2011 Skeena and Nass Lakes Hydroacoustic Surveys

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Abstract

Hydroacoustic surveys were conducted at five sockeye rearing lakes (Alastair, Damdochax, Kitsumkalum, Lakelse, and McDonell Lakes) in the Skeena and Nass watersheds. The main objectives of the surveys were to enumerate and sample the sockeye fry population and to estimate the species composition of each lake. Densities ranged from 291 sockeye fry per hectare at Kitsumkalum Lake to 1,830 sockeye fry per hectare at Alastair Lake. Juvenile sockeye were the dominant species in all of the lakes surveyed except for at Alastair Lake, where threespine stickleback dominated the pelagic limnetic environment. While the sockeye fry populations of each of the surveyed lakes appears to be stable compared to estimates from hydroacoustic surveys of previous years, the fry biomass appears to be less than the estimated rearing capacity (Cox-Rogers et.al. 2004) for each lake with the exception of Alastair Lake.

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Introduction

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

Hydroacoustic surveys were conducted at five sockeye rearing lakes in the Skeena and Nass watersheds during the late summer and fall 2011 (Figure 1). The main objectives for these surveys were to estimate the sockeye population size and the relative proportions of juvenile sockeye and competitor limnetic species of each lake.

Alastair Lake is located at the headwaters of the Gitnadoix River, a third order tributary of the Skeena River west of Terrace. Alastair is a clear, productive lake which contains a large population of three-spined stickleback, which may compete for food resources with juvenile sockeye fry (Shortreed, MacLellan and Hume 2010). There was a comparatively large return of sockeye to Alastair Lake in 2010, the brood year for the 2011 fall fry population. The 2010 sockeye escapement to Alastair was 6,800 adults, much higher than the 2000-2009 decadal average of 1,015 adults (Appendix 1, Fisheries and Oceans Canada 2011a). Visual escapement estimates at the Alastair Lake tributaries are complicated by a known population of lakeshore spawners. The last hydroacoustic survey at Alastair Lake was conducted in 2009 by Fisheries and Oceans Canada's Cultus Lake Division. Alastair Lake is within the traditional territories of the Allied Tribes of Lax Kw'alaams.

Damdochax Lake is located at the headwaters of the Damdochax River, a fifth order tributary to the Nass River. Gitksan Watershed Authorities (GWA) conducts annual spawning escapement enumeration counts at Damdochax spawning grounds. Damdochax Lake is located within the traditional territories of the Gitxsan Nation, House of Wiiminosik.

Kitsumkalum Lake is located in the middle of the Kitsumkalum River, a fifth order tributary of the lower Skeena River. Kitsumkalum is a large, deep lake with a surface area of 1,850 hectares, average depth of 75m, and maximum depth of 140m (Table 1). This lake is glacially turbid, and the least productive of all of the lakes surveyed in 2011. Sockeye escapements to Kitsumkalum River have increased steadily since the early 2000s, following the reconstruction of artificial spawning channels that were originally built near the north end of the lake (Gottesfeld and Rabnett 2008). The 2010 sockeye return to Kitsumkalum River was 10,900 spawners, following a decadal average of 5,040 between 2000 and 2009 (Fisheries and Oceans Canada NuSEDs database). Past hydroacoustic surveys were conducted by the Cultus Lake group in 2005, and Skeena Fisheries Commission in 2007 and 2009. Kitsumkalum Lake is in the traditional territory of the Kitsumkalum First Nation.

Lakelse Lake is the source of the Lakelse River, a fifth 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 $1.15x10^8$ m^3 (Table 1). 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 contains 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 Watershed and is considered to be a

Lakelse Lake since 2006. Lakelse is the warmest lake in the Skeena Watershed and is considered to be a very productive system. Sockeye escapement to Lakelse tributaries has been depressed since the 1990s, though appear to have improved somewhat in the past two years. The estimated sockeye escapement to Lakelse tributaries in 2010 was 5,837, higher than the previous decadal average of 2,265 (Fisheries and Oceans Canada 2011a). Preliminary escapement estimates for 2011 were greater than 10,000 (Fisheries and Oceans Canada, 2011b). Lakelse Lake is located in the traditional territory of the Allied Tribes of Lax Kw'alaams.

McDonell Lake is the lowest of a chain of three lakes at the eastern headwaters of the Zymoetz River. The Zymoetz, also known as the Copper River system, is a 6th order tributary of the Skeena River and drains an area of 3,028 km^2 (Hall and Harris 2007). McDonell is a clear, productive lake with a mean depth of only 8m. Gitksan Watershed Authorities have conducted annual sockeye spawning escapement counts in the upper Zymoetz since 2002. Gitksan Watershed Authorities (GWA) and the SFC have conducted annual hydroacoustic surveys at McDonell Lake since 2005. McDonell Lake is located within the traditional territories of the Gitxsan and Wet'suwet'en First Nations.

Table 1. Physical characteristics of lakes surveyed in 2011

Lake	Watershed	Watershed Drainage (km2)	Elevation (m)	Average Depth (m)	Maximum Depth (m)	Surface Area (ha)	Clarity
Alastair	Gitnadoix	546	45	21	79	686	Clear
Damdochax	Damdochax	116	590	10	21	148	Clear
Kitsumkalum	Kitsumkalum	2,255	45	75	140	1,850	Glacial
Lakelse	Lakelse	589	77	9	32	1,360	Clear
McDonell	Zymoetz	3,028	828	8	15	232	Clear

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, and both forms are referred to as "O. nerka" in this report.

Methods

Acoustic sampling

Hydroacoustic surveys were conducted using similar methods and technology as in previous years (Hall 2007, 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 single downward-pointing transducer was pole-mounted to our inflatable vessel, a Bombard Commando C-4. Hydroacoustic data were collected to an acoustic threshold of -100 dB using Biosonics Visual Acquisition software as the vessel proceeded along transects at a constant speed of 0.7 m/sec.

The hydroacoustic survey at Alastair Lake (Figure 2) was conducted along transects that were established prior to the 2011 survey. Hydroacoustic surveys at Damdochax (Figure 3), Kitsumkalum (Figure 4), Lakelse (Figure 5), and McDonell (Figure 6) lakes were conducted along transects that had been established during previous surveys. The Damdochax Lake survey was designed in 2007 by SFC. The survey designs for Kitsumkalum, Lakelse and McDonell lakes were established by the Cultus Lake Laboratory of Fisheries and Oceans Canada.

Hydroacoustic estimates are based on lake volumes that were calculated using bathymetric maps produced from lake depth data collected during our surveys at Alastair (Figure 7) and Damdochax lakes. Lake volumes were previously calculated for Kitsumkalum, Lakelse, and McDonell lakes using bathymetric maps provided by the provincial Ministry of Environment.

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. 5.00). Data analysis was conducted using the same methodology as in previous years (Hall & Carr-Harris 2008, Hall 2007). Target densities were calculated using two 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 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. Data from the down-looking transducer were analyzed separately for each transect in 2m depth layers for Damdochax, Kitsumkalum, Lakelse, and McDonell lakes, and in 4 m depth layers for Alastair Lake.

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” 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 decibels. 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. In addition, Swedish gillnets were used to capture fish from 0-2m depth in the littoral zones at Lakelse Lake. These gillnets consisted of 4 variable mesh sizes between ½" and 1". Gillnets were set at dusk and allowed to soak for the duration of the survey.

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

Temperature and Dissolved Oxygen

Temperature 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 was not collected during the 2011 program because of equipment failure.

Results and Discussion

Alastair Lake

Alastair Lake was surveyed on the nights of August 29 and 30, 2011. The surface temperature was 15.3^{o}C degrees, with a gradual decline to 11.3 ^{o}C at 7 m, and a thermocline between 7 and 11 m with another gradual decline to a hypolimnion of 5 ^{o}C below 21 m (Figure 8).

We captured 59 age-0 O. nerka and 132 threespine sticklebacks (*Gasterosteus aculeatus*) during three trawl tows with a combined length of about 1.6 km (Table 2). We also captured 12 juvenile coho (*Oncorhyncus kisutch)* and two threespine sticklebacks in one gillnet, which was set for a very short period of time (Table 3). The average length of O. nerka fry captured by trawl was 46.8 mm, with an average weight of 1.0 grams. The average length and weight of trawl captured sticklebacks was 51.2 mm and 1.4 grams, respectively (Table 4). All of the O. nerka fry were age-0, or young of the year fry.

Hydroacoustic data were collected from eleven transects across the long axis of the lake. Most fish targets were found above 30 m depth in the water column, with peak densities occurring at the thermocline depth of 10m depth (Figure 13). High densities of fish targets were observed throughout Alastair Lake, primarily concentrated in the south end (Figure 18). The hydroacoustic estimate for "small" size fish in Alastair Lake ranged from 4.2 x 10^6 (Integration) to 4.4 x 10^6 (Tracked target) (Table 5). "Small" fish densities ranged from 5,981 (Integration) to 6,197 (Tracked target) fish per hectare (Table 5). "Large" fish densities ranged from 6 (Integration) to 8 (Tracked target) fish/hectare (Table 5). Based on our trawl catch, approximately one third of the "small" fish estimate can be apportioned as age-0 O. nerka. Thus the age-0 O. nerka population is estimated at 1.3 x 10^6, with a biomass of 1,311 kg (Table 6).

The PR capacity model (Cox-Rogers et. al 2004) provides a benchmark that can be used to compare an observed sockeye fry biomass with the rearing capacity of a given lake. According to the PR capacity model, the biomass of O. nerka fry observed during the 2011 hydroacoustic survey represents 77% of the rearing capacity, or R_{max}, at Alastair Lake (Table 6).

The 2011 Alastair Lake fall fry population estimate is significantly higher than the 2009 hydroacoustic estimate of 3.7 x 10^5 (MacLellan and Hume, 2011, Table 7). The numbers of "small" fish observed at Alastair lake were similar in 2009 and 2011, at 4.4 x 10^6 and 4.3 x 10^6 respectively, but the proportion of trawl captured O. nerka age-0 O. nerka was much higher in 2011 than in 2009. Furthermore, the 2009 trawl catch included an equal proportion of age-0 and age-1 O. nerka (MacLellan and Hume 2011), while the 2011 trawls captured only age-0 O. nerka. This difference might be because the adult sockeye escapement to Alastair Lake of 6,800 in 2010 was so much larger than the 2009 return of 1,250 (DFO 2011a), that the age-0 year class dominated the 2011 fall fry population. The 2008 return to Alastair Lake was presumably low, with only a few adult sockeye observed compared to the 2007 adult sockeye return of 1,000 *(*DFO 2011a), which might have created the opposite effect, with a greater contribution from the 2007 brood *y*ear causing age-1 O. nerka to dominate the fall fry population in 2009. Another factor to consider is the potential size bias introduced by the trawl net, which might select for smaller fish (McQueen *et. al.* 2007).

Damdochax Lake

Damdochax Lake was surveyed on August 25, 2011. Water levels were higher and surface temperatures cooler than during fall fry surveys in previous years. The surface temperature was 12.8 ^{o}C with a gradual decline to 10.4 ^{o}C at 9 metres depth, and a small thermocline between 9 and 13 meters to a hypolimnion on 8.2 degrees ^{o}C (Figure 9).

Fifty seven O. nerka juveniles were captured in three trawl tows with a combined length of 1.3 km (Table 2). No gillnets were set at Damdochax Lake, and no other fish species were captured during the 2011 survey. The average length of trawl captured O. nerka was 54.5 mm, with an average weight of 1.9 grams (Table 4). All of the O. nerka fry captured at Damdochax Lake were age-0.

Most of the fish targets were found mid-water between 5 and 10 meters depth (Figure 16). The highest densities of fish targets were found in the northeast section of the lake (Figure 19). The hydroacoustic estimate for "small" size fish in Damdochax Lake ranged from 1.5 x 10^5 (Integration) to 1.8 x 10^5 (Tracked target). "Small" fish densities ranged from 1,031 fish/hectare (Integration) to 1,241 fish/hectare (Tracked target). "Large" fish densities ranged from 206 fish/hectare (Integration) to 265 fish/hectare (Tracked target).

Since there were no other species of fish captured at by trawl at Damdochax Lake, we can apportion 100% of the "small" size class from the hydroacoustic estimate to age-0 O. nerka. Given the average weight from the trawl sample, the estimated biomass is 290 kg, or 25% of R_{max} .

Kitsumkalum Lake

Kitsumkalum Lake was surveyed on August 4 and 5, 2011. The surface temperature was relatively cool at 12.4°C with a gradual decline to a thermocline between 11 and 15 metres depth, and a steady decline to 9.2 °C at 29 meters depth, the bottom of our temperature profile (Figure 10).

We captured 56 O. nerka juveniles and two threespine stickleback in two trawl tows with a combined distance of 1.7 km. No gillnets were set at Kitsumkalum Lake. The average length and weight for O. nerka fry was 40.4 mm and 0.8 grams respectively. All of the O. nerka fry were age-0.

Acoustic data were collected from seven transects across the long axis of the lake. Most fish targets were located in the top 15 meters of the water column (Figure 14) in the north end of the lake (Figure 20). The hydroacoustic estimate for "small" size fish in Kitsumkalum Lake ranged from 5.0×10^5 (Tracked target estimate) to 5.5×10^5 (Integration) (Table 5). "Small" fish densities ranged from 271 fish/hectare (Tracked target) to 589 fish/hectare (Integration). The "large" fish density was 2 fish/hectare using both the Integration and Tracked target analysis methods (Table 5).

Based on the trawl catch, 98.2% of the "small" size class hydroacoustic estimate can be assigned to age-0 O. nerka. The observed biomass for age-0 O. nerka at Kitsumkalum Lake is 438 kg, or 9% of R_{max} (Table 6). While the observed fall fry population at Kitsumkalum Lake is far below the rearing capacity, the 2011 hydroacoustic estimate is similar to that of past years (Table 7).

Lakelse Lake

Lakelse Lake was surveyed on the night of September 2 and 3, 2011. Due to high winds, we did not complete trawling on the first night of the survey and were unable to return until October 1. The acoustic survey was completed on the first night, however the choppy conditions caused the fish tracks to break up in the echograms. As a result, the Integration estimate is the only method of analysis available for this survey.

During the first night of our survey, the surface temperature was 15 °C, with an epilimnion to 11 meters depth, a thermocline between 19 and 23 metres, and a hypolimnion of 11 degrees below 23 metres. By October 1, the water column was nearly isothermal, with an epilimnion of 11.5 °C between 0 and 11 metres depth, then a gradual decline to 10.4 °C at 25 meters depth.

We captured five O. nerka fry and one prickly sculpin (*Cottus asper*) in three trawls with a combined length of 1.1 km on September 2. The average length and weight of trawl-captured O. nerka on September 3 were 62.8 mm and 3.1 grams, respectively. On October 1, we captured 13 O. nerka fry, 9 prickly sculpin, 4 threespine stickleback, and 3 lamprey (*Lampetra* spp.) in ten trawls with a combined length of 5.7 km. The lamprey were too small to identify by species. By October 1, the average length of trawl captured O. nerka was 69.9 mm with an average weight of 4.2 grams. We set two gillnets on October 1, with a combined soak time of 28 hours. The gillnet catch included five age -0 O. nerka, two large whitefish (*Prosopium sp.*), three redside shiners (*Richardsonius balleatus*), six large rainbow trout (*Oncorhyncus mykiss*), one large bull trout (*Salvelinus confluentus*), and one spawned-out adult male sockeye. The average length and weight of gillnet captured O. nerka fry were 81.5 mm and 5.2 mm respectively (Table 4). All O. nerka from both nights of trawling and gillnets were age-0.

Acoustic data were collected from seven transects in the north basin, and one transect in the south basin of the lake. Most of the fish targets were at the bottom of the water column, below 10 m depth (Figure 15). Within the north end of the lake, most fish targets are found in the deepest part of the lake at the center of the north basin (Figure 21). The hydroacoustic estimate for "small" fish in the north basin of Lakelse Lake was 3.9 x 10^5 (Integration estimate) with a density of 618 fish/hectare (Table 5). The "large" fish density was 61 large fish/hectare, for a total population estimate was 3.8 x 10^4 (Table 5).

Few fish were captured by trawl at Lakelse, but if we consider the entire catch from both nights of trawling, excluding sculpin and lamprey, which do not have air bladders, 83% of the trawl catch consisted of age-0 O. nerka. A rough estimate of biomass can be made by using the average weight from the first night of trawling (conducted at the same time as the acoustic survey). The biomass estimated in this manner is approximately 1003 kg, or 8% of R^{max}.

We observed 7.3 x 10^4 "small" and no "large" fish in the south end of Lakelse Lake. This estimate is based on a single transect, and this is a noteworthy contribution to the total population estimate of 4.6 x 10^5 for Lakelse Lake. Future surveys should include additional transects and gillnetting in the south end of the lake.

Acquiring a sufficient fish sample at Lakelse Lake has been challenging for the past two years. It is likely that in this productive system, fry quickly grow large enough to be able to escape the trawl net. Adequate trawl samples were collected during hydroacoustic surveys in 2008 and 2009, which were both conducted earlier in the season. We recommend that future surveys at Lakelse be conducted prior to the middle of August for this reason.

McDonell Lake

McDonell Lake was surveyed on August 22, 2011. The surface temperature was cool, at 14 ^oC, with a thin epilimnion to a depth of 1 meter. There was a weak thermocline between 3 and 7 meters, and a hypolimnion of 12.4 ^oC below 11 meters.

We captured 102 O. nerka fry during five trawls with a combined length of 1.5 km. No gillnets were set and no other fish species were captured at McDonell Lake. The average length of trawl-captured O. nerka fry was 49.4 mm, with an average weight of 1.4 grams (Table 4). All O. nerka fry were age-0.

Acoustic data were collected from eight transects across the long axis of the lake, and from zigzags between each transects. Only the data from the transects and not the zigzags, were considered during data analysis for this report. Fish targets were mostly clustered between a depth of 10 meters and the bottom of the water column (Figure 17), and were horizontally distributed relatively evenly throughout the lake (Figure 22). Hydroacoustic estimates ranged from 3.3 x 10^5 (Integration) to 3.6 x 10^5 (Tracked target) "small" class fish, with densities between 1,535 (Integration) and 1,683 (Tracked target). "Large" fish densities ranged from 33 (Integration) to 42 (Tracked target) fish per hectare.

Based on the trawl catch, 100 % of the "small" class hydroacoustic estimate may be apportioned to age-0 O nerka. The observed biomass is 461 kg, or 47% of R^{max}.

Conclusion

Hydroacoustic surveys allow us to gauge trends in fry populations in lakes that represent ongoing or potential conservation concerns. Regular hydroacoustic surveys provide a baseline that we can use to compare estimates across years. Where escapement is known, hydroacoustic data provides an indicator of freshwater survival.

The 2011 fall fry population estimates at Damdochax, Kitsumkalum, Lakelse and McDonell Lakes appear to be similar to hydroacoustic estimates generated in recent past years (Table 7). The O. nerka fry population appears to be stable but less than the rearing capacity of each of these lakes. The portion of the rearing capacity used in 2011 ranged between 8% and 47%. The productivity of Lakelse and Kitsumkalum Lakes (8% and 9%) is especially poor. The increased sockeye fry population at Alastair Lake likely reflects improved escapement to that system in 2010.

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References

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

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

Carr-Harris 2009 (2). Skeena and Nass Sockeye Lakes Hydroacoustic Surveys 2008. Skeena Fisheries Commission, prepared for the Pacific Salmon Commission.

Carr-Harris 2009 (3). McDonell Lake Hydroacoustic Surveys 2008. Skeena Fisheries Commission, Prepared for Gitksan Watershed Authorities.

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

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

Hall and Harris 2007. McDonell and Stephens Lakes Hydroacoustic Survey Report 2005. Gitksan Watershed Authorities. Prepared for Fisheries and Oceans Canada.

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

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

Fisheries and Oceans Canada 2011a. NuSEDs database.

Fisheries and Oceans Canada 2011b. 2011 Post-Season Review: Salmon North Coast Areas 1-6 & Central Coast Areas 7-10.

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

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

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

MacLellan, S.G., and Hume, J.M.B. 2010. An Evaluation of Methods Used by the Freshwater Ecosystems Section for Pelagic Fish Surveys of Sockeye Rearing Lakes in British Columbia. Fisheries and Oceans Canada, Science Branch, Pacific Region. Canadian Technical Report of Fisheries and Aquatic Sciences 2886.

MacLellan, S.G., and Hume, J.M.B. 2011. Pelagic Fish Surveys of 20 Lakes in Northern British Columbia From: 2006 to 2009. Salmon and Freshwater Ecosystems Division, Science Branch, Pacific Region. Cultus Lake Salmon Research Laboratory, Fisheries and Oceans Canada. Canadian Technical Report of Fisheries and Aquatic Sciences 2950.

Macphail, J.D. The Freshwater Fishes of British Columbia. 2007. University of Alberta Press.

McQueen, D.J., K.D. Hyatt, D.P. Rankin, and C.J. Ramcharan. 2007. Changes in algal species composition affect juvenile sockeye salmon production at Woss Lake, British Columbia: A lake fertilization and food web analysis. North American Journal of Fisheries Management. 27: 369-386.

Parker-Stetter, S., Rudstam, L., Sullivan, P., Warner, D. 2009. Standard Operating Procedures for Fisheries Acoustic Surveys in the Great Lakes. Prepared for the Study Group on Fisheries Acoustics in the Great Lakes, Great Lakes Fishery Commission. Special Publication 09-01.

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

Shortreed, K.S., J.M.B. Hume, K.F. Morton, and S.G. MacLellan. 1998. Trophic status and rearing capacity of smaller sockeye nursery lakes in the Skeena River system. Can. Tech. Rep. Fish. Aquat. Sci. 2240: 78p.

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

Table 2. 2011 Hydroacoustic surveys trawl summary

Lake	Date	Trawl #	Time start	Time end	Distance (m)	Easting Start	Northing Start	Easting End	Northing End	Depth (m)	ON	PS	TS	LP
Alastair	30-Aug-11	1	2110	2119	800	448462	5993479	487610	5993615	12	3		3	
Alastair	30-Aug-11	2	2309	2318	400	487844	5991852	48778	5992326	12	31		75	
Alastair	30-Aug-11	3	2330	2340	400	487837	5992454	487836	5992945	12	25		54	
Damdochax	25-Aug-11	1	2223	2230	200	555548	6262614	555749	6262733	7	8			
Damdochax	25-Aug-11	2	0054	0111	500	555141	6263297	554706	6263567	7	38			
Damdochax	26-Aug-11	3	0117	0128	400	555426	6262792	555258	6263179	7	11			
Kalum	04-Aug-11	1	2310	2330	880	514835	6071454	514882	6072299	10	44			
Kalum	04-Aug-11	2	0002	0020	780	514149	6071464	514846	6071247	10	12		1	
McDonell	22-Aug-11	1	2232	2240	340	589155	6071193	589462	6071386	8	42			
McDonell	22-Aug-11	2	2248	2255	350	589592	6071431	589279	6071250	8				
McDonell	22-Aug-11	3	2327	2335	330	589584	6071195	589982	6071365	8	3			
McDonell	23-Aug-11	4	0041	0046	50	590834	6071418	590844	6071475	8				
McDonell	23-Aug-11	5	0152	0200	380	591260	6071681	591629	6071714	8	57			
Lakelse	02-Sep-11	1	0045	0051	300	529349	6027546	529019	6027609	18	2			
Lakelse	02-Sep-11	2	0054	0058	180	529240	6027651	529071	6027722	21	4	1		
Lakelse	02-Sep-11	3	0110	0122	570	529916	6027644	529347	6027807	21				
Lakelse	01-Oct-11	4	1950	1958	420	529551	6027597	529955	6027399	12	1	3	1	
Lakelse	01-Oct-11	5	2006	2015	480	529023	6027806	529490	6027659	13		3		1
Lakelse	01-Oct-11	6	2029	2039	790	529738	6027375	529007	6027703	16	2	1		
Lakelse	01-Oct-11	7	2052	2109	790	528996	6027810	529831	6027392	18	5		1	
Lakelse	01-Oct-11	8	2112	2129	650	529659	6027446	529072	6027773	18		1		
Lakelse	01-Oct-11	9	2133	2142	370	529305	6027697	529607	6027462	18	1		1	
Lakelse	01-Oct-11	10	2146	2156	400	529002	6027313	529252	6027636	12	2			
Lakelse	01-Oct-11	11	2200	2215	680	529492	6027917	529046	6027351	13	2	1		
Lakelse	01-Oct-11	12	2229	2245	610	529809	6027544	529184	6027774	18			1	
Lakelse	01-Oct-11	13	2247	2259	550	529266	6027873	529780	6027554	16				2

ON: O. nerka fry, PS: Prickly sculpin, TS: Threespine stickleback, LP: Lamprey

Table 3. 2011 Hydroacoustic surveys gillnet summary

Lake	Date	Gillnet #	Easting	Northing	Time Set	Time retrieved	Soak time	ON (fry)	CO	TS	WF	RSS	RT	BT	ON-Adult
Alastair	29-Aug-11	1			1900	1910	< 1		12	2					
Lakelse	01-Oct-11	1	530186	6029034	1905	0845	14	3			2	1	3		
Lakelse	01-Oct-11	2	529705	6029212	1915	0900	14	2				2	3	1	1

ON: Juvenile O. nerka, CO: Juvenile coho, TS: Threespine stickleback, WF: Whitefish species, RSS: Redside shiner, BT: Bull trout, ON Adult: Sockeye adult
Note: WF, RT, BT all large, >15cm length

Table 4. 2011 Fish sample summary

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
Alastair	Gillnet	Coho	12	66.5	53.0	81.0	9.8	4.4	2.1	7	1.7
		Threespine stickleback	2	61.0	57.0	65.0	5.7	1.9	1.6	2.2	0.4
	Trawl	Age- 0 *O. nerka*	59	46.8	33.0	58.0	6.1	1.0	0.3	1.8	0.3
		Threespine stickleback	132	51.2	0.0	68.0	7.5	1.4	0.6	3.3	0.5
Damdochax	Trawl	Age- 0 *O. nerka*	57	54.5	41.0	67.0	6.6	1.9	0.7	3.6	0.7
Kalum	Trawl	Age- 0 *O. nerka*	56	40.4	25.0	50.0	4.9	0.8	0.2	1.5	0.3
		Stickleback	1	27.0	27.0	27.0		0.2	0.2	0.2	
Lakelse	Gillnet	Redside shiner	3	80.3	79.0	82.0	1.5	4.2	3	4.9	1.0
		Age- 0 *O. nerka*	4	81.5	78.0	88.0	4.4	5.2	4	6	1.1
	Trawl	Lamprey	3	103.0	77.0	124.0	23.9	1.7	0.8	2.5	0.9
		Prickly sculpin	10	43.0	27.0	86.0	18.6	1.3	0.2	7.4	2.2
		Age- 0 *O. nerka*	19	67.7	49.0	88.0	10.5	3.9	1.7	7.9	1.7
		Threespine stickleback	4	30.8	29.0	33.0	1.7	0.3	0.3	0.3	0.0
McDonell	Trawl	Age- 0 *O. nerka*	102	49.4	36.0	68.0	6.0	1.4	0.6	3.6	0.5

Table 5. 2011 Hydroacoustic survey estimates

Lake	Estimate method	Class	Density (n/ha)	95 % Confidence Interval (% of n)	Population	95% Confidence interval (n)
Alastair	**Integration**	**Small fish**	**5,981**	**21.9%**	**4,286,378**	**940,072**
		Large fish	**6**	**91.4%**	**4,257**	**3,889**
		Age-0 *O. nerka*	**1,830**	**21.9%**	**1,311,203**	**287,568**
	Tracked Target	Small fish	6,197	25.2%	4,441,357	1,117,030
		Large fish	8	85.4%	5,606	4,788
		Age-0 *O. nerka*	1,896	25.2%	1,358,611	341,699
Damdochax	**Integration**	**Small fish**	**1,031**	**59.3%**	**152,426**	**90,374**
		Large fish	**206**	**68.4%**	**30,418**	**20,819**
		Age-0 *O. nerka*	**1,031**	**59.3%**	**152,426**	**90,374**
	Tracked Target	Small fish	1,241	58.7%	183,570	107,796
		Large fish	265	67.6%	39,144	26,449
		Age-0 *O. nerka*	1,241	58.7%	183,570	107,796
Kitsumkalum	**Integration**	**Small fish**	**296**	**54.8%**	**547,749**	**300,332**
		Large fish	**2**	**128.9%**	**3,713**	**4,785**
		Age-0 O. nerka	**291**	**54.8%**	**538,140**	**295,063**
	Tracked Target	Small fish	271	84.2%	500,482	421,300
		Large fish	2	126.8%	4,417	5,600
		Age-0 O. nerka	266	84.2%	491,702	413,909
Lakelse North Basin	**Integration**	**Small fish**	**618**	**54.7%**	**390,207**	**213,330**
		Large fish	**61**	**78.7%**	**38,432**	**30,234**
		Age-0 O. nerka	**433**	**54.7%**	**273,145**	**149,331**
Lakelse South Basin	**Integration**	**Small fish**	**100**		**73,180**	
		Large fish	**0**		**0**	
McDonell	**Integration**	**Small fish**	**1,535**	**38.0%**	**329,199**	**125,163**
		Large fish	**33**	**49.4%**	**7,132**	**3,524**
		Age-0 O. nerka	**1,535**	**38.0%**	**329,199**	**125,163**
	Tracked Target	Small fish	1,683	36.5%	360,957	131,671
		Large fish	42	48.2%	8,961	4,320
		Age-0 O. nerka	1,683	36.5%	360,957	131,671

Bold type indicates preferred method of estimation.

Table 6. PR Capacity proportions of 2011 hydroacoustic estimates

Lake	2011 Hydroacoustic Estimate	Estimation method	Average weight (g)	Observed biomass (kg)	Rmax**	% Rmax
Alastair	1.3E+06	Integration	1.0	1,311	7990*	16%
Damdochax	1.5E+05	Integration	1.9	290	1179**	25%
Kalum	5.5E+05	Integration	0.8	438	5000*	9%
Lakelse (north basin)	3.2E+05	Integration	3.1	1,003	12156*	8%
McDonell	3.3E+05	Integration	1.4	461	972*	47%

*Shortreed et. al. 2007, **Shortreed et.al. 2008 `

Table 7. Past hydroacoustic estimates for lakes surveyed in 2010

Lake	Year	Date	Age-0 sockeye		Method	Source
			n/ha	n		
Alastair	2009	13-Sep	544	371,654	Integration	MacLellan and Hume 2011
	2011	**29-Aug**	**1,830**	**1,311,203**	**Integration**	
Damdochax	2007	17-Sep	652	92,262	Integration	Hall and Carr-Harris 2008
	2008	08-Sep	1,665	246,152	Integration	Carr-Harris 2009 (2)
	2009	17-Sep	764	113,017	Tracked targets	Unpublished data
	2011	**25-Aug**	**1,031**	**152,426**	**Integration**	
Kalum	2005	04-Sep	279	516,475	Tracked targets	Hume and MacLellan 2008
	2007	18-Oct	222	410,907	Integration	Hall and Carr-Harris 2008
	2009	01-Sep	325	584,842	Tracked targets	Unpublished data
	2011	**04-Aug**	**291**	**538,140**	**Integration**	
Lakelse (north basin)	2003	30-Sep	90	123,036	Tracked targets	Hume and MacLellan 2008
	2004	25-Sep	158	215,365	Integration	Hume and MacLellan 2008
	2005	05-Sep	288	391,401	Integration	Hume and MacLellan 2008
	2006	10-Oct	128	71086*	Tracked targets	Hall 2007
	2007	26-Sep	218	202474*	Integration	Hall and Carr-Harris 2008
	2008	29-Aug	474	299,149	Integration	Carr-Harris 2008
	2009	25-Aug	719	453,798	Integration	Unpublished data
	2010	30-Sep	385	242900*	Integration	Carr-Harris 2011
	2011	**03-Sep**	**433**	**273,145**	**Integration**	
McDonell	2001	10-Sep	352	75510*	Tracked targets	Hume and MacLellan 2008
	2002	13-Sep	595	127,494	Integration	Hume and MacLellan 2008
	2005	22-Sep	490	190,000	Integration	Hall and Harris 2007
	2006	09-Aug	371	40,318	Integration	Carr-Harris 2009 (1)
	2007	26-Sep	949	203,587	Integration	Carr-Harris 2009 (1)
	2008	18-Aug	1,486	318,614	Integration	Carr-Harris 2009 (3)
	2009	17-Aug	846	181,465	Tracked targets	Unpublished data
	2010	06-Aug	1,607	344,493	Integration	Carr-Harris 2011
	2011	**22-Aug**	**1,535**	**329,199**	**Integration**	

* small fish estimate only, insufficient trawl catch to apportion hydroacoustic estimate

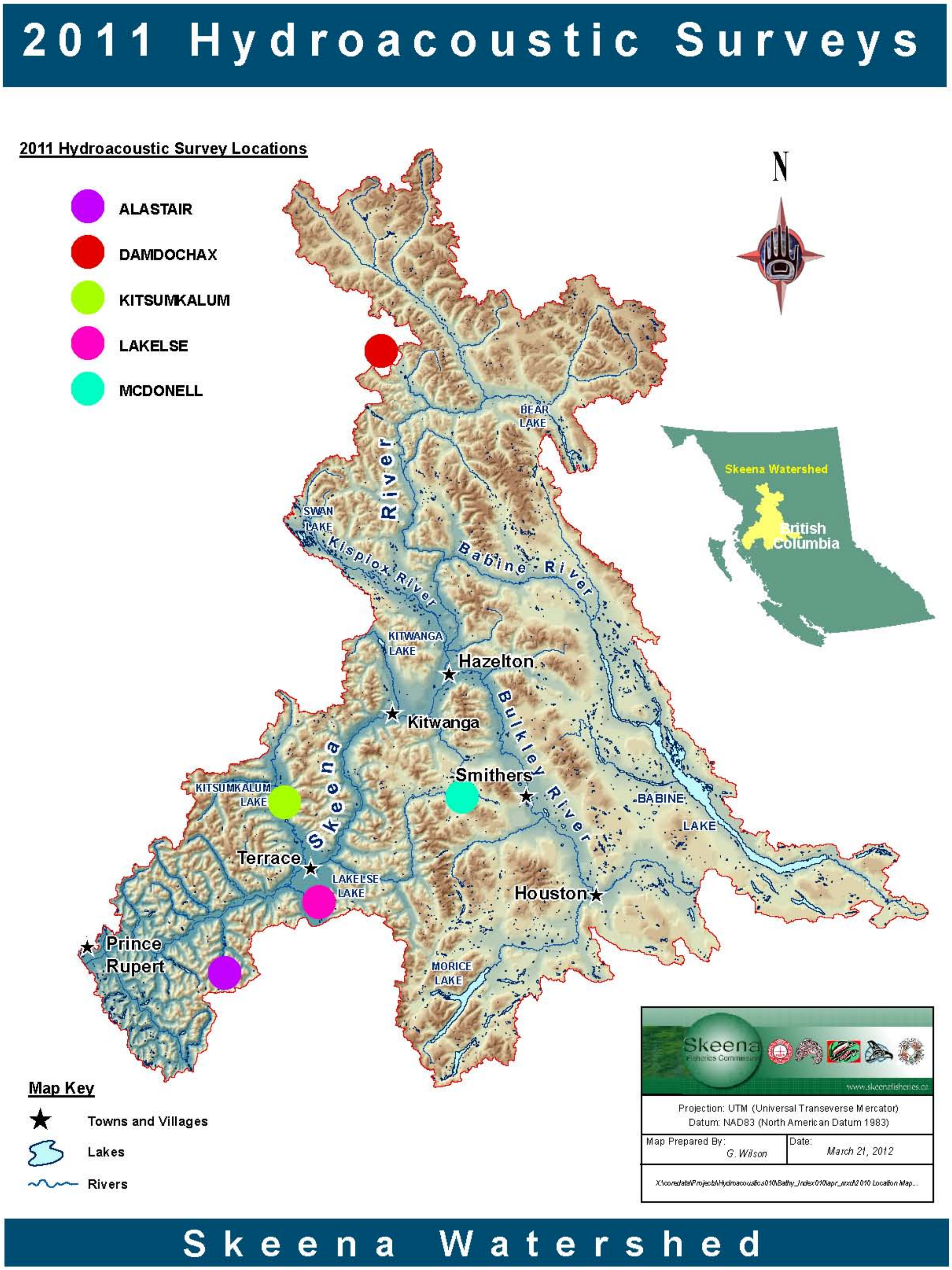


Figure 1. Location map of 2011 hydroacoustic surveys

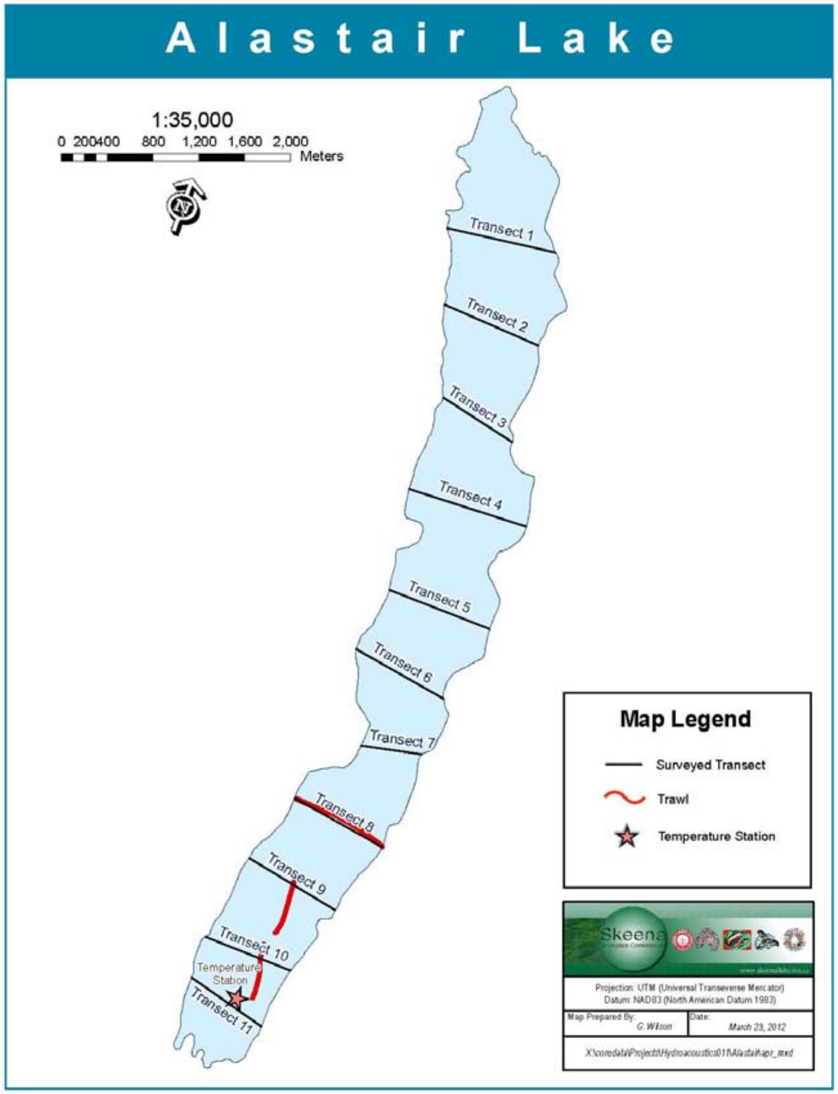


Figure 2. Alastair Lake hydroacoustic survey map

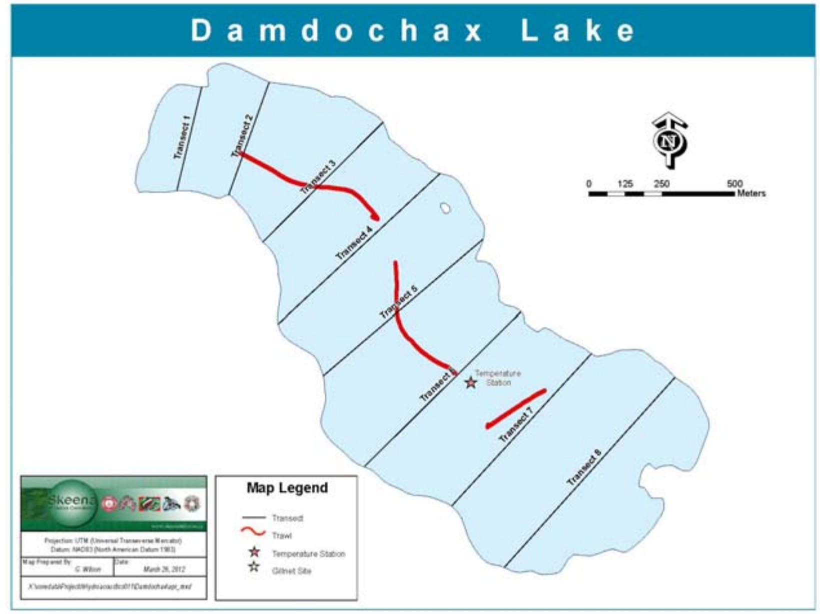


Figure 3. Damdochax Lake hydroacoustic survey map.

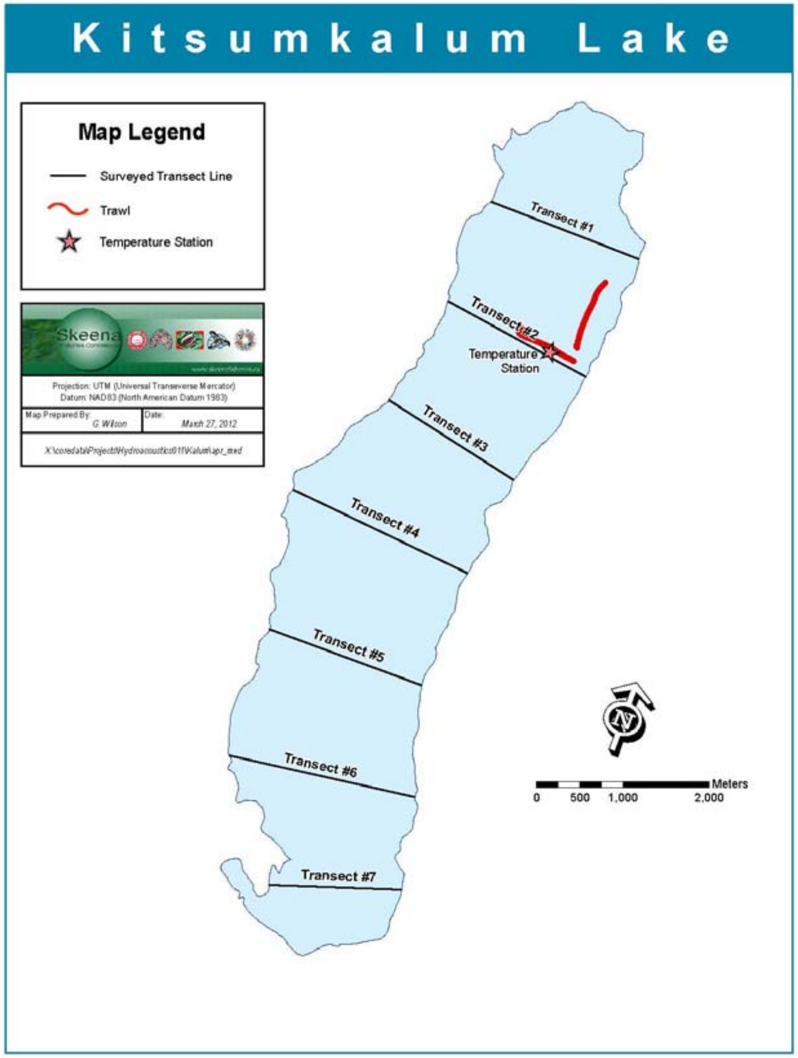


Figure 4. Kitsumkalum Lake hydroacoustic survey map

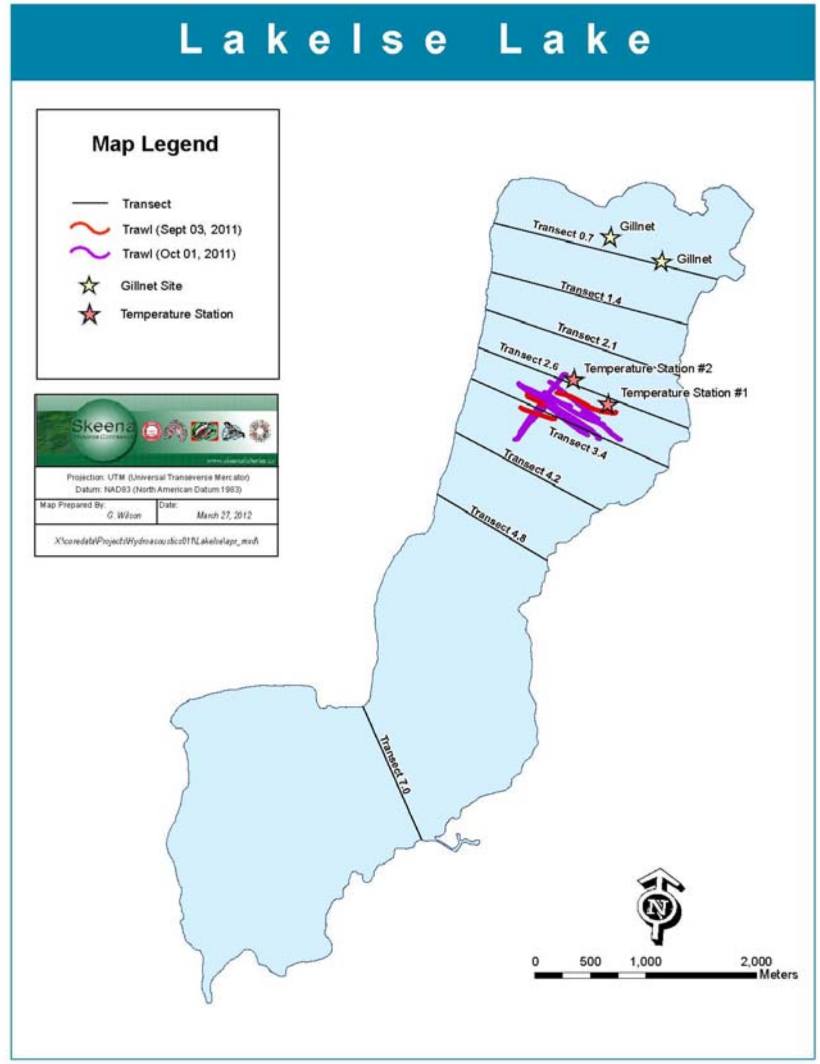


Figure 5. Lakelse Lake hydroacoustic survey map

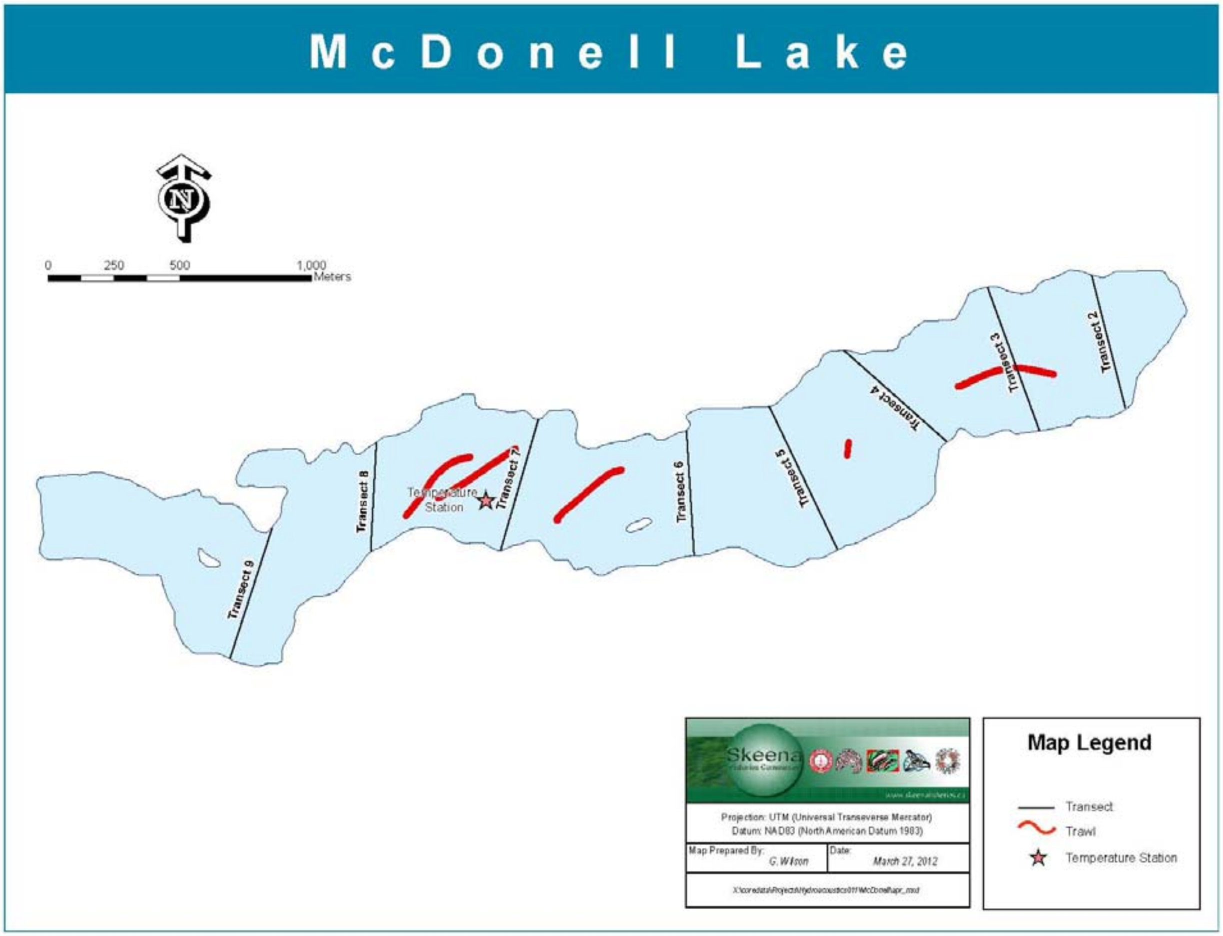
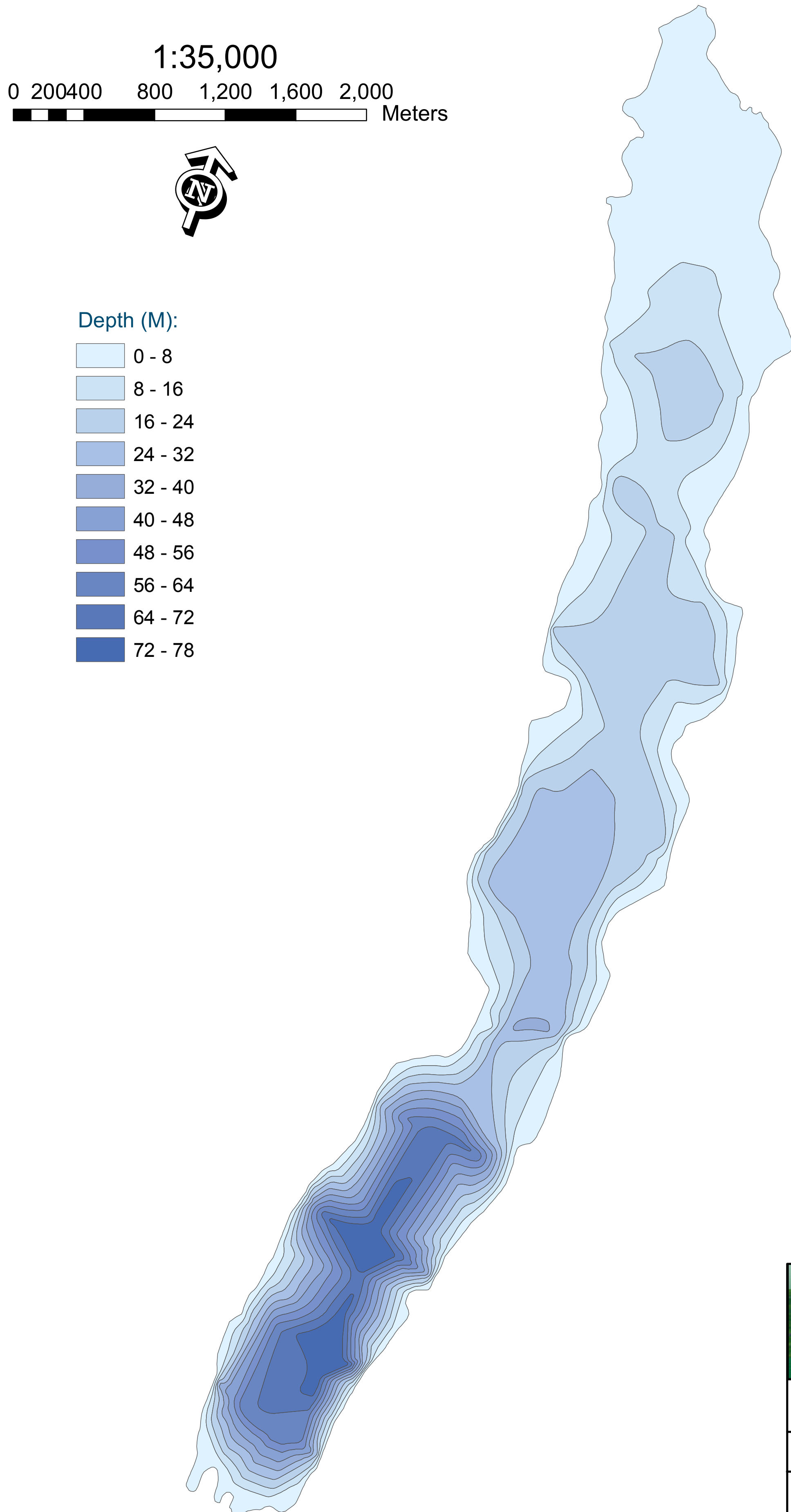


Figure 6. McDonell Lake hydroacoustic survey map

Alastair Lake



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Projection: UTM (Universal Transeverse Mercator)
Datum: NAD83 (North American Datum 1983)

Map Prepared By:	Date:
G. Wilson	*Nov 30, 2011*

X:\coredata\Projects\X:\coredata\Projects\Hydroacoustics011\Alastair\apr_mxd\Alastair Bathy.mxd

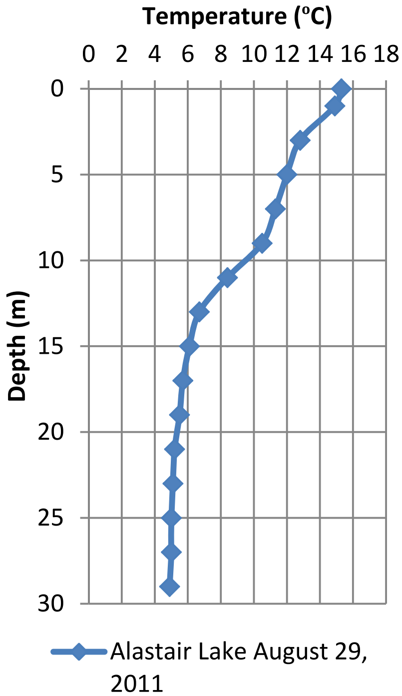


Figure 8. Alastair Lake temperature profile

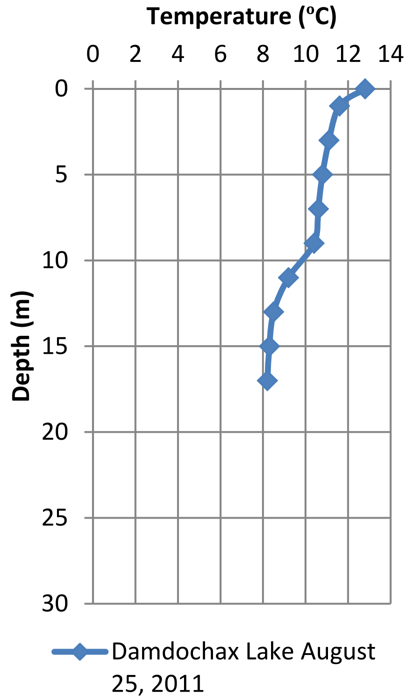


Figure 9. Damdochax Lake temperature profile

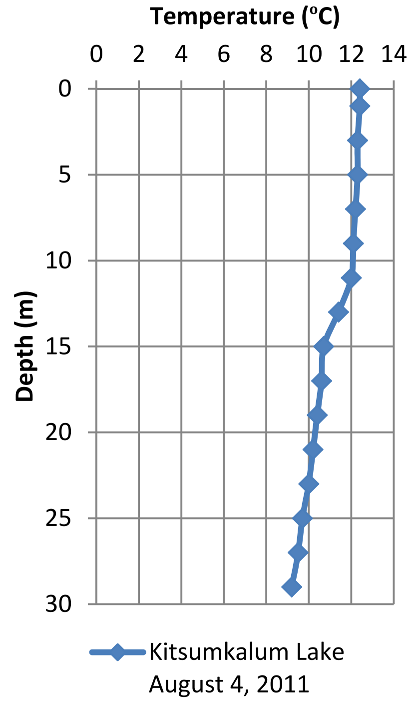


Figure 10. Kitsumkalum Lake temperature profile

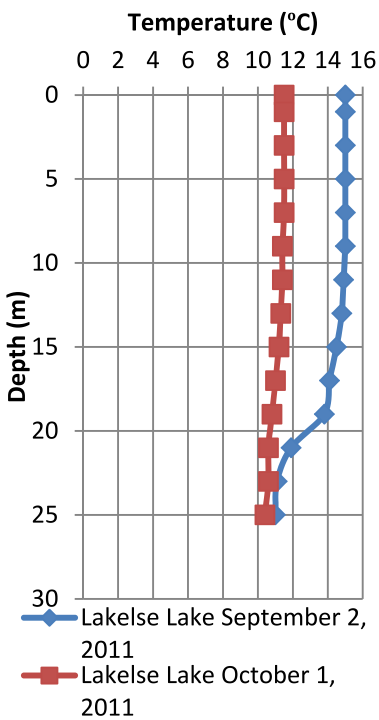


Figure 11. Lakelse Lake temperature profiles

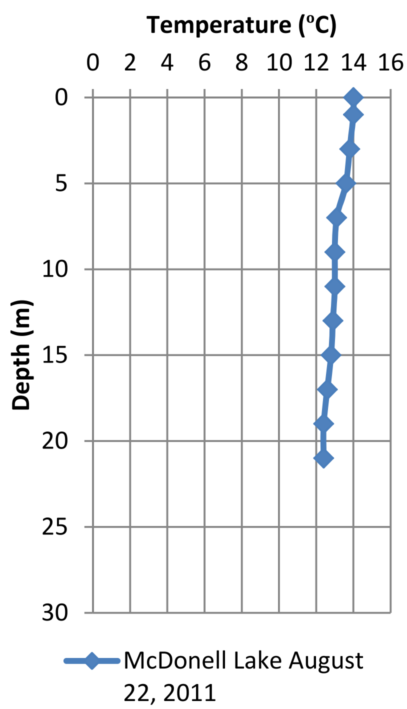


Figure 12. McDonell Lake temperature profile

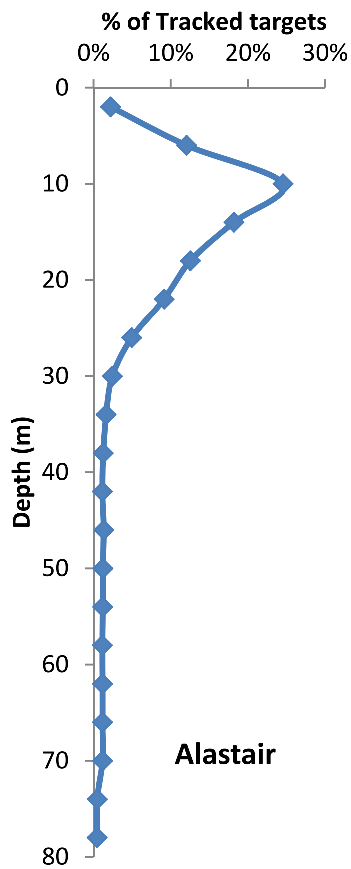


Fig 13. Alastair Lake vertical distribution of tracked targets

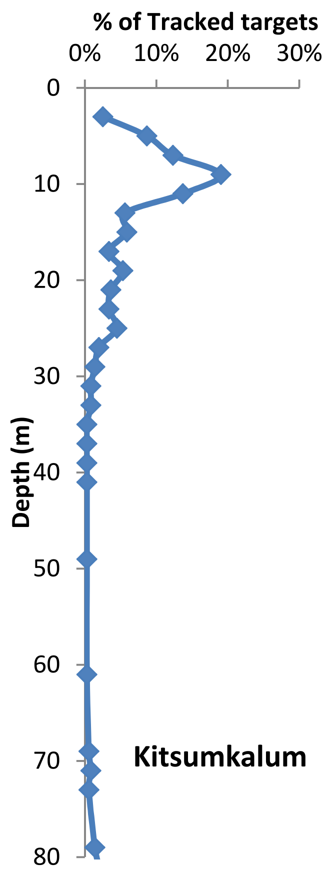


Fig 14. Kitsumkalum Lake vertical distribution of tracked targets

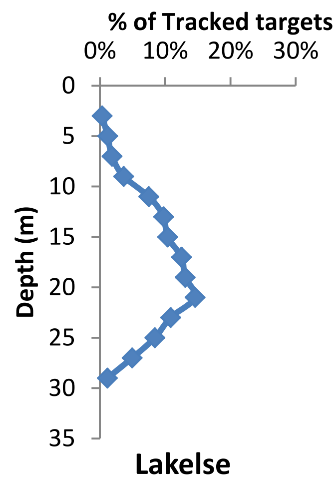


Fig 15. Lakelse Lake vertical distribution of tracked targets

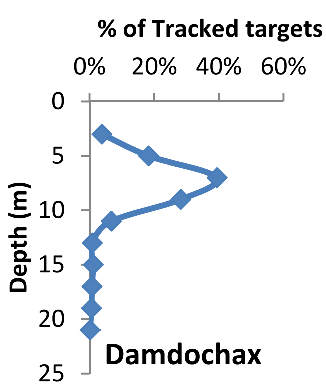


Fig 16. Damdochax Lake vertical distribution of tracked targets

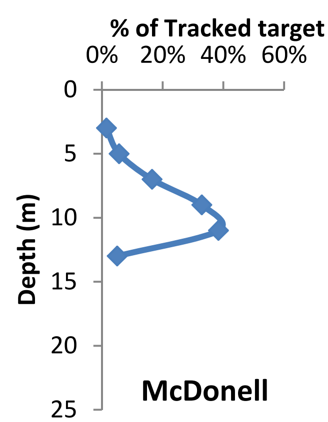


Fig 17. McDonell Lake vertical distribution of tracked targets

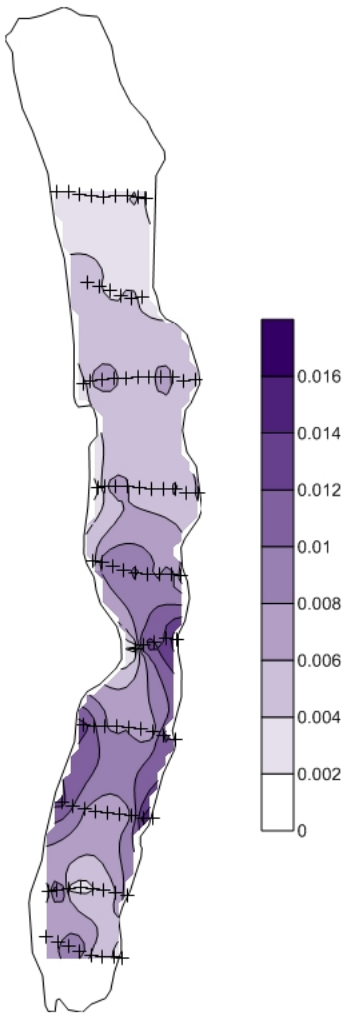


Figure 18. Alastair Lake horizontal distribution of tracked target density

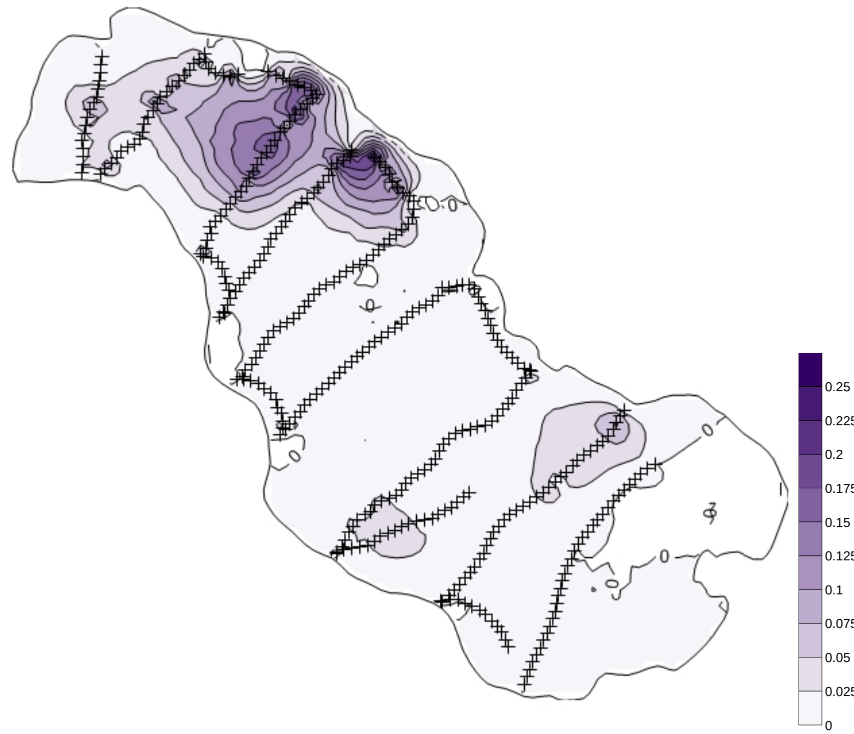


Figure 19. Damdochax Lake horizontal distribution of tracked target density

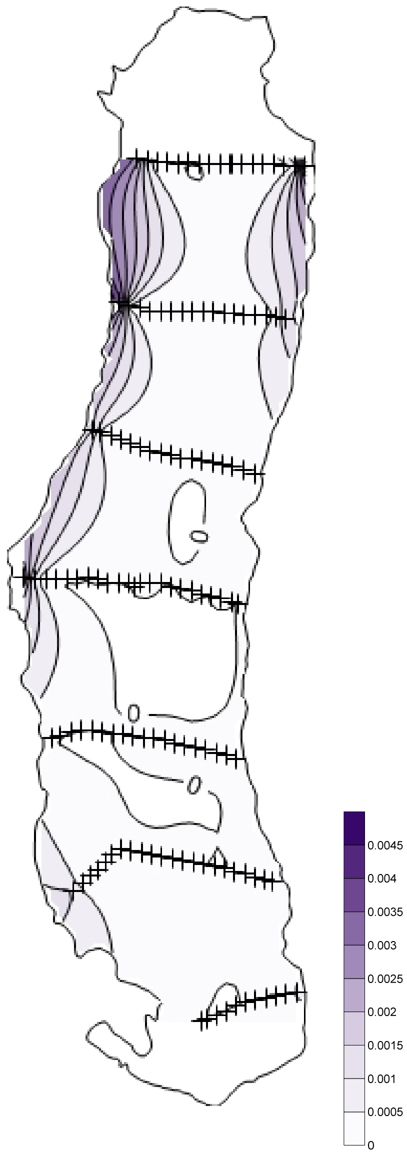


Figure 20. Kitsumkalum Lake horizontal distribution of tracked target density

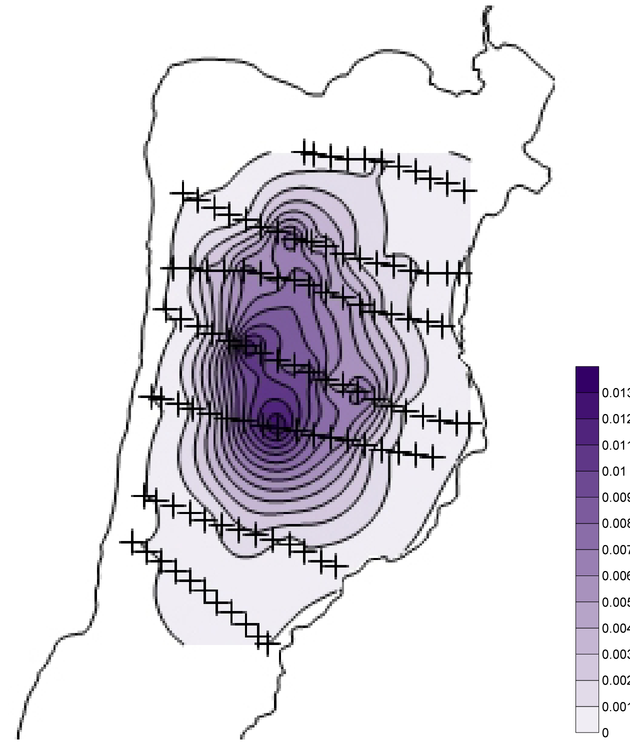


Figure 21. Lakelse Lake (north basin) horizontal distribution of tracked targets

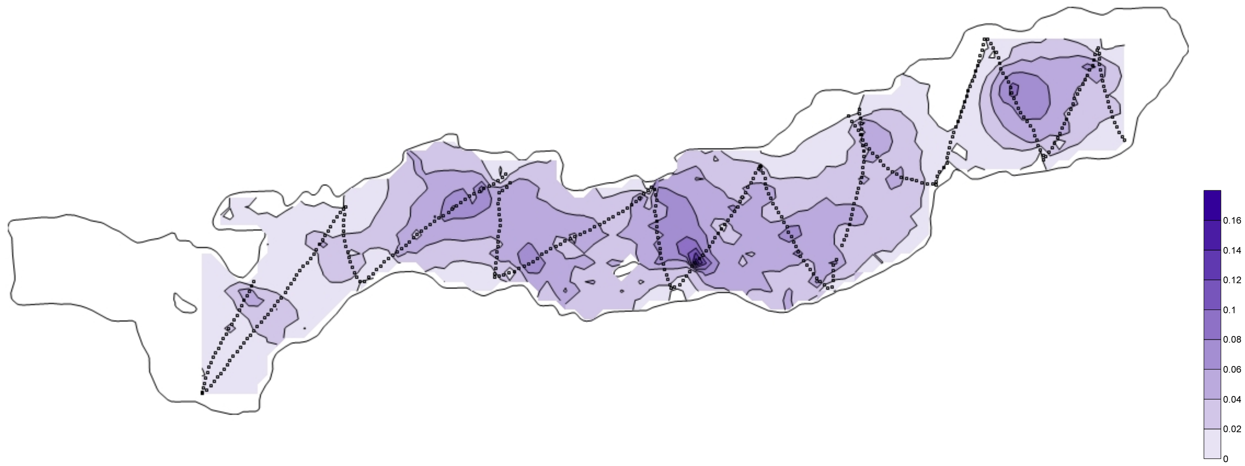


Figure 22. McDonell Lake horizontal distribution of tracked target density

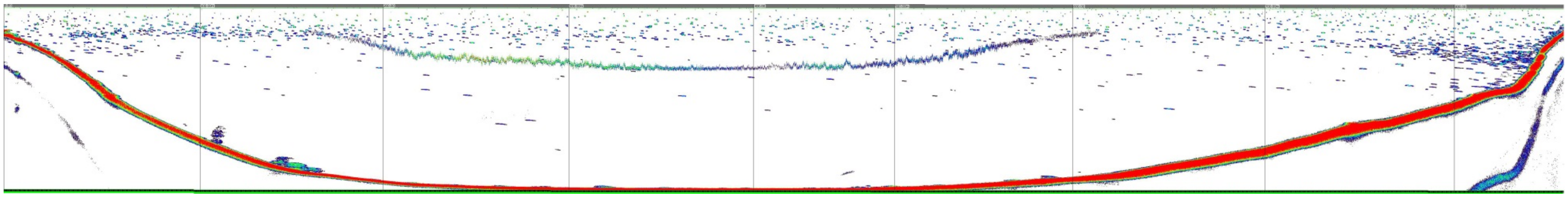


Figure 23. Alastair Lake Transect 9 echogram

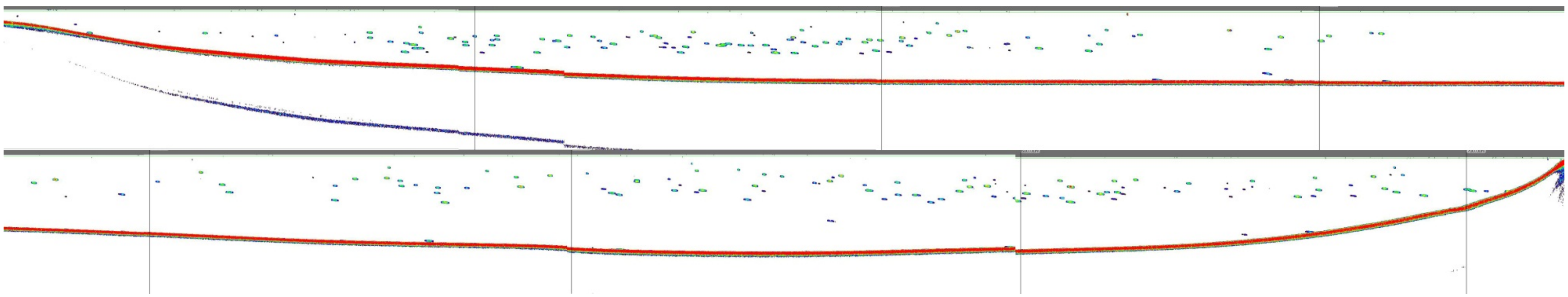


Figure 24. Damdochax Lake Transect 6 echogram

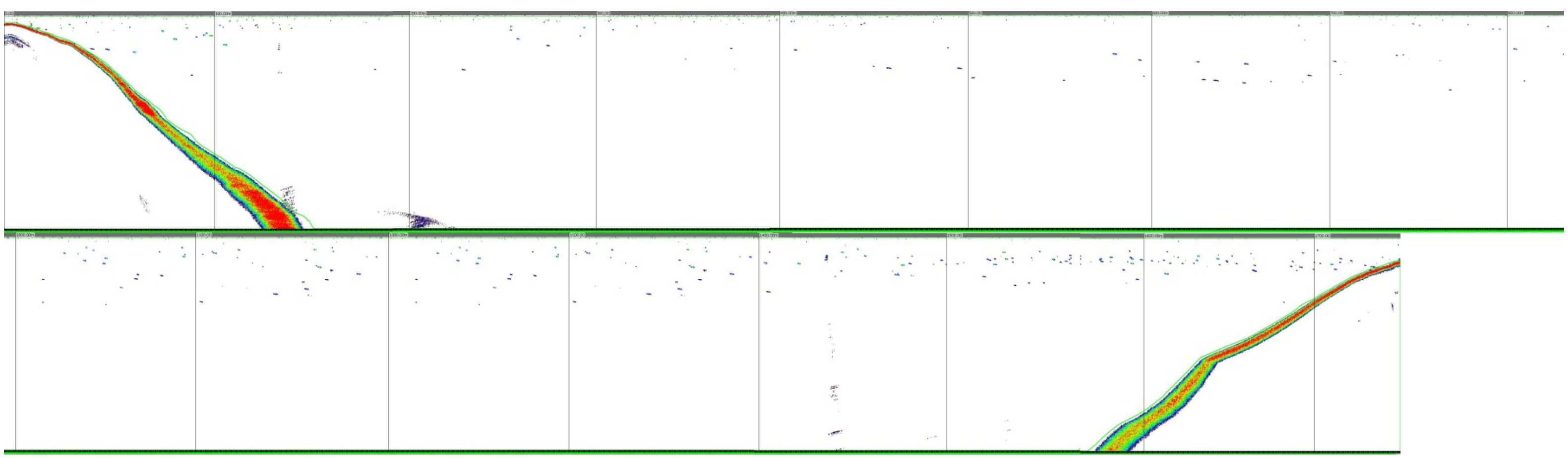


Figure 25. Kalum Lake Transect 2 echogram

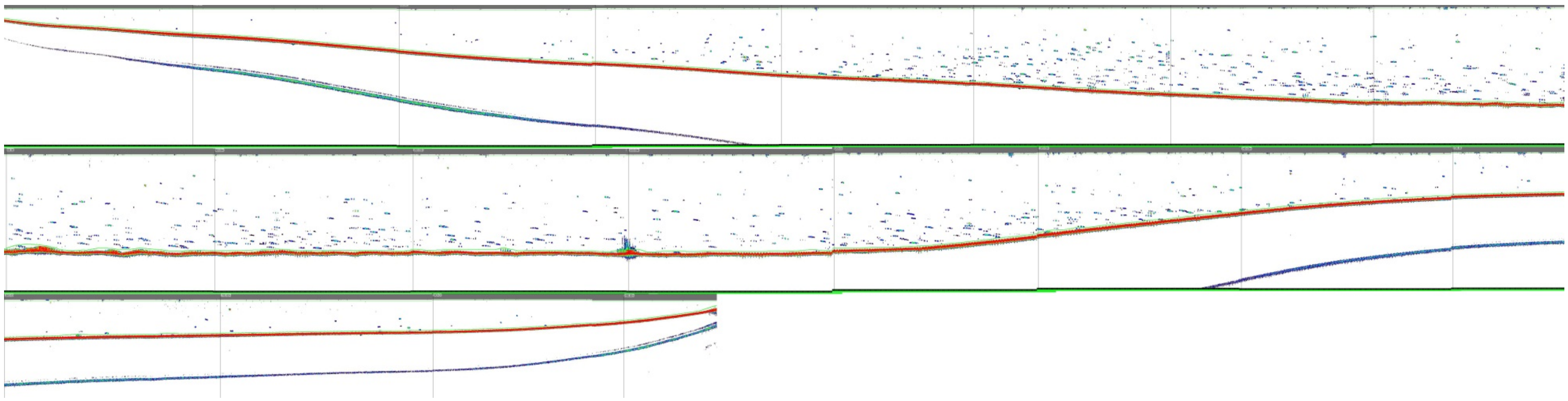


Figure 26. Lakelse Lake Transect 2.6 echogram

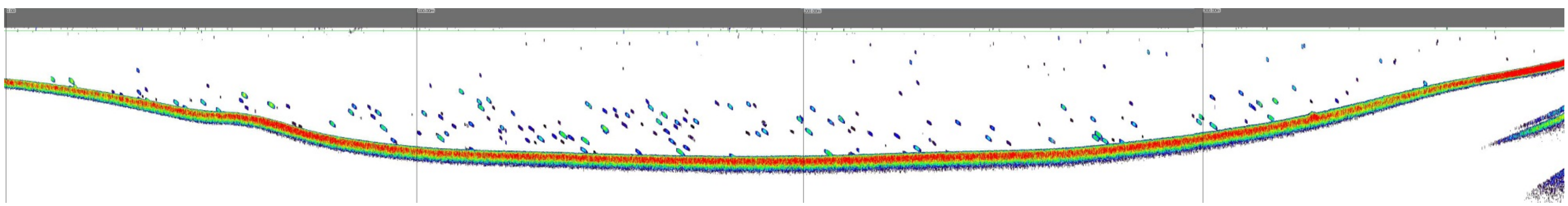
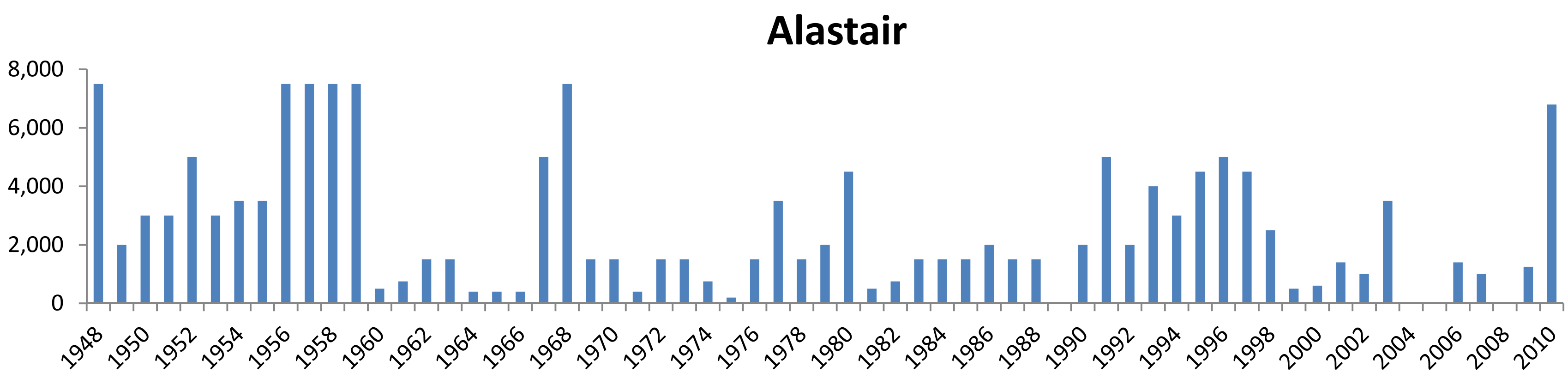
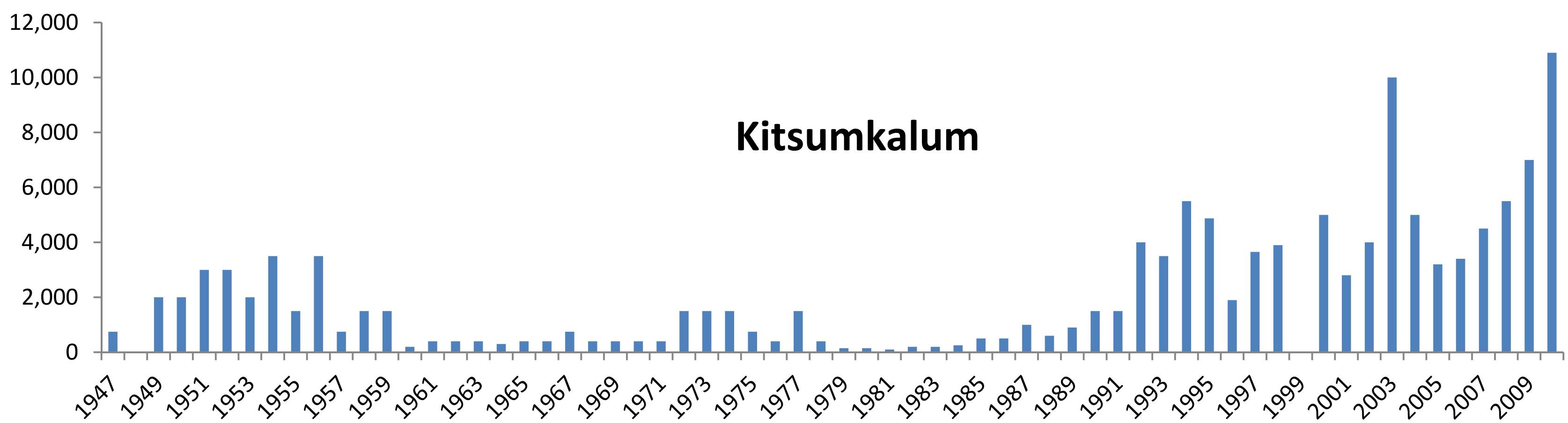


Figure 27. McDonell Lake Transect 7 echogram

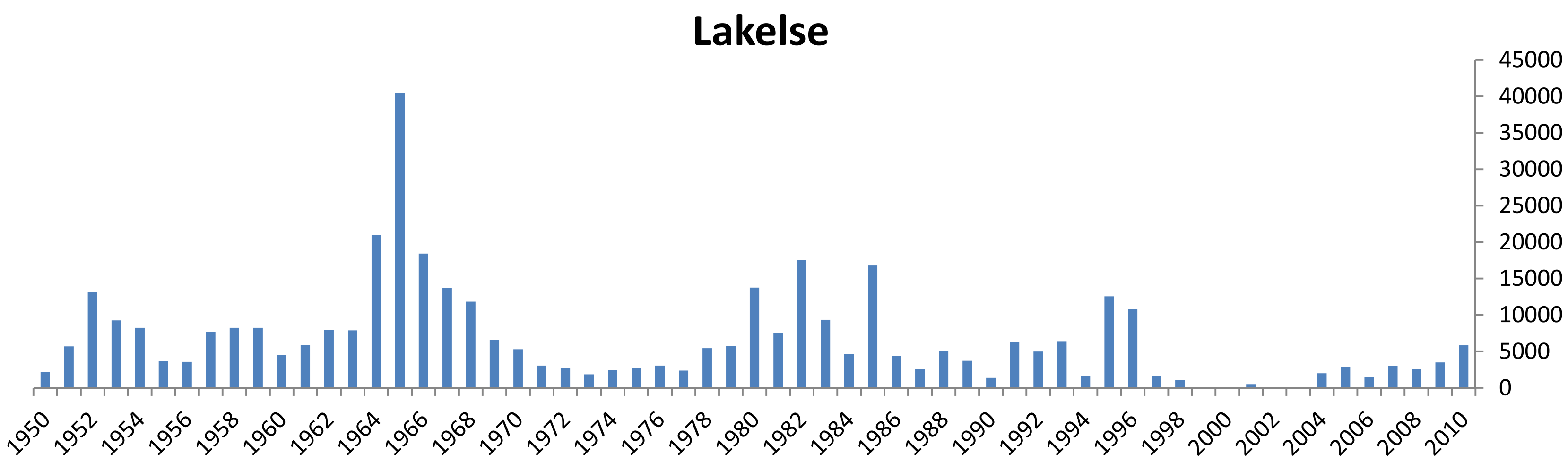
Appendix 1. Alastair sockeye escapement 1948-2010[1]



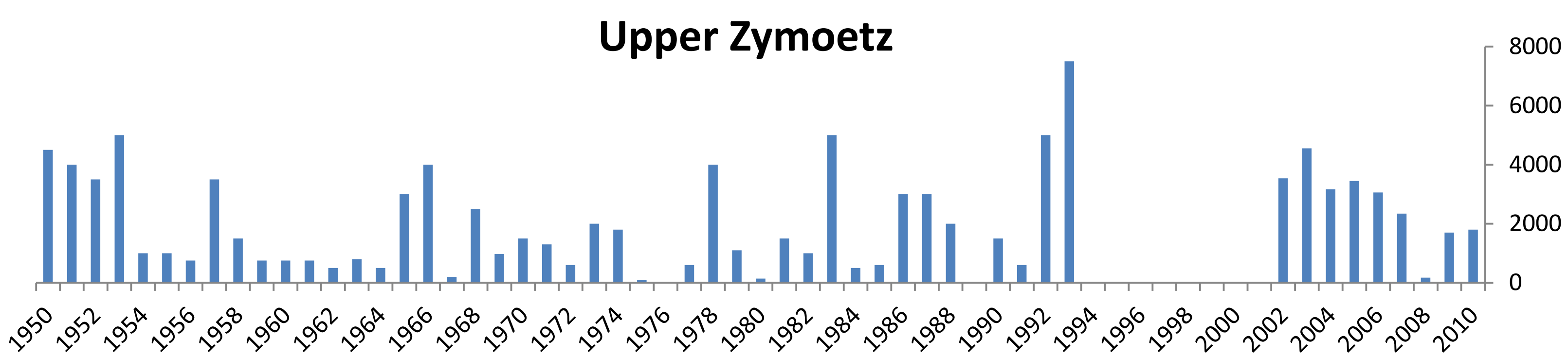
Appendix 2. Kitsumkalum sockeye escapement 1947-2010[1]



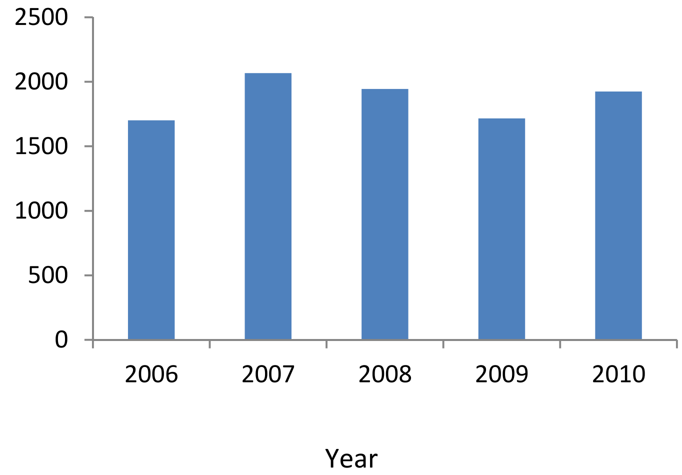
Appendix 3. Lakelse Lake sockeye escapement 1950-2010[1]



Appendix 4. Upper Zymoetz sockeye escapement 1950-2010[1]



Appendix 5. Damdochax sockeye escapement 2006-2010[2]



[1] Fisheries and Oceans Canada NuSEDS database 2011

[2] Tim Wilson (Gitxsan Watershed Authorities) pers. comm.