Skeena & Nass Sockeye Lakes Hydroacoustic Surveys 2012

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ABSTRACT

Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys of three juvenile sockeye rearing lakes (Fred Wright, Bear, and Azuklotz Lakes) in the Skeena and Nass Watersheds in 2012. The main objectives of the surveys were to enumerate and sample the sockeye fry population and to estimate the species composition of each lake. The results of these surveys are contained in this report.

Hydroacoustic sampling was conducted using a DT-X echosounder with a downward-pointing split-beam 199 kHz transducer. Fish samples were captured with mid-water trawl and gillnet gear. The trawl sample was used to determine the species composition of pelagic “small” size fish at each lake.

The 2012 juvenile sockeye population estimates at Fred Wright, Bear, and Azuklotz lakes appear to be significantly higher than hydroacoustic estimates generated in previous surveys of the same lakes. The increase in the juvenile sockeye population at Fred Wright Lake is most likely due to the “Kwinageese Manoeuvre” which helped increase the sockeye return to the Kwinageese watershed in 2011. The increases observed at Bear and Azuklotz Lake may also be the result of strong sockeye returns in 2011. Even though the juvenile sockeye populations appear to have increased at Fred Wright, Bear, and Azuklotz lakes, they are still below the rearing capacity of each of these lakes.

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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.

During the late summer and fall of 2012, the Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys of three juvenile sockeye rearing lakes in the Skeena and Nass watersheds (Figure 1). The main objectives of these surveys were to estimate the sockeye population size and the relative proportions of juvenile sockeye and competitor limnetic species of each lake.

Fred Wright Lake (Figure 1) is the largest and most productive of the sockeye nursery lakes in the Kwinageese River watershed which drains into the Nass River. Fred Wright Lake is located at an elevation of 572 m and covers approximately 393 ha with a mean and maximum depth of approximately 18 m and 41 m, respectively (Table 1). The lake characteristics are described extensively in Shortreed et al. (2001).

Bear Lake (Figure 1) drains into the Bear River, a 5th order tributary to the Sustut River, in the northeastern Skeena Watershed. The Bear River watershed drains an area of approximately 452 km^2 (Gottesfeld & Rabnett 2008). Bear Lake covers approximately 1961 hectares with a volume of approximately 2.6×10^8 m^3 (Table 1). There are two distinct basins in the north and south ends of with maximum depths of 44 and over 70 m respectively. Tsaytut Bay is a large littoral area that covers 440 ha on the east side of Bear Lake. Sockeye escapement estimates are not available as stock assessment has never been conducted regularly at Bear Lake. Bear Lake is located within the traditional territories of the Gitxsan First Nation. The last hydroacoustic survey of Bear Lake was conducted in 2008.

Azuklotz Lake (Figure 1) is a clear, shallow lake located in the Northeast section of the Skeena watershed adjacent to Bear Lake, which empties into the Bear River which drains into the Sustut River, a tributary of the upper Skeena River. Azuklotz Lake has a surface area of 166 hectares, a maximum depth of 9.5 m and an average depth of 4 m (Table 1). Azuklotz Lake is located within the traditional territories of the Gitxsan First Nation and was last surveyed in 2009.

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. In this report they will be referred to as "O. nerka".

Table 1. Physical characteristics of lakes surveyed in 2012

Lake	Watershed	Elevation (m)	Average Depth (m)	Maximum Depth (m)	Surface Area (ha)	Clarity
Fred Wright	Kwinageese	572	18	41	393	Clear
Bear	Bear	789	13.5	70	1961	Clear
Azuklotz	Bear	789	4	9.5	166	Clear

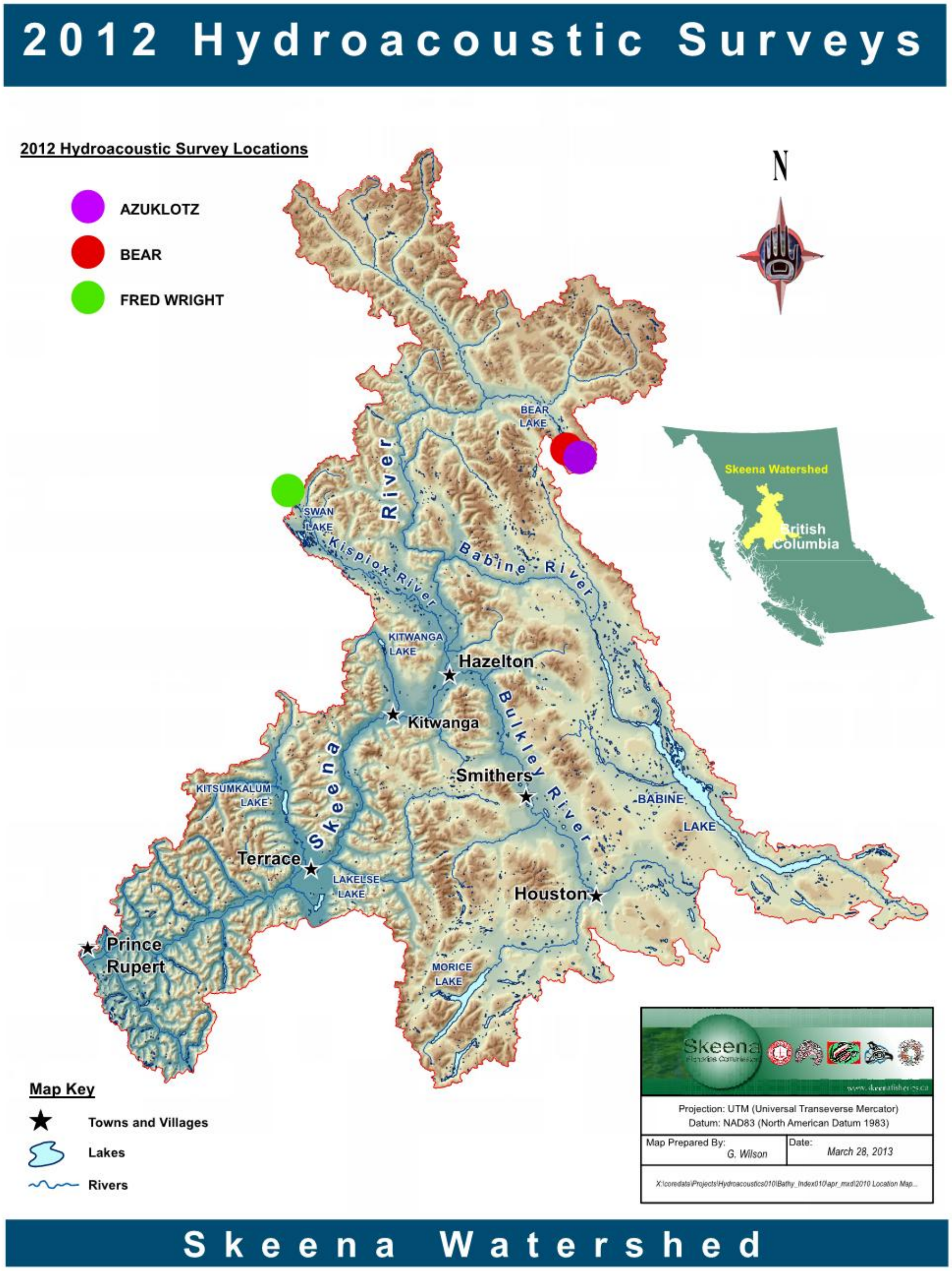

Figure 1. Location of the surveyed lakes in the Skeena and Nass watersheds

METHODS

Hydroacoustic Survey

Hydroacoustic surveys were conducted using similar methods and technology as in previous years (Hall 2007, Hall and Carr-Harris 2008) and described in MacLellan and Hume 2010 and Parker-Stetter *et. al.* 2009. Transects were sampled using a Biosonics DT-X echosounder with a 200 kHz split-beam transducer producing a 6 degree beam. The single downward-pointing transducer was pole-mounted to our inflatable vessel, a Bombard Commando C-5 (Figure 2). Hydroacoustic data were collected to an acoustic threshold of -100 dB using Biosonics Visual Acquisition software as the vessel proceeded along transects at a constant speed of 0.7 m/sec.

Figure 2. Photo of the inflatable vessel with the hydroacoustic gear at Bear Lake.

The Fred Wright Lake survey design (Figure 3) was created by SFC in 2012. The surveys at Bear and Azuklotz lakes were conducted along previously established transects (Figures 4 and 5). The Bear Lake survey design (Figure 4) was established by the Department of Fisheries & Oceans Cultus Lake Research Laboratory in 2003 (Hume & Shortreed 2004). We completed twelve of the sixteen transects from the original Bear Lake survey design. The survey design for Azuklotz Lake was established by the Department of Fisheries & Oceans Cultus Lake Research Laboratory in 2003 (Hume & Shortreed 2004).

Hydroacoustic estimates for Fred Wright Lake are based on depth layer volumes that were calculated using bathymetric maps produced from lake depth data collected during the 2012 surveys, using our DT-X system. BC Ministry of Environment (MOE) bathymetric maps were used to calculate depth layer volumes for Azuklotz Lake. The depth layer volumes for Bear Lake were calculated using bathymetry data collected during a hydroacoustic survey conducted in 2008, combined with existing bathymetric data from the BC 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 would be applied prior to post-processing of the data.

Post-processing of hydroacoustic data was performed using Echoview software (v. 5.30). Data analysis was conducted using the same methodology as in previous years (Hall & Carr-Harris 2008, Hall 2007). Acoustic targets below -65 decibels were eliminated from analysis using the Parker-Stetter (2009) method of linking the Sv threshold to a TS threshold of -71 decibels, in order to include off-axis sub-threshold targets that would exceed the -65 threshold once compensation for their position is applied by the ST, or single target detection algorithm.

Fish densities were calculated using three different methods for down-looking acoustic data: integration, single target (ST), and tracked target (TT). The integration method integrates the average acoustic energy from the Sv output for each depth layer by the average target strength volumetric fish density for the stratum (n/m^3). In single target echo counting analysis (ST) the water column was sampled ping by ping (Simmonds and MacLennan 2005), and the number of single targets detected are summed by the post-processing software (Echoview v. 5.30). For each transect interval, the number of single target detections was divided by the sum of the individual ping sample volumes to produce an absolute fish density for the interval.

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

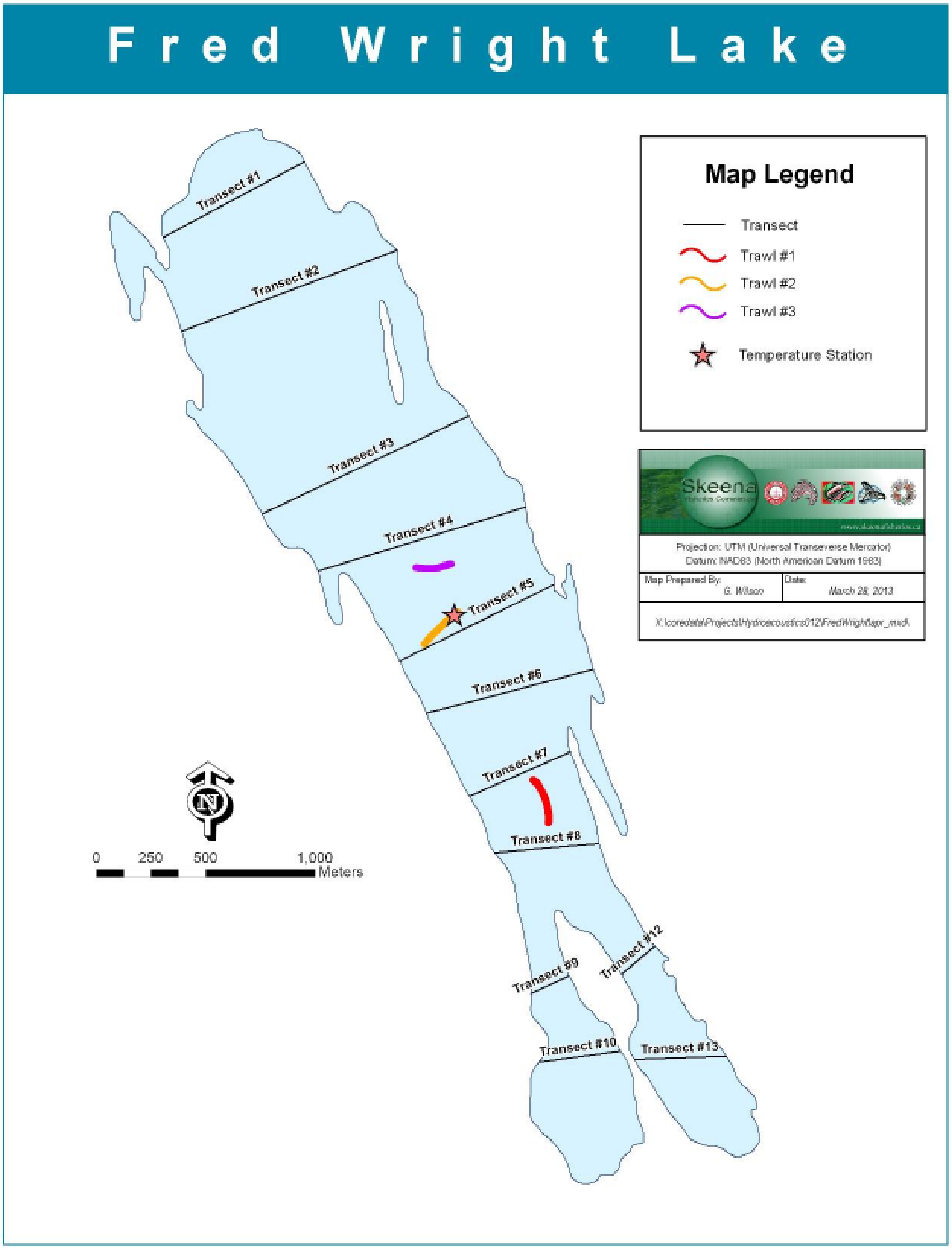

Figure 3. Fred Wright Lake survey map.

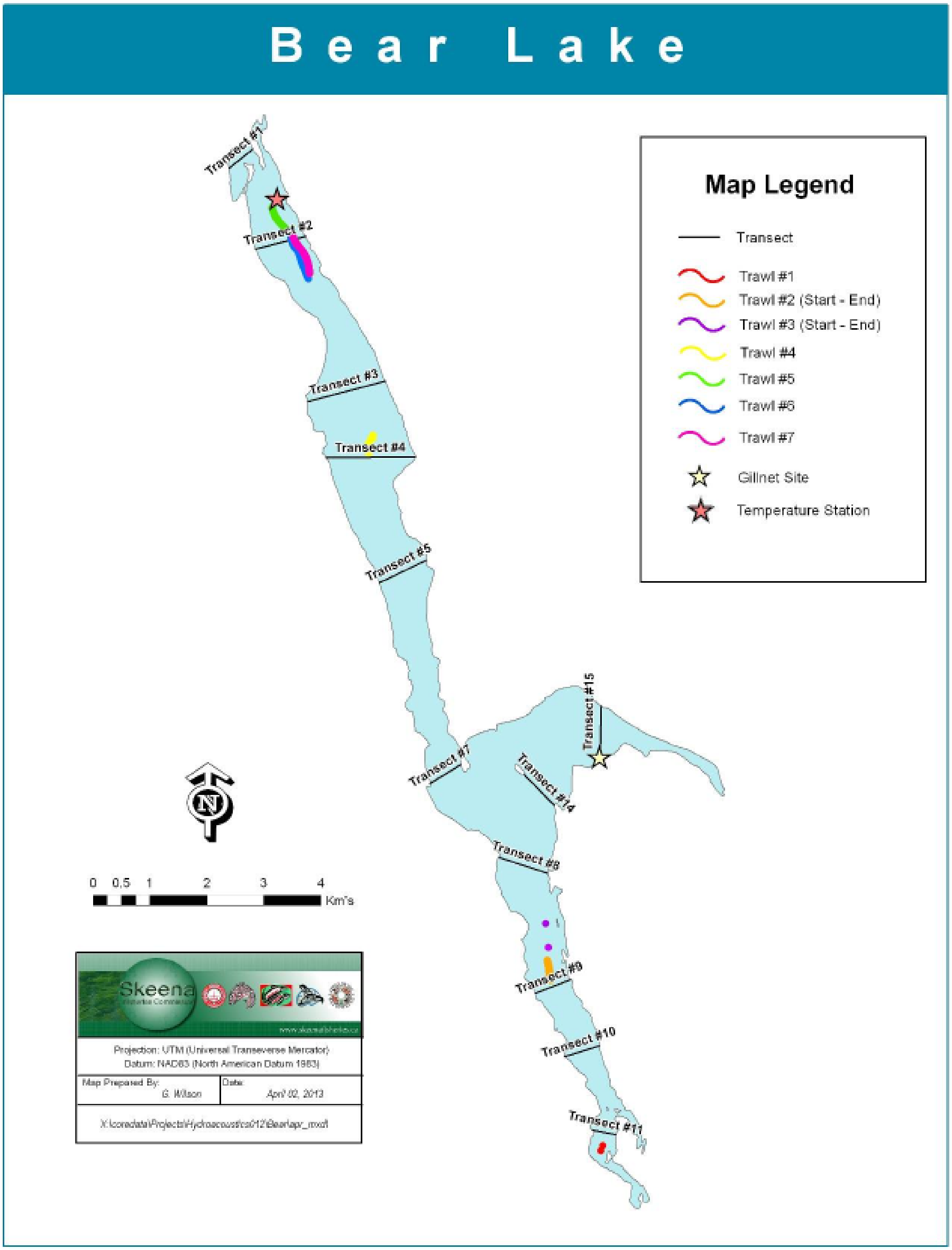

Figure 4. Bear Lake survey map.

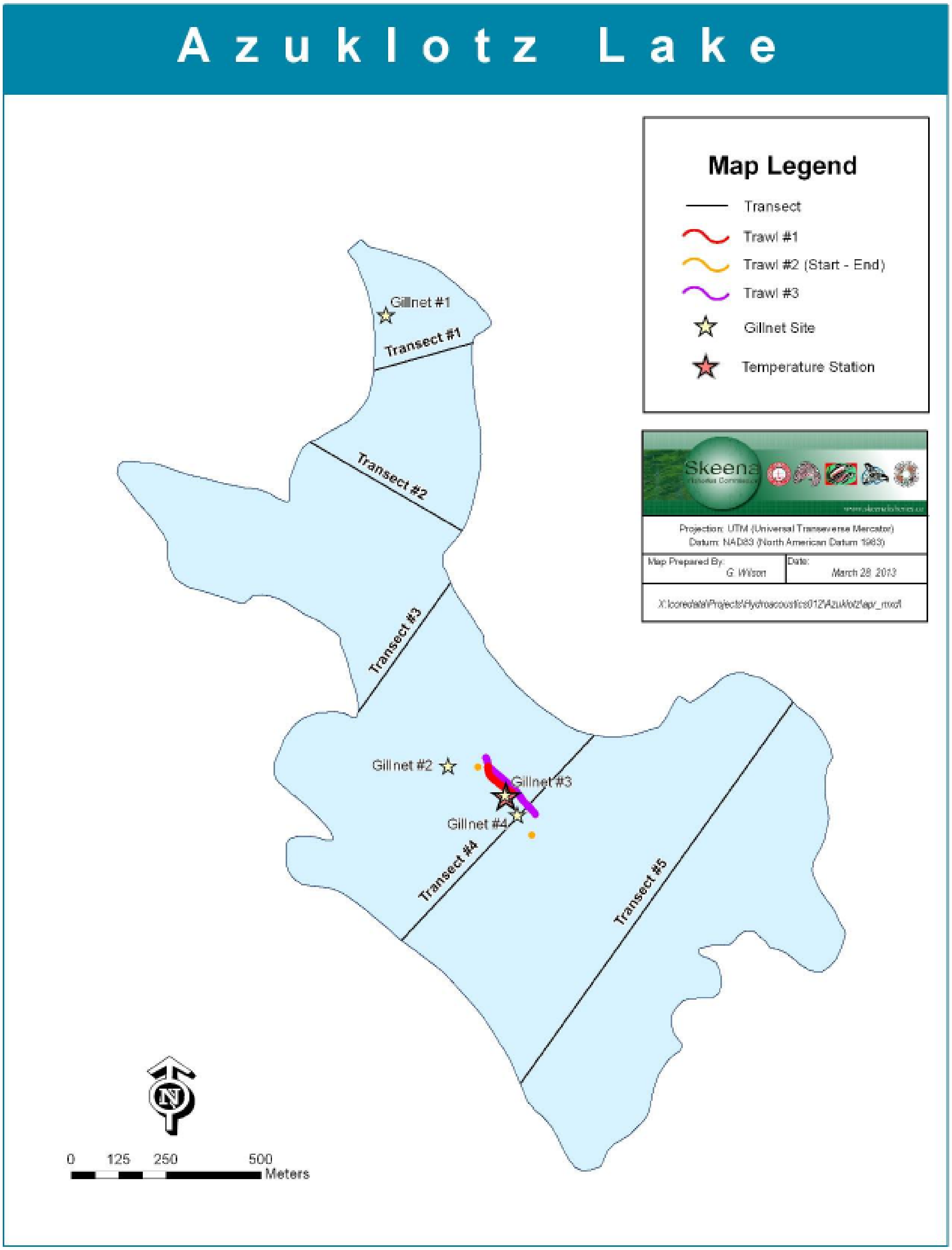

Figure 5. Azuklotz Lake survey map

Following the general guidelines of MacLellan and Hume 2010, only population estimates calculated using the integration method are presented in this report because the total estimated fish densities are above 500 fish/ha for all three lakes surveyed in 2012. Results using the single target (ST) and tracked target (TT) methods are presented for comparison in Appendix 1.

Primary analysis outputs from Echoview were processed in Excel to calculate estimates of total age-0 *O.nerka* for each lake. Population estimation procedures were consistent with a stratified random transects sampling technique described by MacLennan and Simmonds (2005), and used by MacLennan and Hume (2010), and by SFC (ex. Carr-Harris 2012). Data from each transect were analyzed in 2m depth layers (Fred Wright and Bear lakes), or in 1m depth layers (Azuklotz). The volumetric densities calculated for each transect layer are multiplied by the layer volume of the lake area represented by that transect to produce a transect layer population estimate. Transect estimates are produced from the sum of layer population estimates. Transect densities are averaged and multiplied by the whole surface area of the lake to produce the total fish estimate for the entire lake or lake section.

The fish estimates were divided into "small" and "large" fish based on the distribution of target strengths from each transect and each layer. "Small" fish were classified as fish with target strengths between –64 and –46 dB. This target strength is approximately equivalent to salmoniform fish <135 mm in length, based on Love (1977) 45^{o} aspect formula. Small fish were apportioned into "O. nerka" and "other small fish" based on the relative proportion of species in the trawl and gillnet catch. Temperature profile was also used to assist in determining where juvenile sockeye were likely to be at night based on their apparent preference for temperatures between 6 and 13 °C (Brett 1952).

Confidence intervals (95%) for fish densities and population estimates are determined by using each transect as a separate sample. The variability between transects within a lake or lake basin determines the error estimate around the average density or population estimate.

The variance calculated using the stratified random transects technique reflects the statistical confidence in the precision of the population estimate and is largely driven by the horizontal fish distribution throughout the lake. During data analysis, we observed that most of the fish targets, likely age-0 *O.nerka*, were constrained within specific depth layers, close to the thermocline. The age-0 *O. nerka* density varied greatly from depth layer to depth layer, which contributed to an increase in the variance calculated using the stratified random transects technique. In order to reduce the overall variance, we tested an alternative stratified random population estimation procedure that exploited this vertical distribution characteristic of age-0 *O. nerka,*. The area surveyed was stratified by depth layers instead of transect, and each transect provided one replicate for each depth stratum. The mean volumetric fish density was calculated for each depth stratum, and multiplied by the total layer volume to obtain an estimate of abundance for each depth stratum. All the abundance estimates were then summed to a total population for the lake. Variance was calculated for each depth stratum then summed, and the 95% confidence interval was calculated for the whole lake.

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 depths in the littoral zones at Bear and Azuklotz lakes. These gillnets consisted of 4 variable mesh sizes between ½" and 1". Gillnets were set at dusk and allowed to soak for the duration of the survey.

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

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen data were collected at all lakes using a hand held YSI meter (model 85) with a maximum cable length of 30 m. The YSI meter was calibrated to the nearest 100' elevation and allowed to stabilize for at least 15 minutes before data were recorded.

RESULTS AND DISCUSSION

Stratification by transect versus stratification by depth layer

O.nerka population abundance estimates for Fred Wright, Bear, and Azuklotz lakes calculated using the stratification by transect and the stratification by depth layer population estimation procedures are compared in Figure 6. The estimates using stratification by depth layer are somewhat higher than the estimates using stratification by transect for Fred Wright and Bear lakes, but fall within the 95% confidence of the stratification by transect estimates. The results of the two estimation methods are nearly identical for Azuklotz Lake. For all surveys, stratification by depth layer method resulted in lower confidence intervals than stratification by transect. Thus, population estimates calculated using the stratification by depth layer are more precise than those produced using stratification by transect, which demonstrates that the vertical distribution of O. nerka in these three lakes varies more than the horizontal distribution.

Previous hydroacoustic reports by SFC and the Cultus Lake Salmon Research Laboratory have always presented age-0 *O.nerka* population estimates using the stratification by transect procedure. While the current report contains results obtained using both estimation methods, we have selected estimates calculated the stratification by transect method in order to maintain consistency with and compare to past estimates.

Fred Wright Lake

Fred Wright Lake was surveyed on the nights of August 14 and 15, 2012. The surface temperature was 19.6ºC degrees, with a gradual decline to 13.6 ºC at 4 m, and a small thermocline between 4 and 6 m with another gradual decline to a hypolimnion of 4.5 ºC below 20 m (Figure 8).

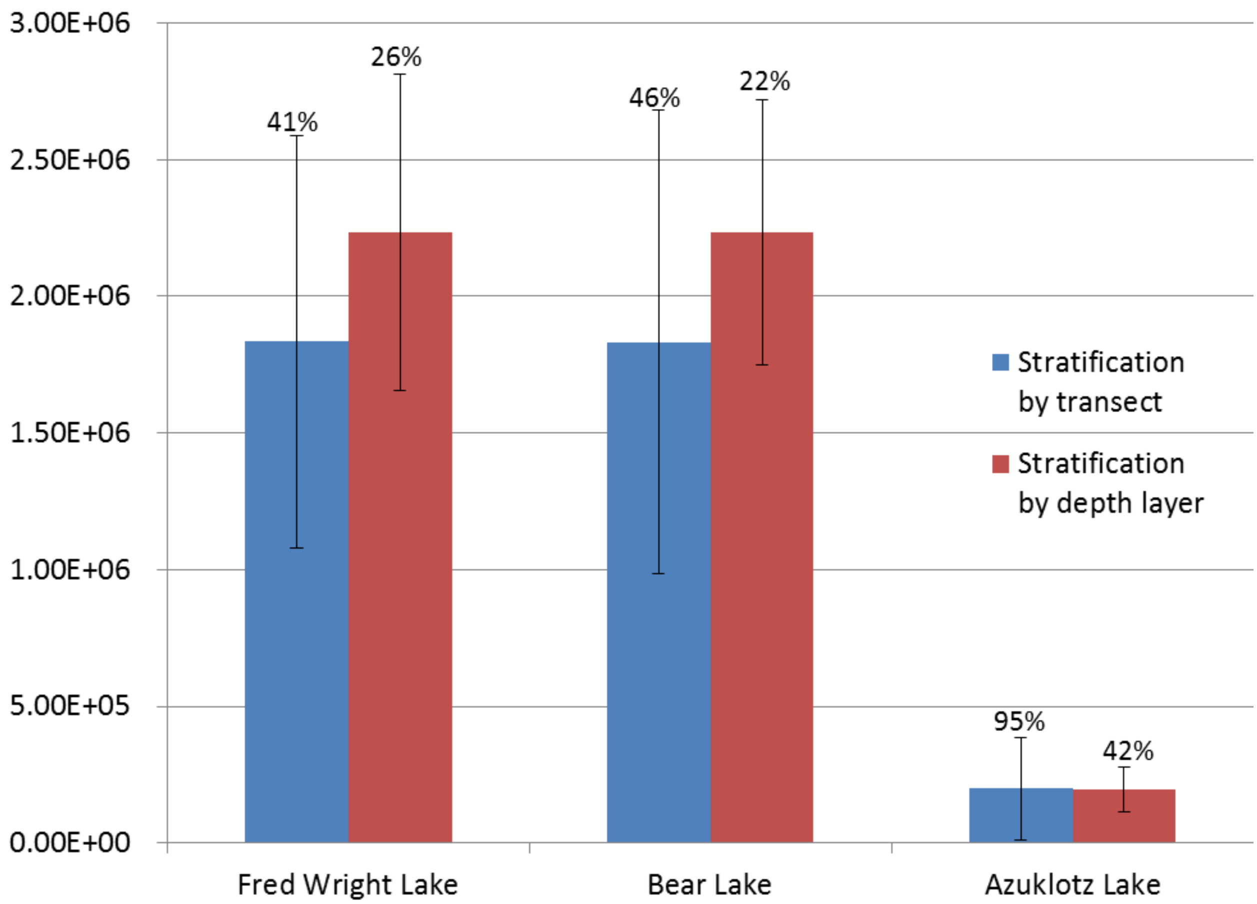

Figure 6. Graph showing age-0 *O.nerka* population abundance estimates for Fred Wright, Bear, and Azuklotz lakes, using the stratification by transects and the stratification by depth layers population estimation procedures. The error bars show the 95% confidence intervals.

We captured 109 age-0 O. nerka during three trawl tows with a combined length of about 0.6 km (Figures 3, 6 and Table 2). The average length of O. nerka fry captured by trawl was 50.3 mm, with an average weight of 1.3 grams (Table 4). All of the O. nerka fry were age-0, or young of the year fry.

Hydroacoustic data were collected from twelve transects across the long axis of the lake. Most fish targets were found above 28 m depth in the water column, with peak densities occurring at the thermocline depth of 5m depth (Figures 10 and 13). High densities of fish targets were observed throughout Fred Wright Lake (Figure 11). The hydroacoustic population estimate for age-0 *O.nerka* in Fred Wright Lake ranged from 1.83 x 10^6 or 4,654/ha ± 41% (stratification by transect) to 2.23 x 10^6 or 5,671 ± 26% (stratification by layer) (Figure 8 and Table 5). The total age-0 *O.nerka* biomass ranged from 2,384 kg (stratification by transect) to 2,905 kg (stratification by layer) (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 2012 hydroacoustic survey represents 44% (stratification by transect) or 53% (stratification by layer) of the rearing capacity, or R_{max}, at Fred Wright Lake (Table 6).

The 2012 Fred Wright Lake sockeye fry population estimate is significantly higher than the estimates from hydroacoustic surveys undertaken since 2001 (Table 7). This significant increase in the abundance of age-0 *O. nerka* in 2012 is most likely the results of the 'Kwinageese Manoeuvre' (Nisga'a Fish and Wildlife Department, 2011), which was undertaken in August 2011 and re-established fish passage through the Kwinageese River. Sockeye count at the Kwinageese weir was 10,273 in 2011, after counts of only 107 and 48 in 2009 and 2010, respectively (Nisga'a Fish and Wildlife Department, 2011). This is equivalent to a production of 179 juvenile per returning adult at the Kwinageese weir.

Figure 7. Photo of juvenile sockeye caught by trawl at Fred Wright Lake. August 15, 2012.

Bear Lake

Bear Lake was surveyed on the nights of August 16, 17, and 19, 2012. The surface temperature was 18.9ºC degrees, with a gradual decline to 16.9 ºC at 4 m, and a thermocline between 4 and 10 m with another gradual decline to a hypolimnion of 6.0 ºC below 28 m (Figure 9).

We conducted 7 tows with a total length of about 3.7 km at Bear Lake (Figure 4 and Table 2). The total trawl catch was 92 *O.nerka*, 6 Pygmy whitefish (*Prosopium coulteri*) and 4 char (*Salvelinus sp.*) (Figure 7). Juvenile sockeye were caught in all the trawls, at depths ranging from approximately 15m to 21m. One gillnet was set at Bear Lake for 11 hours (Figure 4 and Table 3). The gillnet catch included 4 juvenile *O. nerka*, and 66 redside shiners. All *O. nerka* caught in the gillnet or in the trawl were age-0, or young of the year fry. The average length of O. nerka fry captured was 65.6 mm, with an average weight of 3.3 grams (Table 4).

We did not survey transects 12 and 13 based on advice from previous surveys that they were shallow with few fish. We abandoned Transect 16 in the field because of low water conditions. Transect 6 was abandoned during analysis because it was too short and created an obvious over estimation of the fish population.

Most fish targets at Bear Lake were found above 30 m depth in the water column, with peak densities occurring at depths ranging from 5m to 20m (Figures 9 and 14). High densities of fish targets were observed throughout Bear Lake (Figure 12).

The Bear Lake age-0 sockeye population estimate ranged from 1.83 x 10^6 or 944 age-0 *O.nerka*/ha ± 46% (stratification by transect) to 2.23 x 10^6 or 1,150 ± 22% (stratification by layer) (Figure 8 and Table 5). The total age-0 *O.nerka* biomass ranged from 6,050 kg (stratification by transect) to 7,373 kg (stratification by layer) (Table 6). This estimated biomass is equivalent to 30% (stratification by transect) of the Rmax for Bear Lake (Table 6).

The most recent hydroacoustic surveys of Bear Lake prior to this one were completed in 2003 by the Cultus Lake Salmon Research Laboratory, and again in 2008 by the SFC (Table 7). The 2012 age-0 *O.nerka* estimate is significantly larger than the estimates from 2003 and 2008. There is little available recent sockeye escapement data for Bear Lake, where sockeye enumeration is complicated by the known presence of lakeshore spawners (Gottesfeld & Rabnett, 2008). A strong sockeye return to the Bear Lake system in 2011 may explain this significant increase in the abundance of age-0 *O. nerka* in the summer of 2012.

Azuklotz Lake

Azuklotz Lake was surveyed on August 18, 2011. The surface temperature was 18.8 ºC with a gradual decline to 16.0 ºC at 3 metres depth, and a small thermocline between 3 and 4 meters to a hypolimnion on 11.2 degrees ºC (Figure 9).

Five O. nerka juveniles were captured in three trawl tows with a combined length of 0.6 km (Figure 5 and Table 2). Two gillnets were set twice at Azuklotz Lake for a total soak time of approximately 13 hours, and 22 redside shiners were captured during the 2012 survey (Figure 5 and Table 3). The average length of trawl captured O. nerka was 47.8 mm, with an average weight of 1.1 grams (Table 4). All of the O. nerka fry captured at Azuklotz Lake were age-0. Most of the fish targets were found around 5m (Figures 10 and 15). The highest densities of fish targets were found in the deepest section of the lake, along Transect 4.

Figure 8. Photo of juvenile sockeye caught by trawl at Bear Lake. August 19, 2012.

The age-0 *O. nerka* population estimate for in Azuklotz Lake ranged from 1.95 x 10^5 or 1173/ha ± 42% (stratification by layer) to 1.99 x 10^5 or 1201/ha ± 95%(stratification by transect) (Figure 8 and Table 5). Given the average weight from the trawl sample, the estimated biomass ranged from 214 kg (stratification by layer) to 219 kg, or approximately 10% of Rmax (Table 6). The 2012 age-0 *O.nerka* population estimate for Azuklotz Lake is significantly higher than the estimates obtained in September 2003, and in September 2009 (Table 7); however the age-0 *O.*nerka biomass estimated in 2012 is relatively similar to the age-0 *O.*nerka biomass of 313 kg estimated in 2003 by Shortreed and Hume (2004).

Escapement data for Azuklotz Lake in 2011 was 2,547 (Fisheries and Oceans Canada 2011 NuSEDS database). This is equivalent to a production of 78 juvenile per returning adult.

CONCLUSION

Hydroacoustic surveys allow us to gauge trends in juvenile sockeye 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 2012 juvenile sockeye population estimates at Fred Wright, Bear, and Azuklotz lakes appear to be significantly higher than hydroacoustic estimates generated in previous surveys of the same lakes (Table 7). The increase at Fred Wright Lake is most likely due to the "Kwinageese Manoeuvre" which helped increase the sockeye return to the Kwinageese watershed in 2011. The increases observed at Bear and Azuklotz lakes may also be the result of the strong sockeye returns from 2011. Even though the juvenile sockeye population appears to have increased at Fred Wright, Bear, and Azuklotz lakes, it is still well below the rearing capacity of each of these three lakes. The portion of the rearing capacity used in 2012 for Fred Wright Lake was 44%, for Bear Lake was 30%, and for Azuklotz Lake was 10%.

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Table 2. 2012 Hydroacoustic surveys trawl summary by lake

Lake	Date	Trawl #	Time Start	Time End	Easting Start	Northing Start	Easting End	Northing End	Depth (m)	ON	WF	CH
Fred Wright	14-Aug-12	1	0224	0229	515627	6201688	515579	6201860	7	39		
Fred Wright	15-Aug-12	2	2341	2345	515062	6202498	515216	6202646	7	32		
Fred Wright	15-Aug-12	3	0001	0004	515025	6202852	515186	6202864	5.5	38		
Bear	17-Aug-12	1	2255	2257	638283	6212218	638319	6212305	16	1		1
Bear	17-Aug-12	2	0018	0025	637395	6215203	637340	6215557	15	12		1
Bear	17-Aug-12	3	0042	0050	637360	6215781	637315	6216200	16	14		
Bear	17-Aug-12	4	0424	0430	634206	6224457	634280	6224768	15	2		
Bear	17-Aug-12	5	0456	0511	632977	6228045	632507	6228771	21	18	4	
Bear	19-Aug-12	6	2205	2220	632837	6228252	633143	6227511	18	9	2	2
Bear	19-Aug-12	7	2236	2251	633167	6227603	632844	6228345	21	36		
Azuklotz	18-Aug-12	1	0527	0533	640857	6217007	640789	6217080	6	1		
Azuklotz	18-Aug-12	2	0537	0542	640904	6216899	640762	6217078	7	3		
Azuklotz	18-Aug-12	3	0546	0550	640913	6216953	640784	6217100	7	1		

ON: *O. nerka*; PWF: Pygmy whitefish; CH: Char sp

Table 3. 2012 Gillnet location and effort by lake

Lake	Date	Gillnet #	Time Start	Time End	Northing	Easting	ON	RSS
Bear	18-Aug-12	1	1941	0630	638258	6219128	4	66
Azuklotz	18-Aug-12	1	2125	0020	640459	6218255	0	22
Azuklotz	18-Aug-12	2	2200	0120	640684	6217082	0	0
Azuklotz	18-Aug-12	3	0119	0450	640834	6217006	0	0
Azuklotz	18-Aug-12	4	0137	0426	640867	6216953	0	0

ON: *O. nerka*; RSS: redside shiner

Table 4. 2012 Fish sample summary

Lake	Gear	Species	n	Mean Length (mm)	Max. Length (mm)	Min. Length (mm)	Std. Dev Length (mm)	Mean Weight (g)	Max. Weight (g)	Min. Weight (g)	Std. Dev Weight (g)
Fred Wright	Trawl	O. nerka	109	50.3	73	32	7.0	1.3	3.7	0.3	0.6
Bear	Trawl	O. nerka	92	65.6	86	31	9.6	3.3	7.3	0.2	1.4
Bear	Trawl	Pygmy whitefish	6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bear	Trawl	*Salvelinus sp.*	4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bear	Gillnet	O. nerka	4	75	90	69	10.0	4.8	8.0	3.6	2.1
Bearx	Gillnet	Redside shiner	66	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Azuklotz	Trawl	O. nerka	5	47.8	53	42	4.7	1.1	1.5	0.8	0.3
Azuklotz	Gillnet	Redside shiner	22	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 5. 2007 and 2008 Lakelse Lake hydroacoustic estimates by method

Lake	Estimate Method	Size Class	Density		Population	
			n/ha	95% C.I.	n	95% C.I.
Fred Wright	Integration (Stratification by transect)	Age-0 nerka	4,654	41%	1,833,806	41%
		Other Small	n/a	n/a	n/a	n/a
		Large	34	176%	13,565	176%
	Integration (Stratification by layer)	Age-0 nerka	5,671	26%	2,234,274	26%
		Other Small	n/a	n/a	n/a	n/a
		Large	41	138%	16,112	138%
Bear	Integration (Stratification by transect)	Age-0 nerka	944	46%	1,833,444	46%
		Other Small	260	43%	506,032	43%
		Large	61	47%	117,779	47%
	Integration (Stratification by layer)	Age-0 nerka	1,150	22%	2,234,269	22%
		Other Small	336	60%	653,451	60%
		Large	97	38%	188,744	38%
Azuklotz	Integration (Stratification by transect)	Age-0 nerka	1,201	95%	199,059	95%
		Other Small	575	85%	95,341	85%
		Large	48	96%	8,009	96%
	Integration (Stratification by layer)	Age-0 nerka	1,172	42%	194,650	42%
		Other Small	678	65%	112,532	65%
		Large	46	55%	7,694	55%

Table 6. PR Capacity comparison chart

Lake	Adjusted Rmax	Acoustic survey date	Estimation Method	Observed O. nerka fall fry	Avg. Weight	Observed biomass (kg)	% Rmax (adjusted)
Fred Wright	5465*	14-15-Aug-12	Integration	1,833,806	1.3	2384	44%
Bear	20166**	16-17-19-Aug-12	Integration	1,833,444	3.3	6050	30%
Azuklotz	2201**	18-Aug-12	Integration	199,059	1.1	219	10%

*- From Shortreed and Hume 2009

**- From Shortreed *et al.* 2007

Table 7. Past hydroacoustic estimates for lakes surveyed in 2012

Lake	Year	Date	Age-0 sockeye		Method	Source
			n/ha	n		
Fred Wright	1978	05-Oct	3,300	1,297,000	Integration	Simpson *et al.*(1981)
	1991	08-Sept	1,090	428,000	Integration	Rankin and Hyatt (2002)
	1992	17-Sept	380	149,375	Integration	McCreith *et al.* (1993)
	2001	07-Oct	209	82,137	Integration	Bussanich and Degan (2001)
	2002	03-Oct	1,086	426,767	Integration	Bussanich *et al.* (2003)
	2003	23-Sept	706	277,667	Integration	Bussanich (2005)
	2004	04-Oct	616	509,349	Integration	Bussanich (2005)
	2009	4-21 Sept	735	280,866	Integration	Hume *et al.* (2010)
Bear	2003	26-Aug	125	238,025	Integration	Shortreed and Hume (2004)
	2008	29-30-Sept	201*	390,656*	Integration	Carr-Harris (2009)
Azuklotz	2003	27-Aug	383	63,428	Integration	Shortreed and Hume (2004)
	2009	24-Sept	179	29,670	Integration	Carr-Harris (2010)

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

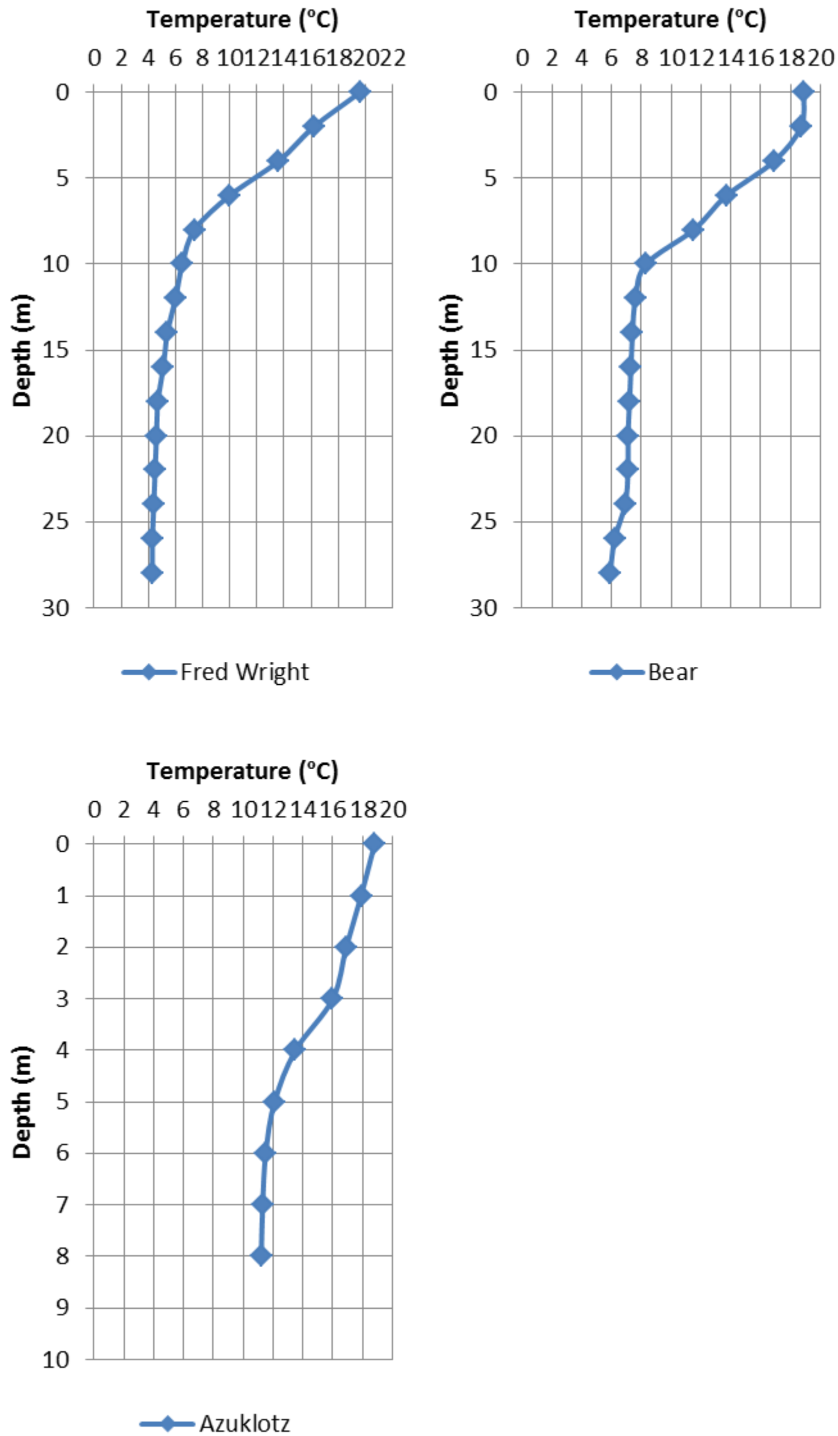


Figure 9. Temperature profiles for lakes surveyed in 2012. Note different scales.

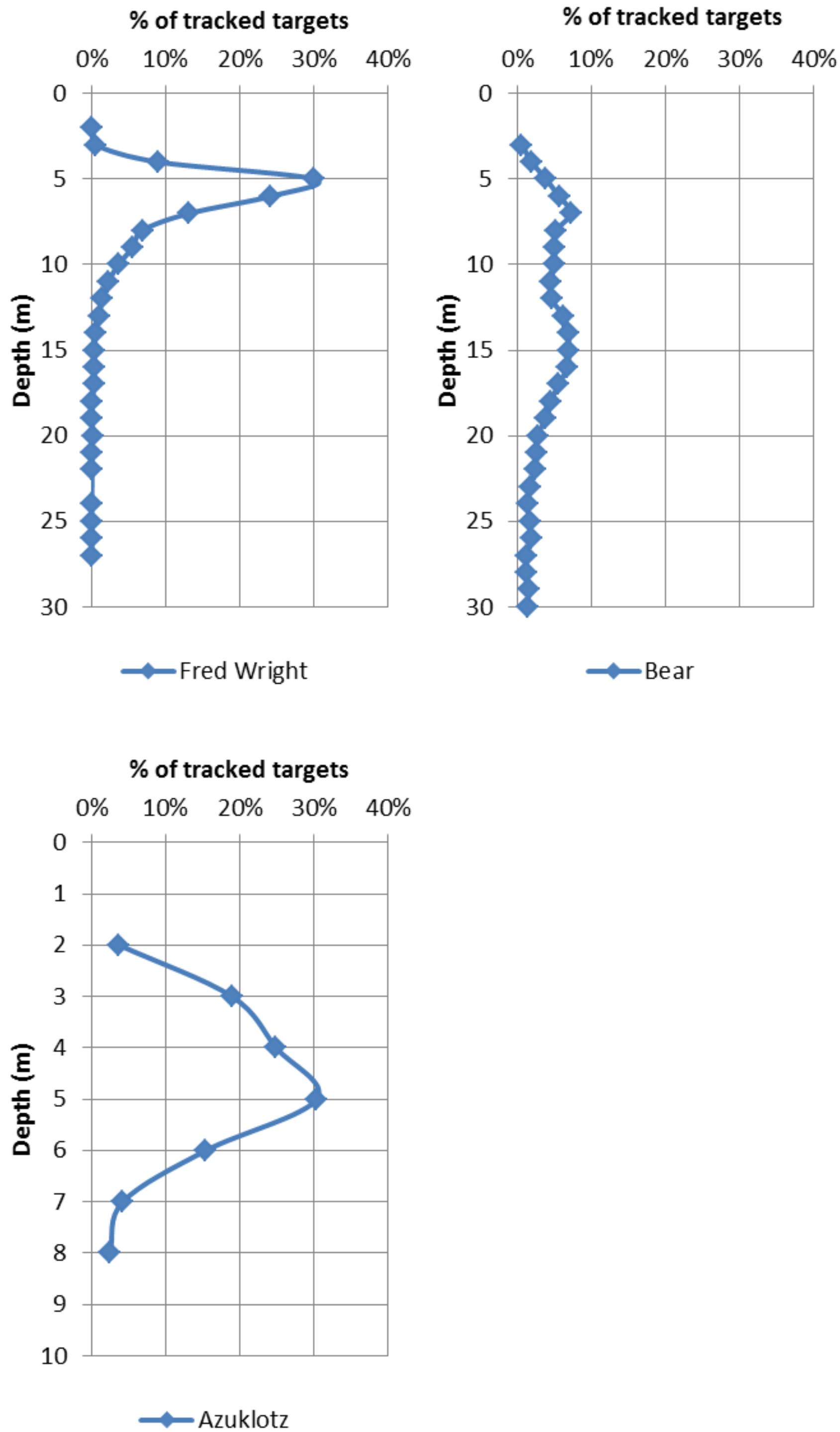


Figure 10. Vertical distribution of target density for 2012 lake surveys. Note different scales

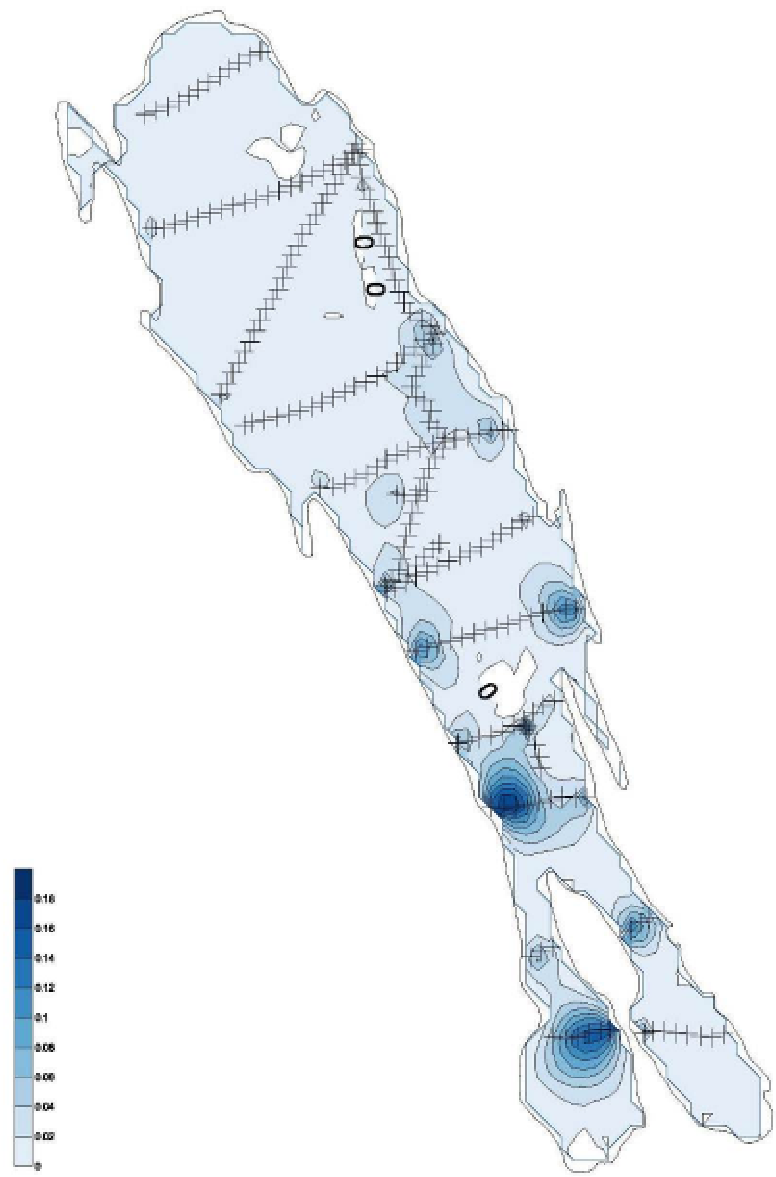


Figure 11. Surface distribution of fish targets (fish/m3) at Fred Wright Lake.

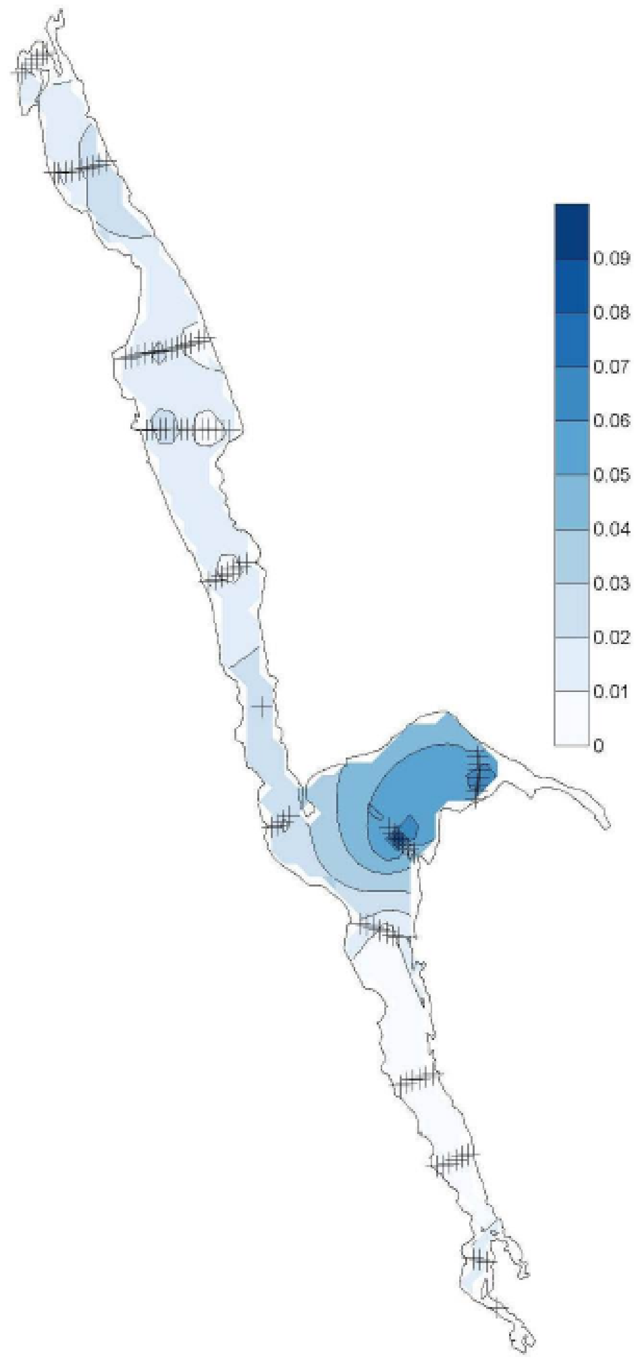


Figure 12. Surface distribution of fish targets (fish/m3) at Bear Lake.

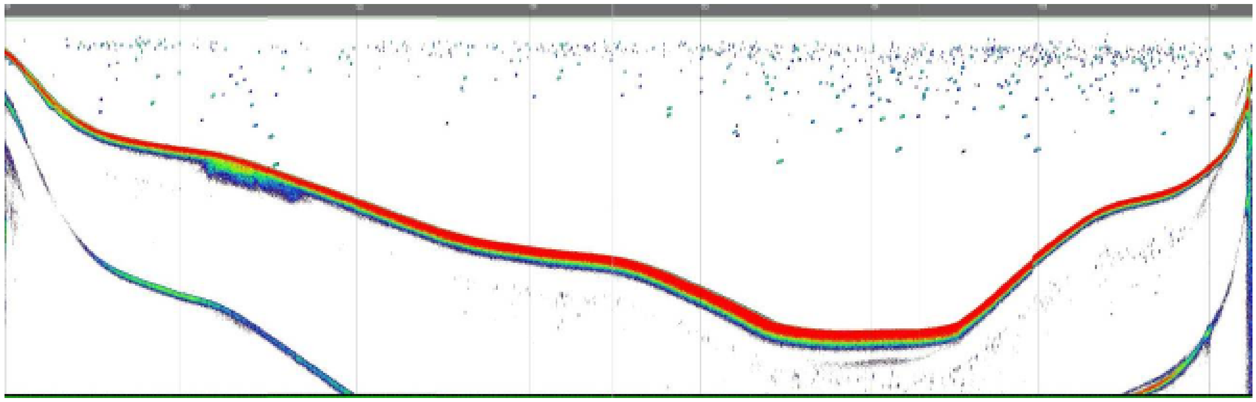


Figure 13. Fred Wright Lake transect 7 echogram

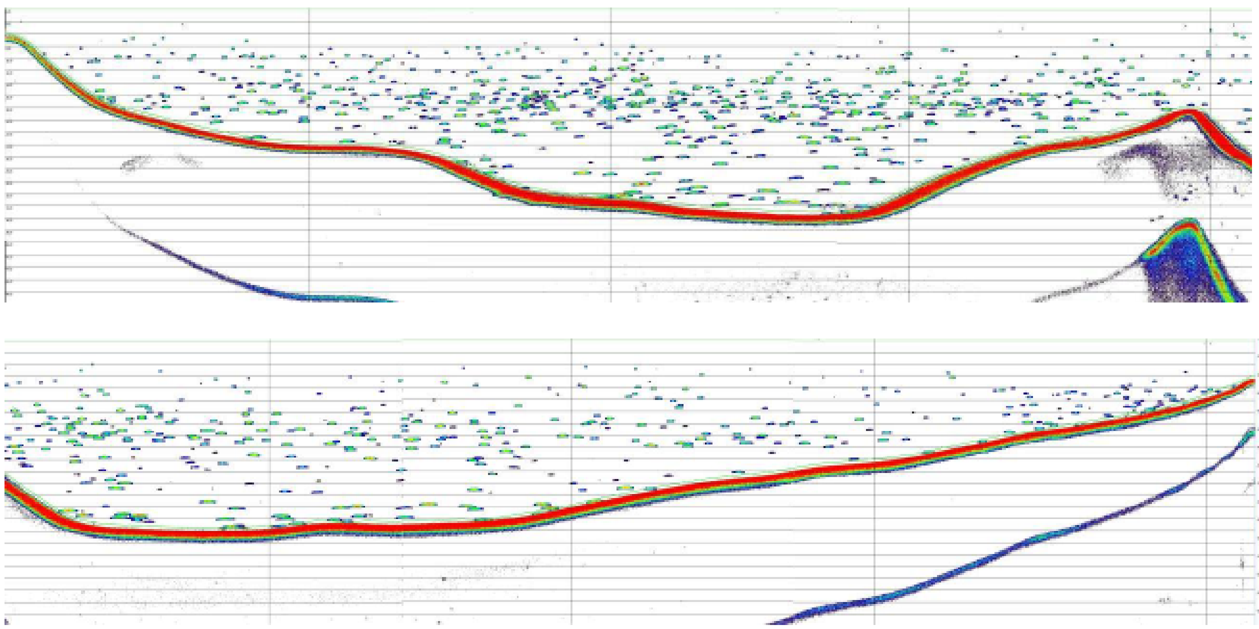


Figure 14. Bear Lake transect 2 echogram

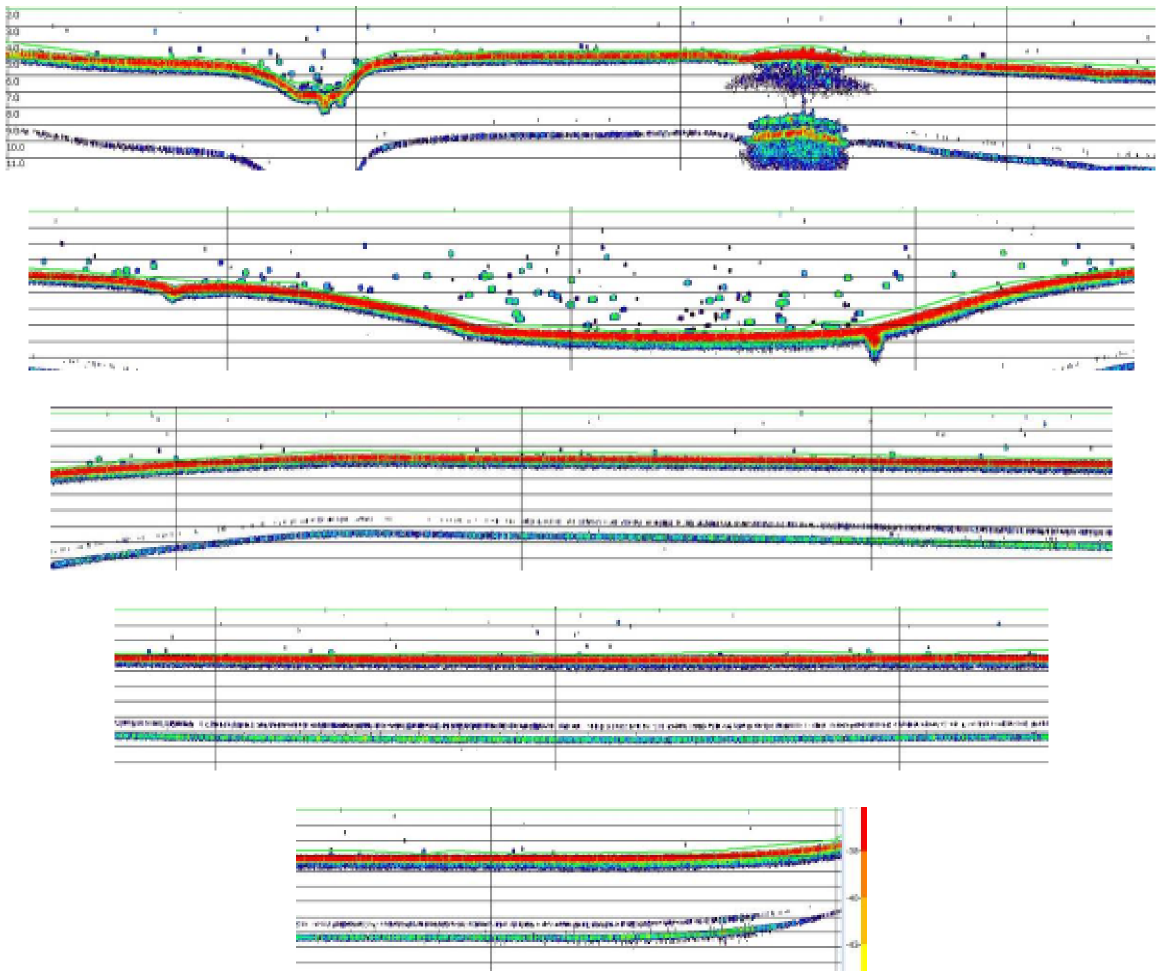
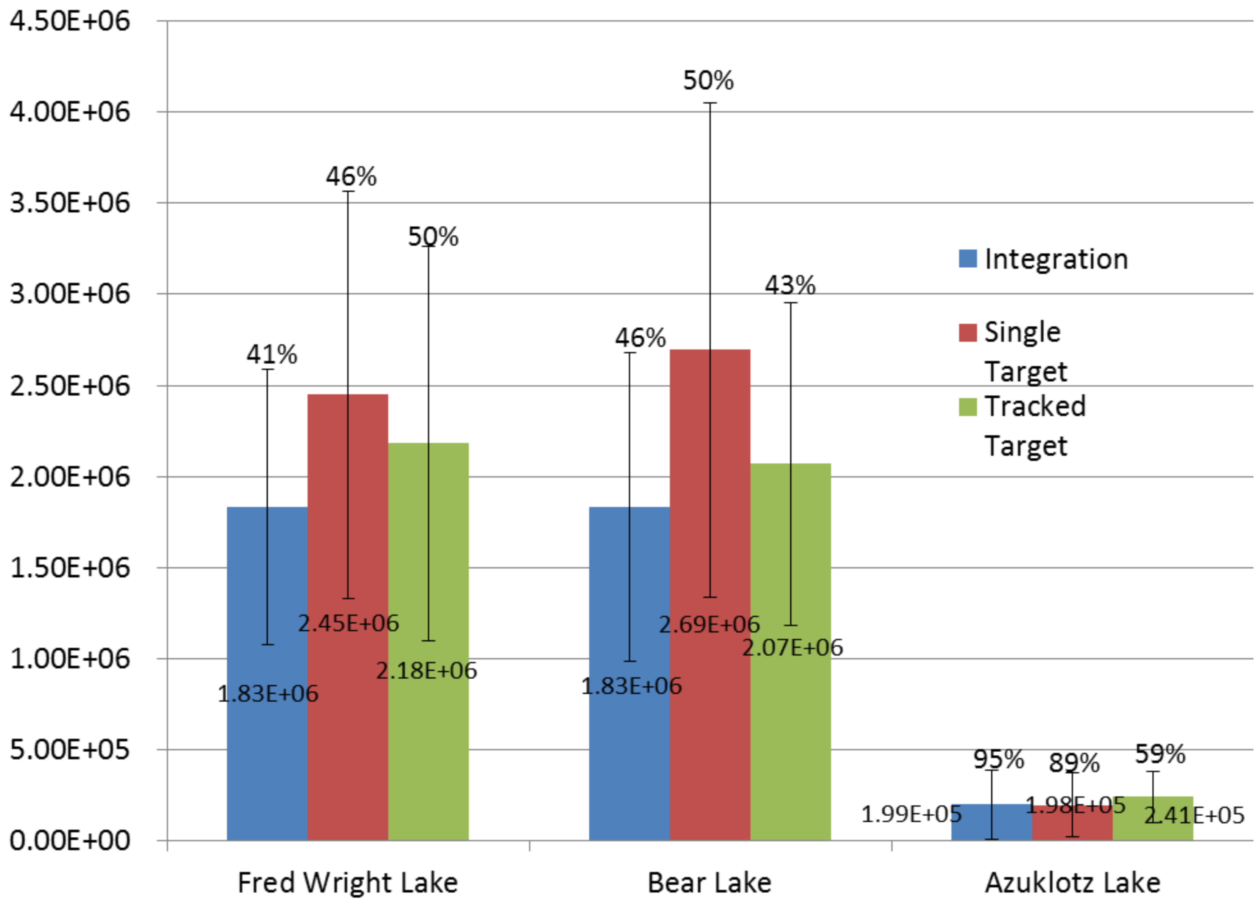


Figure 15. Azuklotz Lake transect 4 echogram

APPENDIX I.



Comparison between three hydroacoustic analysis methods: Integration, Single Target, and Tracked Target. All using stratification by transect as estimation method. The error bars show the 95% confidence intervals.