Skeena Sockeye Lakes Hydroacoustic Surveys 2010

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Executive Summary

The Skeena Watershed Commission conducted hydroacoustic surveys at nine Skeena sockeye salmon rearing lakes (McDonell, Swan, Stephens, Sustut, Johanson, Johnston, Minerva, Lakelse, and Bulkley Lakes) during the 2010 field season (Figure 1). The main objectives of these surveys were to enumerate and sample the sockeye fry populations and estimate the species composition at each lake. The results of these surveys are contained in this report.

O. nerka fry densities ranged from143 fish/hectare at Swan Lake to 6,660 fish/hectare at Johnston Lake. Johnston was the second smallest lake that was surveyed in 2010, but it contained the highest density, population, and biomass observed in this report. It appears that the *O. nerka* population is less than the carrying capacity of all the lakes that we surveyed, especially at Lakelse and Swan Lakes. No *O. nerka* fry were observed in Minerva or Bulkley Lakes.

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Introduction

Salmon are well known for their ability to return to their streams of origin. Lake rearing sockeye salmon (*Oncorhynchus nerka*) are the most specific homing populations among the salmon, which results in a high level of specialization of sockeye to individual lake systems. This is the reason that most of the Conservation Units (CUs) for salmon in British Columbia have been designed to evaluate, protect and manage lake sockeye populations. The evaluation of the status of the 31 or so Skeena sockeye CUs requires accurate, repeatable surveys of the size and productivity of the populations. Most of the Skeena sockeye populations are remote from roads, and many of those that are reachable are often hard to count since lake spawners are generally not visible. By using hydroacoustic gear to measure fry abundance, we can replace adult escapement estimates with juvenile counts and in many ways produce better data. Hydroacoustic surveys are reliable and relatively cheap, and can be carried out on most of sockeye lakes.

Skeena Fisheries Commission (SFC) has conducted mobile hydroacoustic surveys in small lakes throughout the Skeena Watershed since 2005. During this interval 25 of the Skeena sockeye lakes have been surveyed at least once by hydro-acoustics. Fall fry abundance data obtained by hydroacoustic techniques for sockeye in their critical rearing habitats can be directly compared to lake productivity potential (Cox-Rogers et. al 2004) to provide an unbiased estimate of the status of the sampled conservation unit. If these surveys are carried out periodically, a record of the population status and a measure of the stock productivity are established.

The species "*Oncorhynchus nerka*" may include both anadromous (sockeye) and nonanadromous forms (kokanee) in all lakes surveyed. Separation of the two forms was not conducted as part of this study. They are referred to as "*O. nerka*" in this report.

With the help of grants from the Pacific Salmon Commission and the Skeena Watershed Initiative, the Skeena Fisheries Commission conducted surveys at nine lakes in the Skeena watershed in the late summer and fall of 2010 (Figure 1). The main objective of these surveys was to enumerate and sample the sockeye fry populations, and to estimate the sockeye component of the total fish at each lake.

McDonell Lake is the lowest of a chain of three lakes at the headwaters of the Zymoetz River. The Zymoetz, also known as the Copper 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 has a volume of approximately 1.9×10^7 m^3 and a surface area of 232 ha. Gitksan Watershed Authorities (GWA) and the SFC have conducted annual hydroacoustic surveys at McDonell Lake since 2005.

Swan and Stephens Lakes are located in the upper Kispiox watershed, a 5^{th} 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 is the larger of the two lakes at the head of the drainage, with a surface area of

1,760 Ha, maximum depth of 69 m and average depth of 19 m. Swan has complicated bathymetry, with at least three well-defined basins punctuated with over 30 islands and a number of shoals. The last hydroacoustic survey at Swan Lake was conducted in 2002 by Fisheries and Oceans Canada Cultus Lake division. Stephens Lake is smaller and more productive than Swan, with a surface area of 197 ha, maximum depth of about 25 m, and average depth of 11 m. Stephens Lake was surveyed by the SFC in 2005 and 2009.

Sustut and Johanson Lakes are in the Sustut Watershed. The Sustut River is a high interior river approximately 97 km in length that drains into the Upper Skeena River (Gottesfeld and Rabnett 2008). 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 392 hectares, maximum depth of 18 m, and average depth of 6 m.

Johanson Lake is located at the headwaters of Johanson creek, tributary to the upper 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 147 hectares, maximum depth of 51m, and average depth of 15m. The last hydroacoustic surveys at Sustut and Johanson Lakes were conducted in 2004 by Fisheries and Oceans Canada, Cultus Lake division.

On the coastal end of the Skeena, Johnston Lake is located 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). The water at Johnston Lake is 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.

Minerva Lake is located at the headwaters of the McNeil, formerly known as the Green River, at an elevation of 800 m. McNeil River is a small 2^{rd} order creek that drains into the right side of the Skeena estuary almost directly opposite the mouth of the Ecstall River. Pink and coho salmon have been observed in the McNeil system (Fisheries and Oceans Canada BC16 archives) but Minerva is not a known sockeye spawning lake. Minerva is a small deep lake with a surface area of 138 ha, maximum depth of 71 m, and average depth of 25 m.

Lakelse Lake is the source of the Lakelse River, a 5th order tributary of the lower Skeena that drains a watershed area of approximately 589 km^2. The surface area of the lake is approximately 1,360 ha with a volume of 1.15x108 m^3. The average depth of the lake is 8.5 m and the maximum depth is approximately 32 m. The southwest basin of the lake is an extensive littoral area that covers 42% of the lake surface (Gottesfeld & Rabnett 2008). SFC has conducted annual hydroacoustic surveys of Lakelse Lake since 2006. Lakelse is the warmest lake in the Skeena, and is a very productive system, but Lakelse sockeye stocks have been in decline since the 1970s.

Bulkley Lake is located at the top of the Upper Bulkley River, near the community of Houston, BC at an elevation of 730 m. Bulkley is a shallow, productive lake with a surface area of 249 ha, average depth of 7m, and maximum depth of 14m. Sockeye escapement to the Upper Bulkley River historically ranged from 50 to 600 returning adults, but very few sockeye have been observed in the Upper Bulkley above the Morice River confluence in recent years.

Methods

Acoustic sampling

The 2010 hydroacoustic surveys at McDonell (Figure 1), Stephens (Figure 2), and Lakelse Lakes (Figure 9) were conducted along previously established transects at each lake. The McDonell and Stephens Lake transect designs were established by Fisheries and Oceans Canada, Cultus Lake division, who had conducted prior surveys at these lakes. The Lakelse Lake transect design was revised by the SFC in 2007 (Hall & Carr-Harris 2008). The transect designs for Swan (Figure 4), Sustut (Figure 5), Johanson (Figure 6), Johnston (Figure 7), Minerva (Figure 8), and Bulkley Lakes (Figure 10) were established prior to our 2010 surveys. Hydroacoustic estimates are based on lake volumes that were calculated using bathymetric maps produced from lake depth data collected during our 2010 surveys at Swan (Figure 11), Sustut (Figure 12), Johanson (Figure 13), Johnston (Figure 14), Minerva (Figure 15), and Bulkley (Figure 16) Lakes . Lakelse Lake volumes are based on bathymetric data collected during the 2007 hydroacoustic survey. McDonell and Stephens Lake volumes were previously calculated using bathymetric maps provided by the provincial Ministry of Environment.

Hydroacoustic surveys were conducted using similar methods and technology as in previous years (Hall 2006, Hall & Carr-Harris 2008) and described in MacLellan *et al.* 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 downward-pointing transducer was pole-mounted to our inflatable vessel, a Bombard Commando C-4. Where conditions allowed, we mounted a second transducer with the same specifications horizontally at an 84º angle to the down-looking transducer to collect acoustic data from the surface layers of the water column. Hydroacoustic data from both transducers were collected to an acoustic threshold of -100 dB using Biosonics Visual Acquisition software as the vessel proceeded along transects at a constant speed.

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 to be applied prior to post-processing of the data.

Post-processing of hydroacoustic data was performed using Echoview v. 4.90. Data analysis was conducted using the same methodology as in previous years (Hall & Carr-Harris 2008, Hall 2007). Target densities were calculated using three different methods for down-looking acoustic data. The integration method divides the average acoustic energy for each depth layer by the average target strength. The single target method divides the sum of only those targets that have specific acoustic characteristics of single fish by the sampled beam volume. The tracked target estimate is produced by grouping single targets into individual fish tracks, then dividing the total number of fish tracks by the sampled wedge volume. Depending on the conditions at each lake, not all estimate methods are suitable for all surveys. Data from the down-looking transducer were analyzed separately for each transect in 2m depth layers for McDonell, Stephens, Sustut, Johansen, Johnston, and Bulkley Lakes, and in 4 m depth layers for Swan and Minerva Lakes.

When data from the side-looking transducer was available, each transect was analyzed using the tracked target method in a single 18 m wide band that represented the top 4 m of the water column along one side of the transect. In 2010, Johnston was the only survey for which the side-looking transducer produced data suitable for analysis.

The target 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.

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

The fish estimates were divided into “small” fish 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, based on Love’s (1977) 45^{o} aspect formula. Small fish were apportioned into “*O. nerka*” and “other small fish” based on the relative proportion of species in the trawl catch.

Fish Sampling

Pelagic fish were sampled using a 2 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. Swedish gillnets were used to capture fish from 0-2m depth in the littoral zones of McDonell, Stephens, Swan, Stephens, Minerva, Lakelse, and Bulkley Lakes. These gillnets consisted of 4 variable mesh panels with sizes between ½” and 1”. Gillnets were set at dusk and allowed to soak for the duration of the survey.

Large fish were counted and released. Small fish were sorted by species and stored in either 10% formaldehyde or 95 % ethanol and weighed and measured after at least 30 days of preservation. Scales were removed and inspected under a compound microscope to determine the age of salmonid fishes.

Temperature and Dissolved Oxygen

Temperature profiles 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. Dissolved oxygen information were not collected during the 2010 program because of equipment failure.

Results

McDonell Lake

McDonell Lake was surveyed on the night of 7-8 August, 2010. At the time of our survey, the surface temperature was nearly 19°C, with an epilimnion to 3m, and a thermocline between 3 and 10m depth, which was the deepest point of the temperature profile at 12.9°C (Figure 17).

Eighty-two *O. nerka* juveniles and one prickly sculpin (*Cottus asper*) were captured in 4 trawls with a combined distance of 1.4 km. (Table 1). No other fish species were captured by trawl. We set two gillnets with a combined soak time of 12 hours. The gillnet catch consisted of eleven northern pikeminnow (*Ptychocheilus oregonensis*) (Table 2). The trawl sample was preserved in 95% ethanol. The average length and weight of *O. nerka* juveniles after preservation were 46mm and 0.9 grams respectively (Table 3). Ethanol preservation reduced our ability to remove scales from the smaller fish from McDonell Lake and from subsequent collections. Scales were removed and analyzed from a sample of 12 specimens, all of which were determined to be age-0, or young of the year fry.

The hydroacoustic estimate for "small" size fish in McDonell Lake ranged from 335,000 (integration estimate) to 430,000 (tracked target). "Small" fish densities ranged from 1,562 fish/hectare (integration) to 2,005 fish/hectare (tracked target). "Large" fish densities ranged from 45 fish/hectare (integration) to 56 fish/hectare (tracked target), with a population ranging from 9,630 (integration) to 11,900 (tracked target) (Table 4).

100% of the "small" size class acoustic estimate may be apportioned to age-0 nerka, based on the trawl catch and assuming that all of the trawl-captured *O. nerka* were age-0. Prickly sculpin was not included in the species composition of the acoustic estimate because sculpin are demersal, have no air bladders, and are therefore unlikely to produce an acoustic signal within the range of juvenile salmonids. Based on the integration estimate, the observed biomass of age-0 nerka from the 2010 McDonell Lake hydroacoustic survey is 285 kg, or 29% of the optimal smolt biomass, or R_{max} of 972 kg (Table 5).

That the McDonell Lake survey was conducted early in the season is reflected in the small size of the *O. nerka* specimens as well as in the target strength distribution of the acoustic data, which is normal with a mean of -53 dB (Figure 22). Most fish targets were distributed vertically between 6m depth and the bottom (Figure 31). The horizontal distribution of fish targets shows a higher concentration of fish in the eastern half of the lake (Figure 40).

Swan Lake

The 2010 acoustic survey was carried out from August 10-13, 2010. Acoustic data were collected on the nights of August 10-11 and 11-12, trawl sampling was conducted on the night of August 12-13, and bathymetric data and gillnet samples were collected every day during the survey.

Surface water temperatures at the time of our survey were very warm with an epilimnion of over 19°C to 3m depth, an abrupt thermocline from 5-11 m depth, and a gradual decline between 11-29 m depth to a hypolimnion of 4.8°C (Figure 18).

We captured 63 *O. nerka* juveniles during six trawls with a combined distance of 3.7 km. No other fish species were captured by trawl (Table 1). Six gillnets were set with a combined soak time of 104 hours. The gillnet catch included one juvenile *O. nerka*, ten rainbow trout (*Oncorhynchus mykiss*) and four coho salmon (*Oncorhynchus kisutch*) (Table 2). The average length and weight of trawl-captured *O. nerka* juveniles were 44 mm and 0.7 grams respectively (Table 3). Scales were removed and analyzed from a sample of 33 trawl-captured *O. nerka* juveniles, of which of which 31 were age-0, and two were age-1. The gillnet-captured *O. nerka* was age-1, measured 120 mm and weighed 17.6 grams (Table 3).

The hydroacoustic population estimate for “small” size fish in Swan Lake ranged from 253,000 (Integration estimate) to 325,000 (tracked target. “Small” fish densities ranged from 143 fish/hectare (integration) to 184 fish/hectare (tracked target). “Large” fish densities ranged from 53 fish/hectare (integration) to 71 fish/hectare (tracked target), with a population ranging from 9,410 (integration) to 12,500 (tracked target) (Table 4).

100% of the “small” size class acoustic estimate may be apportioned to age-0 nerka based on the trawl catch and assuming that all of the trawl-captured *O. nerka* which were not aged were age-0. Based on the tracked target estimate, the observed biomass of age-0 nerka from the 2010 Swan Lake hydroacoustic survey is 230 kg, or 4% of the optimal smolt biomass, or R_{max} of 5,900 kg (Table 5).

The target strength distribution for this survey showed a higher proportion of large fish at Swan Lake than in any other lake that was surveyed in 2010. The distribution is bimodal, and shows that 40% of fish targets had signal strengths between -44 and -34 dB (Figure 23). The fish layer was concentrated between 5 and 12 m depth (Figure 32), and most fish targets were located in the northwest and southeast sections of the lake (Figure 32).

Stephens Lake

Stephens Lake was surveyed on the night of August 13, 2010. The surface temperature was over 20°C and the temperature profile resembled that of Swan Lake, with an epilimnion to 3m depth, an abrupt thermocline from 5-11 m depth, and a gradual decline between 11-23 m depth to a hypolimnion of 5.3°C (Figure 18).

In four trawls with a combined distance of 1.5km, 70 *O. nerka* juveniles were captured. No other fish species were captured by trawl (Table 1). We set two gillnets with a combined soak time of 16 hours. The gillnet catch consisted of one *O. nerka* and nine coho fry (Table 2). The average length and weight of trawl-captured *O. nerka* were 70 mm and 3.7 grams respectively (Table 3). Scales were removed from a sample of 47 trawl captured *O. nerka* juveniles, all were age-0. The gillnet-captured *O. nerka* was age-1, measured 62 mm and weighed 2.3 grams (Table 3).

The hydroacoustic estimate for "small" size fish in Stephens Lake ranged from 168,000 (Integration estimate) to 237,000 (tracked target. "Small" fish densities ranged from 853 fish/hectare (integration) to 1,207 fish/hectare (tracked target). "Large" fish densities ranged from 224 fish/hectare (integration) to 347 fish/hectare (tracked target), with a population ranging from 4,400 (integration) to 6,810 (tracked target) (Table 4).

Based on the trawl catch and assuming that all of the trawl-captured *O. nerka* which were not aged were age-0, 100% of the "small" size class acoustic estimate may be apportioned to age-0 nerka. The observed biomass of age-0 nerka from the 2010 Stephens Lake hydroacoustic survey (integration estimate) was 386 kg, or 23% of the optimal smolt biomass, or R_{max} of 972 kg (Table 6).

The average target strength distribution at Stephens Lake was -51 dB with a mode of 46 dB (Figure 24). Fish targets were present throughout the water column, with the highest concentration observed in a layer between 7 and 10 m depth (Figure 33). Most fish targets were located in the southeast arm of the lake (Figure 42).

Sustut Lake

Sustut Lake was surveyed on the night of August 31-September 1, 2010. The temperature profile showed Sustut to be nearly isothermal at the time of our survey, ranging from a surface temperature of 12.9°C to 12.8°C at 9 m depth (Figure 19).

We captured 81 *O. nerka* juveniles and one redside shiner (*Richardsonius balteatus*) during three trawls with a combined length of 1.9 km (Table 1). No gillnets were set during this survey. The average length and weight of trawl captured *O. nerka* were 53 mm and 1.2 grams respectively (Table 2). Scales were removed and analyzed from a sample of 70 specimens, and all were determined to be age-0.

The hydroacoustic estimate for "small" size fish in Sustut Lake ranged from 250,000 (integration estimate) to 312,000 (tracked target. "Small" fish densities ranged from 976 fish/hectare (integration) to 1,221 fish/hectare (tracked target). "Large" fish densities ranged from 30 fish/hectare (single target) to 62 fish/hectare (tracked target), with a population ranging from 7,640 (single target) to 15,900 (tracked target) (Table 4).

Based on the trawl catch, 99% of the "small" size class acoustic estimate may be apportioned as age-0 nerka. The observed biomass of age-0 nerka from the 2010 Sustut Lake hydroacoustic survey (Integration estimate) is 325 kg, or 48% of the optimal smolt biomass, or R_{max} of 670 kg (Table 5).

The target strength distribution at Sustut Lake was slightly bimodal, with a mean of -53 dB (Figure 25). Fish targets were present throughout the water column, but most dense near the bottom (Figure 34). The areal distribution of tracked target density shows that most of the fish targets were concentrated in the deeper waters near the center of the lake (Figure 43).

Johanson Lake

Johanson Lake was surveyed on the night of September 3-4, 2010. The surface temperature was 2°C less than at Sustut Lake with an epilimnion of 10.7 between 0 and 10m depth, a thermocline between 11 and 17m, then a gradual decline to 5.5 degrees at 25m (Figure 19).

We captured 33 *O. nerka* juveniles during four trawls with a combined distance of 3.5 km (Table 1). No other species of fish were captured by trawl and no gillnets were set at Johanson Lake. The average length and weight of trawl-captured *O. nerka* fry were 53 mm and 1.2 grams respectively (Table 3). Scales were removed and analyzed from all of the specimens in this sample, and all were determined to be age-0.

The hydroacoustic estimate for “small” size fish in Johanson Lake ranged from 75,700 (integration) to 86,300 (tracked target). “Small” fish densities ranged from 555 fish/hectare (Integration) to 589 fish/hectare (tracked target). “Large” fish densities ranged from 65 fish/hectare (integration) to 70 fish/hectare (tracked target), with a population ranging from 9,620 (integration) to 10,300 (tracked target) (Table 4).

Based on the trawl catch, 100% of the “small” size class acoustic estimate may be apportioned to age-0 *O. nerka*. The observed biomass of age-0 nerka from the 2010 Johanson Lake hydroacoustic survey (integration estimate) is 91 kg, or 12% of the optimal smolt biomass, or R_{max} of 972 kg (Table 5).

The distribution of target strengths at Johanson Lake somewhat resembles that at Sustut Lake, but it is more compact with a shift toward slightly lower target strengths, with an average target strength of -54 dB (Figure 26). Most fish targets were distributed vertically between the surface and 15 m depth, but there were a few targets throughout the water column (Figure 35). The horizontal distribution of tracked targets shows that fish targets are fairly evenly distributed throughout Johanson Lake, except for the shallow sections in the north and south end (Figure 44).

Johnston Lake

Johnston Lake was surveyed on the night of September 8-9, 2010. The temperature profile showed a thermocline between the surface and 5 m, a gradual decline to about 10 degrees at 15 m, then another abrupt decline to a hypolimnion of 4.3 degrees below 25 m (Figure 20).

We captured 118 *O. nerka* juveniles and 3 threespine stickleback (*Gasterosteus aculeatus*) during two trawls with a combined distance of 1.7 km (Table 1). No gillnets were set at Johnston Lake. The average length and weight of trawl captured *O. nerka* juveniles were 46 mm and 0.76 grams respectively (Table 3). Scales were removed and analyzed from a sample of 28 *O. nerka* specimens, all of which were determined to be age-0.

Johnston Lake had the highest density and population of all the lakes that were surveyed in 2010. The hydroacoustic estimate for “small” size fish in Johnston Lake ranged from 1,280,000 (tracked target) to 1,600,000 (single target). “Small” fish densities ranged from 6,567 fish/hectare (tracked target) to 8,333 fish/hectare (single target). “Large” fish densities ranged from 20 fish/hectare (tracked target) to 22 fish/hectare (single target), with a population ranging from 3,860 (tracked target) to 4,250 (single target) (Table 4).

98% of the “small” size class acoustic estimate may be apportioned to age-0 nerka, based on the trawl catch and assuming that the proportion of trawl-captured *O. nerka* which were not aged were all age-0. Based on the tracked target estimate, the observed biomass of age-0 nerka from the 2010 Johnston Lake hydroacoustic survey is 978 kg, or 30% of the optimal smolt biomass, or R_{max} of 3,243 kg (Table 5).

The target strength distribution at Johnston Lake is normal, with a mean of -54 dB (Figure 27). There are two distinct fish layers, with most fish targets near the surface in a dense, compact layer between 0 and 17 m depth. There is a second, more dispersed layer between 20 and 40m depth, and few fish targets below 60 m (Figure 36). Fish targets are well distributed horizontally throughout the lake (Figure 45) with the highest densities in the shallower water near the shoreline.

Minerva Lake

We surveyed Minerva Lake on the night of 9-10 September 2010. The surface temperature was 15°C, with a thin epilimnion to 1 m depth, a thermocline between 1 and 13 m depth and a gradual decline to a hypolimnion of 4.6°C below 23 m depth (Figure 20). Few fish were observed during the acoustic survey and no trawls were conducted. We captured a single juvenile Dolly Varden (*Salvelinus malma)* in two gillnets with a combined soak time of 20 hours (Table 2).

There was a significant amount of background noise in the surface layers of the acoustic data from Minerva Lake that was likely produced by *Chaoborus* or a similar organism (Figure 52). As a result, we were unable to build integration or single target estimates for this survey, and used the modified tracked target method described in MacLellan 2010. The "small" size fish density at Minerva Lake (tracked target only) was 141 fish/hectare with a population of 20,200. The "large" size fish density was 6 fish/hectare with a population of 8,100 (Figure 4).

Lakelse Lake

Lakelse Lake was surveyed on the night of September 30– October 1, 2010. Our fish catch was poor and we returned on the night of October 8-9 to resume trawling. During the first night of our survey, the surface temperature was 13.1°C, and the temperature profile was nearly isothermal with a hypolimnion of 12.3°C starting at 19 m (Figure 21).

During the first night of the survey, we captured one prickly sculpin juvenile and one juvenile lamprey (*Lampetra* spp.) in two trawls with a combined distance of 1.7 km (Table 1). During the second night of trawling on October 8, we captured two *O. nerka* fry, four prickly sculpin, one river lamprey (*Lampetra ayresii*) and one juvenile lamprey in six trawls with a combined distance of 4 km (Table 1). We set three gillnets with a combined soak time of 28 hours during the second night of trawling. The gillnet catch consisted of three age-0 nerka, one nerka which had been mostly eaten by predators and one large cutthroat trout (*Oncorhynchus clarki clarki*) (Table 2).

The hydroacoustic estimate for "small" size fish in the north basin of Lakelse Lake ranged from 215,000 (integration estimate) to 220,000 (tracked target. "Small" fish densities in the north basin ranged from 340 fish/hectare (integration) to 349 fish/hectare (tracked target). "Large" fish densities in the north basin ranged from 47 fish/hectare (Integration) to 95 fish/hectare (tracked target), with a population ranging from 29,990 (integration) to 37,300 (tracked target) (Table 4).

The hydroacoustic estimate for "small" size fish in the south basin of Lakelse Lake ranged from 37,200 (tracked target) to 74,400 (single target). "Small" fish densities in the south basin ranged from 48 fish/hectare (tracked target) to 97 fish/hectare (single target). "Large" fish densities in the south basin ranged from 7 fish/hectare (tracked target) to 95 fish/hectare (single target), with a population ranging from 5,310 (tracked target) to 10,600 (single target) (Table 4).

Not enough fish were sampled during the combined effort of both nights of fishing to be able to apportion the "small" size fish estimate by species. Were we to assume that 100% of the "small" size fish estimate consisted of juvenile sockeye and that the small trawl sample of 2 specimens were representative of the size distribution of O. nerka at Lakelse Lake, the observed biomass in the north basin would be 794 kg, or 7% of R_{max} (Table 5).

The distribution of target strength at Lakelse Lake was bimodal (Figure 29) with an average target strength of -53 dB. Fish were well dispersed throughout the water column with the highest densities between 11 and 17m depth (Figure 37). Most fish targets were found in the middle of the North basin of the lake (Figure 46).

Bulkley Lake

Bulkley Lake was surveyed on the night of October 4-5, 2010. The temperature profile was nearly isothermal with an epilimnion of 11.2 degrees from 0-7 m with a slight decline to a hypolimnion of to 10.8 degrees at 13m (Figure 21).

No *O. nerka* fry were captured in two trawls with a combined length of 1.3 km. The trawl catch included 10 redside shiners, 46 Northern pikeminnow, and one Pacific lamprey (*Lampetra tridentata*). One northern pikeminnow and one redside shiner were captured in two gillnets with a combined soak time of 8 hours.

The acoustic data contained a considerable amount of noise (Figure 55), and we were unable to produce estimates using the integration and single target methods. The Bulkley Lake hydroacoustic estimate was produced using the modified tracked target method as for the Minerva Lake estimate (above). The “small” size class fish population estimate for Bulkley Lake was 274,000 with a density of 1,101 fish/hectare. The “large” size fish population estimate was 5,300 with a density of 223 fish/hectare.

The size distribution of the trawl catch suggests that had significant numbers of *O. nerka* fry been present in Bulkley Lake, that they would have appeared in our trawl catches. Based on the trawl catch, we cannot assign any of the “small” size hydroacoustic population estimate from Bulkley Lake to age-0 nerka.

Discussion

Annual hydroacoustic surveys have been conducted at McDonell Lake every year since 2005, and the *O. nerka* fry population appears to be relatively stable. The Gitksan Watershed Authorities has conducted sockeye stream spawner counts in the Upper Zymoetz since 2002. The decadal average return for sockeye is about 2,600 adults (Appendix 1). In 2009, the brood year for the 2010 fall fry population, the adult sockeye return to the Upper Zymoetz was 1,700 spawners (Appendix 1).

The provincial Ministry of Environment (MoE) operates a counting facility on the Sustut River downstream of the Sustut/Johansen confluence. In 2009, the brood year for the 2010 fall fry populations, only 540 adult sockeye were recorded at the counting weir (Appendix 2). This figure is inconsistent with the hydroacoustic population estimate of 325,000 (Integration estimate) age-0 nerka for Sustut and Johanson Lake combined. The 2004 hydroacoustic surveys at both lakes observed about 833,000 age-0. *O. nerka* in Sustut and Johanson Lakes combined, after a brood year escapement estimate of 4,992 returning adults to the Sustut weir in 2003. The discrepancy between adult counts and juvenile counts suggest either that the Sustut weir does not count all sockeye that pass or that there are significant numbers of kokanee in the upper Sustut lakes. Examination of the otoliths of the Sustut Lake *O. nerka* fry might provide an answer to this problem.

Gitksan Watershed Authorities also enumerates returning adult sockeye in the spawning areas adjacent to Swan Lake, and the aggregate Kispiox population includes the broodstock for Swan, Stephens, and Club Lakes (Appendix 3). The decadal average for Kispiox sockeye adults is just under 6,700, which is similar to the average since 1950 of 5,400. The 2009 adult sockeye escapement was 8,837, slightly less than in 2001, the brood year for the fall fry populations that were surveyed at Swan and Stephens Lakes in 2002. The 2002 combined fall fry estimate for Stephens and Swan Lakes was 752,000, compared to 492,000 in 2010.

The PR capacity model provides a benchmark that can be used to compare an observed sockeye fry population with the rearing capacity of a given lake. Swan Lake was the largest lake that we looked at in 2010, but contained the second lowest observed biomass of *O. nerka* fry (Table), just 4% of R_{max}, which suggests that the *O. nerka* population in Swan Lake is far below its rearing capacity. Stephens Lake, which is downstream of Swan Lake is a fraction of the size of Swan Lake, but had a higher overall biomass comprising 23% of its R_{max}. Trawl-captured *O. nerka* fry from Stephens Lake were an average of 17mm longer than their Swan Lake counterparts. It is apparent that Swan and Stephens have very different nutrient regimes. The presence of kokanee in both Swan and Stephens lakes was suggested by the observation of a handful of age-1 *O. nerka* (second summer) in the Swan Lake trawl and gillnet samples, and one age-1 nerka in the Stephens Lake gillnet sample.

Sockeye enumeration at Johnston Lake is complicated by known lakeshore spawners in the system. Few sockeye have ever been observed in Johnston Creek. Sockeye escapement data for Johnston Lake is only available to 2003, but it appears that following a steep decline in the 1970s and 80s, that sockeye escapement to Johnston Lake has increased since 1995 to an average of 4,400 between 1995 and 2003.

Johnston Lake had the highest *O. nerka* fry density, population, and biomass of all of the lakes surveyed in 2010. Even though the Johnston survey occurred fairly late in the season, the average size of *O. nerka* fry captured in Johnston Lake was very small compared to other lakes. The *O. nerka* biomass was still only 30% of the R_{max}, for Johnston Lake. The small size of Johnston Lake sockeye, which was also observed in the 2004 survey (Hume 2008), suggests a poor nutrient regime and/or overcrowding.

Despite the fact that the 2010 trawl catch was insufficient to apportion the 2010 Lakelse hydroacoustic estimate by species, the sockeye population at Lakelse Lake appears to be well below its rearing capacity. If we were to consider all “small” size fish in the calculation for biomass using the relatively high average fry weight of the nerka that were captured during this survey, the total biomass is still only 7% of R_{max}. The Lakelse sockeye population was enhanced from 2007-2009 with a fry implantation program of up to 300,000 fry each year. The 2010 program was postponed and there was no fry implant in 2010. The 2009 hydroacoustic estimate was over 450,000, the highest observed in recent years (Table 6). The 2010 hydroacoustic estimate, while lower than the 2009 estimate, is not significantly different from the 2007 or 2008 Lakelse Lake fall fry estimates (Table 6).

We observed no *O. nerka* fry in either Minerva or Bulkley Lakes. There are no records of sockeye presence in the McNeill River, and it is unlikely that this was ever a Skeena sockeye rearing lake. We do not believe that future hydroacoustic surveys at Minerva Lake would be of any value.

The Upper Bulkley sockeye stocks are at severe risk of extirpation, and in order to determine that this has not already occurred, more intensive sockeye escapement surveys and fry sampling could be undertaken. The results of the 2010 hydroacoustic survey at Bulkley Lake suggest that while there are relatively high densities of other species present, the B**u**lkley Lake sockeye stocks are at very low densities, if not already extirpated. SFC conducted a hydroacoustic survey at nearby Maxan Lake in 2009, and the results were similar. Only one of fifty fish captured at Maxan Lake was an *O. nerka* fry. Historical sockeye escapements to the Upper Bulkley River have been as high as 500 spawners, but few have been observed since the 1970s.

The error estimates of many of the fish populations (Table 4) are larger than we would like to see. In the future we will attempt to modify our sampling strategy and statistical analysis to improve the quality of estimates of sockeye populations.

Hydroacoustic surveys allow us to gauge trends in sockeye fry populations. Regular hydroacoustic surveys provide a baseline that we can use to compare estimates across years. It is a powerful tool for investigating sockeye lakes with demonstrated or potential conservation concerns. Where escapement is known, hydroacoustic data provides an indicator of freshwater sockeye productivity. The fry model we use is compatible with the PR capacity model that predicts potential sockeye productivity. The range of sockeye densities measured in the past two years (Table 5 and Carr-Harris 2009) shows sockeye fry levels ranging from 4 to 51% of theoretical capacity. Of the 9 lakes with sockeye, only 3 had sockeye densities over 30% of capacity. This is an alarming situation that points to a wide-spread conservation problem. This is a problem that may be hard to rectify as the commercial fishing pressure was much reduced in 2009 without a marked improvement in the 2010 sockeye fry levels. Other controlling factors such as marine survival are unlikely to be manipulated.

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Tables

Table 1. 2010 Hydroacoustic surveys trawl summary

Lake	Date	Trawl #	Time start	Time end	Depth (m)	Distance (m)	Start lat	Start long	End lat	End long	ON	PS	RSS	PM	TS	LA
Mcdonell	07-Aug-10	1	0019	0024	7	210	54.777	-127.622	54.779	-127.620	0					
Mcdonell	07-Aug-10	2	0058	0105	10	400	54.779	-127.618	54.781	-127.613	18	3				
Mcdonell	07-Aug-10	3	1250	0110	10	150	54.781	-127.612	54.781	-127.609	0					
Mcdonell	07-Aug-10	4	0120	0132	10	640	54.781	-127.609	54.781	-127.599	64	1				
Swan	12-Aug-10	1	2206	2210	7.5	130	55.813	-128.684	55.813	-128.686	0					
Swan	12-Aug-10	2	2217	2236	9	970	55.811	-128.688	55.803	-128.689	1					
Swan	12-Aug-10	3	2307	2327	9	810	55.802	-128.645	55.796	-128.640	0					
Swan	12-Aug-10	4	2336	2350	11	700	55.797	-128.639	55.803	-128.640	4					
Swan	12-Aug-10	5	0009	0029	10	900	55.804	-128.643	55.797	-128.640	46					
Swan	12-Aug-10	6	0049	0055	10	180	55.781	-128.641	55.778	-128.638	12					
Stephens	13-Aug-10	1	0049	0055	8	380	55.773	-128.591	55.776	-128.591	2					
Stephens	13-Aug-10	2	2349	2359	10	280	55.773	-128.581	55.771	-128.579	9					
Stephens	13-Aug-10	3	0102	0108	10	460	55.771	-128.578	55.768	-128.574	9					
Stephens	13-Aug-10	4	0112	0122	10	400	55.769	-128.573	55.772	-128.576	50					
Sustut	31-Aug-10	1	2325	2338	8	460	56.572	-126.454	56.569	-126.450	4		1			
Sustut	31-Aug-10	2	2344	2359	14	530	56.570	-126.451	56.573	-126.453	1					
Sustut	31-Aug-10	3	0008	0026	15	930	56.571	-126.452	56.566	-126.448	76					
Johanson	03-Sep-10	1	2324	2334	11	580	56.581	-126.167	56.583	-126.174	2					
Johanson	03-Sep-10	2	2348	0011	10	1080	56.584	-126.179	56.592	-126.186	1					
Johanson	03-Sep-10	3	0018	0048	13	1190	56.592	-126.185	56.584	-126.175	26					
Johanson	03-Sep-10	4	0054	0107	8	630	56.582	-126.173	56.580	-126.164	4					
Johnston	08-Sep-10	1	0016	0033	10	800	53.876	-129.443	53.876	-129.455	0				1	
Johnston	08-Sep-10	2	0041	0055	13	850	53.874	-129.453	53.876	-129.444	118				4	
Lakelse	01-Oct-10	1	0251	0307	18	500	54.395	-128.549	54.395	-128.545	0					1
Lakelse	01-Oct-10	2	0323	0342	18	1180	54.396	-128.542	54.402	-128.553	0	1				
Bulkley	04-Oct-10	1	2239	2252	7	560	54.381	-126.094	54.381	-126.102	0			16		1
Bulkley	04-Oct-10	2	2259	2315	7	760	54.380	-126.106	54.380	-126.112	0		10	30		
Lakelse	08-Oct-10	1	1934	1949	18	650	54.393	-128.540	54.393	-128.550	0	1				
Lakelse	08-Oct-10	2	2001	2013	14	710	54.394	-128.552	54.389	-128.552	2					
Lakelse	08-Oct-10	3	2021	2037	14	740	54.389	-128.551	54.396	-128.552	0	3				
Lakelse	08-Oct-10	4	2046	2056	21	570	54.395	-128.551	54.393	-128.544	0	1				2
Lakelse	08-Oct-10	5	2107	2120	21	640	54.394	-128.547	54.392	-128.551	0					
Lakelse	08-Oct-10	6	2124	2138	18	670	54.392	-128.552	54.397	-128.552	0					

ON: O. nerka, PS: Prickly sculpin, RSS: Redside shiner, PM: Northern pikeminnow, TS: Threespine stickleback, LA: Lamprey (all species)

Table 2. 2010 hydroacoustic surveys gillnet summary

Lake	GN #	Date	Time set	Time end	Easting	Northing	Depth (m)	Soak time (hours)	ON	PM	RSS	CT	RT	CO	DV	Comments
Mcdonell	1	07-Aug-10	2210	400	591744	6071705	0	6		6						
Mcdonell	2	07-Aug-10	2230	420	590514	6071364	0	6		5						Released 3 pikeminnow, retained 2 for sampling
Swan	1	10-Aug-10	2123	1352	523139	6179931	0	16.5					1	1		
Swan	2	10-Aug-10	2140	1410	523848	6179198	0	17								
Swan	3	11-Aug-10	1643	1430	522146	6182797	0	22					8	2		
Swan	4	11-Aug-10	1700	1452	522308	6181895	0	22					1	1		
Swan	5	12-Aug-10	1500	1035	521876	6180574	0	17.5								
Swan	6	12-Aug-10	1510	1045	522410	6180550	0	17.5								
Stephens	1	13-Aug-10	2201	152	525993	6181325	0	4	1					4		
Stephens	2	13-Aug-10	2210	1015	525993	6181325	0	12						5		
Minerva	1 & 2	09-Sep-10	2341	900	436961	6014246	0	10							1	Two adjacent gillnets, same location
Lakelse	1	08-Oct-10	1908	1015	530576	6029070	10	13	4			1				Released cutthroat. One nerka partially eaten by predator, not sampled
Lakelse	2	08-Oct-10	1915	2215	530528	6029232	0	3								Reset at same location as GN 3
Lakelse	3	08-Oct-10	2220	1020	530528	6029232	0	12				4				Released cutthroat
Bulkley	1	04-Oct-10	1935	2330	686513	6030110	0	4		1	1					
Bulkley	2	04-Oct-10	2004	2345	686719	6029770	0	4								

ON: O. nerka, PM: Northern pikeminnow, RSS: Redside shiner, CT: Cutthroat trout, RT: Rainbow trout, CO, Coho salmon, DV: Dolly Varden.

Table 3. 2010 hydroacoustic surveys sample data

Lake	Gear	Species	n	Mean length (mm)	Min. length (mm)	Max length (mm)	Std. dev length (mm)	Mean weight (g)	Min. weight (g)	Max weight (g)	Std. dev. weight (g)	Notes
Mcdonell	Gillnet	Northern pikeminnow	8	137	114	156	13	24.8	12.6	35.3	6.9	11 pikeminnow captured in gillnets, 3 released live
	Trawl	age-0 nerka	12	53	49	60	3	1.3	1	2	0.3	
		nerka, not aged	70	45	36	51	3	0.8	0.3	1.1	0.2	
		Prickly sculpin	2	38	17	59	-	1.2	0.02	2.1	-	4 prickly sculpin captured in trawls, 2 sampled
Swan	Gillnet	*O. kisutch*	4	80	66	103	16	6.4	2.7	13.4	4.8	
		age-1 nerka	1	120	120	120		17.6	17.6	17.6		
		O. mykiss	10	137	108	169	24	28.2	11.8	50.2	14.7	
	Trawl	age-0 nerka	31	47	39	59	5	0.8	0.4	2.8	0.4	
		age-1 nerka	3	57	47	72	13	1.6	0.7	3	1.2	
		nerka, not aged	29	41	34	47	3	0.5	0.2	0.8	0.1	
Stephens	Trawl	age-0 nerka	47	65	56	78	5	2.6	1.5	3.8	0.6	
		nerka, not aged	23	58	46	67	5	1.8	0.8	3.1	0.5	
	Gillnet	Coho	9	70	65	82	6	3.7	2.5	6.1	1.2	
		age-0 nerka	1	62	62	62	--	2.3	2.3	2.3	--	
Sustut	Trawl	age-0 nerka	70	55	39	65	6	1.3	0.5	2.4	0.4	No gillnets set
		nerka, not aged	11	45	38	56	5	0.7	0.4	1.4	0.3	
Johansen	Trawl	age-0 nerka	33	54	46	60	3	1.2	0.7	1.8	0.3	No gillnets set
Johnston	Trawl	age-0 nerka	28	53	47	60	3	1.1	0.7	1.8	0.2	No gillnets set
		nerka, not aged	90	44	37	52	3	0.6	0.3	1	0.2	
		Threespine stickleback	5	43	39	47	3	0.6	0.5	0.7	0.1	
Minerva	Gillnet	Dolly Varden	1	126	126	126	-	15.4	15.4	15.4	-	No trawls

Table 3 cont'd.

Lake	Gear	Species	n	Mean length (mm)	Min. length (mm)	Max length (mm)	Std. dev length (mm)	Mean weight (g)	Min. weight (g)	Max weight (g)	Std. dev. weight (g)	Notes
Lakelse	Trawl	age-0 nerka	2	71	62	80	13	3.7	1.9	5.5	2.5	
		Prickly sculpin	5	38	33	45	4	0.4	0.3	0.8	0.2	
		River lamprey	1	155	155	155	-	3.5	3.5	3.5	-	
		Lampetra spp.	2	89	58	119	43	1.2	0.2	2.2	1.2	
Lakelse	Gillnet	age-0 nerka	3	84	83	85	1	5.7	5.1	6.3	0.6	
		Cutthroat trout	1									Not measured, released
Bulkley	Trawl and Gillnet	Pacific lamprey	1	139	139	139	-	3.9	3.9	3.9	-	
		Northern pikeminnow	47	78	37	176	32	8.4	0.5	63.3	14.3	Trawl and gillnet samples combined in lab
		Redside shiner	11	65	41	86	17	4.2	1.1	8.7	3.2	

Table 4. 2010 hydroacoustic estimates

Lake	Class	Method	n/ha	95% CI	n	95% CI (n)	95 % CI (%)
Mcdonell	All fish	Integration	**1,607**	**555**	**3.44E+05**	**1.19E+05**	**34.5%**
	Age "0" sockeye		**1,562**	**534**	**3.35E+05**	**1.14E+05**	**34.2%**
	Large fish		**45**	**33**	**9.63E+03**	**7.07E+03**	**73.5%**
	All fish	Single target	1,673	494	3.59E+05	1.06E+05	29.5%
	Age "0" sockeye		1,627	486	3.49E+05	1.04E+05	29.9%
	Large fish		46	23	9.87E+03	4.83E+03	48.9%
	All fish	Tracked target (vertical only)	2,060	616	4.42E+05	1.32E+05	29.9%
	Age "0" sockeye		2,005	591	4.30E+05	1.27E+05	29.5%
	Large fish		56	33	1.19E+04	7.09E+03	59.5%
Swan	All fish	Integration	197	50	3.47E+05	8.76E+04	25.2%
	Age-0 sockeye		143	36	2.53E+05	6.29E+04	24.8%
	Large fish		53	21	9.41E+04	3.79E+04	40.3%
	All fish	Single target	243	69	4.29E+05	1.21E+05	28.2%
	Age-0 sockeye		176	46	3.10E+05	8.21E+04	26.5%
	Large fish		67	30	1.19E+05	5.23E+04	44.0%
	All fish	Tracked target (vertical only)	**254**	**62**	**4.49E+05**	**1.10E+05**	**24.4%**
	Age-0 sockeye		**184**	**40**	**3.25E+05**	**7.09E+04**	**21.8%**
	Large fish		**71**	**30**	**1.25E+05**	**5.31E+04**	**42.5%**
Stephens	All fish	Integration	**1,077**	**701**	**2.12E+05**	**1.38E+05**	**65.1%**
	Age-0 sockeye		**853**	**384**	**1.68E+05**	**7.55E+04**	**45.1%**
	Large fish		**224**	**239**	**4.40E+04**	**4.69E+04**	**106.6%**
	All fish	Single target	1,350	862	2.65E+05	1.69E+05	63.8%
	Age-0 sockeye		1,060	676	2.08E+05	1.33E+05	63.7%
	Large fish		289	372	5.69E+04	7.30E+04	128.4%
	All fish	Tracked target (vertical only)	1,554	1,072	3.05E+05	2.11E+05	69.0%
	Age-0 sockeye		1,207	797	2.37E+05	1.57E+05	66.0%
	Large fish		347	457	6.81E+04	8.99E+04	132.0%

Table 4 cont'd.

Lake	Class	Method	n/ha	95% CI	n	95% CI (n)	95 % CI (%)
Sustut	All fish	Integration	**1,022**	**696**	**2.61E+05**	**1.78E+05**	**68.1%**
	Age-0 sockeye		**976**	**645**	**2.50E+05**	**1.65E+05**	**66.1%**
	Large fish		**36**	**52**	**9.23E+03**	**1.34E+04**	**145.0%**
	All fish	Single target	1,053	721	2.70E+05	1.84E+05	68.4%
	Age-0 sockeye		1,013	684	2.59E+05	1.75E+05	67.5%
	Large fish		30	35	7.64E+03	9.03E+03	118.1%
	All fish	Tracked target (vertical only)	**1,295**	**1,089**	**3.31E+05**	**2.79E+05**	**84.0%**
	Age-0 sockeye		**1,221**	**993**	**3.12E+05**	**2.54E+05**	**81.4%**
	Large fish		**62**	**94**	**1.59E+04**	**2.39E+04**	**150.7%**
Johanson	All fish	Integration	**680**	**148**	**9.97E+04**	**2.17E+04**	**21.7%**
	Age-0 sockeye		**516**	**201**	**7.57E+04**	**2.94E+04**	**38.8%**
	Large fish		**65**	**64**	**9.50E+03**	**9.43E+03**	**99.3%**
	All fish	Single target	733	198	1.07E+05	2.90E+04	27.0%
	Age-0 sockeye		555	247	8.13E+04	3.62E+04	44.5%
	Large fish		66	59	9.62E+03	8.61E+03	89.4%
	All fish	Tracked target (vertical only)	742	197	1.09E+05	2.88E+04	26.5%
	Age-0 sockeye		589	246	8.63E+04	3.60E+04	41.7%
	Large fish		70	66	1.03E+04	9.69E+03	94.2%
Johnson	All fish	Integration	7,555	869	1.45E+06	1.67E+05	11.5%
	Age "0" sockeye		7,535	874	1.45E+06	1.68E+05	11.6%
	Large fish		21	15	3.96E+03	2.96E+03	74.9%
	All fish	Single target	8,355	656	1.61E+06	1.26E+05	7.8%
	Age "0" sockeye		8,333	667	1.60E+06	1.28E+05	8.0%
	Large fish		22	18	4.25E+03	3.45E+03	81.2%
	All fish	Tracked target (vertical only)	6,588	664	1.27E+06	1.28E+05	10.1%
	Age "0" sockeye		6,567	672	1.29E+06	1.29E+05	10.2%
	Large fish		20	11	3.86E+03	2.11E+03	54.6%
	All fish	Tracked target (vertical and horizontal)	**6,680**	**690**	**1.29E+06**	**1.33E+05**	**10.3%**
	Age "0" sockeye		**6,660**	**699**	**1.28E+06**	**1.35E+05**	**10.5%**
	Large fish		**20**	**11**	**3.86E+03**	**2.11E+03**	**54.6%**

Table 4 cont'd.

Lake	Class	Method	n/ha	95% CI	n	95% CI (n)	95 % CI (%)
Minerva	All fish	Tracked target (vertical only)	147	60	2.02E+04	8.26E+03	40.9%
	Small fish		141	66	1.94E+04	9.11E+03	47.0%
	Large fish		6	7	8.10E+02	9.84E+02	121.4%
Lakelse (North Basin)	All fish	Integration	385	182	2.43E+05	1.15E+05	47.2%
	Small fish		340	163	2.15E+05	1.03E+05	48.1%
	Large fish		47	20	2.99E+04	1.27E+04	42.4%
	All fish	Single target	403	181	2.55E+05	1.14E+05	44.8%
	Small fish		343	143	2.17E+05	9.06E+04	41.8%
	Large fish		55	23	3.45E+04	1.46E+04	42.4%
	All fish	Tracked target (vertical only)	406	176	2.57E+05	1.11E+05	43.3%
	Small fish		349	142	2.20E+05	8.98E+04	40.8%
	large		59	26	3.73E+04	1.66E+04	44.5%
Lakelse (South Basin)	All fish	Integration	74		5.65E+04		
	Small fish		64		4.95E+04		
	Large fish		9		7.06E+03		
	All fish	Single target	111		8.50E+04		
	Small fish		97		7.44E+04		
	Large fish		14		1.06E+04		
	All fish	Tracked target (vertical only)	55		4.25E+04		
	Small fish		48		3.72E+04		
	Large fish		7		5.31E+03		
Bulkley	All fish	Tracked target (vertical only)	1,232	726	3.06E+05	1.81E+05	58.9%
	Small fish		1,101	447	2.74E+05	1.11E+05	40.6%
	Large fish		223	213	5.54E+04	5.30E+04	95.8%

Table 5. PR Capacity proportion of 2010 hydroacoustic estimates

Lake	2010 Hydroacoustic Estimate	Estimation method	Average weight (g)	Observed biomass (kg)	Rmax	% Rmax	Comments
Mcdonell	3.35E+05	Integration	0.85	285	972[2]	29%	
Swan	3.25E+05	Tracked target	0.71	230	5,900[1]	4%	
Stephens	1.68E+05	Integration	2.30	386	1,700[1]	23%	
Sustut	2.50E+05	Integration	1.30	325	670[1]	48%	
Johanson	7.57E+04	Integration	1.20	91	760[1]	12%	
Johnston	1.29E+06	Tracked target	0.76	978	3,243[2]	30%	
Lakelse (north basin)	2.15E+05	Integration	3.70	794	12,156[2]	7%	Small fish estimate only

[1] Cox-Rogers *et. al*, 2004

[2] Shortreed *et. al*., 2007

Table 6. Past hydroacoustic estimates for lakes surveyed in 2010.

Lake	Year	Date	Age-0 sockeye		Method	Source	Comments
			n/ha	n			
Mcdonell	2001	10-Sep	352	7.55E+04	Tracked targets	Hume and MacLellan 2008	"small" fish estimate, no fish captured by trawl
	2002	13-Sep	595	1.27E+05	Integration	Hume and MacLellan 2008	
	2005	22-Sep	490	1.90E+05	Integration	Hall and Harris 2007	
	2006	09-Aug	371	4.03E+04	Integration	Carr-Harris 2009 (1)	
	2007	26-Sep	949	2.04E+05	Integration	Carr-Harris 2009 (1)	
	2008	18-Aug	1486	3.19E+05	Integration	Carr-Harris 2009 (3)	
	2009	17-Aug	846	1.81E+05	Tracked targets	Unpublished data	
	2010	**06-Aug**	**1607**	**3.44E+05**	**Integration**		
Swan	2002	06-Sep	329	5.76E+05	Tracked targets	Hume and MacLellan 2008	
	2010	**11-Aug**	**184**	**3.25E+05**	**Tracked targets**		
Stephens	2002	10-Sep	897	1.76E+05	Integration	Hume and MacLellan 2008	
	2005	13-Oct	1200	2.30E+05	Integration	Hall and Harris 2007	
	2009	04-Oct	226	4.45E+04	Tracked targets	Unpublished data	"small" fish estimate
	2010	**13-Aug**	**853**	**1.68E+05**	**Integration**		
Sustut	2004	12-Sep	3007	6.63E+05	Integration	Shortreed and Hume 2005	
	2010	31-Aug	976	2.50E+05	Integration		

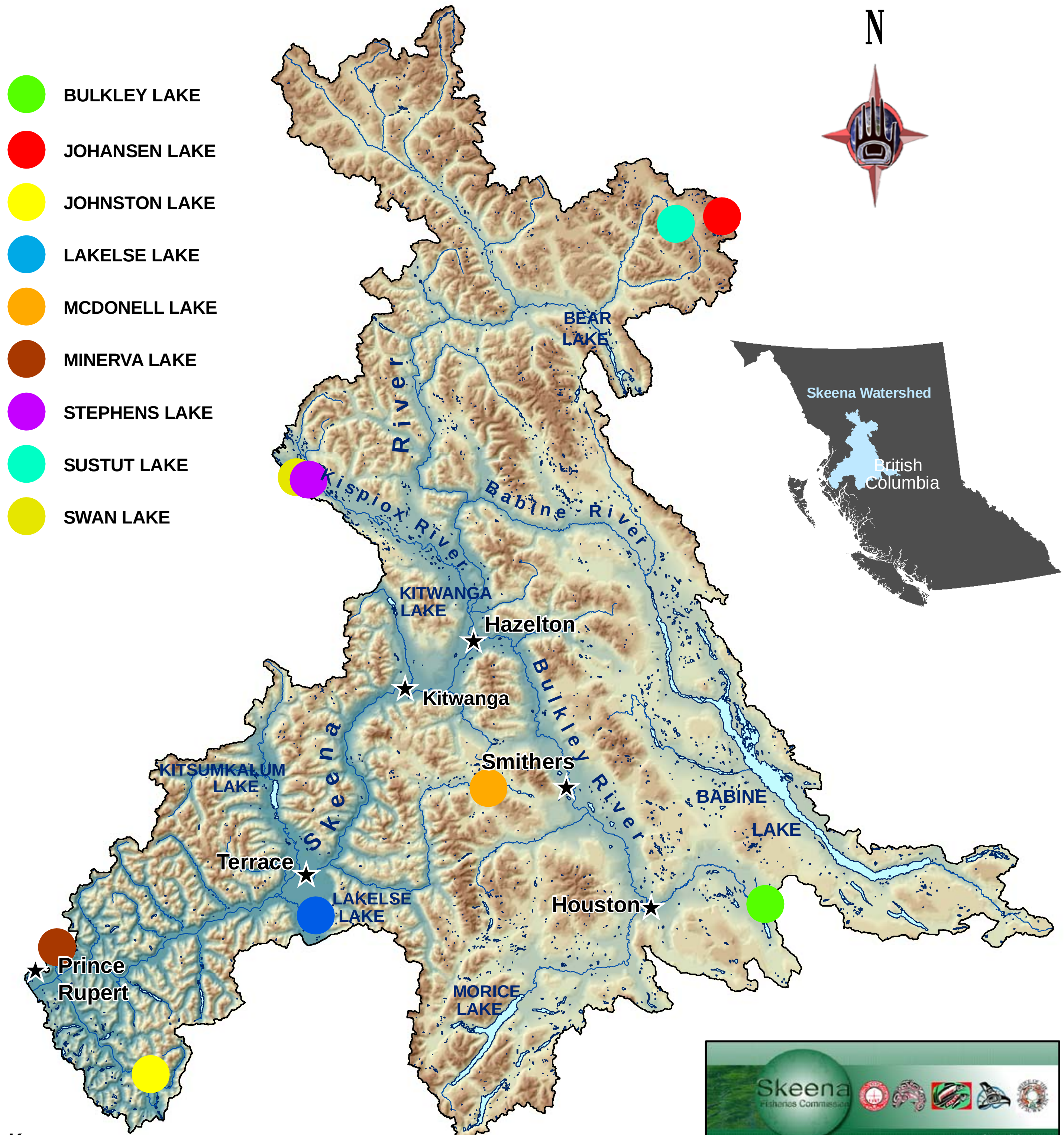
Table 6 cont'd

Lake	Year	Date	Age-0 sockeye		Method	Source	Comments
			n/ha	n			
Johanson	2004	12-Sep	1195	1.70E+05	Integration	Hume and MacLellan 2008	
	2010	**03-Sep**	**680**	**9.97E+04**	**Integration**		
Lakelse	2003	30-Sep	90	1.23E+05	Tracked targets	Hume and MacLellan 2008	
	2004	25-Sep	158	2.15E+05	Integration	Hume and MacLellan 2008	
	2005	05-Sep	288	3.91E+05	Integration	Hume and MacLellan 2008	
	2006	10-Oct	128	7.11E+04	Tracked targets	Hall 2007	"small" fish estimate
	2007	26-Sep	218	2.02E+05	Integration	Hall and Carr-Harris 2008	"small fish" estimate
	2008	29-Aug	474	2.99E+05	Integration	Carr-Harris 2008	
	2009	25-Aug	719	4.54E+05	Integration	Unpublished data	
	2010	**30-Sep**	**385**	**2.43E+05**	**Integration**		
Johnston	2005	01-Sep	6084	1.14E+06	Integration	Hume and MacLellan 2008	
	2010	**08-Sep**	**6680**	**1.29E+06**	**Tracked target**		

Figures

2010 Hydroacoustic Surveys

2010 Hydroacoustic Survey Locations



Map Key

- ★ Towns and Villages
- Lakes
- Rivers

Skeena Fisheries Commission
www.skeenafisheries.ca

Projection: UTM (Universal Transeverse Mercator) Datum: NAD83 (North American Datum 1983)	
Map Prepared By: *G. Wilson*	Date: *April 06, 2011*
X:\coredata\Projects\Hydroacoustics010\Bathy_Index010\apr_mxd\2010 Location Map...	

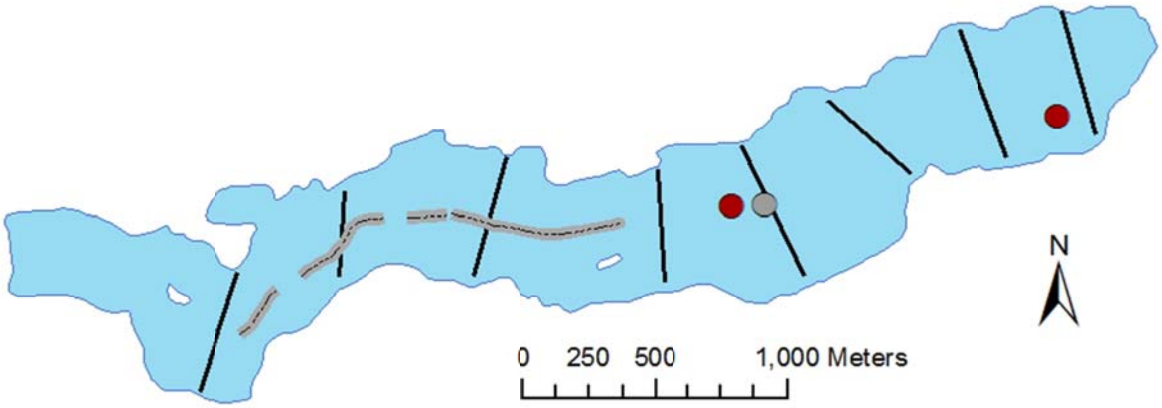


Figure 2. McDonell lake hydroacoustic survey map

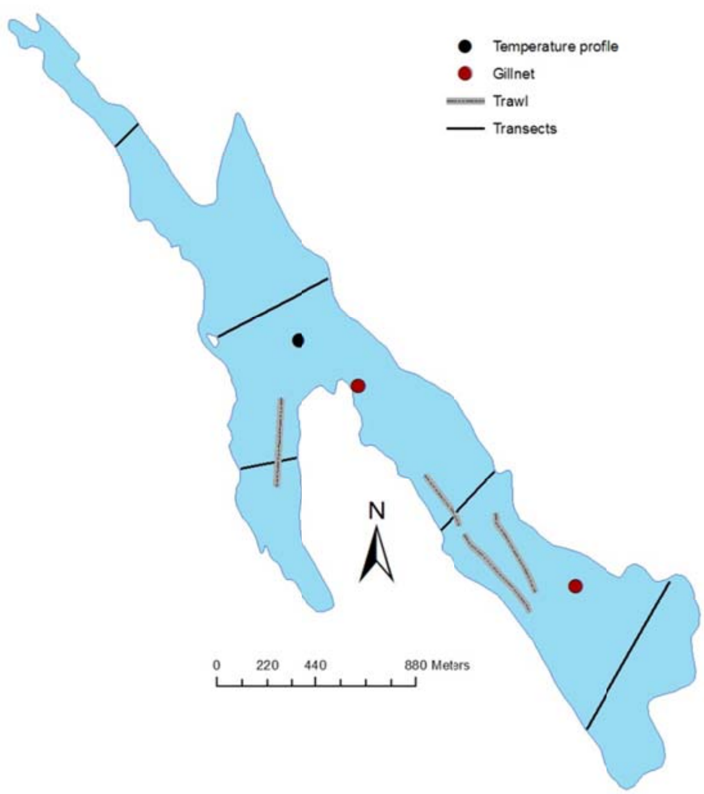


Figure 3. Stephens lake hydroacoustic survey map

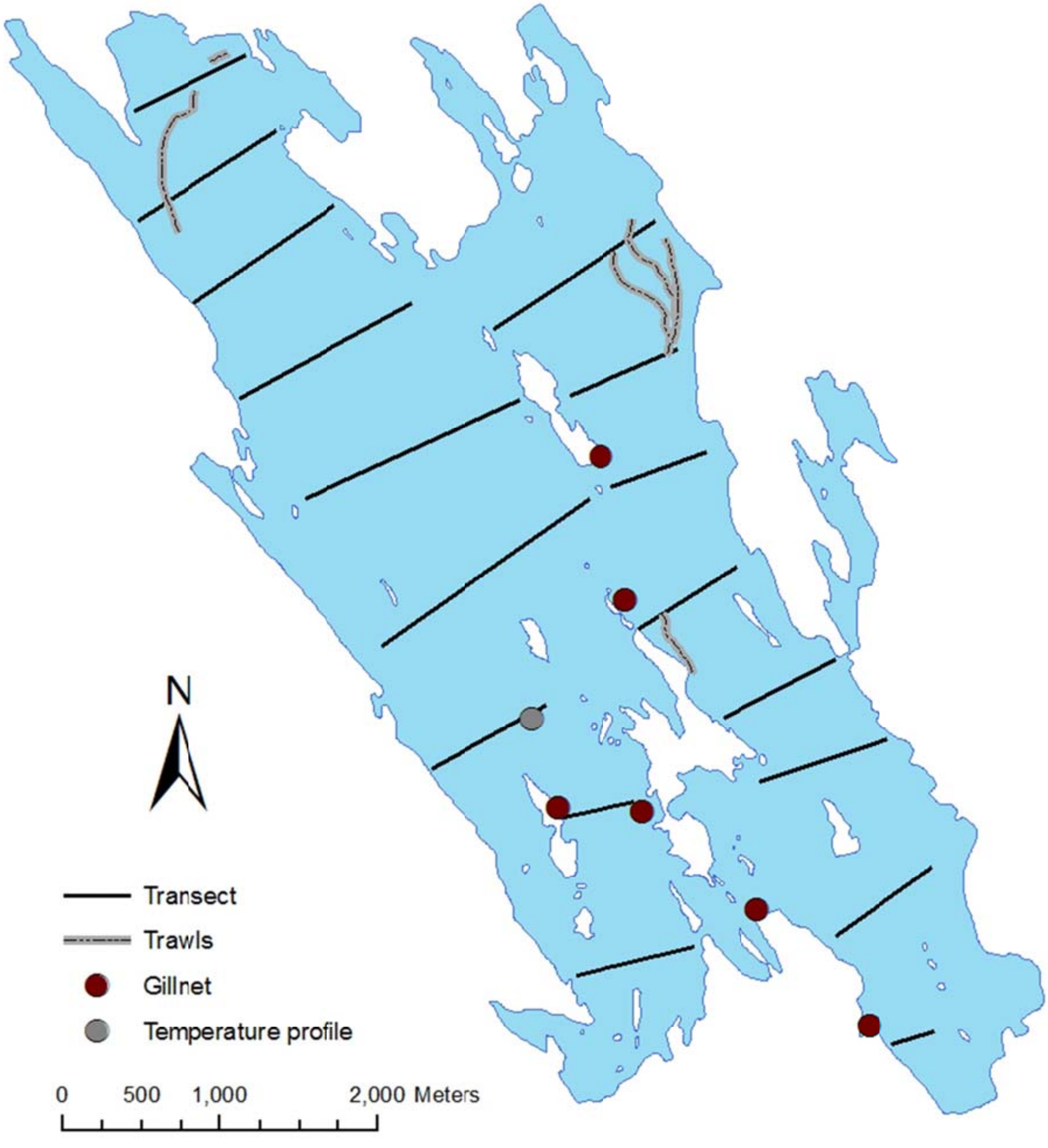


Figure 4. Swan lake survey map

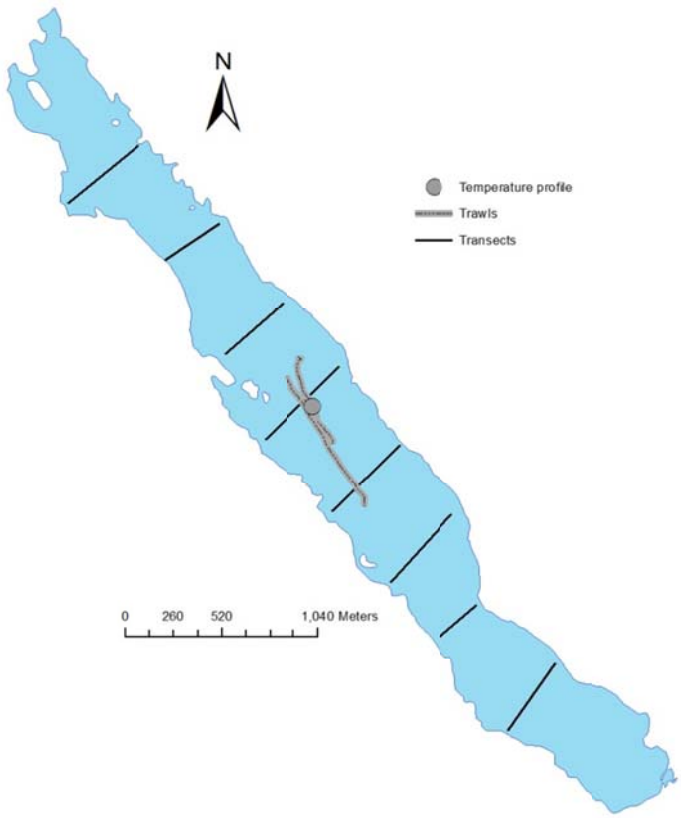


Figure 5. Sustut lake survey map

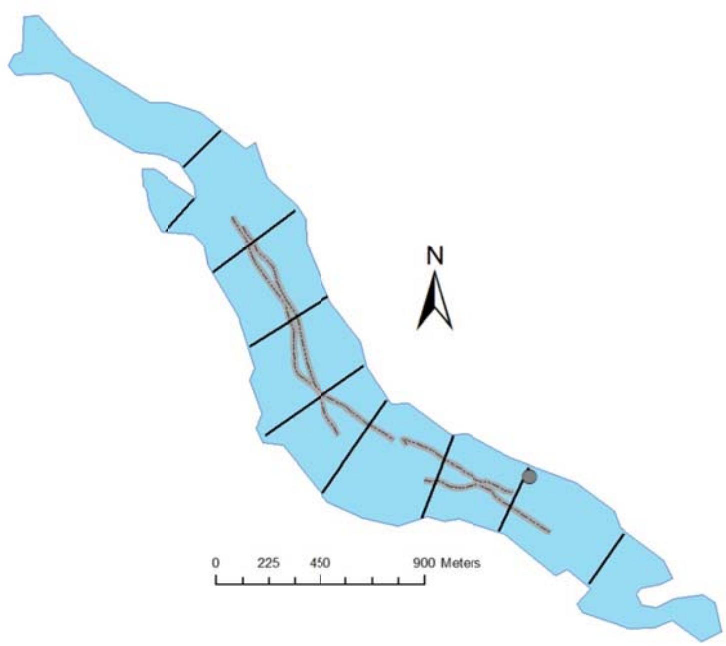


Figure 6. Johanson lake survey map

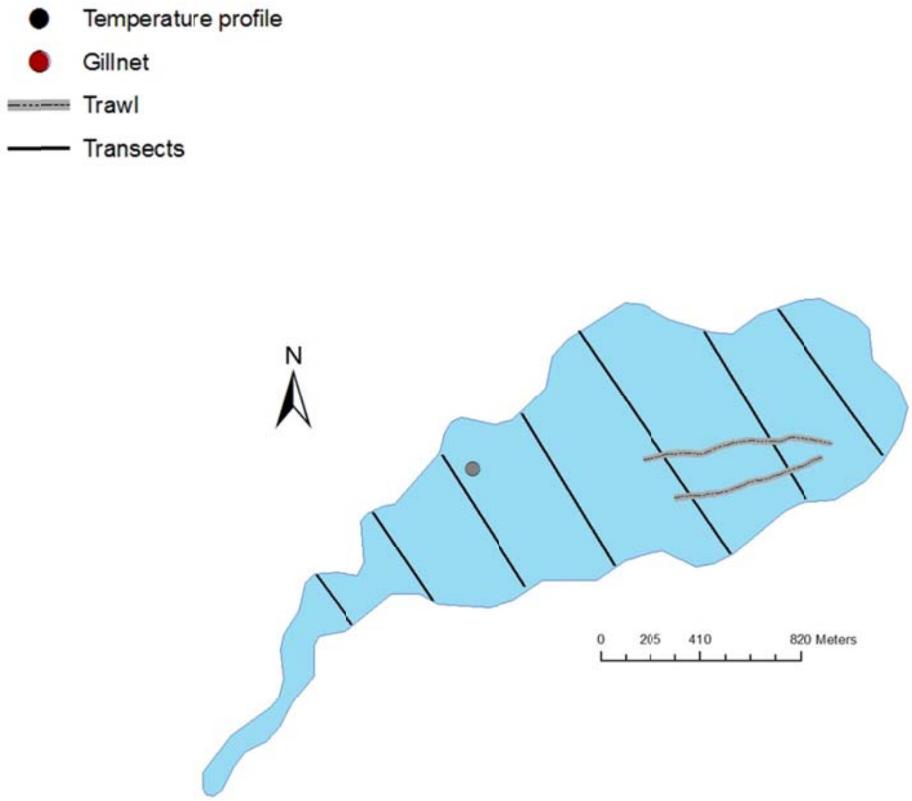


Figure 7. Johnston lake survey map

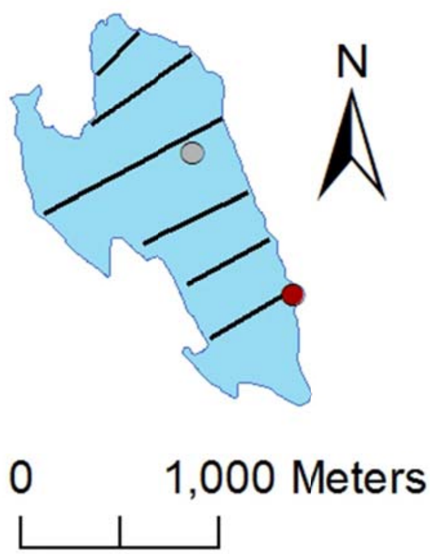


Figure 8. Minerva Lake survey map

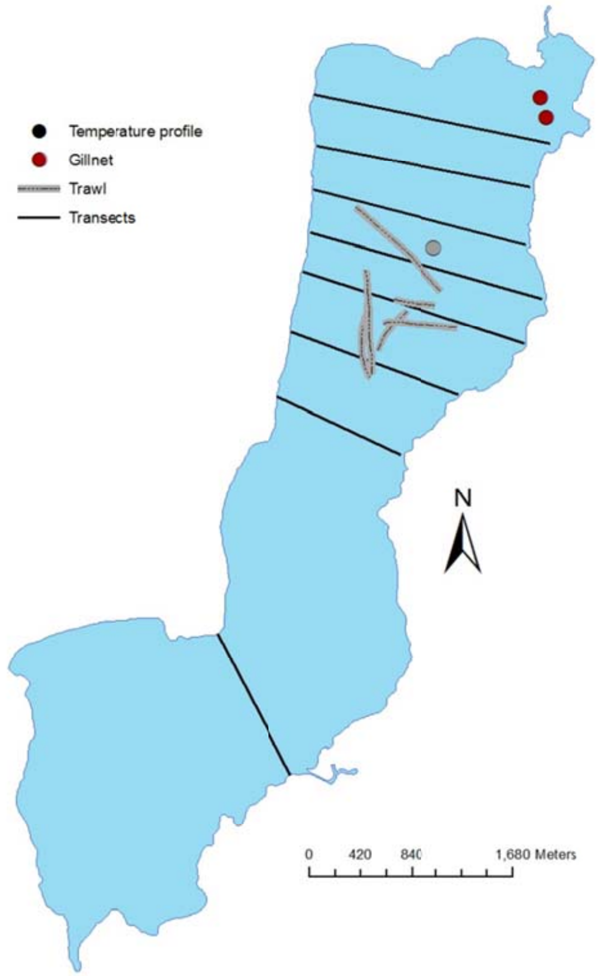


Figure 9. Lakelse lake survey map

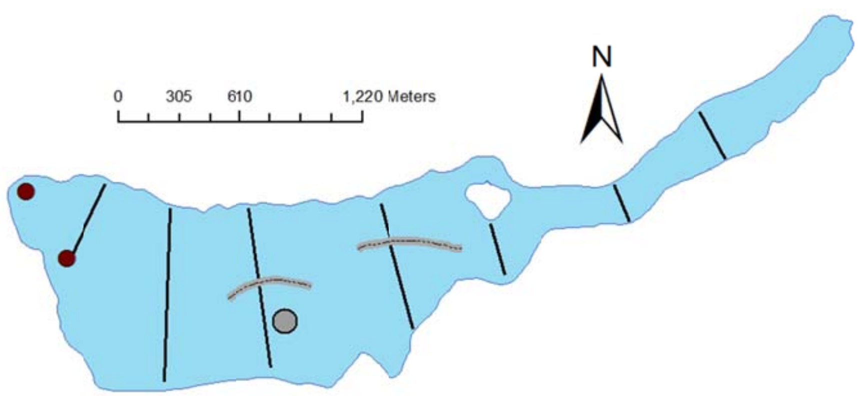


Figure 10. Bulkley lake survey map

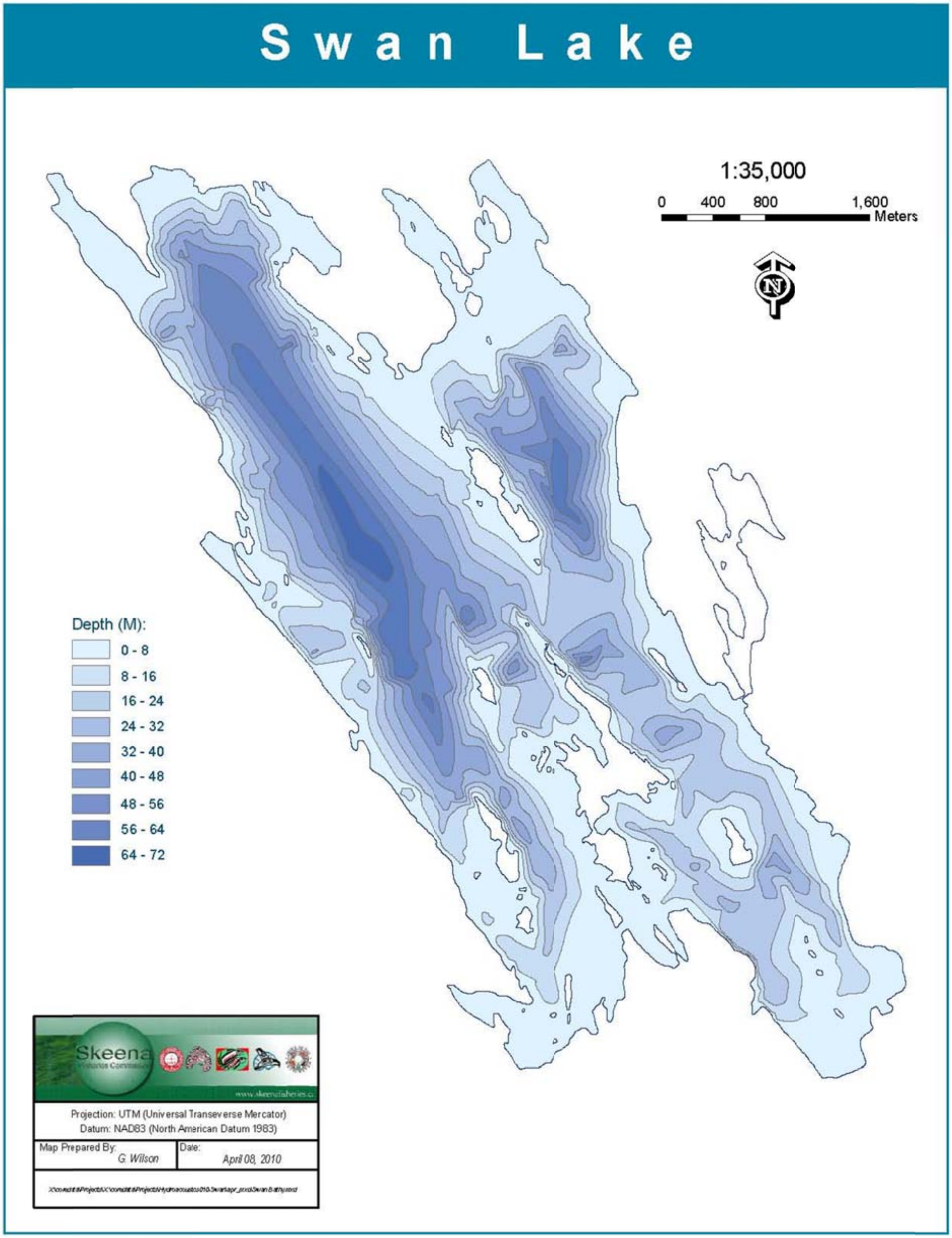


Figure. 11 Swan lake bathymetric map

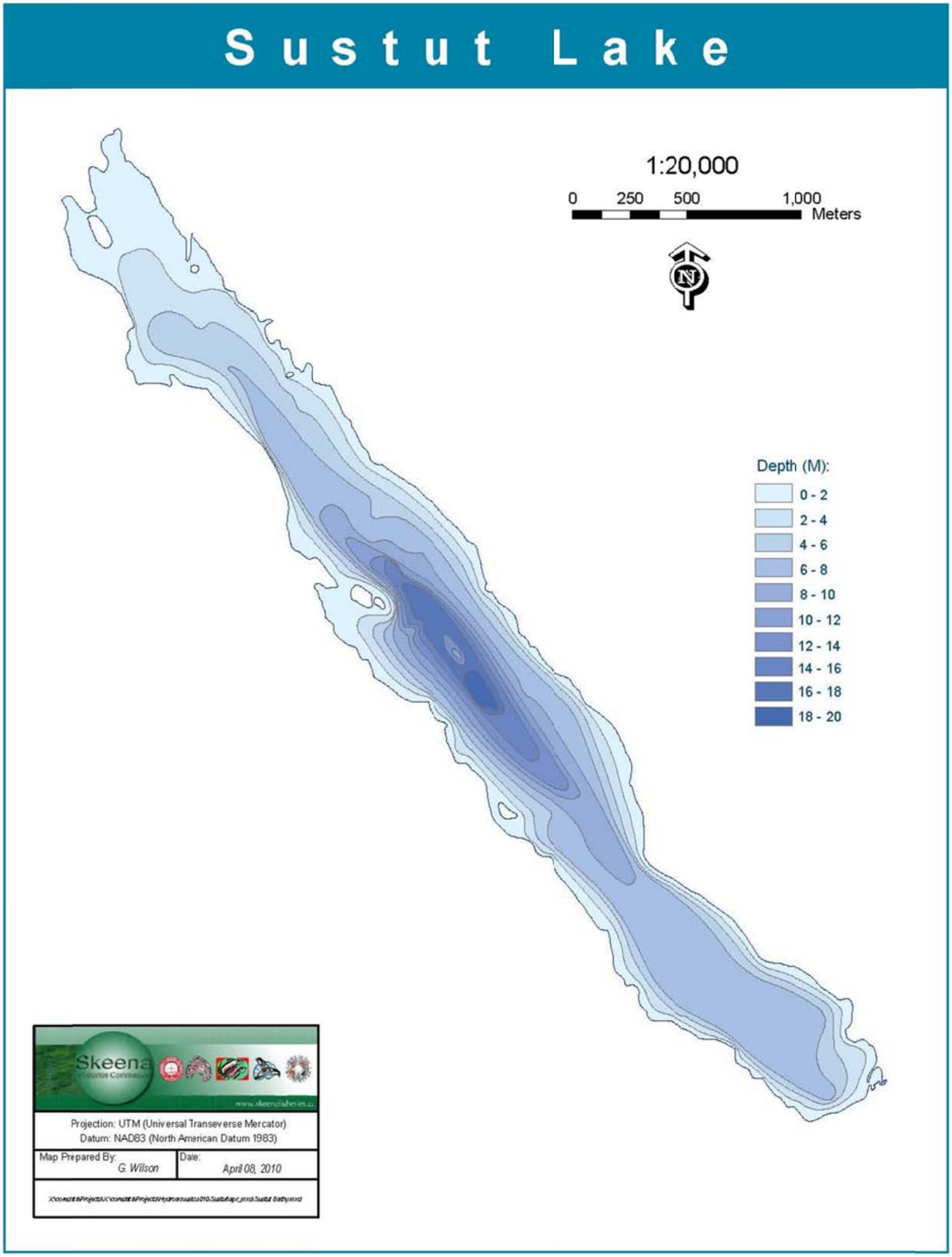


Figure 12. Sustut lake bathymetric map

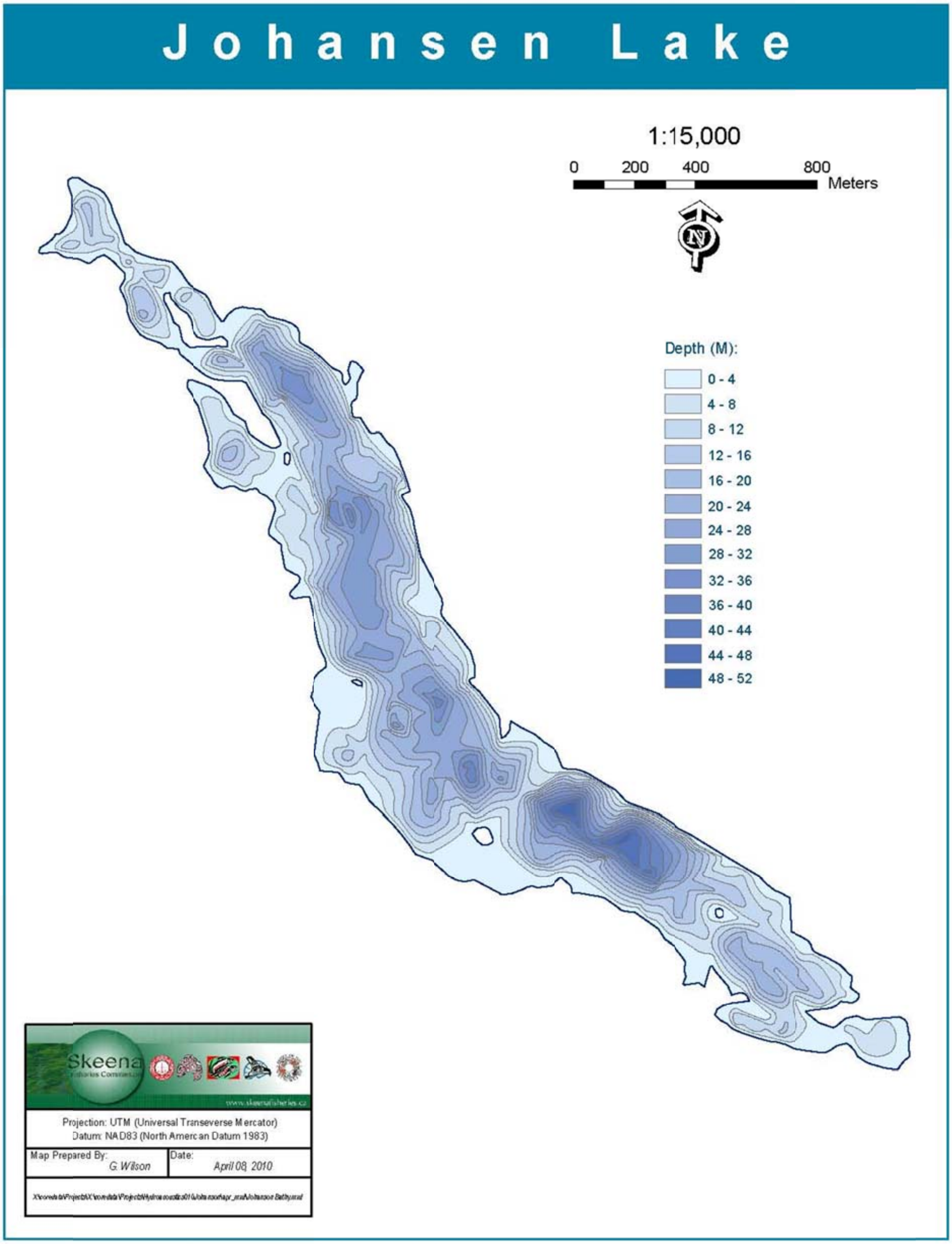


Figure 13. Johanson lake bathymetric map

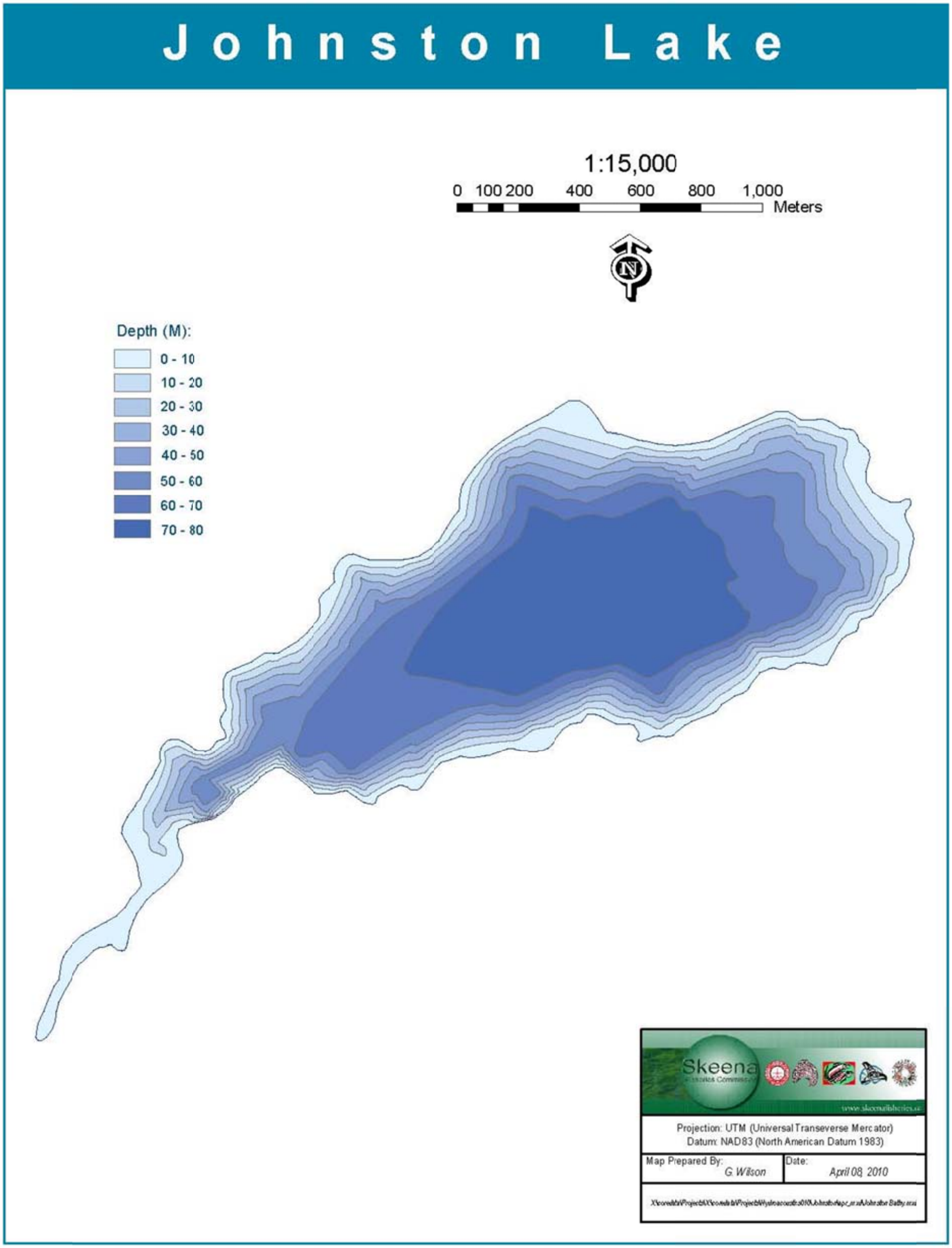


Figure 14. Johnston lake bathymetric map

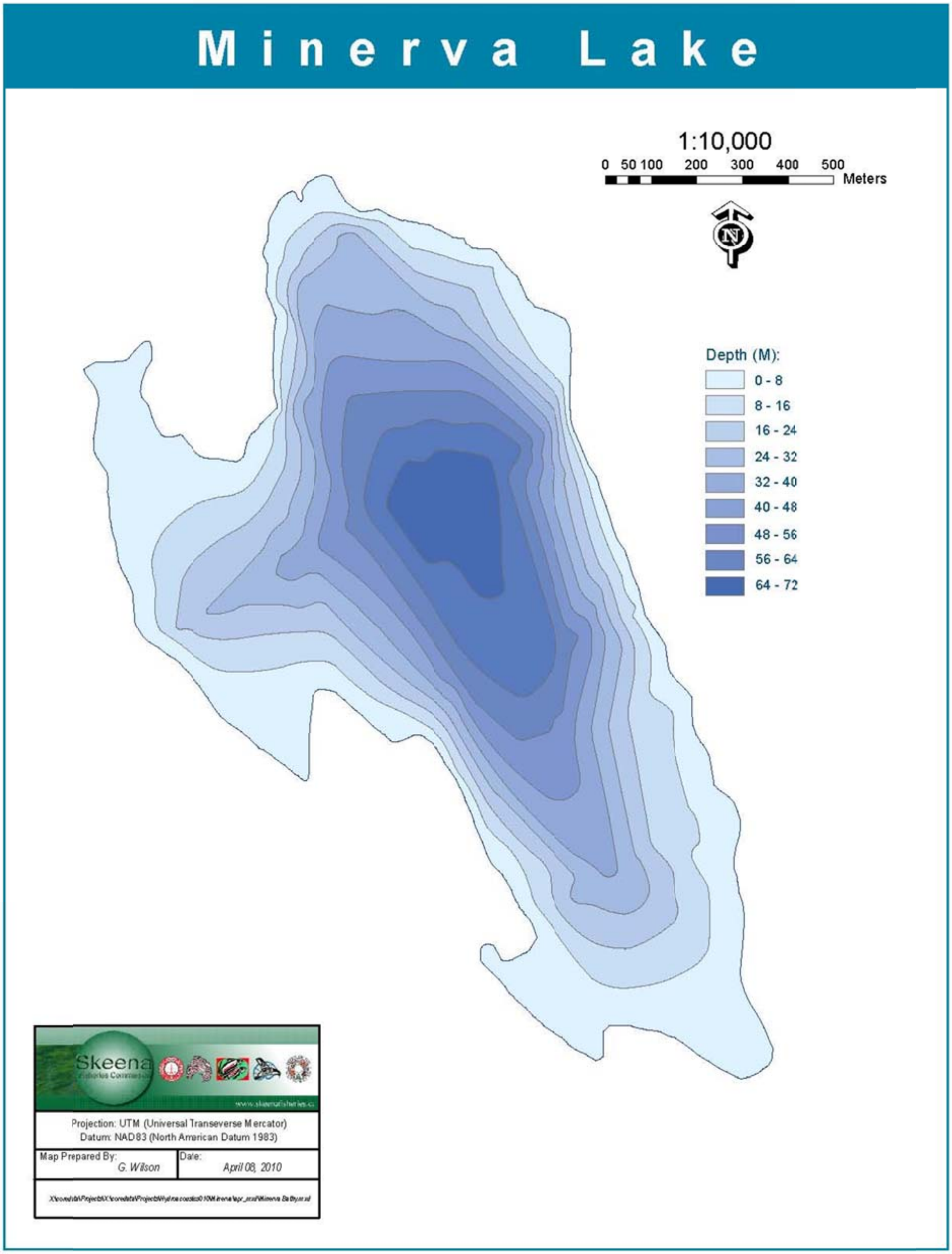


Figure 15. Minerva lake bathymetric map

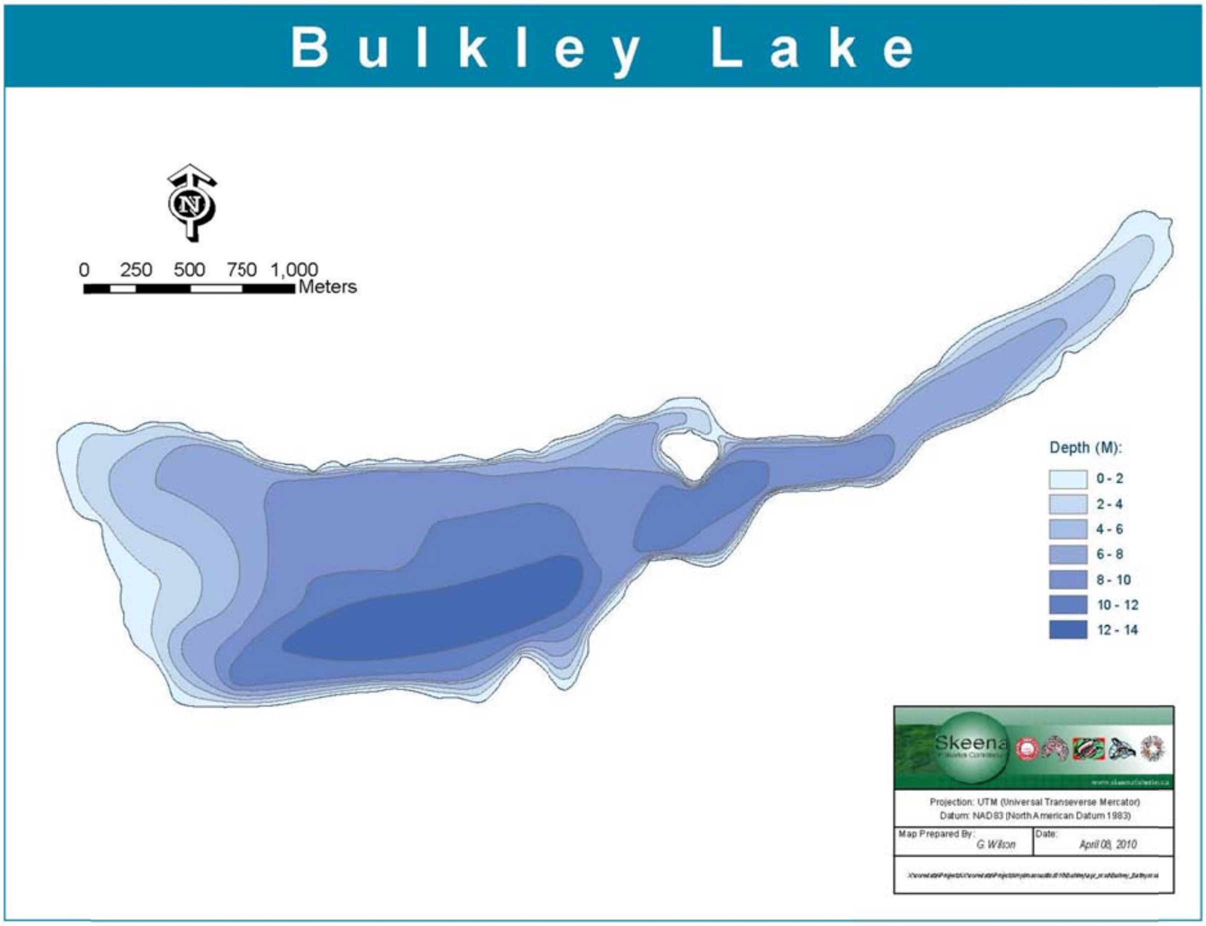


Figure 16. Bulkley lake bathymetric map

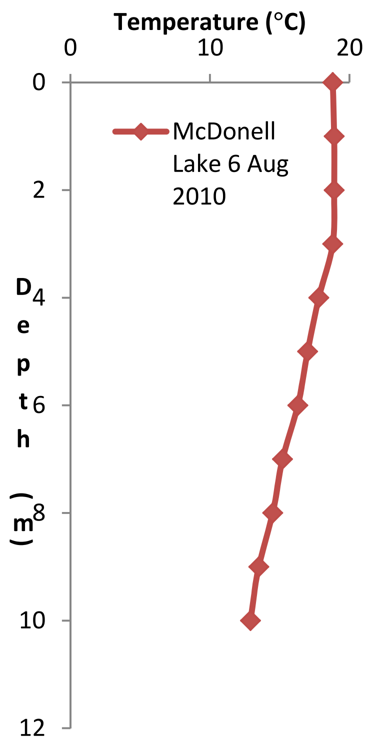


Figure 17. McDonell lake temperature profile

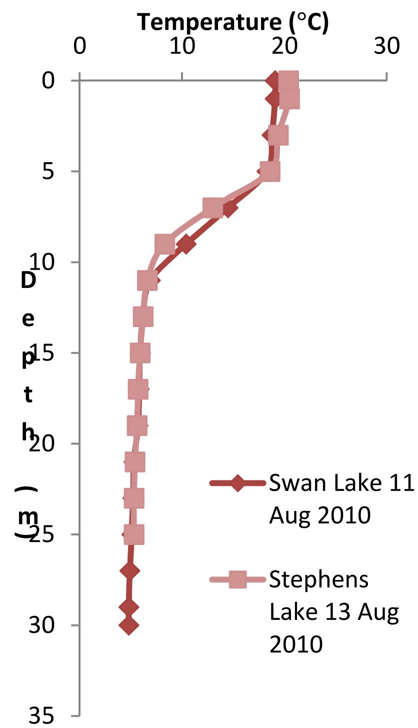


Figure 18. Swan and Stephens lakes temperature profiles

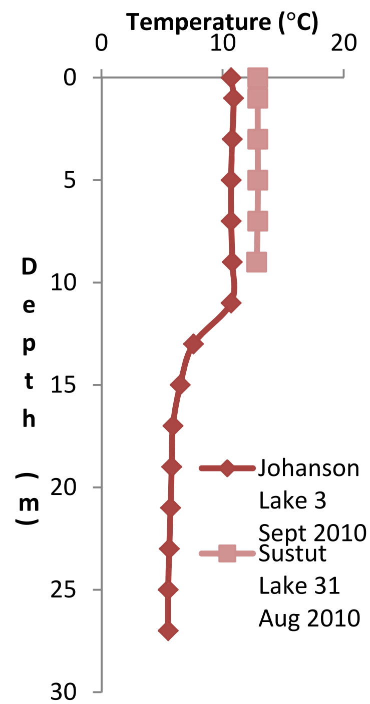


Figure 19. Sustut and Johanson lakes temperature profiles

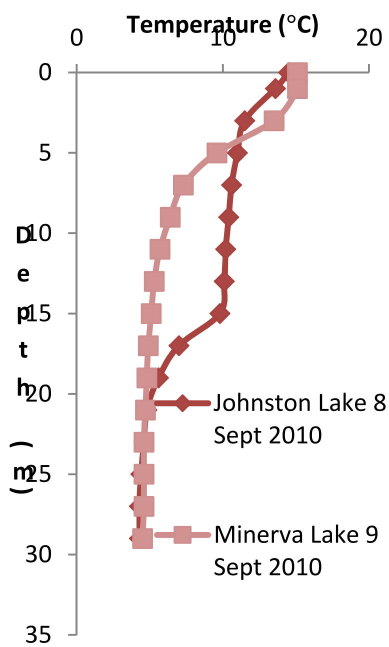


Figure 20. Johnston and Minerva lakes temperature profiles

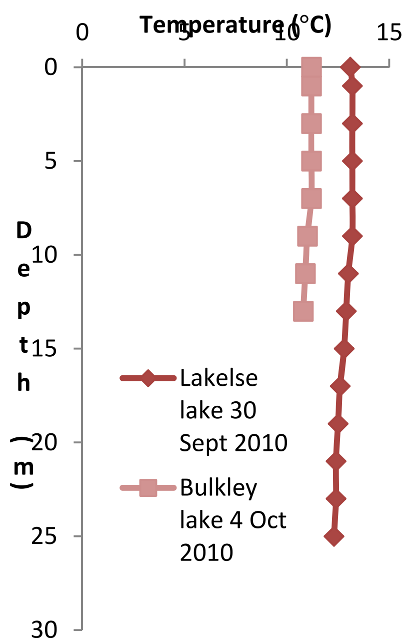


Figure 21. Lakelse and Bulkley lakes temperature profiles

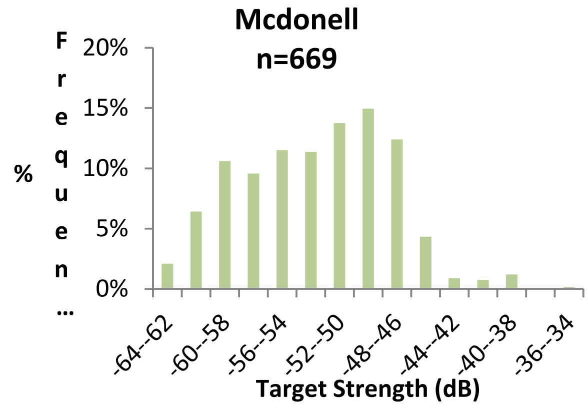


Figure 22. Mcdonell lake hydroacoustic survey target strength distribution

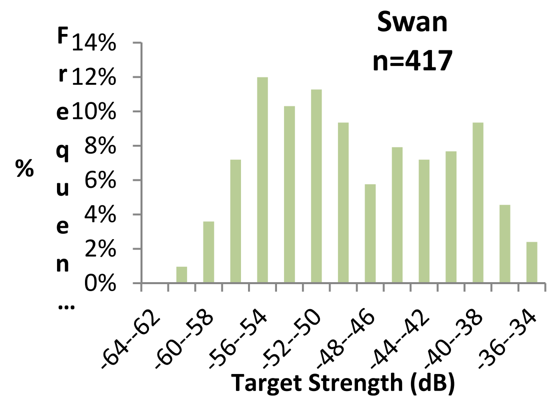


Figure 23. Swan lake hydroacoustic survey target strength distribution

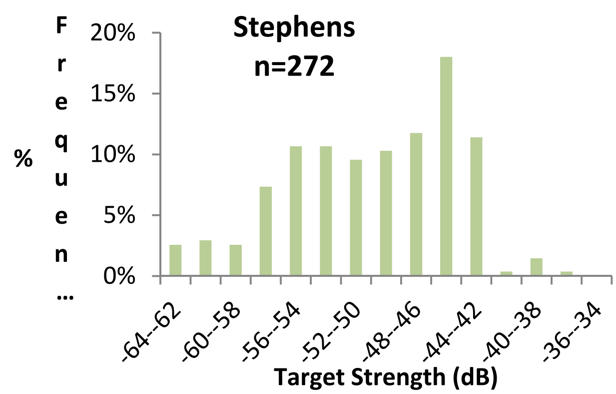


Figure 24 Stephens lake hydroacoustic survey target strength distribution

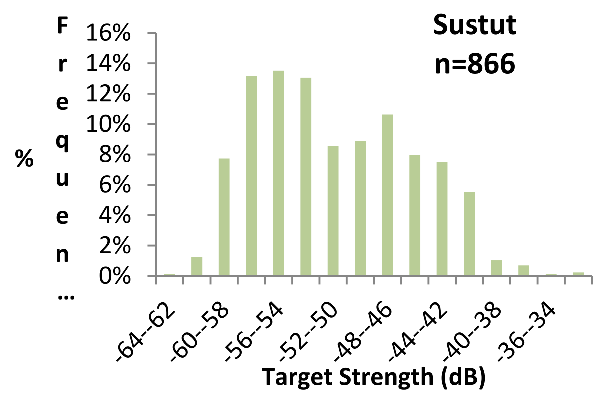


Figure 25. Sustut lake hydroacoustic survey target strength distribution

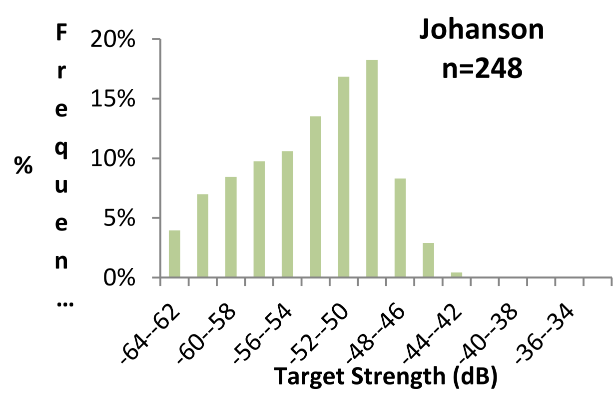


Figure 26. Johanson lake hydroacoustic survey target strength distribution

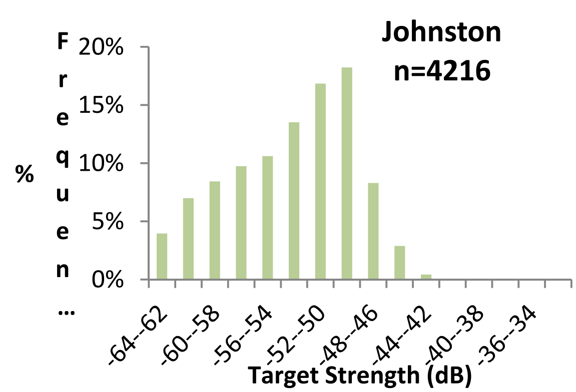


Figure 27. Johnston lake hydroacoustic survey target strength distribution

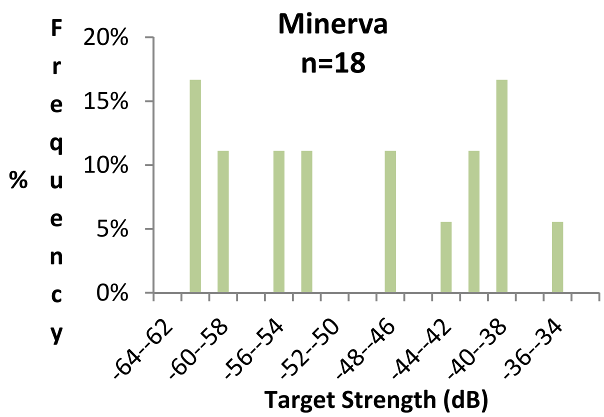


Figure 28. Minerva lake hydroacoustic survey target strength distribution

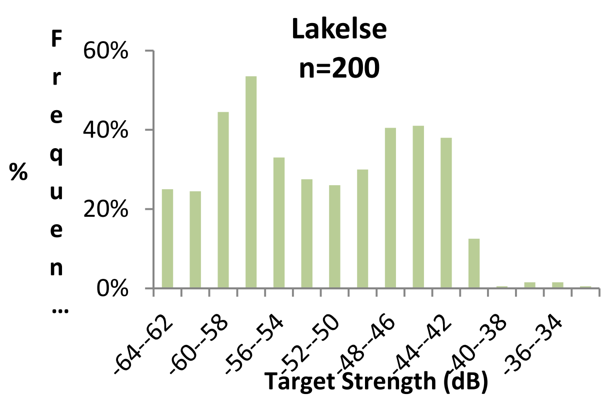


Figure 29. Lakelse lake hydroacoustic survey target strength distribution

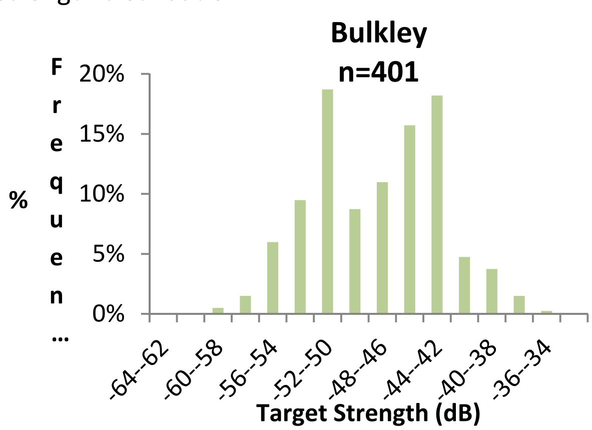


Figure 30. Bulkley lake hydroacoustic survey target strength distribution

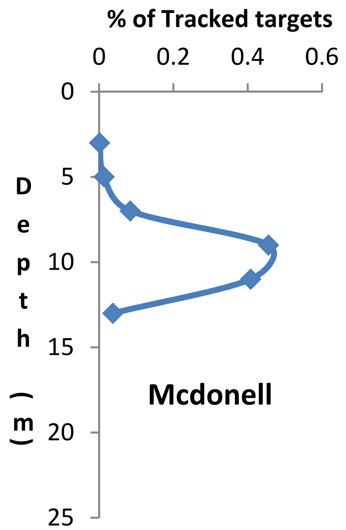


Figure 31. McDonell lake vertical distribution of tracked targets

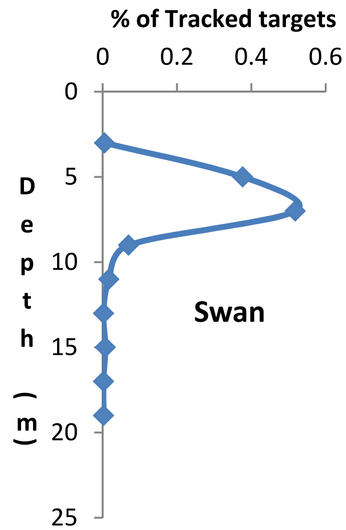


Figure 32. Swan lake vertical distribution of tracked targets

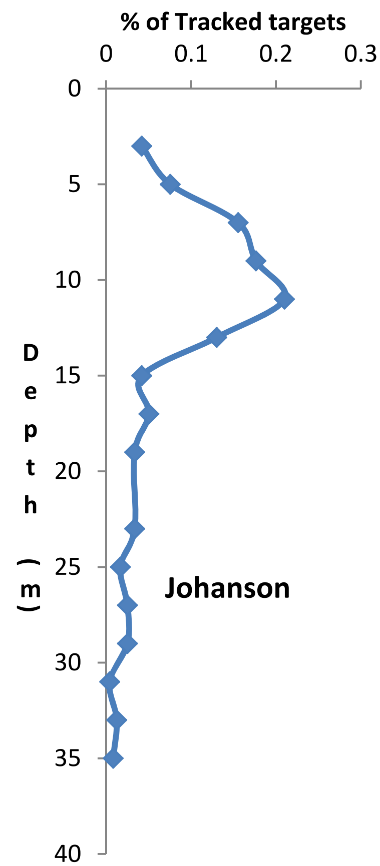


Fig 35. Johanson lake vertical distribution of tracked targets

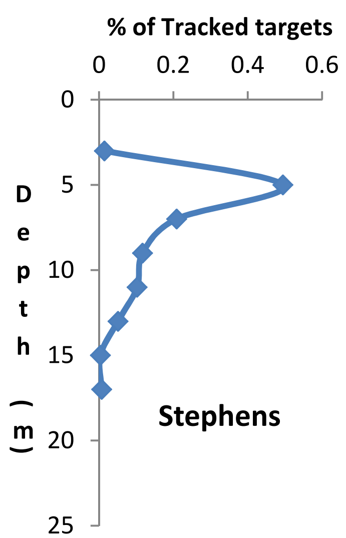


Figure 33. Stephens lake vertical distribution of tracked targets

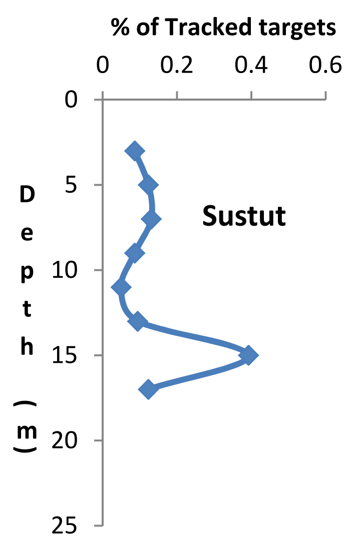


Figure 34. Sustut lake vertical distribution of tracked targets

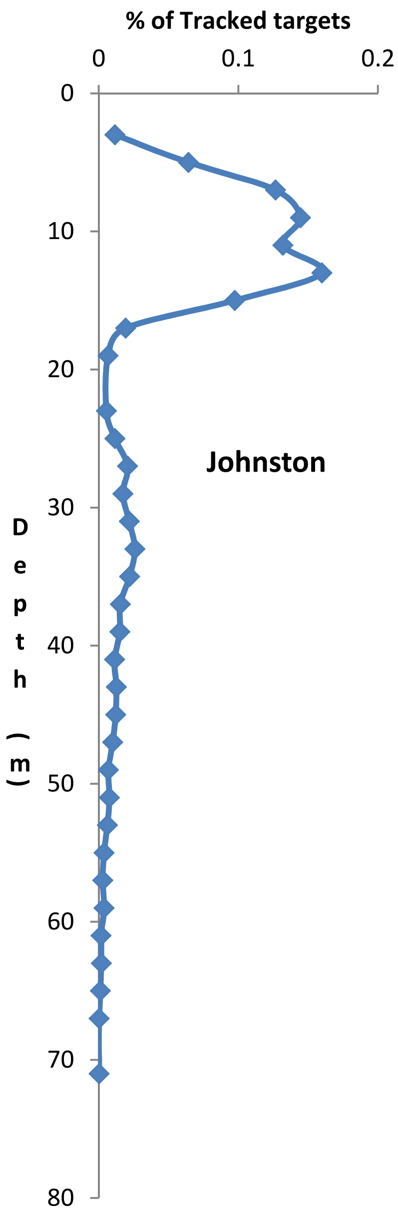


Figure 36. Johnston lake vertical distribution of tracked targets

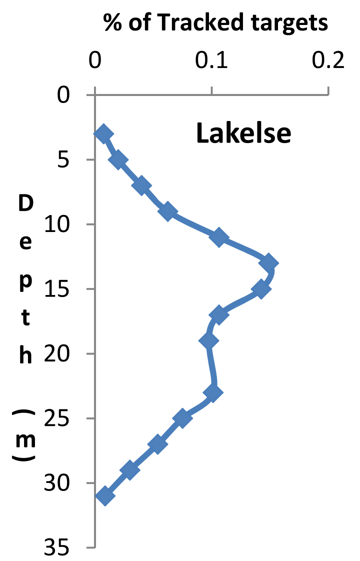


Figure 37. Lakelse lake vertical distribution of tracked targets

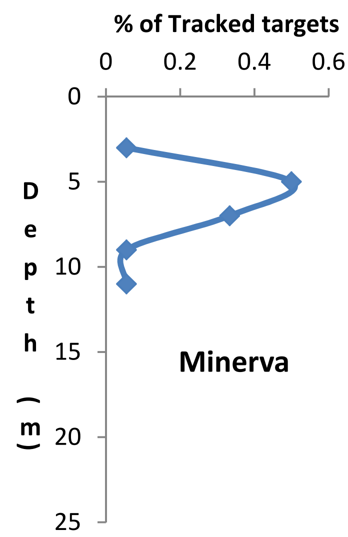


Figure 38. Minerva lake vertical distribution of tracked targets

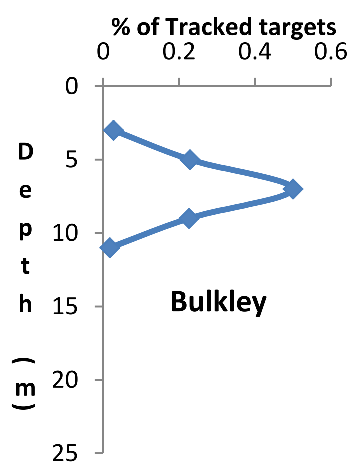


Figure 39. Bukley lake vertical distribution of tracked targets

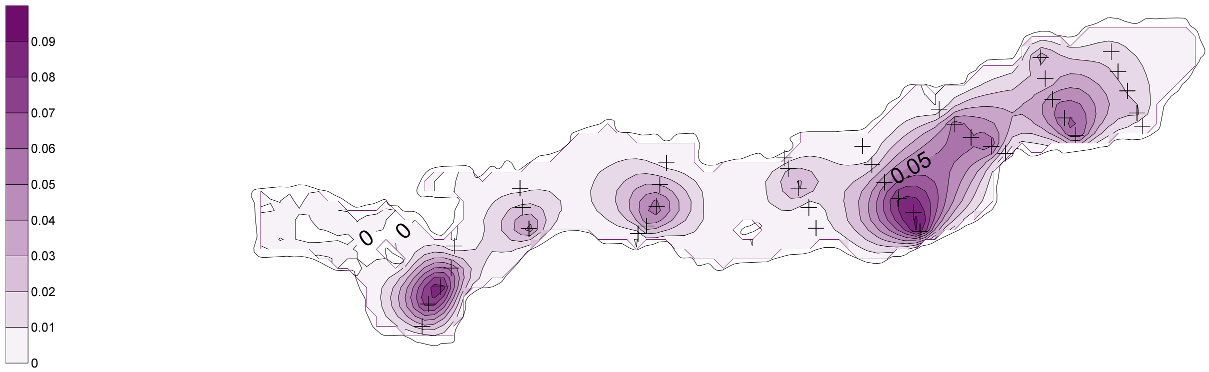


Figure 40. McDonell lake horizontal distribution of tracked target density (tracked targets/m^3)

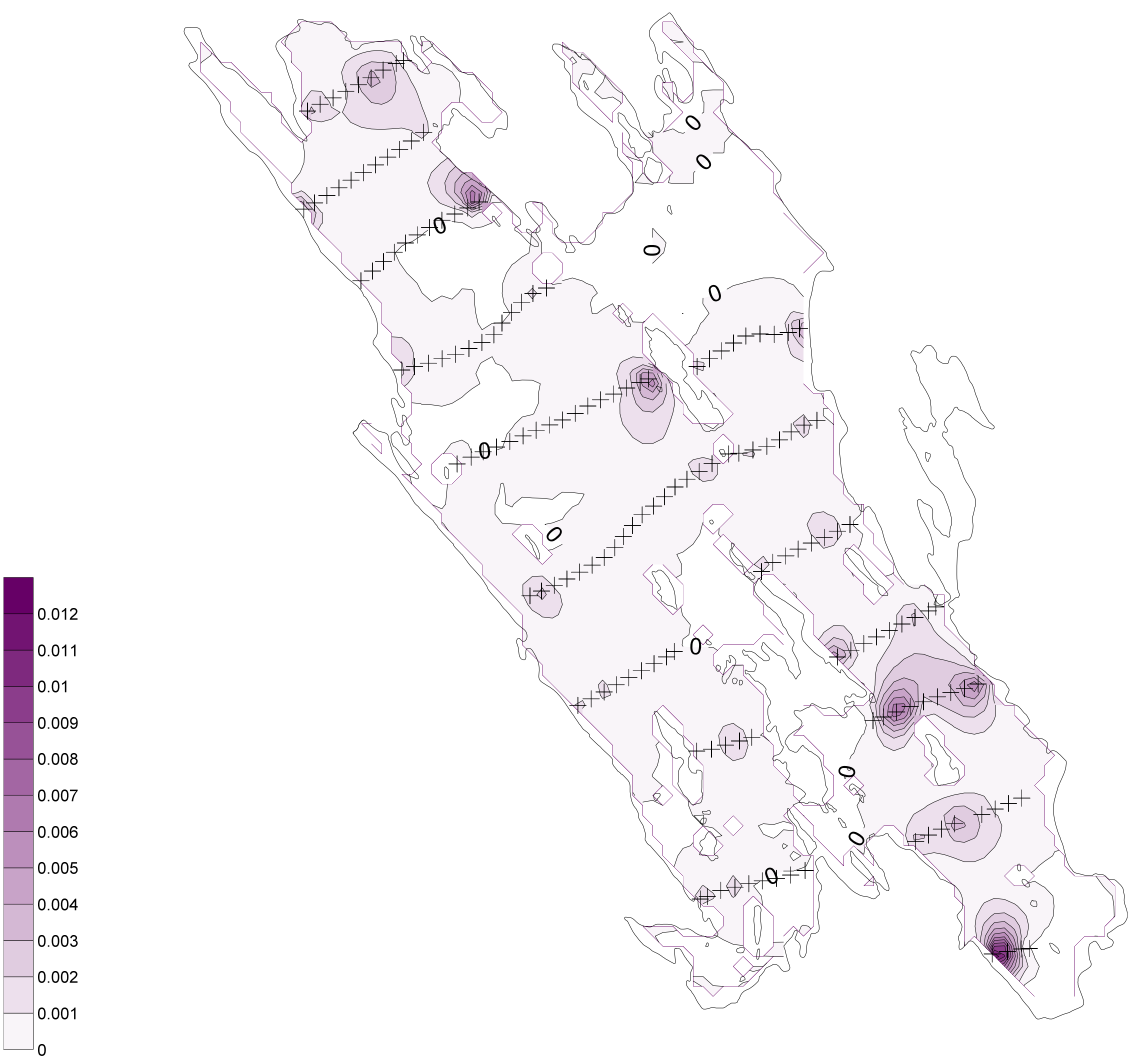


Figure 41. Swan lake horizontal distribution of tracked target density (tracked targets/m^3). Note different scales.

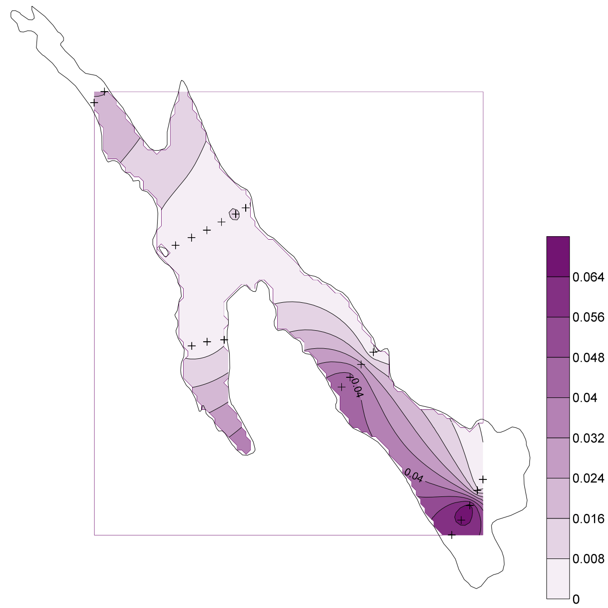


Figure 42. Stephens lake horizontal distribution of tracked target density (tracked targets/m^3)

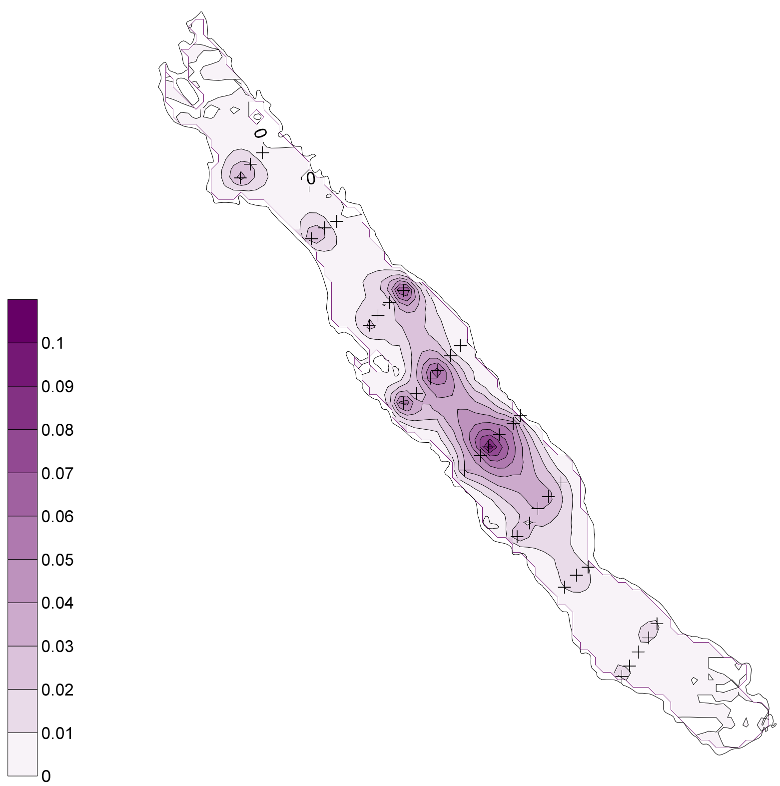


Figure 43. Sustut lake horizontal distribution of tracked target density (tracked targets/m^3). Note different scales.

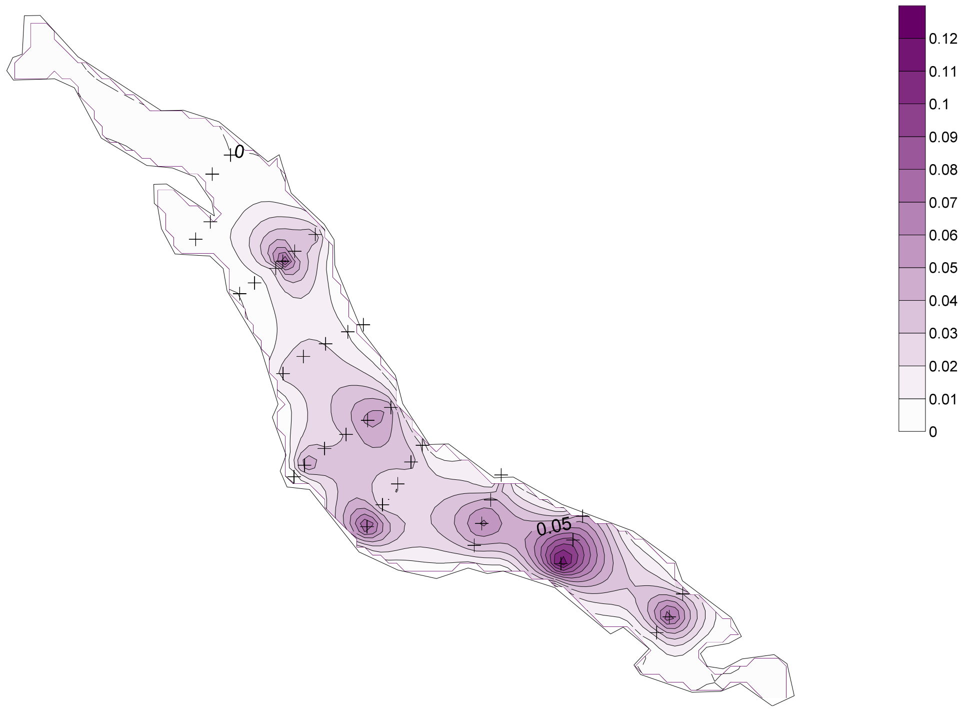


Figure 44. Johanson lake horizontal distribution of tracked target density (tracked targets/m^3)

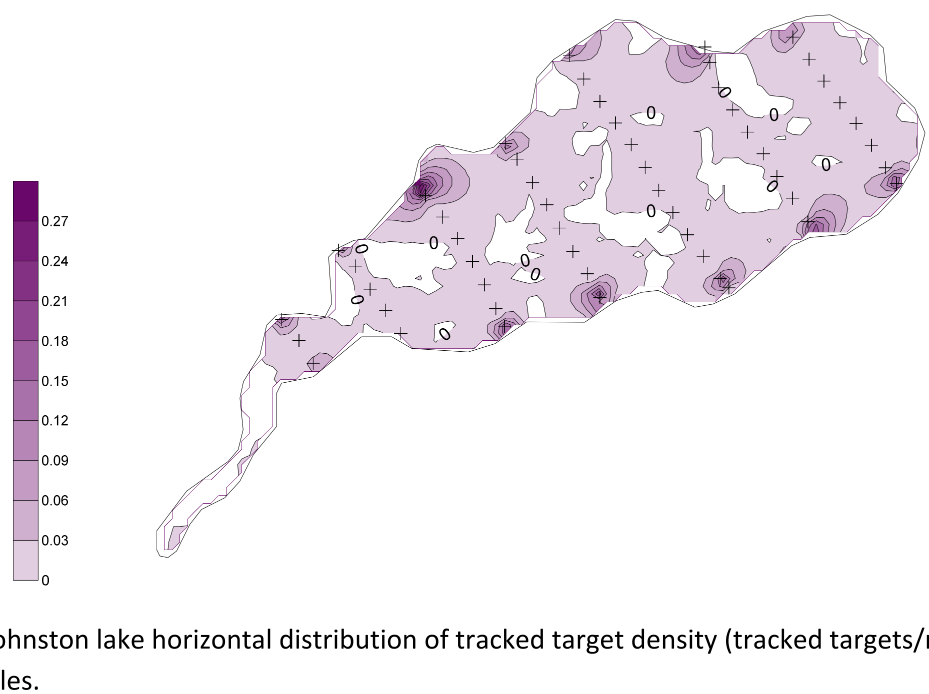


Figure 45. Johnston lake horizontal distribution of tracked target density (tracked targets/m^3). Note different scales.

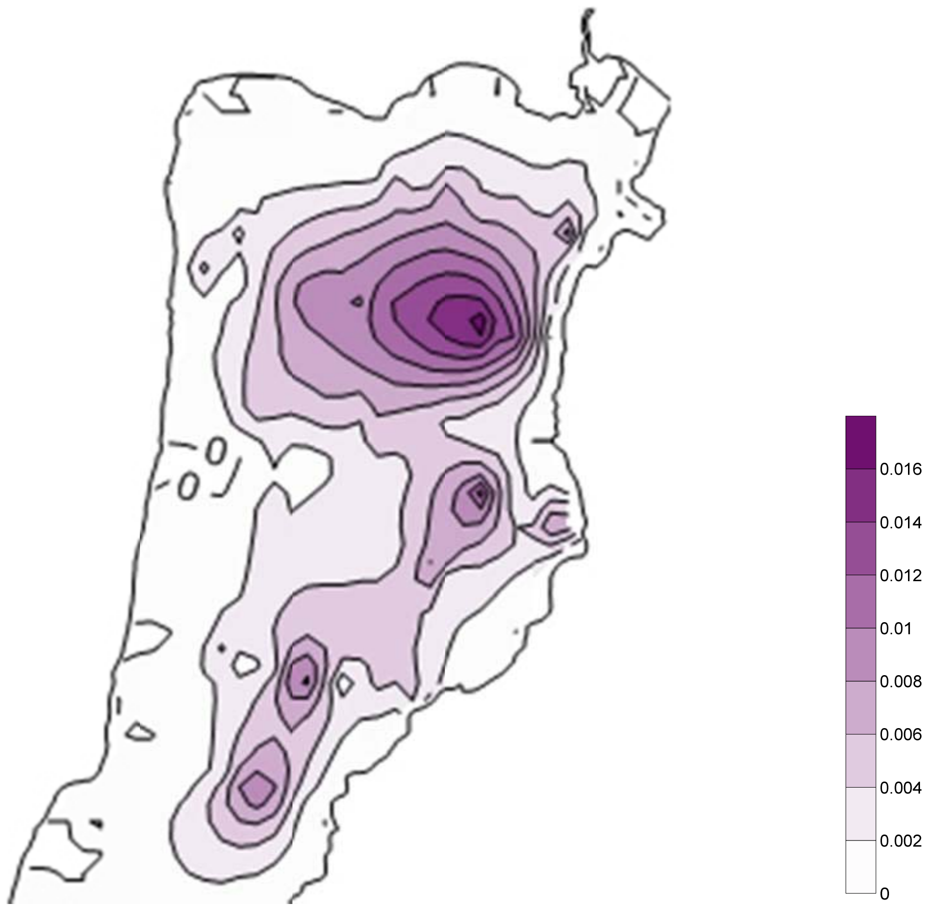


Figure 46. Lakelse lake (north basin only) horizontal distribution of tracked target density (tracked targets/m^3)

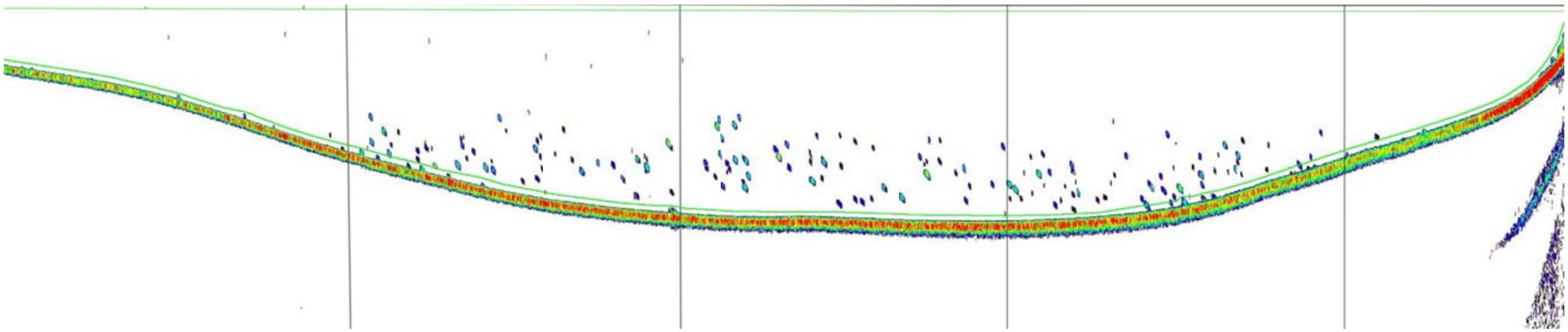


Figure 47. Mcdonell lake transect 4 echogram

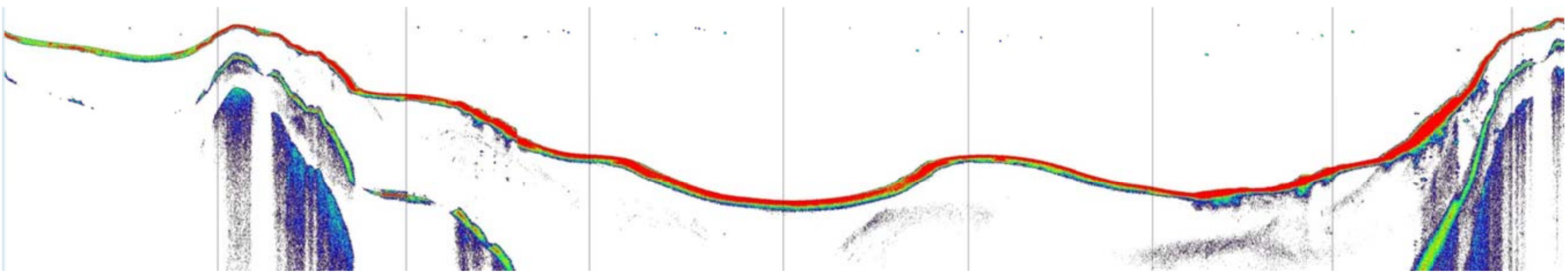


Figure 48. Swan lake transect 15 echogram

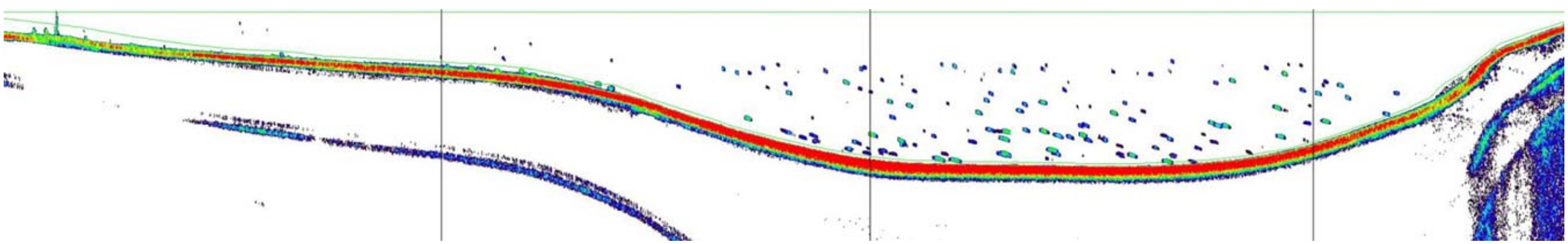


Figure 49. Stephens lake transect 4 echogram

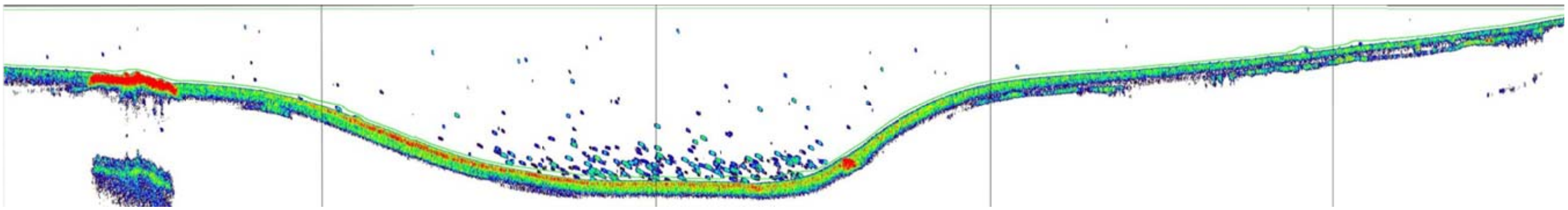


Figure 50. Sustut lake transect 4 echogram

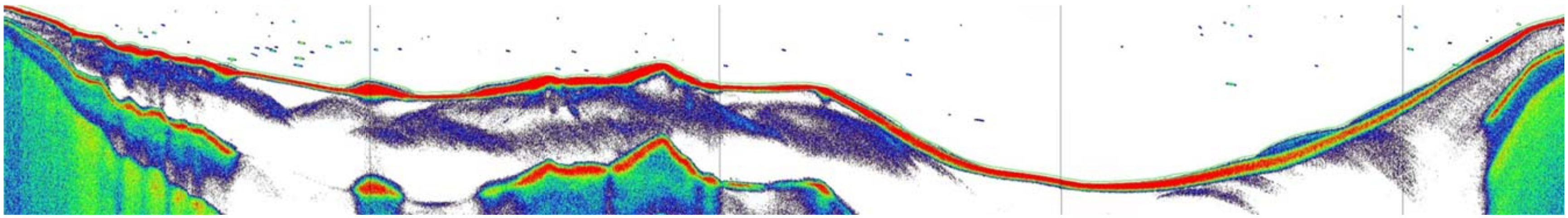


Figure 51. Johansen lake Transect 6 echogram

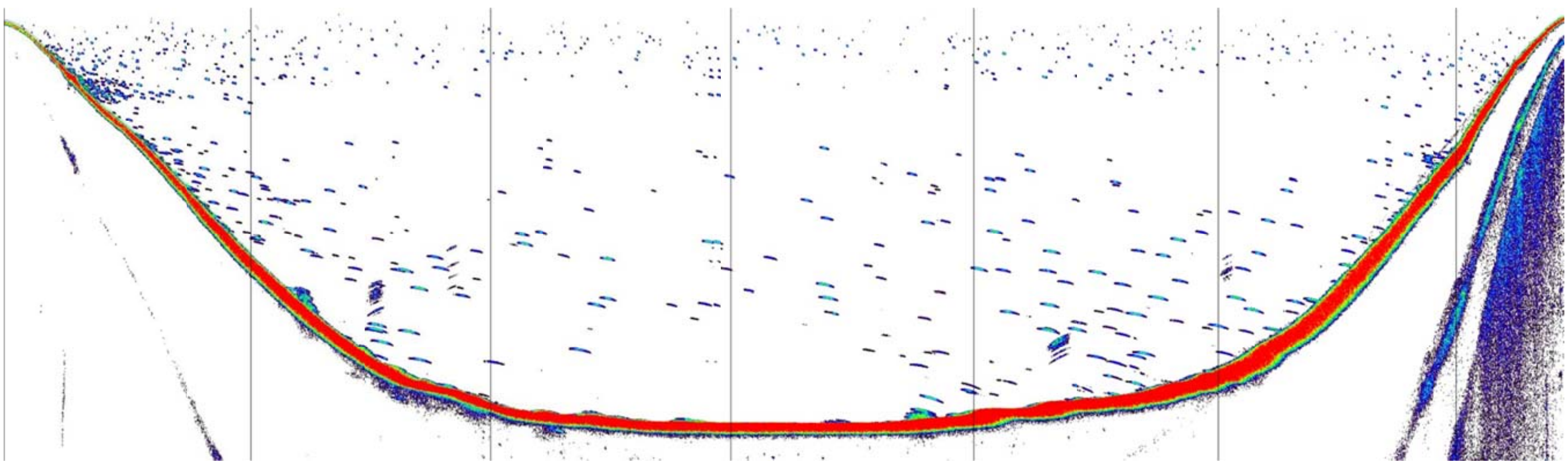


Figure 52. Johnston lake transect 3 echogram

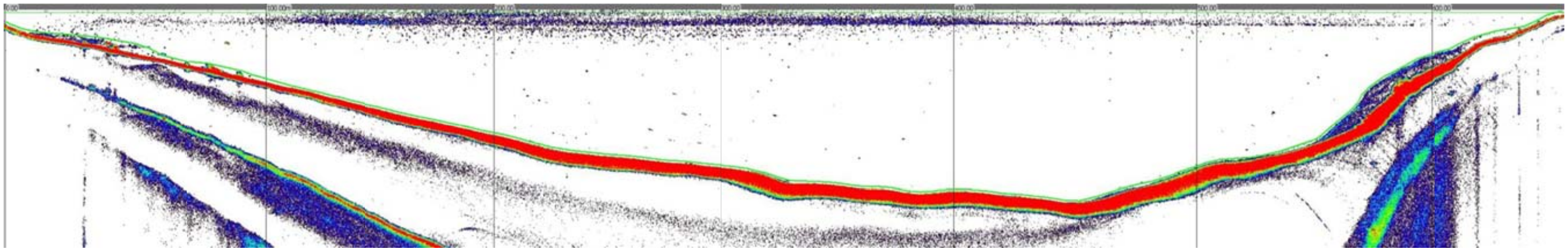


Figure 53. Minerva lake transect 2 echogram

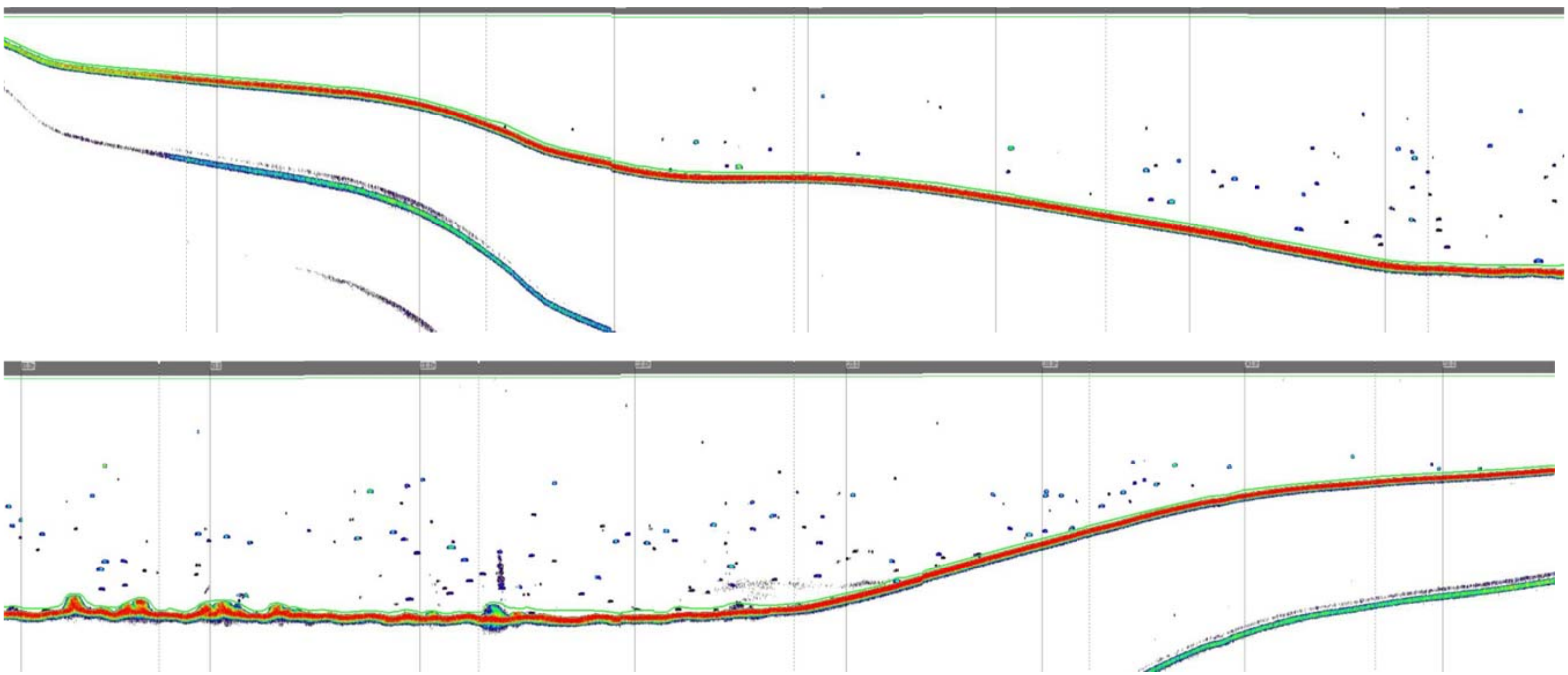


Figure 54. Lakelse lake transect 2.6 echogram

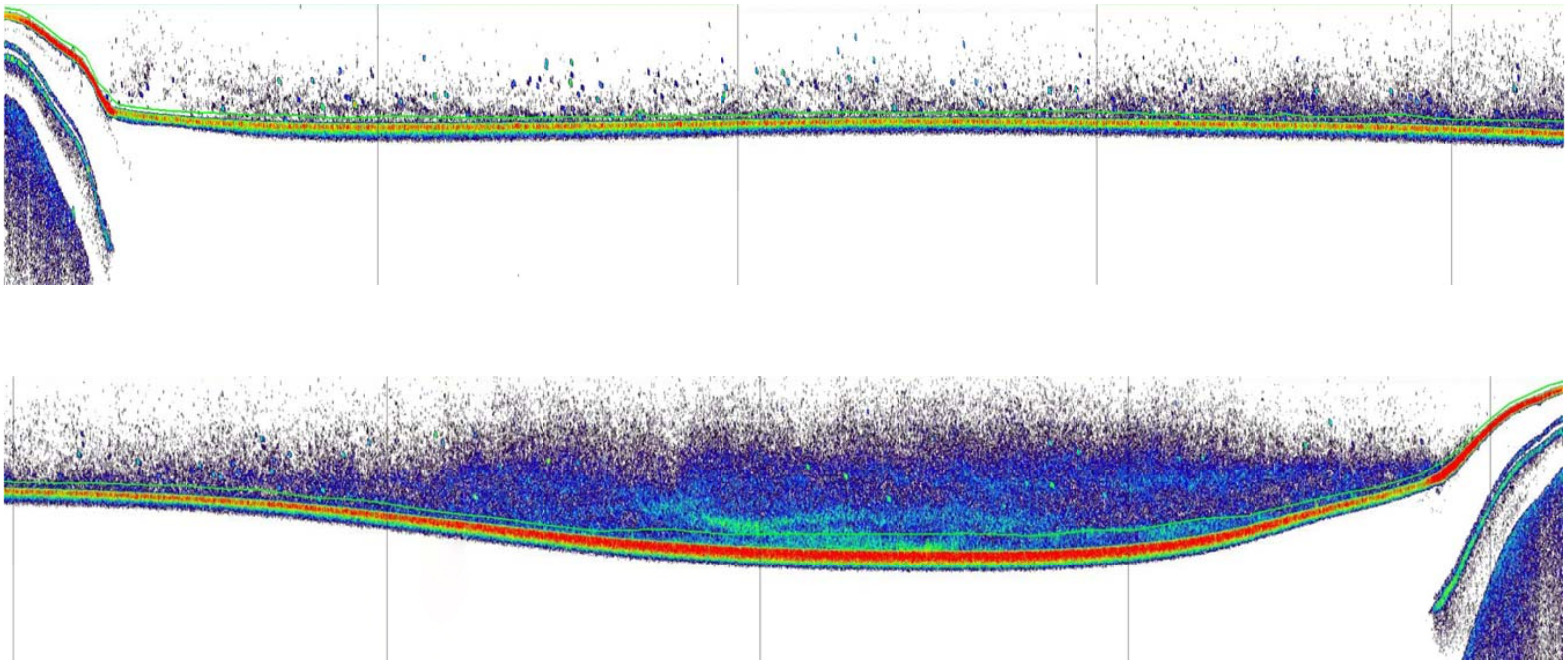
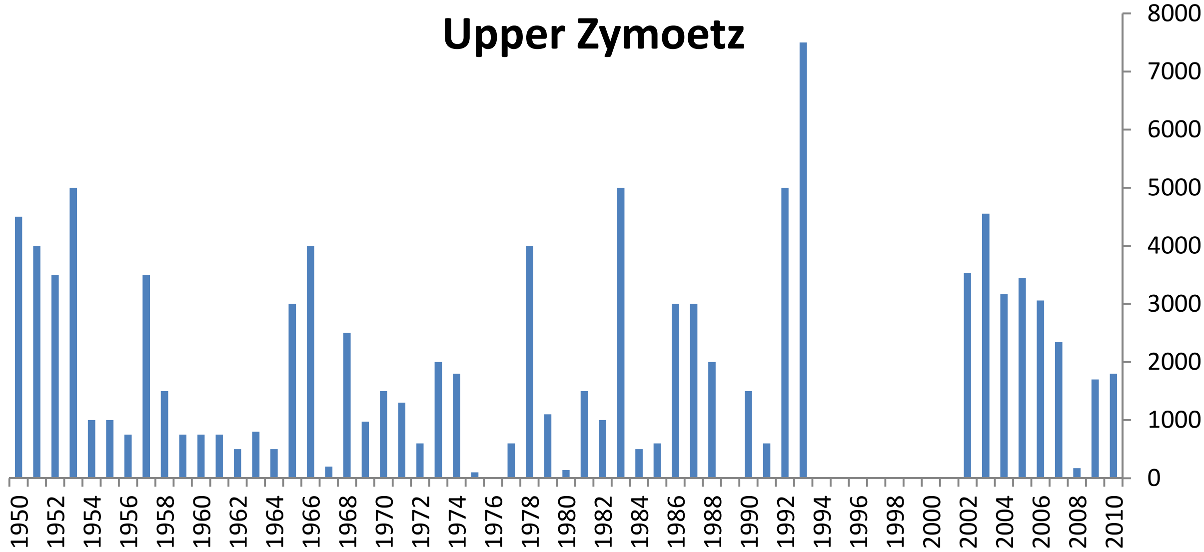
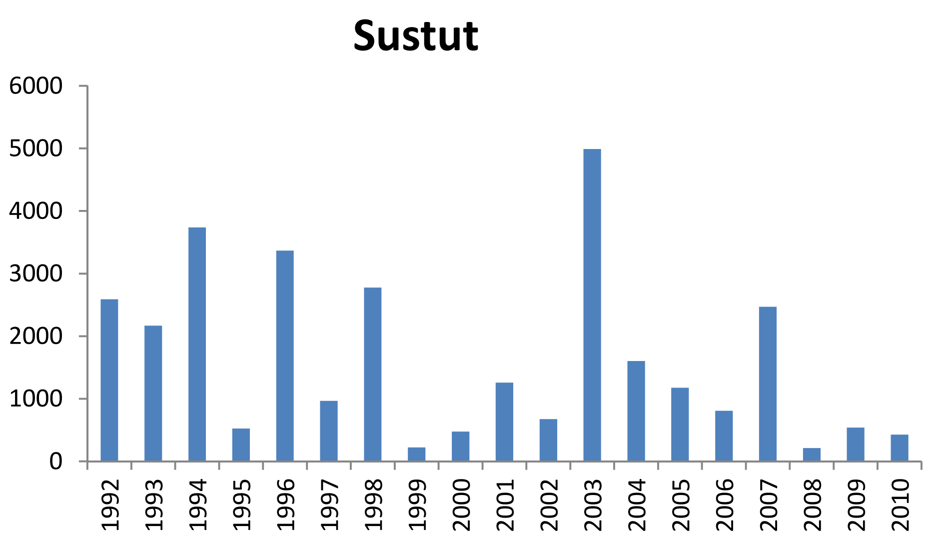


Figure 55. Bulkley lake transect 5 echogram

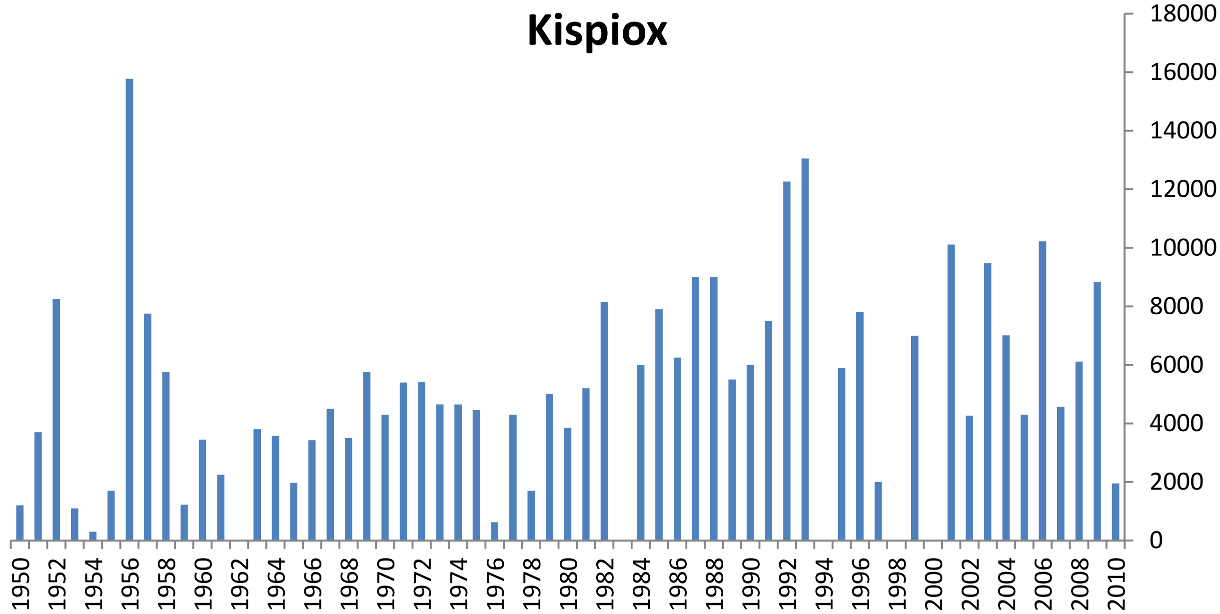
APPENDICES



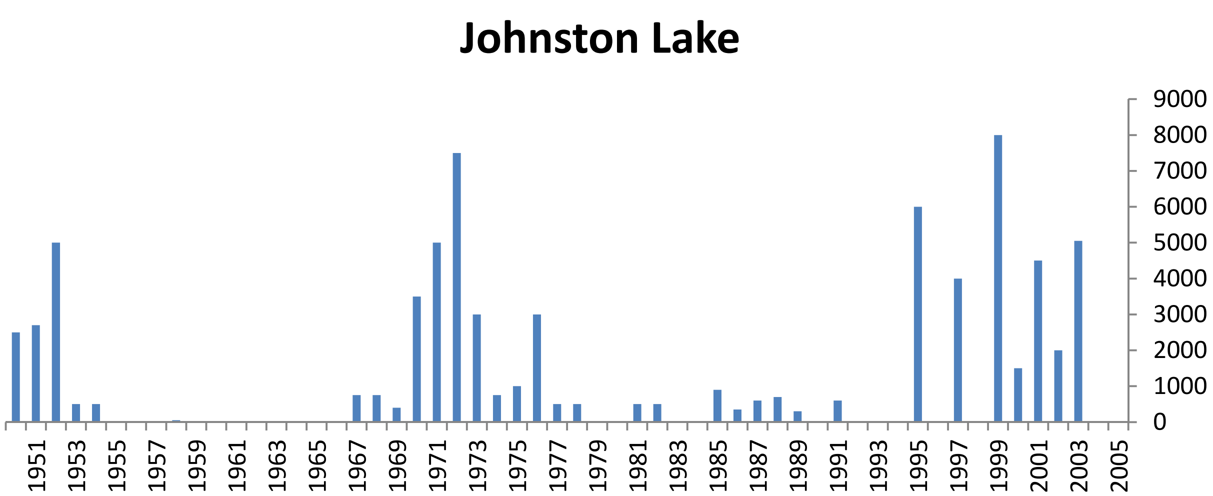
Appendix 1. Upper Zymoetz River sockeye escapement 1950-2010



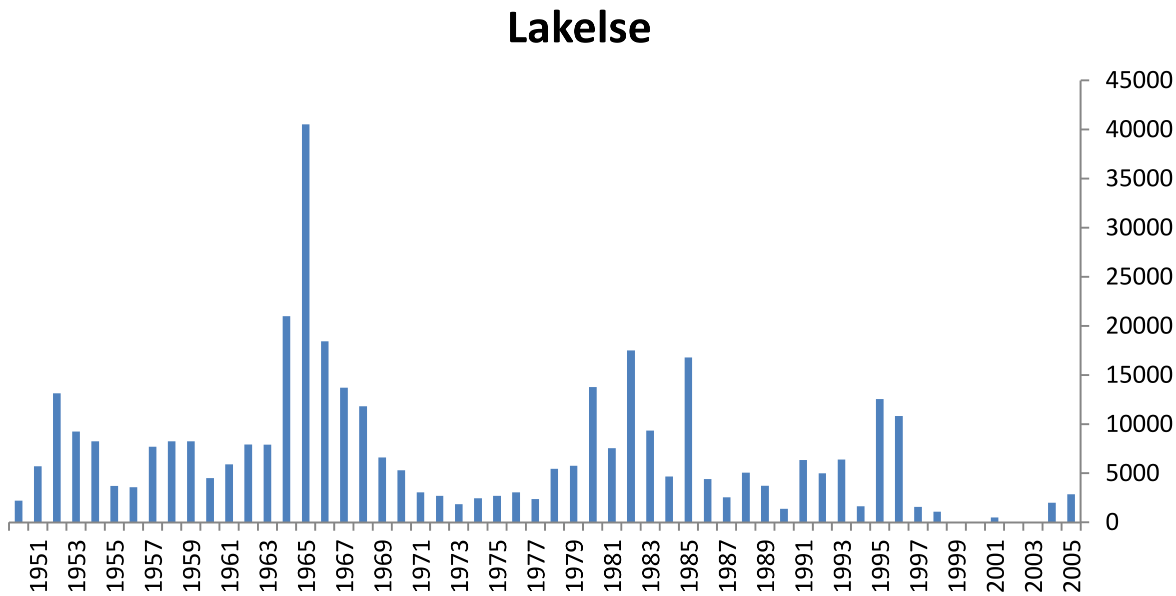
Appendix 2. Sockeye escapement from the Sustut River counting fence 1992-2010



Appendix 3. Aggregate Kispiox Watershed sockeye escapement 1950-2010



Appendix 4. Johnston Lake sockeye escapement 1950-2005



Appendix 5. Lakelse Lake sockeye escapement 1950-2010