nerka*	54	48.1	75	28	11.1	1.2	4	0.1	0.9
Sustut	Trawl	Peamouth chub	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sustut	Gillnet	*O.nerka* Age n/a – assumed age-0	11	70.1	77	56	6.6	n/a	n/a	n/a	n/a

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)
Sustut	Gillnet	*O.nerka* Age n/a – assumed age-1	12	92.8	100	85	5.2	n/a	n/a	n/a	n/a
Sustut	Gillnet	Kokanee	1	142	--	--	--	n/a	--	--	--
Sustut	Gillnet	Peamouth chub	3	57.3	59	56	1.5	1.6	1.8	1.4	0.2
McDonell	Trawl	Age-0 *O.nerka*	50	50.1	67	42	5.7	1.4	3.6	0.8	0.6
Ecstall	Trawl	Age-0 *O.nerka*	17	57.4	75	43	8.3	2.2	4.9	0.6	1.1
Ecstall	Trawl	Threespine stickleback	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 6. 2015 lakes hydroacoustic estimates by method

Lake	Estimate Method	Size Class	Density (n/ha)	Population	95% C.I.
Bear	Single Target	Age-0 nerka	958	1,860,819	398,601
		Other small	709	1,377,418	1,331,353
		Large	270	525,026	172,678
	Tracked Target	Age-0 nerka	903	1,754,400	363,805
		Other small	391	760,141	570,340
		Large	232	449,870	143,196
	Integration	**Age-0 nerka**	**717**	**1,393,760**	**255,943**
		Other small	**320**	**621,177**	**529,426**
		Large	**197**	**382,229**	**148,251**
Azuklotz	Single Target	Age-0 nerka	577	95,569	23,268
		Age-1 nerka	18	2,956	720
		Other small	530	87,897	92,080
		Large	14	2,264	1,198
	Tracked Target	Age-0 nerka	626	103,688	30,261
		Age-1 nerka	19	3,207	936
		Other small	380	63,044	55,292
		Large	21	3,457	2,663
	Integration	**Age-0 nerka**	**430**	**71,323**	**25,941**
		Age-1 nerka	**10**	**1,596**	**1,307**
		Other small	**265**	**43,927**	**48,988**
		Large	**15**	**2,449**	**2,051**
Johanson	Single Target	Age-0 nerka	n/a	n/a	n/a
		Other Small	n/a	n/a	n/a
		Large	n/a	n/a	n/a
	Tracked Target	**Age-0 nerka**	**457**	**66,950**	**12,306**
		Other Small	**0**	**0**	**--**
		Large	**96**	**14,011**	**6,450**
	Integration	Age-0 nerka	244	35,771	12,272
		Other Small	0	0	--
		Large	41	6,027	2,717
Sustut		Age-0 nerka	840	214,901	77,148
		Age-1 nerka	159	40,804	14,648
		Other Small	64	16,322	5,859
		Large	67	17,178	11,480
	Tracked Target	Age-0 nerka	738	188,789	68,918
		Age-1 nerka	140	35,846	13,086

		Other Small	56	14,338	5,234
		Large	63	16,072	9,039
	Integration	**Age-0 nerka**	**625**	**159,985**	**71,265**
		Age-1 nerka	**119**	**30,377**	**13,531**
		Other Small	**47**	**12,151**	**5,413**
		Large	**45**	**11,539**	**5,835**
McDonell August 9th	Single Target	Age-0 nerka	464	99,599	45,306
		Other Small	268	57,563	28,052
		Large	113	24,157	13,110
	Tracked Target	Age-0 nerka	391	83,860	27,591
		Other Small	173	37,024	12,735
		Large	95	20,276	10,853
	Integration	**Age-0 nerka**	**399**	**85,536**	**23,131**
		Other Small	**132**	**28,324**	**13,783**
		Large	**108**	**23,212**	**16,124**
McDonell August 10th	Single Target	Age-0 nerka	329	70,529	40,701
		Other Small	328	70,234	31,903
		Large	79	16,971	12,831
	Tracked Target	Age-0 nerka	409	87,802	42,744
		Other Small	246	52,763	25,016
		Large	80	17,180	14,429
	Integration	**Age-0 nerka**	**403**	**86,436**	**40,423**
		Other Small	**173**	**37,038**	**16,875**
		Large	**50**	**10,662**	**9,271**
Ecstall	Single Target	Age-0 nerka	178	19,259	7,874
		Other Small	30	3,195	2,043
		Large	22	2,401	2,202
	Tracked Target	**Age-0 nerka**	**179**	**19,370**	**6,808**
		Other Small	**20**	**2,152**	**756**
		Large	**18**	**1,909**	**1,520**
	Integration	Age-0 nerka	167	18,089	8,783
		Other Small	19	2,010	976
		Large	11	1,166	960

Bold type indicates preferred method of estimation

Table 7. PR Capacity comparison chart - Unless noted otherwise, the age-0 *O.nerka* mean weights were calculated using trawl caught fish only.

Lake	Adjusted Rmax (kg)	Acoustic survey date	Estimation Method	Observed *O.nerka* fall fry	Avg. Weight	Observed biomass (kg)	% Rmax
Bear	8,974*	12-13-15-Aug-15	Integration	1,393,760	2.8	3,903	43%

Azuklotz	1,445*	14-Aug-15	Integration	71,323	4.0**	285	20%
Johanson	704*	17-Aug-15	Tracked target	66,950	3.0**	201	29%
Sustut	676*	16-Aug-15	Integration	159,985	1.2	192	28%
McDonell	992*	9-Aug-15	Integration	85,536	1.4	120	12%
		10-Aug-15	Integration	86,436	1.4	121	12%
Ecstall	594*	25-Oct-15	Tracked target	19,370	2.2	43	7%

* - Updated from Cox-Rogers *et al.* 2004

** - Calculated using trawl and gillnet caught fish.

Table 8. Past hydroacoustic estimates for lakes surveyed in 2015 – Unless noted otherwise, the age-0 *O.nerka* mean weights were calculated using trawl caught fish only.

Lake	Year	Date	Age-0 sockeye			Method	Source
			n/ha	Mean weight (g)	Biomass (kg)		
Bear	2003	26-Aug	125	2.1	500	Integration	Shortreed and Hume (2004)
	2008	29-30-Sept	201*	2.5	977*	Integration	Carr-Harris (2009)
	2012	16-17-19-Aug	944	3.3	6,050	Integration	Doire and Carr-Harris (2013)
	2015	12-13-15-Aug	717	2.8	3,903	Integration	
Azuklotz	2003	27-Aug	383	4.8**	305	Integration	Shortreed and Hume (2004)
	2009	24-Sept	179	3.3**	98	Tracked Target	Carr-Harris (2010)
	2012	18-Aug	1,201	1.1	219	Integration	Doire and Carr-Harris (2013)
	2015	14-Aug	430	4.0***	285	Integration	
Johanson	2004	11-Sept	1,195	1.3	221	Integration	Hume and MacLellan (2008)
	2010	3-4 Sept	516	1.2	91	Integration	Carr-Harris (2011)
	2013	6-Aug	331	0.9	44	Tracked Target	Doire and Carr-Harris (2014)
	2015	17-Aug	457	3.0***	201	Tracked Target	
Sustut	2004	10-Sept	3,007	1.3	862	Integration	Hume and MacLellan (2008)
	2010	31-Aug	976	1.2	300	Integration	Carr-Harris (2011)
	2013	6-Aug	2,893	0.7	518	Integration	Doire and Carr-Harris (2014)
	2015	16-Aug	625	1.2	192	Integration	
McDonell	2001	10-Sept	353	No *O.nerka* caught	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)

Lake	Year	Date	Age-0 sockeye			Method	Source
			n/ha	Mean weight (g)	Biomass (kg)		
	2008	18-Aug	1,436	1.5	464	Integration	Carr-Harris (2009) (2)
	2009	17-Aug	846	1.6	290	Tracked Target	Carr-Harris, 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	Doire and Carr-Harris (2014)
	2015	9-Aug	399	1.4	120	Integration	
	2015	10-Aug	403	1.4	121	Integration	
Ecstall	2005	25-Aug	71	1.0	6	Integration	Hume and MacLellan (2008)
	2015	25-Oct	179	2.2	43	Tracked Target	

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

**** - Calculated using gillnet caught fish only.**

***** - Calculated using trawl and gillnet caught fish.**

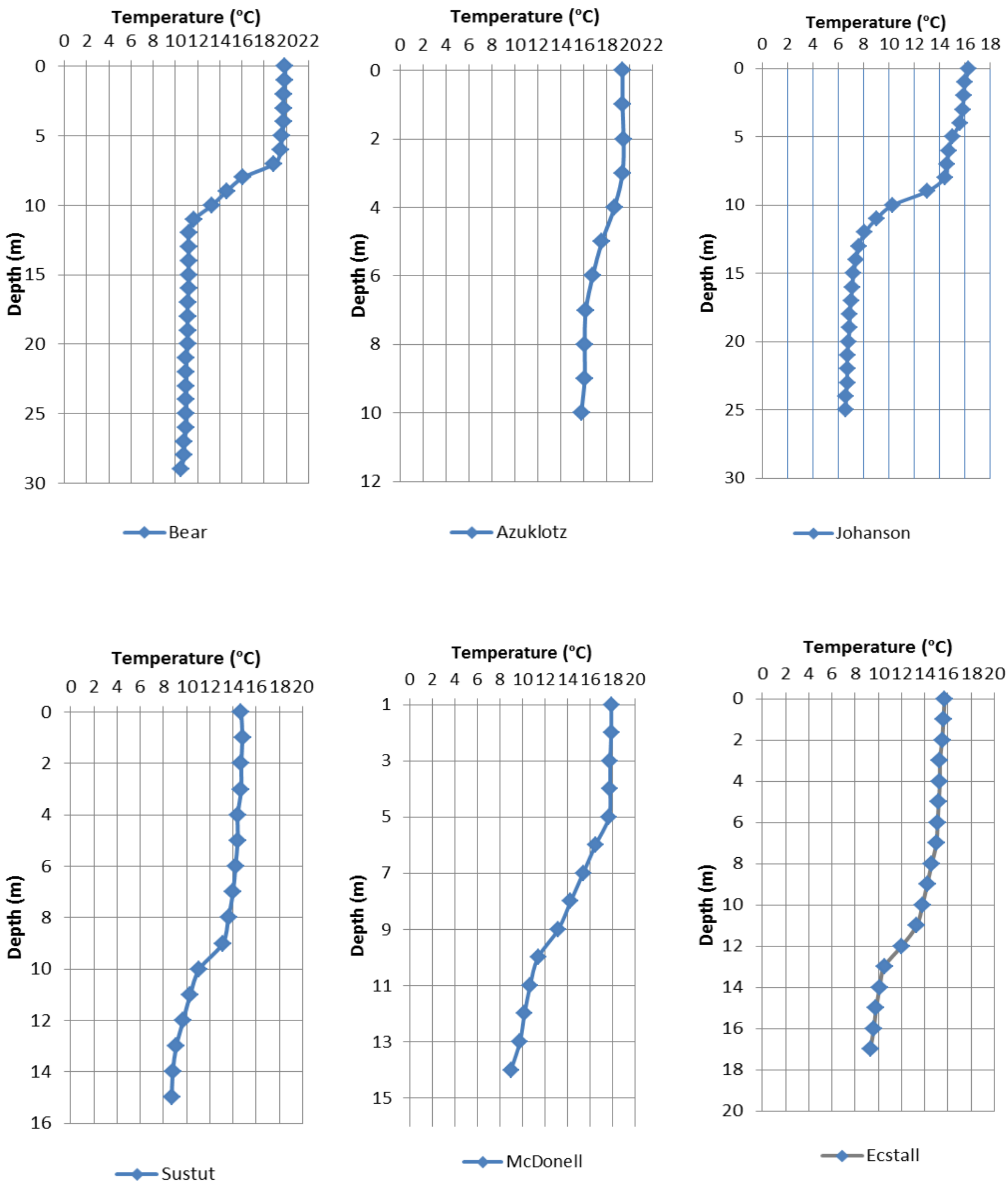

Figure 12. Temperature profiles for lakes surveyed in 2015.

Note different scales.

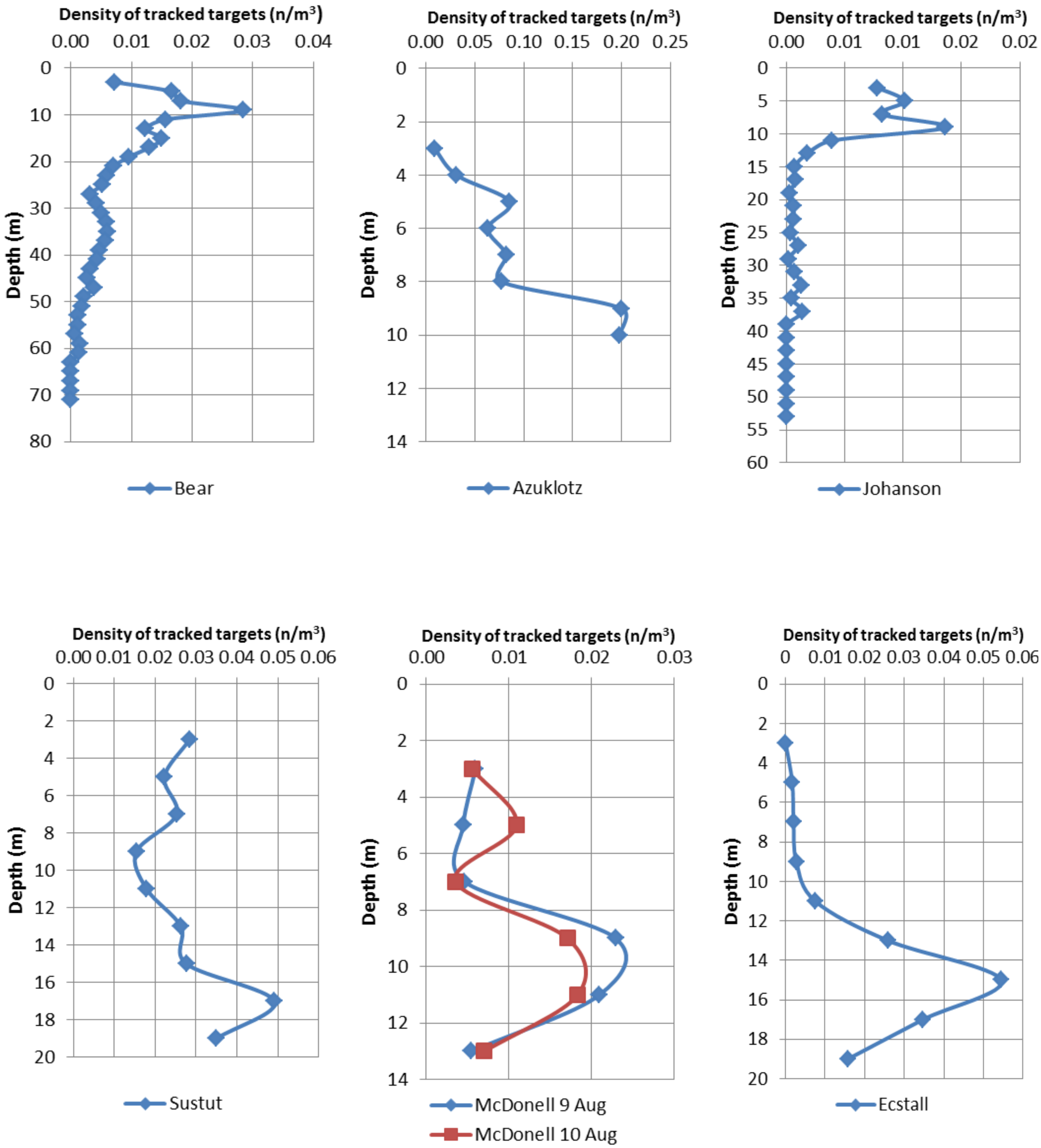

Figure 13. Vertical distribution of targets for lakes surveyed in 2015.

Note different scales

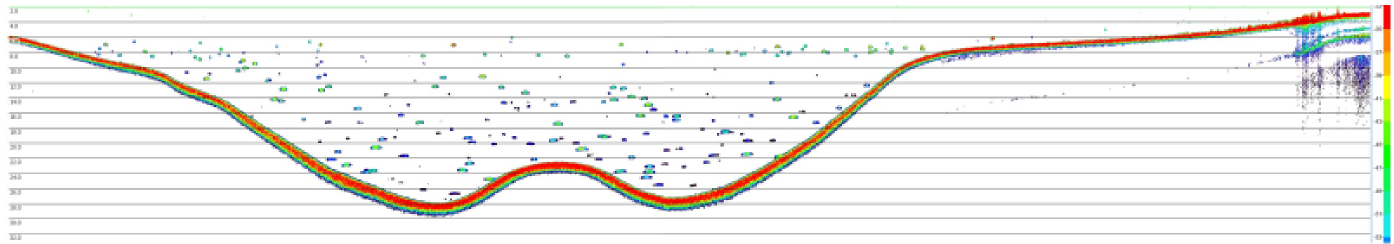

Figure 14. Bear Lake transect 7 echogram

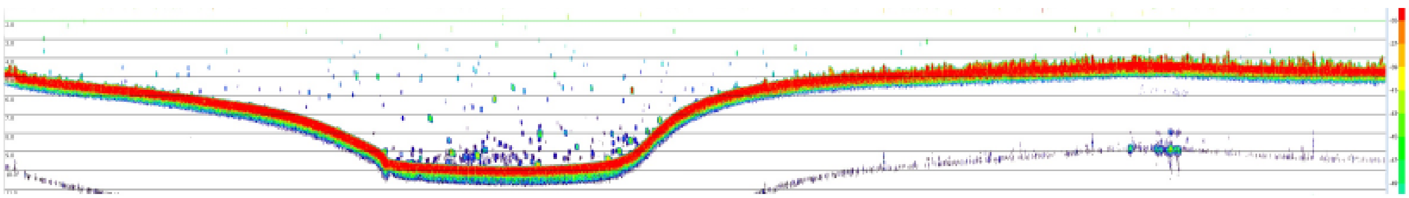

Figure 15. Azuklotz Lake transect 4 echogram

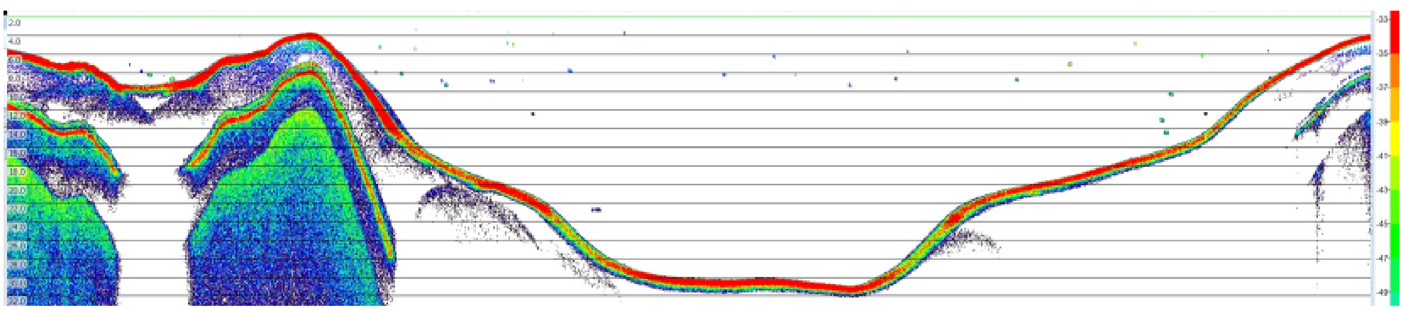

Figure 16. Johanson Lake transect 4 echogram

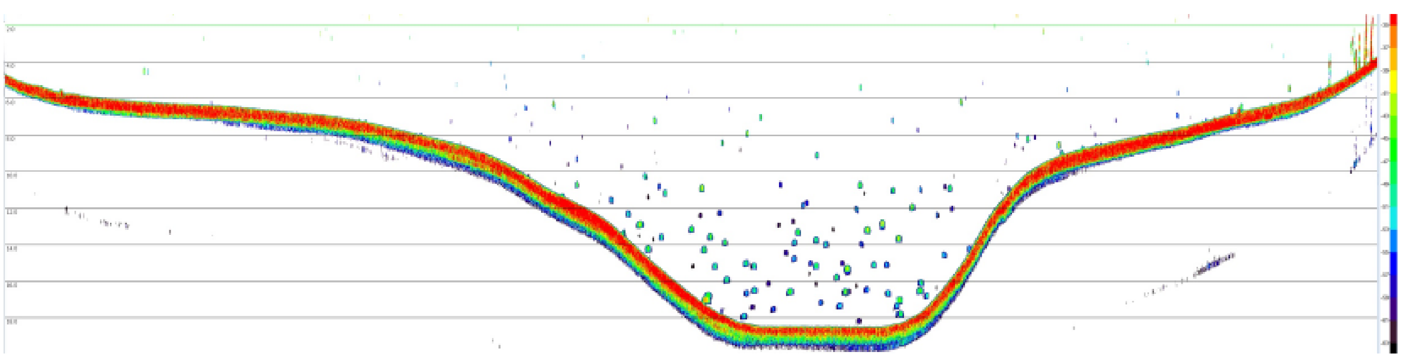

Figure 17. Sustut Lake transect 5 echogram

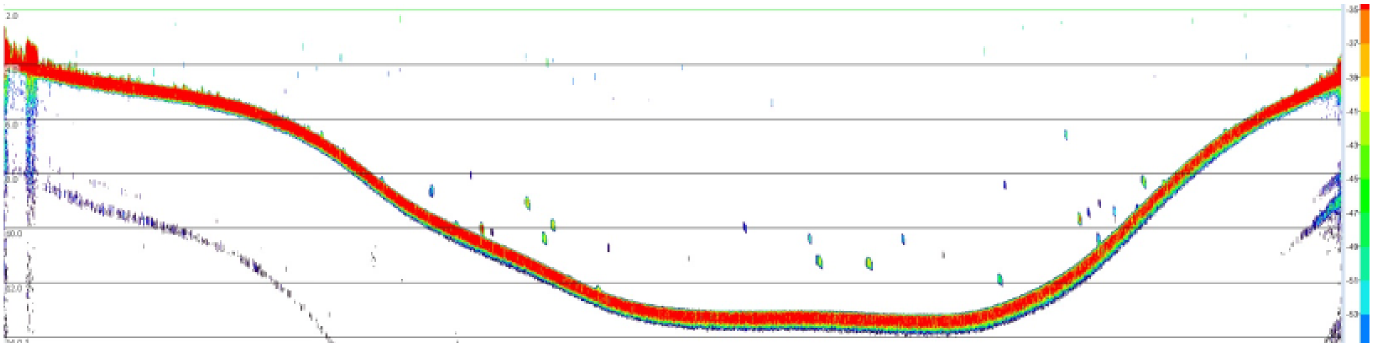

Figure 18. McDonell Lake August 9 transect 3 echogram

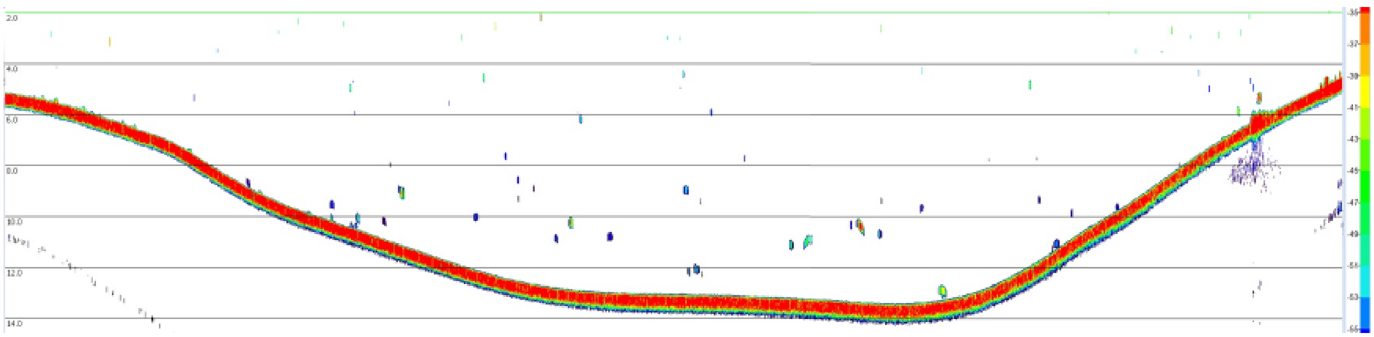

Figure 19. McDonell Lake August 10 transect 3 echogram

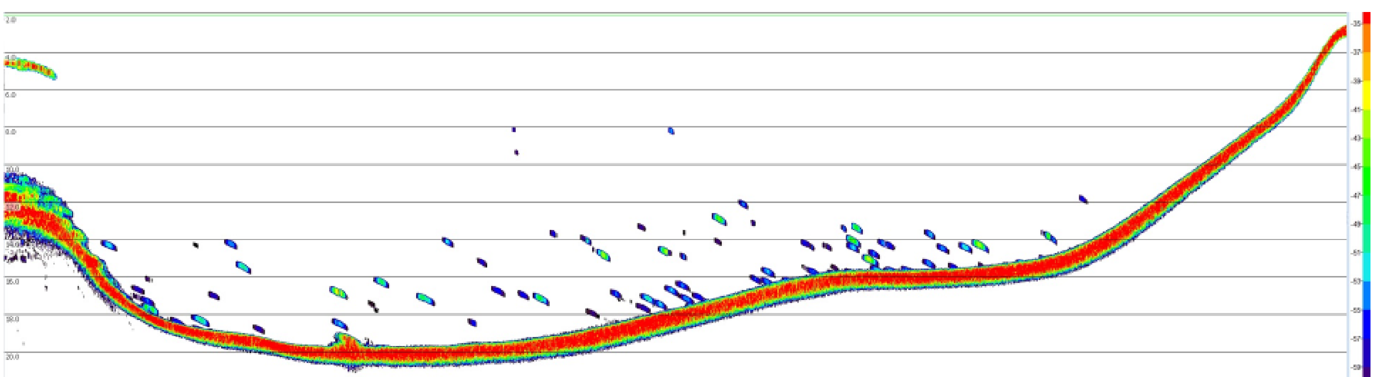

Figure 20. Ecstall Lake transect 6 echogram