McDonell and Stephens Lakes Hydroacoustic Survey Report 2005

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EXECUTIVE SUMMARY

The Gitksan Watershed Authorities commenced their sockeye fry hydroacoustic survey program with a survey of McDonell and Stephens Lakes. Hydroacoustic data was collected using a Biosonics DT-X split beam echosounder with a 200kHz transducer producing a 6° beam. Limnetic fish were sampled using a 2 x 2 m midwater trawl and two 12 m floating Swedish gillnets. Temperature and dissolved oxygen measurements were taken using a YSI meter (model 85) from a location near to the deepest part of the lake.

A total of 200 sockeye/kokanee (*Oncorhynchus nerka*) and 4 sculpins (*Cottus sp.*) were caught in 5 tows of the midwater trawl on McDonell Lake. The mean fork length of the sockeye was 62 mm and the mean weight was 2.4 g. One sockeye, four cutthroat trout (*Oncorhynchus clarki*) and two whitefish (*Prosopium sp.*) were caught in McDonell Lake by two gillnets soaked for 18 to 19 hours overnight. Five tows in Stephens Lake that covered a linear distance of over 3 km caught a total of 59 sockeye/kokanee and 1 sculpin. The mean fork length of the sockeye was 72 mm and the mean weight was 3.8 g. Only one sockeye (82 mm) was caught in the two gillnets set in Stephens Lake overnight (9 to 11 hours soak time).

McDonell Lake age-0 sockeye fry population estimates ranged from 1.6×10^{5} ($\pm7.4\times10^{4}$) using the Single Target analysis method to 2.4×10^{5} ($\pm1.3\times10^{5}$) using the Tracked Target analysis method. Stephens Lake age-0 sockeye fry population estimates ranged from 2.3×10^{5} ($\pm2.8\times10^{5}$) using the Single Target and Integration analysis methods to 3.3×10^{5} ($\pm3.7\times10^{5}$) using the Tracked Target analysis method. Using the average weight of the sockeye caught in the trawl and the Integration population estimate, the estimated biomasses were 450 kg and 870 kg for McDonell and Stephens lakes respectively.

The optimum smolt biomass (R_{max}) for McDonell Lake was predicted to be 870 kg or 1.9×10^{5} smolts at 4.5 g based on the Photosynthetic Rate (PR) model and the adjusted R_{max} was predicted to be 360 kg (Cox-Rogers *et al.* 2004). The estimated fry biomass at the time of sampling in 2005 was 450 kg which exceeded the adjusted R_{max} by 25%. If the 2005 sockeye fry population exceeded the optimum rearing capacity of McDonell Lake we would expect to see reduced fry growth due to intraspecific competition for increasingly scarce food resources. Sockeye fry weights measured in 2002 however, were less than those measured in 2005 with a much smaller estimated population size which suggests that fry densities were not limiting growth in 2005.

The optimum smolt biomass (R_{max}) for Stephens Lake was predicted to be 1,700 kg or 3.8×10^{5} smolts at 4.5 g based on the PR model (Cox-Rogers *et al.* 2004). The estimated fry biomass at the time of sampling in 2005 was 870 kg and the estimated population was 2.3×10^{5}. In 2002 the estimated fry biomass was 440 kg and the estimated population was 1.8×10^{5}. The much larger biomass estimate from 2005 compared with 2002 is mostly due to the 45% larger fry weight.

The predicted optimum smolt biomass for Stephens Lake adjusted for historical exploitation rates (Adjusted R_{max}) was estimated at 710 kg (Cox-Rogers *et al.* 2004). The estimated fry biomass in 2005 exceeded this predicted optimum by 23%. The adjusted R_{max} value however may be appropriate given that fry recruitment may be limited by spawning habitat. Similar to the 2005 results from McDonell Lake, Stephens Lake shows a robust stock status relative to lake capacity.

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INTRODUCTION

The Gitksan Watershed Authorities commenced their sockeye fry hydroacoustic survey program with a survey of McDonell and Stephens Lakes (Fig. 1). McDonell Lake (Fig. 2) is located in the headwaters of the Zymoetz River which is a 6^{th} order tributary of the Skeena that drains a watershed area of approximately 3,028 km^2. McDonell Lake is also located in the boundary region between the Gitxsan and Wet'suwet'en traditional territories and is part of a chain of lakes including Dennis and Aldrich Lakes. The surface area of McDonell Lake is approximately 232.3 ha with a volume of $1.9x10^7$ m^3. The average depth of the lake is 8.2 m and the maximum depth is approximately 15 m.

Stephens Lake (Fig. 3) flows into the Kispiox River which is a 5^{th} order tributary of the Skeena that drains a watershed area of approximately 2,088 km^2. Stephens Lake is one of the most important sockeye rearing lakes in the Kispiox watershed (Gottesfeld *et al.* 2002) and is located within Gitxsan traditional territory and is part of a chain of lakes including Club and Swan Lakes. The surface area of Stephens Lake is approximately 196.6 ha with a volume of $2.2x10^7$ m^3. The average depth of the lake is 11.4 m and the maximum depth is approximately 28 m. Despite having a smaller surface area than McDonell Lake, Stephens Lake has a larger volume due to its greater average depth.

METHODS

Hydroacoustic data was collected using a Biosonics DT-X split beam echosounder with a 200kHz transducer producing a 6^o beam. Transect waypoints were obtained from Steven McLellan (DFO Cultus Lake Laboratory) in order to replicate previous surveys completed by the DFO (Fig. 4 & 5). Transect one on McDonell Lake was abandoned after the first survey in 2001 because it was too shallow, however the original transect numbering system has been retained to remain consistent between years. All hydroacoustic data were collected at night. McDonell Lake was surveyed on the night of September 22/23, 2005 and Stephens Lake was surveyed on the night of October 13/14, 2005.

Each transect was analyzed in separate 2 m depth layers. Average target densities were calculated for each layer by three separate methods. Briefly, the Echo Integration calculation method takes the average sound energy return from each layer and divides it by the average target strength to get target densities for each layer. The Single Target calculation method looks at the wave form of the sound energy that returns (the echo), and selects only those echoes that have specific wave form characteristics that are typical of echoes reflected from single fish, classifying these echoes as single targets. The total number of single targets in a layer is then divided by the sum of the volumes sampled by all pings, within the layer, to determine a layer density. The Tracked Target calculation method groups single targets together into individual target (fish) tracks which are divided by a smaller sampled wedge volume, roughly the cross sectional dimensions of the sound beam times the length of the transect, to generate density for each layer.

Once the densities are determined for each layer they are multiplied by the layer volume of the lake area represented by that transect to produce a transect layer population estimate. Volumes for each depth layer and representative transect area in the lake were provided by the DFO Cultus Lake Lab. Layer population estimates are then summed to produce transect estimates which are in turn summed to produce the total fish estimate for the entire lake or lake section. Confidence intervals for fish densities and population estimates are derived by taking 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 from –64 to –46 dB. For salmoniform fish, this target strength is approximately equivalent to fish <135 mm, based on Love's (1977) 45^{o} aspect formula. Small fish were then apportioned into "*O. nerka*" and "other small fish" based on the relative proportion of species in the trawl catch.

Limnetic fish were sampled using two different methodologies. The primary catch method was with a 2 x 2-m midwater trawl. The trawl is fishable to approximately 35 m depth. The second method was with two 12 m floating Swedish gillnets which had variable mesh size panels of ½", 5/7", ¾" and 1" stretched mesh. All fish were preserved in 10% formalin to obtain size and age information and no measurements were taken until the samples had been preserved for at least 30 days to ensure length and weight stabilization.

Temperature and dissolved oxygen measurements were taken using a YSI meter (model 85) from a location near to the deepest part of the lake. The YSI meter was calibrated in elevation to the nearest 100 ft and allowed approximately 15 minutes in order to stabilize before readings were recorded.

RESULTS

Trawl Catch

A total of 200 sockeye/kokanee (*Oncorhynchus nerka*) and 4 sculpins (*Cottus sp.*) were caught in 5 tows of the midwater trawl on McDonell Lake (Table 1). The first two tows caught no fish, likely because the winch failed and the trawl was pulled in slowly by hand. Tows 3-5 were completed 3 days later on September 26th after the winch was repaired and were set deeper to target the high densities observed in the echograms. The locations of each tow are presented in Figure 4.

Five tows in Stephens Lake that covered a linear distance of over 3 km caught a total of 59 sockeye/kokanee and 1 sculpin (Table 2). Catches were much more evenly distributed between tows compared with McDonell Lake. Figure 5 shows the locations of each tow.

Sculpins were the only species other than sockeye caught in the trawl in both lakes. Since sculpins have no air bladder, are a benthic species and are typically small sized, we feel that it is unlikely that many sculpins were detected by the echosounder at our analysis target strength threshold of –65 dB. We therefore apportioned 100% of the small-sized acoustic targets to sockeye.

Gillnet Catch

Two floating gillnets were fished in McDonell Lake (Fig. 4) overnight for a total soak time of 18 to 19 hours (Table 3). One sockeye, four cutthroat trout (*Oncorhynchus clarki*) and two whitefish (*Prosopium sp.*) were caught in McDonell Lake. One sockeye (94 mm) and one cutthroat (184 mm) were retained while the other fish were released alive. Although measurements on the released fish were not recorded, all of the released fish were over 100 mm.

Gillnets in Stephens Lake (Fig. 5) were fished overnight for a total soak time of 9 to 11 hours (Table 3). Only one sockeye (82 mm) was caught in the two gillnets.

Fish Size Distribution

The average fork length of sockeye caught in the trawl was 62 mm from McDonell Lake and 72 mm from Stephens Lake (Table 4). In addition to the differences in lake environments, the Stephens Lake survey was 22 days later in the season. Sockeye caught in the trawl from McDonell Lake had a broader distribution of lengths compared with Stephens Lake (Fig. 6 & 7), which indicates the potential for two age classes. Scales were sampled from most of the trawl caught fish but had not been aged at the time of writing this report.

All sculpins caught in the trawl were small with the largest sculpin caught in Stephens Lake at 56 mm total length (Table 6).

Temperature and Oxygen Profiles

McDonell Lake showed virtually no change in temperature with depth although it was warmer than Stephens Lake (Fig. 8). This is likely a function of the earlier sampling date and the shallower maximum depth of McDonell Lake compared to Stephens Lake. The latter showed a decline in temperature from 10 m depth to the bottom (25 m) of approximately 3^{o} Celsius. The dissolved oxygen profile for Stephens Lake follows the temperature profile closely with a decline of approximately 3 ppm from 10 to 25 m depth (Fig. 9). McDonell Lake showed a rapid decrease in dissolved oxygen in the last 3 m depth from 7 to 5 ppm.

Hydroacoustic Fish Estimates

McDonell Lake age-0 sockeye fry population estimates ranged from $1.6x10^5$ ($\pm 7.4x10^4$) using the Single Target analysis method to $2.4x10^5$ ($\pm 1.3x10^5$) using the Tracked Target analysis method (Table 7 & Fig. 10). Transects 2 and 3 showed the highest densities while transects 5 and 9 showed the lowest age-0 fry densities regardless of which estimate method was used (Fig. 11).

Stephens Lake age-0 sockeye fry population estimates ranged from $2.3x10^5$ ($\pm 2.8x10^5$) using the Single Target and Integration analysis methods to $3.3x10^5$ ($\pm 3.7x10^5$) using the Tracked Target analysis method (Table 8 & Fig. 10). Transect 2 showed the highest density while transect 1 showed the lowest age-0 fry densities which was consistent for all analysis methods (Fig. 12).

The Tracked Target analysis method consistently produced the largest estimates for both lakes. The Integration estimate was larger than the Single Target estimate for McDonell Lake while they were virtually identical for Stephens Lake (Fig. 10). All estimate methods were well within each other's 95% confidence intervals. Stephens Lake estimates had much larger 95% confidence intervals than McDonell Lake due to the lesser number of transects and the higher variability between transects. The integration estimate is used in the discussion of this report in order to remain consistent with previous published reports.

McDonell Lake showed a strong increase in acoustic target density with depth (Fig. 13) compared to Stephens Lake which showed uniform densities throughout the water column (Fig. 14). Average target strengths for each layer also increased with depth in McDonell Lake; however, this trend may not be significant given the small sample size in the upper depth layers (Fig. 13). Stephens Lake showed virtually no change in average target strength with depth (Fig. 14).

In Stephens Lake, a higher age-0 sockeye fry population estimate combined with the slightly smaller surface area, resulted in a higher average density of sockeye fry ($1.2x10^3$ targets/ha) compared with McDonell Lake at $8.8x10^2$ targets/ha. Stephens Lake has a greater average depth than McDonell Lake and targets were found relatively evenly distributed throughout the water column. McDonell Lake has a smaller average depth and the targets were found in greater abundance in the lower depth strata consequently fish targets were more densely packed in McDonell Lake than in Stephens Lake. The large-sized fish population estimate was greatest for Stephens Lake $5.2x10^4$ although in the same order of magnitude as McDonell Lake at $1.2x10^4$. Both lakes had large-sized fish population estimates an order of magnitude less than the sockeye-sized fish population estimates.

Using the average weight of the sockeye caught in the trawl and the Integration population estimate, the estimated biomasses were 450 kg and 870 kg for McDonell and Stephens lakes respectively.

DISCUSSION

McDonell Lake

We attempted to follow the same survey design as described by the staff at the DFO Cultus Lake Laboratory in order to allow for comparisons with earlier surveys (Shortreed *et al.* 2002, Shortreed and Hume 2004). McDonell Lake was previously surveyed September 10, 2001 and September 13, 2002. No fish were caught in one trawl in 2001 (Shortreed *et al.* 2002). In 2002 the same 2x2 m trawl caught 20 sockeye with a mean weight of 1.5 g and a mean length of 52 mm (Shortreed and Hume 2004). The sockeye sampled from the trawl in 2005 were much larger with a mean length of 62 mm and a mean weight of 2.4 g. The larger size in 2005 can be partially explained by the later sampling date (13 days) but other factors must have also played a role in this size discrepancy. The maximum sizes recorded in 2002 are similar to the average sizes observed in 2005.

Gillnet catches from McDonell Lake in 2002 had many more fish and a larger variety of species including bull trout (*Salvelinus confluentus*), coho (*Oncorhynchus kisutch*), lake chub (*Couesius plumbeus*) and rainbow trout (*Oncorhynchus mykiss*) in addition to cutthroat trout which were also caught in 2005. No whitefish were caught in 2002.

The integration density estimate for McDonell Lake age-0 sockeye in 2001 was 352 fish/ha. It was substantially larger in 2002 at 595 fish/ha and in 2005 with 882 fish/ha. Sockeye escapements to the upper Zymoetz River are unavailable for 2000 and 2001 which would be the brood years of the fry estimates in 2001 and 2002 however the 2004 escapement was estimated to be 3,166 sockeye. The 2004 escapement translates to a recruitment of 30 fry per female assuming a 50/50 sex ratio.

The optimum smolt biomass (R_{max}) for McDonell Lake was predicted to be 870 kg or $1.9x10^5$ smolts at 4.5 g based on the Photosynthetic Rate (PR) model (Cox-Rogers *et al.* 2004). The estimated fry biomass at the time of sampling in 2005 was 450 kg and the estimated population was $1.9x10^5$. In 2002 the estimated fry biomass was 210 kg and the estimated population was $1.3x10^5$. Since no sockeye were caught in 2001, no weights were taken and a biomass estimate could not be made, but the population estimate was $7.6x10^4$ sockeye fry. If we use the average fry weight from 2002 (1.5 g) then the sockeye fry biomass in 2001 was approximately 110 kg.

The fry biomass estimates may be underestimated since the 2x2 m trawl is biased against catching fish above 50 mm and the average length caught in the trawl in 2005 was 62 mm. This would result in an underestimate of the mean sockeye fry weight which would bias the biomass estimate lower than the actual value. The 2x2 m trawl net however, appears to be more effective when targeting fish that are packed into a relatively small volume of water as observed in the deeper portions of McDonell Lake during this survey (MacLellan 2006 personal communication).

All of these observed biomasses are well below the optimum for McDonell Lake. The 2005 estimated sockeye fry population, however, was larger than the optimum predicted smolt population because the PR model predicted smolt population optimum is based on 4.5 g smolts. In applying fall fry survey data to the PR model we make the assumption that the biomass remains constant throughout the fall, winter and spring as fry growth is balanced equally by mortality. Only smolt surveys the following spring could validate this assumption and the degree to which our assumption is violated probably varies between lakes and between years.

Cox-Rogers *et al.* (2004) attempted to account for possible overestimation of rearing capacity by calibrating with historical exploitation rates resulting in a reduced predicted optimum smolt biomass for McDonell Lake of 360 kg (Adjusted R_{max}). The estimated fry biomass in 2005 exceeded this predicted optimum by 25%. If the 2005 sockeye fry population exceeded the optimum rearing capacity of McDonell Lake we would expect to see reduced fry growth due to intraspecific competition for increasingly scarce food resources. Sockeye fry weights measured in 2002 however, were less than those measured in 2005 with a much smaller estimated population size, which suggests that fry densities were not limiting growth in 2005.

Another confounding factor for the estimates of sockeye fry and R_{max} for McDonell Lake is the possibility of age-1 sockeye fry which is suggested by the wide range of sockeye lengths caught in the trawl. If age-1 fry are present then the PR estimate of production available to age-0 sockeye would have to be reduced along with the density and biomass estimates of age-0 fry. Scales from these fry will be examined in 2006 to make this determination and be reported with the results from the 2006 survey.

The large estimated biomass from the 2005 survey suggests that the Adjusted R_{max} may also be too low given the observed fry size compared with years of lower population density. Perhaps the unadjusted R_{max} or some value in between the two may be a more appropriate value for McDonell Lake. Much more fry size and density data will need to be collected in order to clarify this issue. Regardless of which value is more appropriate, the large estimated sockeye fry biomass in McDonell Lake is an indication that the McDonell Lake sockeye population is relatively healthy compared to other wild Skeena sockeye stocks (Cox-Rogers *et al.* 2004).

Stephens Lake

The 2005 sockeye fry caught in Stephens Lake were larger than those observed in 2002 where 21 sockeye caught in the trawl had an average length of 58 mm and average weight of 2.1 g compared with 72 mm and 3.8 g in 2005 (n=59). The sampling date for Stephens Lake however was 33 days later in 2005 which may explain much of the size difference.

Gillnet catches from Stephens Lake in 2002 were also more comprehensive compared to 2005 with a large catch of coho (n=38), some rainbow trout, white suckers (*Catostomus commersoni*) and whitefish. Cultus Lake DFO staff apportioned 4% of the small size class acoustical targets to coho because the coho caught in the gillnets had a mean length of 84 mm which clearly overlapped with the sockeye fry.

The integration density estimate for Stephens Lake age-0 sockeye in 2002 was 897 fish/ha which was less than the estimate in 2005 (1,175 fish/ha). The 95% confidence intervals around the estimates are much higher in Stephens Lake than McDonell Lake because there are fewer transects on Stephens Lake although it is roughly the same size as McDonell. Staff at the DFO's Cultus Lake Laboratory are recommending transects be added to the hydroacoustic survey design for Stephens Lake (McLellan 2006 personal communication).

The 2004 sockeye escapement estimate for upper and lower Club Creek was 5,863 which translates to a recruitment of 20 fry per female assuming a 50/50 sex ratio of adult spawners. The 2001 sockeye escapement estimate for upper and lower Club Creek was 8,353 which translates to a much lower recruitment of only 11 fry per female assuming a 50/50 sex ratio of adult spawners. These data indicate poorer fry recruitment at higher spawning densities although there are only two data points to compare with. The primary spawning grounds in the Swan-Stephens system are in Club Creek just upstream of Stephens Lake. This spawning location is unusual for sockeye since the substrate is boulder size material and no redds are built by the spawning sockeye (Foerster 1968). Other factors such as inter annual variation in environmental conditions (temperature, discharge, etc.) can play a major role in fry recruitment.

Estimating fry recruitment from spawners in upper and lower Club Creek assumes that all the sockeye fry travel downstream and rear in Stephens Lake. Swan Lake is located just upstream of these spawning sites (in fact upper Club Creek is the outlet of Swan Lake) and there is no barrier to fry movement upstream. Swan Lake was found to have higher densities (897/ha) of *O. nerka* than Stephens (386/ha) in 2002 but a large proportion of the *O. nerka* surveyed were probably kokanee based on chemical analysis of 12 otoliths (MacLellan 2006. personal communication).

The optimum smolt biomass (R_{max}) for Stephens Lake was predicted to be 1,700 kg or $3.8x10^5$ smolts at 4.5 g based on the PR model (Cox-Rogers *et al.* 2004). The estimated fry biomass at the time of sampling in 2005 was 870 kg and the estimated population was $2.3x10^5$. In 2002 the estimated fry biomass was 440 kg and the estimated population was $1.8x10^5$. The much larger biomass estimate from 2005 compared with 2002 is mostly due to the 45% larger fry weight.

The predicted optimum smolt biomass for Stephens Lake adjusted for historical exploitation rates (Adjusted R_{max}) was estimated at 710 kg (Cox-Rogers *et al.* 2004). The estimated fry biomass in 2005 exceeded this predicted optimum by 23%. The adjusted R_{max} value however may be appropriate given that fry recruitment may be limited by spawning habitat. Similar to the 2005 results from McDonell Lake, Stephens Lake shows a robust stock status relative to lake capacity.

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Table 1. McDonell Lake trawl catch summary

Lake	Tow	Location (Transect)	Length (m)	Average Depth (m)	Sockeye	Sculpin
McDonell	1	3 - 4	730	9	0	0
	2	6 - 3	1,560	7	0	0
	3	4 - 5	500	13	19	1
	4	3 -4	480	12.5	6	2
	5	3 - 5	870	13	175	1
Total	**5**	**n/a**	**4,140**	**n/a**	**200**	**4**

Table 2. Stephens Lake trawl catch summary

Lake	Tow	Location (Transect)	Length (m)	Average Depth (m)	Sockeye	Sculpin
Stephens	1	3	320	18	8	0
	2	3 - 2	560	17	10	0
	3	4	670	17	7	1
	4	4 - 2	1,060	16	14	0
	5	2 - 3	800	17	20	0
Total	**5**	**n/a**	**3,410**	**n/a**	**59**	**1**

Table 3. Gillnet catch summary

Lake	Gillnet	UTM	Soak Time (Hours)	Sockeye	Cutthroat	Whitefish
McDonell	1	09 U 590936 6071460	18	0	3	2
	2	09 U 589829 6071238	19	1	1	0
Stephens	1	09 U 526944 6180455	11	1	0	0
	2	09 U 525502 6182207	9	0	0	0

Table 4. Sockeye size distribution captured in trawl

	McDonell		Stephens	
	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Min	38	0.6	52	1.5
Max	83	5.6	82	5.5
Mean	62.2	2.4	72.2	3.8
n	200	136	59	59

Table 5. Sockeye size distribution caught in gillnets

	McDonell	Stephens
Length	94	82
Weight	9.4	5.1
n	1	1

Table 6. Sculpin size distribution

	McDonell Length (mm)	McDonell Weight (g)	Stephens Length (mm)	Stephens Weight (g)
Min	26	0.2	56	1.6
Max	35	0.6	56	1.6
Average	30.3	0.4	56	1.6
n	4	4	1	1

Table 7. McDonell Lake hydroacoustic fish population estimates

Estimate Method	Size Class	Density N/ha	Density 95% C.I.	Population N	Population 95% C.I.
Integration	*O. nerka*	$8.8x10^{2}$	$4.9x10^{2}$	$1.9x10^{5}$	$1.0x10^{5}$
	Large	$5.6x10^{1}$	$2.6x10^{1}$	$1.2x10^{4}$	$5.6x10^{3}$
Single Target	*O. nerka*	$7.4x10^{2}$	$3.5x10^{2}$	$1.6x10^{5}$	$7.4x10^{4}$
	Large	$5.1x10^{1}$	$3.0x10^{1}$	$1.1x10^{4}$	$6.4x10^{3}$
Tracked Targets	*O. nerka*	$1.1x10^{3}$	$6.1x10^{2}$	$2.4x10^{5}$	$1.3x10^{5}$
	Large	$7.3x10^{1}$	$3.8x10^{1}$	$1.6x10^{4}$	$8.2x10^{3}$

Table 8. Stephens Lake hydroacoustic fish population estimates

Estimate Method	Size Class	Density N/ha	Density 95% C.I.	Population N	Population 95% C.I.
Integration	*O. nerka*	$1.2x10^{3}$	$1.4x10^{3}$	$2.3x10^{5}$	$2.8x10^{5}$
	Large	$2.7x10^{2}$	$2.9x10^{2}$	$5.2x10^{4}$	$5.6x10^{4}$
Single Target	*O. nerka*	$1.2x10^{3}$	$1.4x10^{3}$	$2.3x10^{5}$	$2.7x10^{5}$
	Large	$3.0x10^{2}$	$3.0x10^{2}$	$5.8x10^{4}$	$6.0x10^{4}$
Tracked Targets	*O. nerka*	$1.7x10^{3}$	$1.9x10^{3}$	$3.3x10^{5}$	$3.7x10^{5}$
	Large	$4.2x10^{2}$	$4.3x10^{2}$	$8.2x10^{4}$	$8.5x10^{4}$

Table 9. PR model predicted fry populations and biomass compared to observed results

Lake	Year	PR Model Rmax (kg)	PR Model RmaxN (# smolts)	PR Model Adjusted Rmax (kg)	PR Model Adjusted Rmax (# smolts)	Observed Fry Biomass (kg)	Observed Fry Pop. (# fry)	Observed % Adj. Rmax (kg)
McDonell	2001	870	$1.9x10^{5}$	360	$8.0x10^{4}$	n/a	$7.6x10^{4}$	n/a
	2002					210	$1.3x10^{5}$	53%
	2005					450	$1.9x10^{5}$	125%
Stephens	2002	1,700	$3.8x10^{5}$	710	$1.6x10^{5}$	440	$1.8x10^{5}$	62%
	2005					870	$2.3x10^{5}$	123%

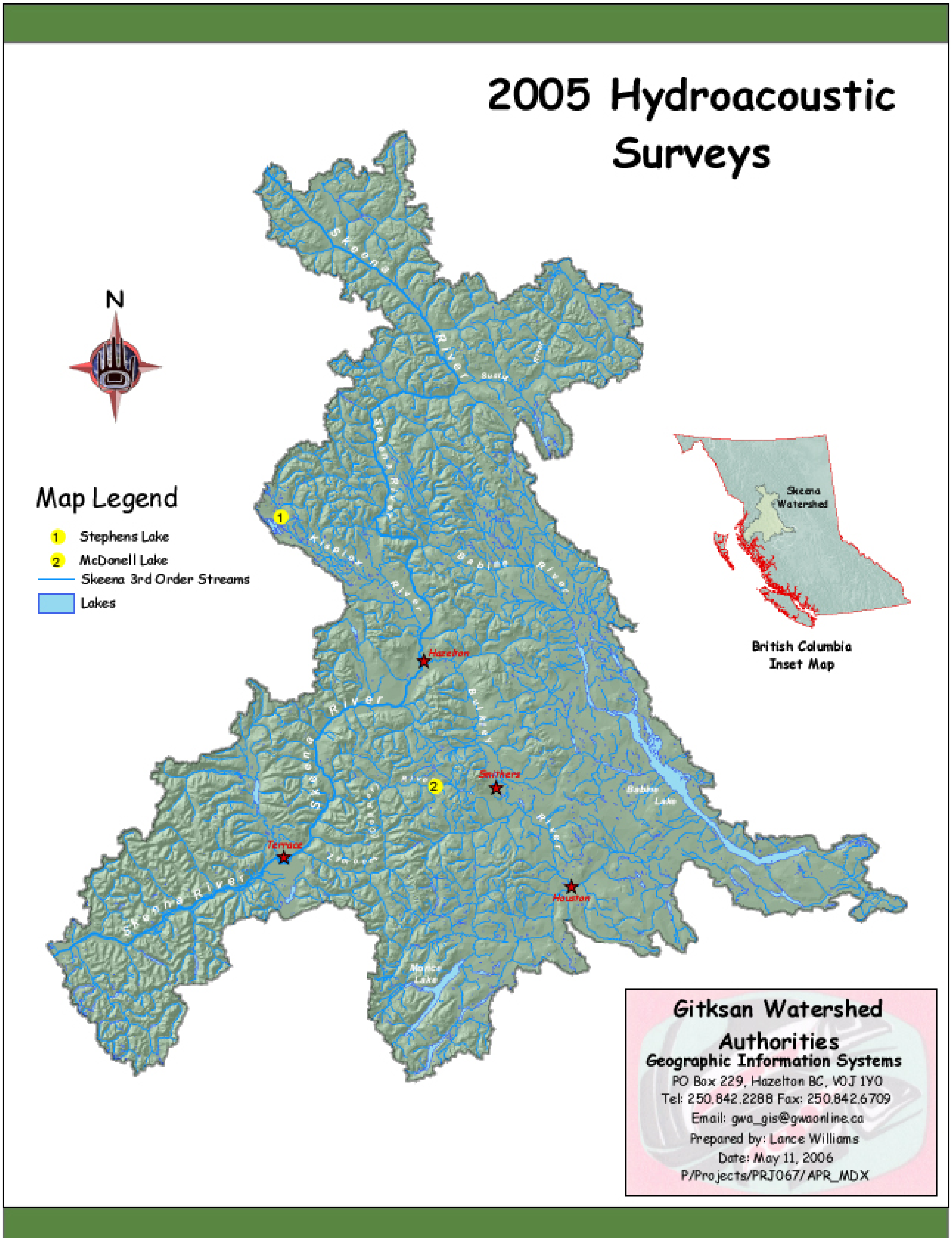

Figure 1. Location of McDonell and Stephens Lake in the Skeena watershed

Figure 2. McDonell Lake air photo (Superfly)

Figure 3. **Stephens Lake Satellite photo (Google Earth)**

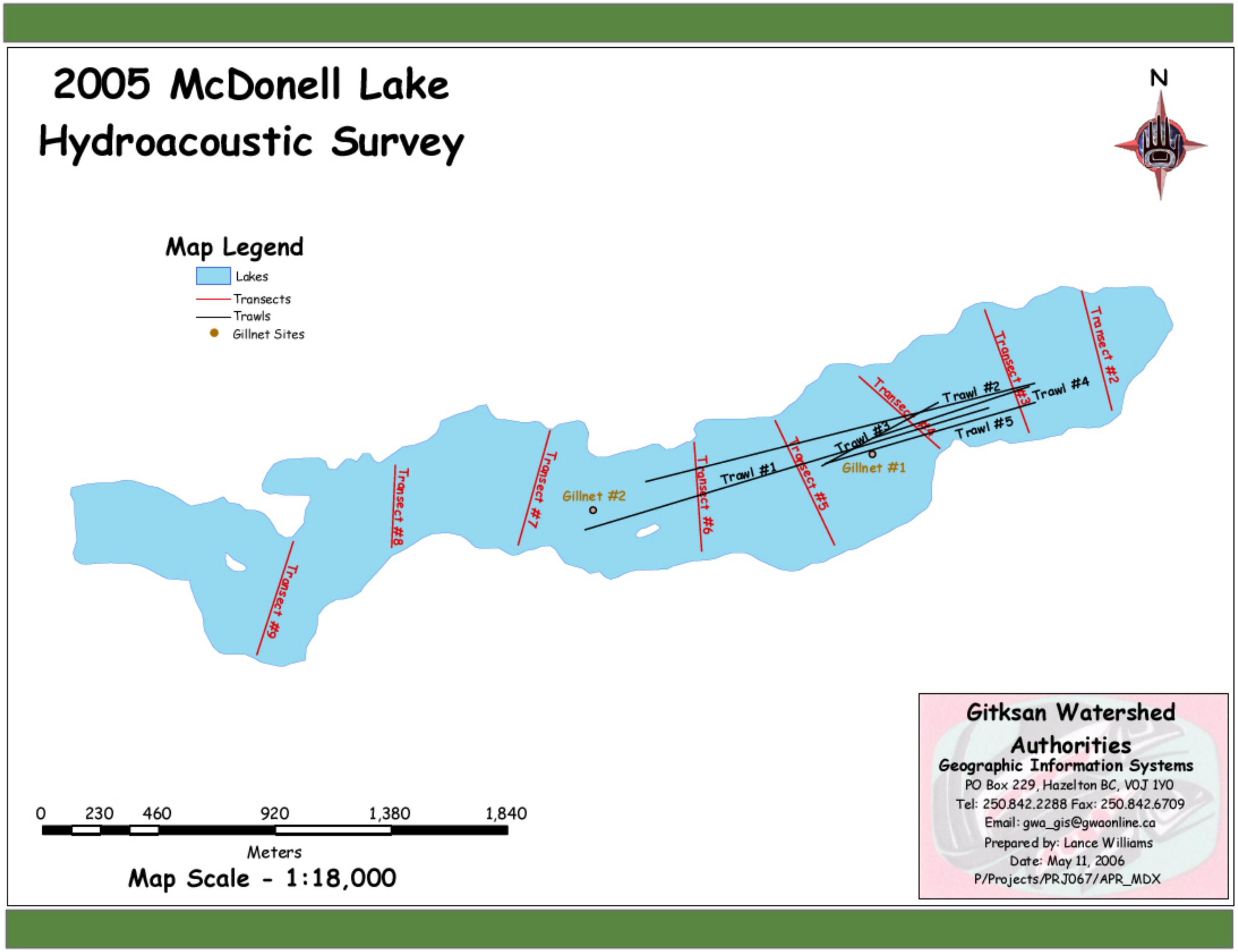

Figure 4. McDonell Lake hydroacoustic transects, trawl tows and gillnet sets

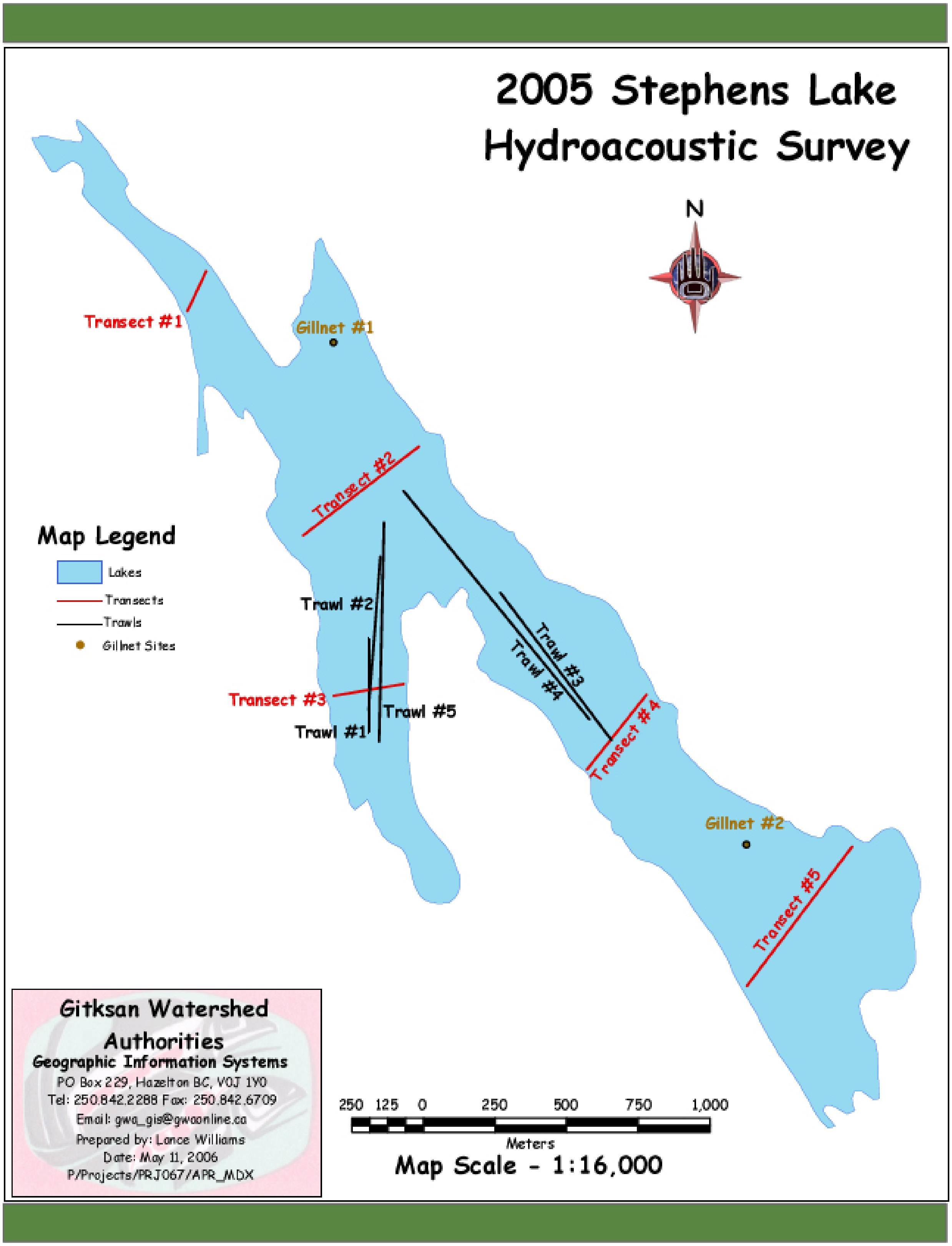

Figure 5. **Stephens Lake hydroacoustic transects, trawl tows and gillnet sets**

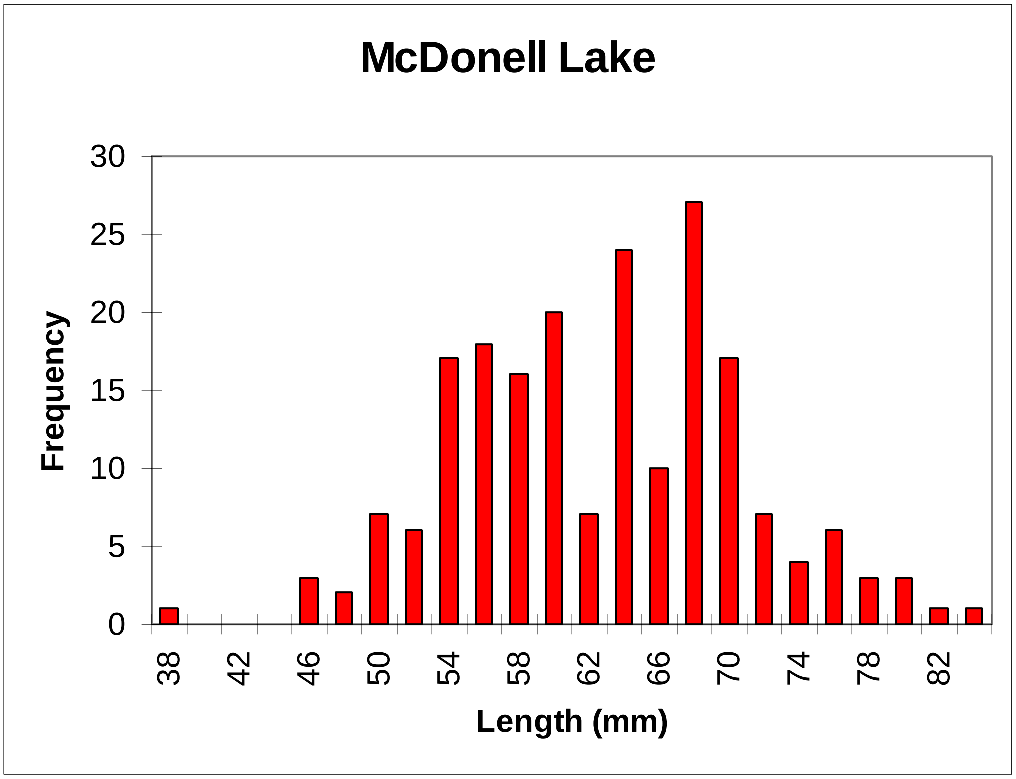

Figure 6. McDonell Lake sockeye length frequency from trawl catch

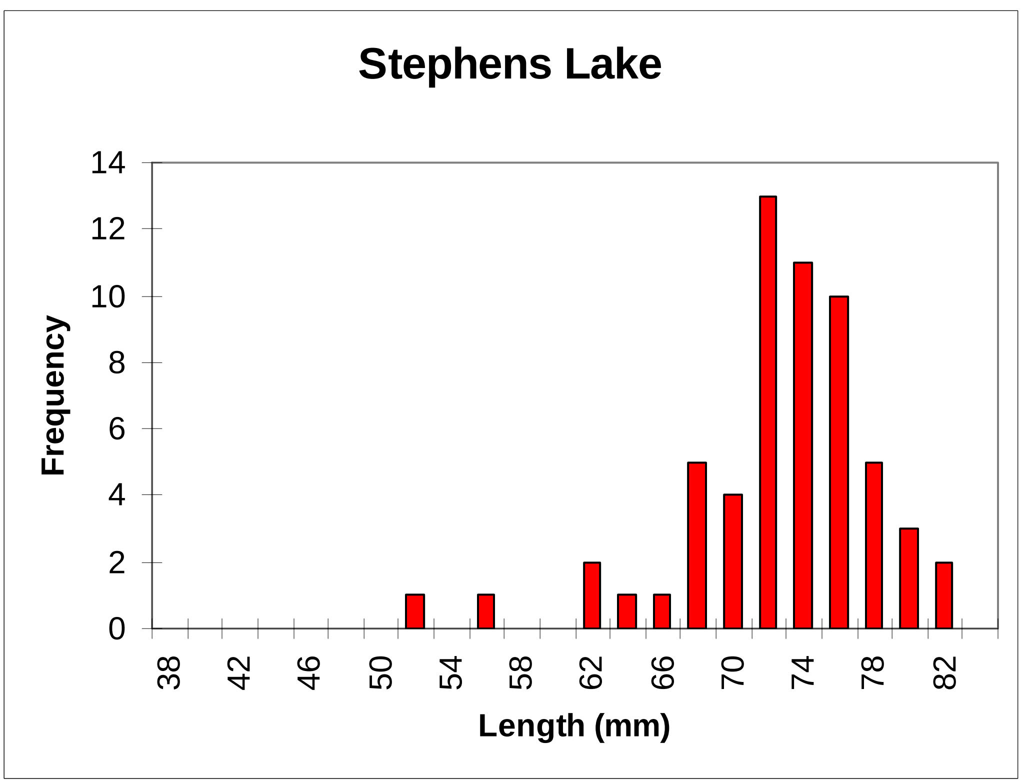

Figure 7. Stephens Lake sockeye length frequency from trawl catch

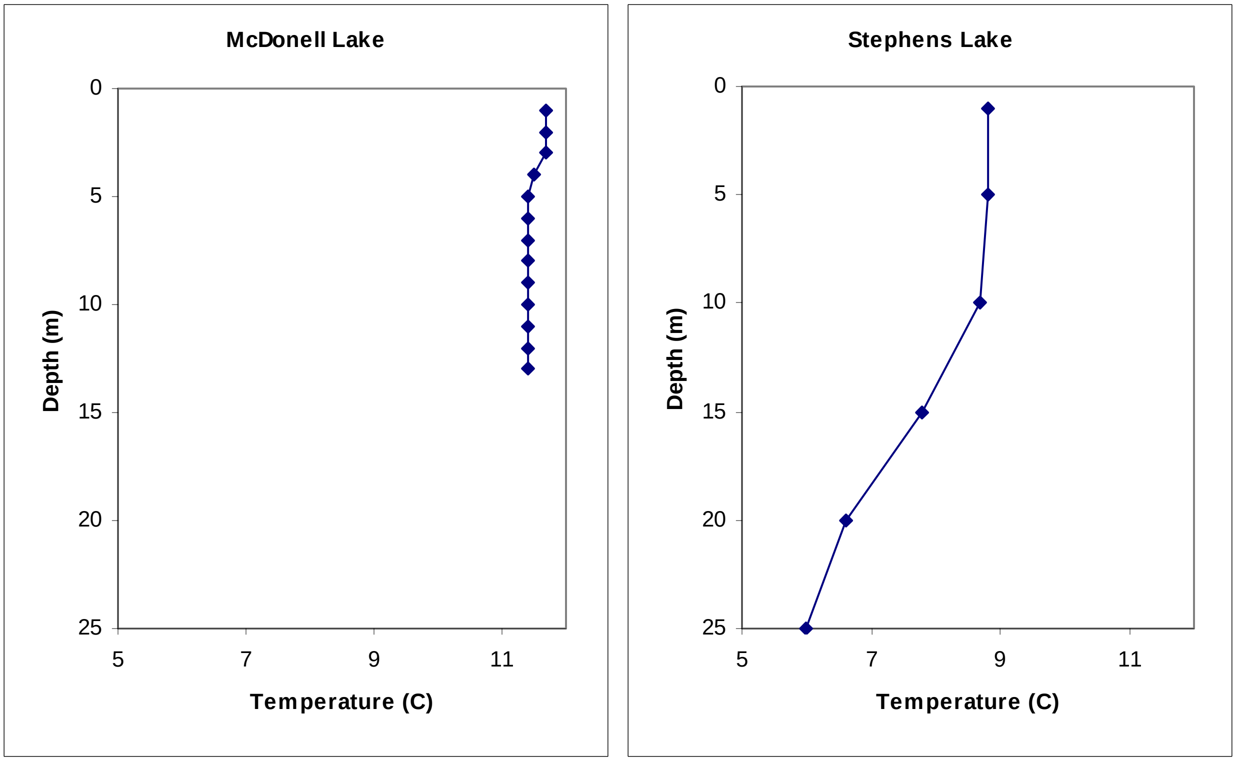

Figure 8. **Temperature (C) profiles for McDonell and Stephens Lakes**

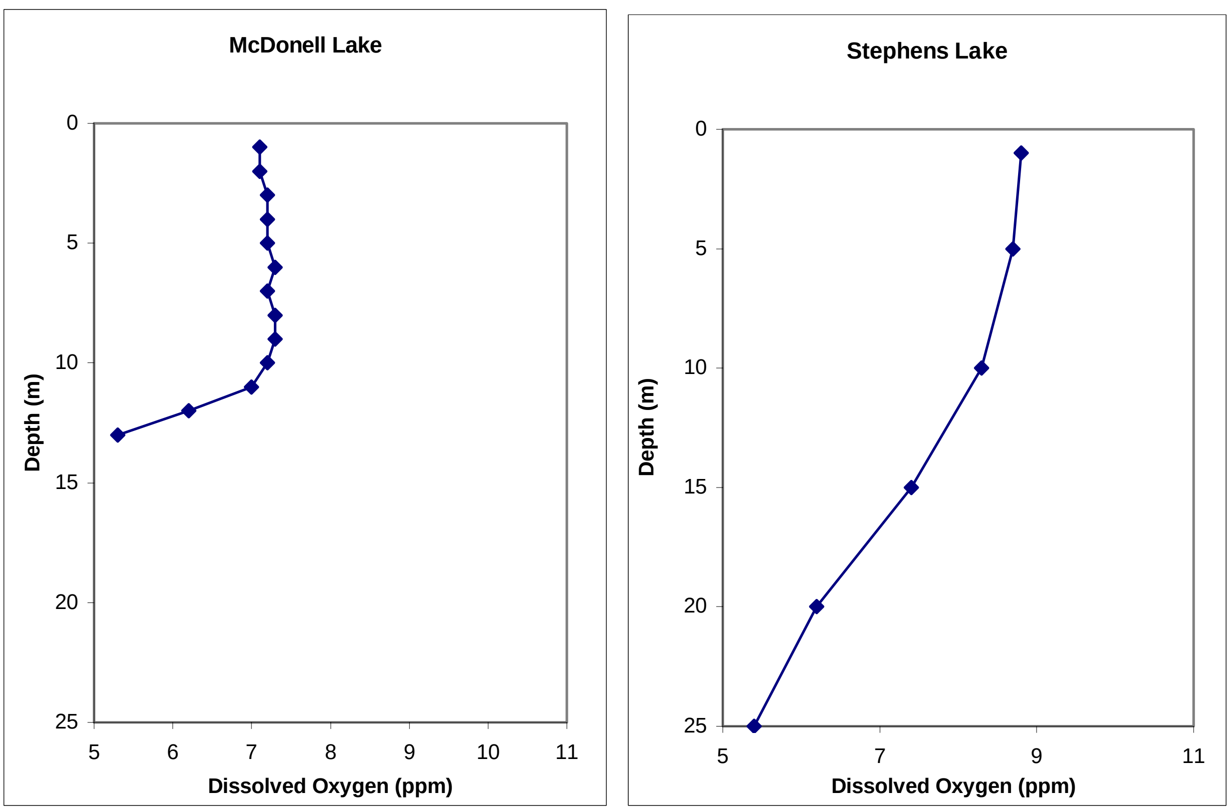

Figure 9. **Dissolved oxygen (ppm) profiles for McDonell and Stephens Lakes**

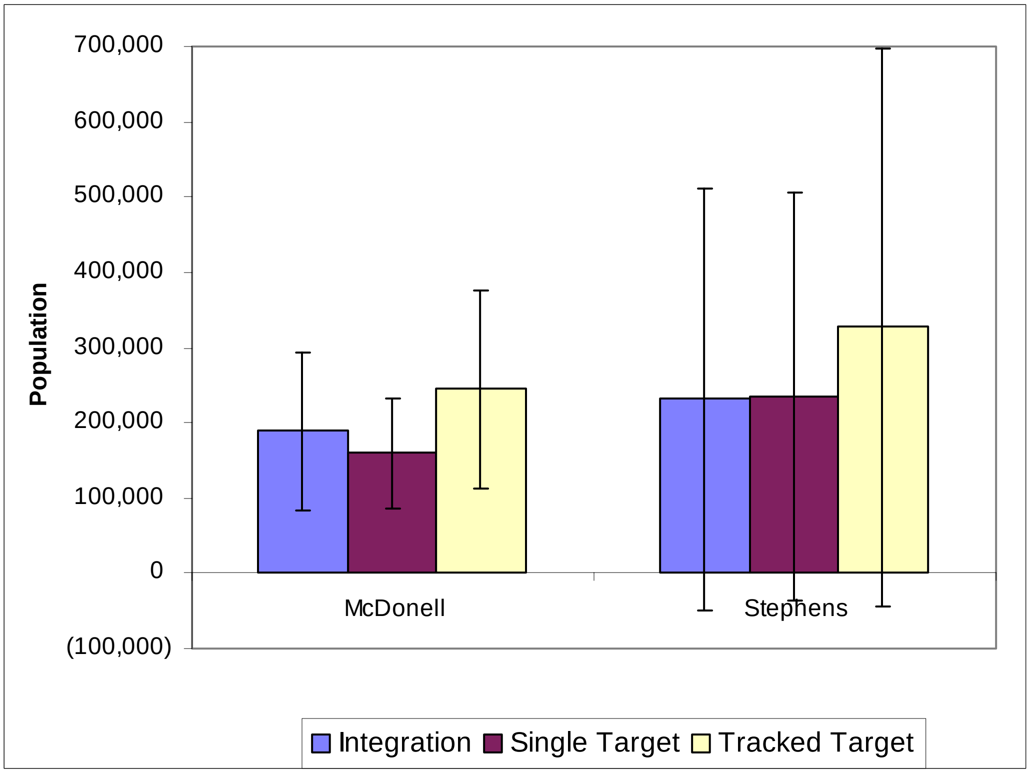

Figure 10. **Age-0 sockeye fry population estimates by analysis method and lake**

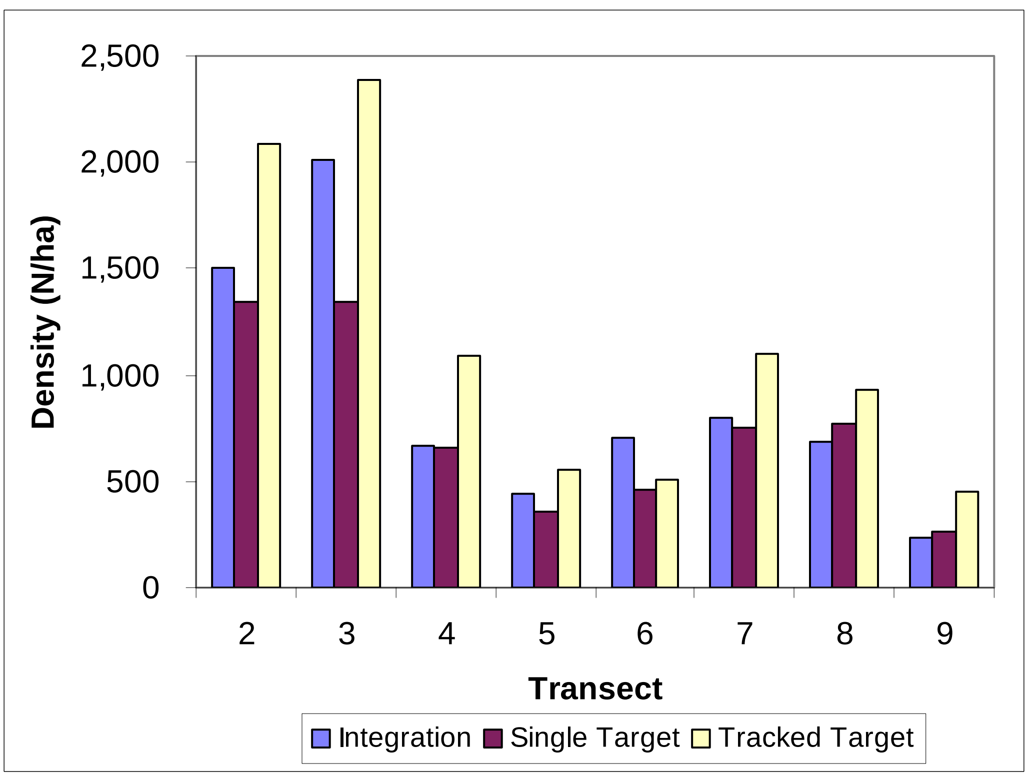

Figure 11. **McDonell Lake age-0 sockeye fry densities by transect and analysis method**

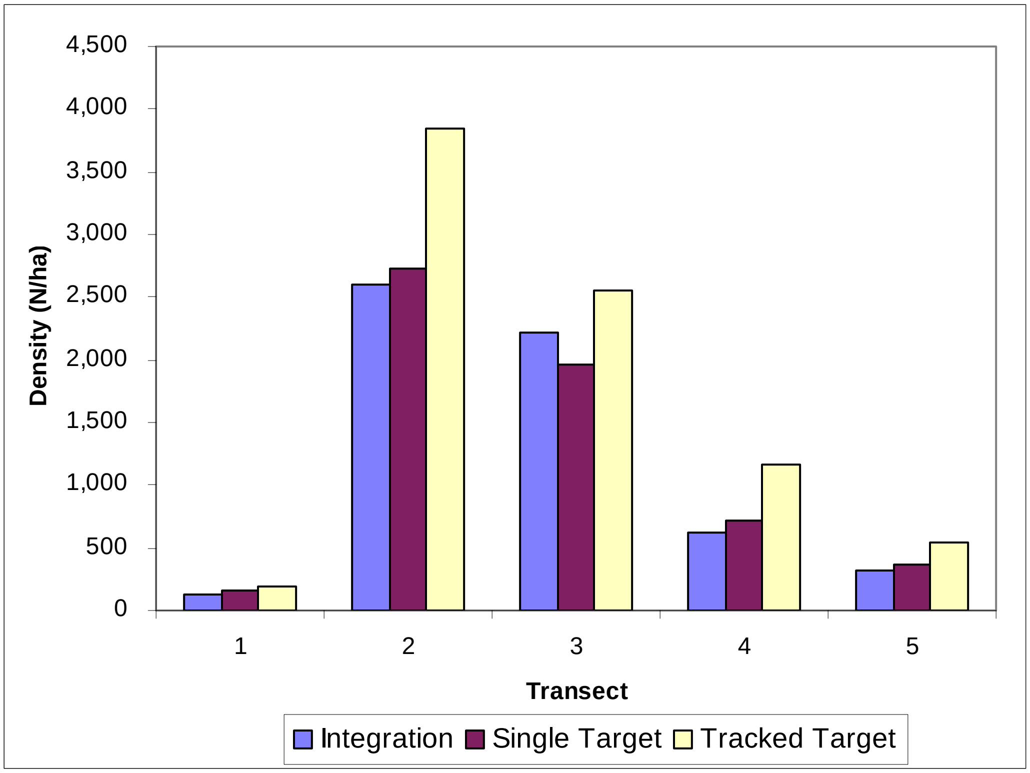

Figure 12. Stephens Lake age-0 sockeye fry densities by transect and analysis method

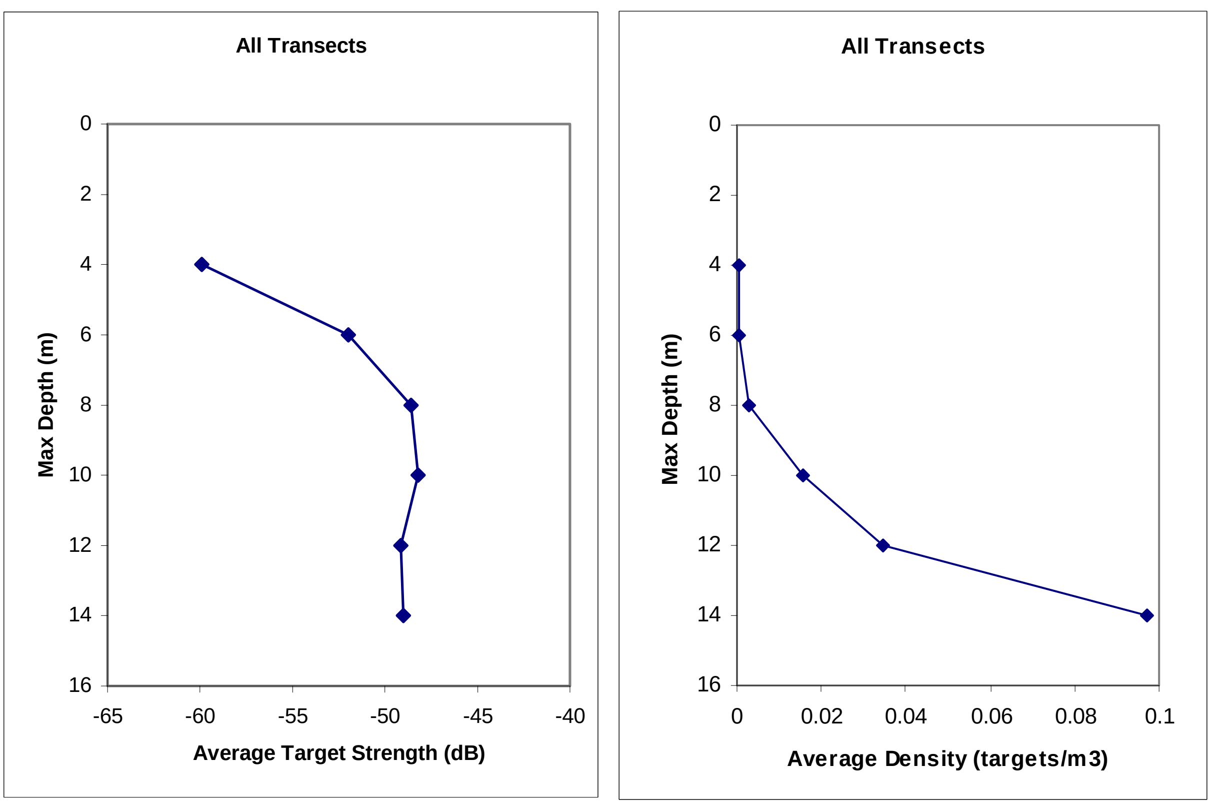

Figure 13. Average target strength and target density profiles of McDonell Lake

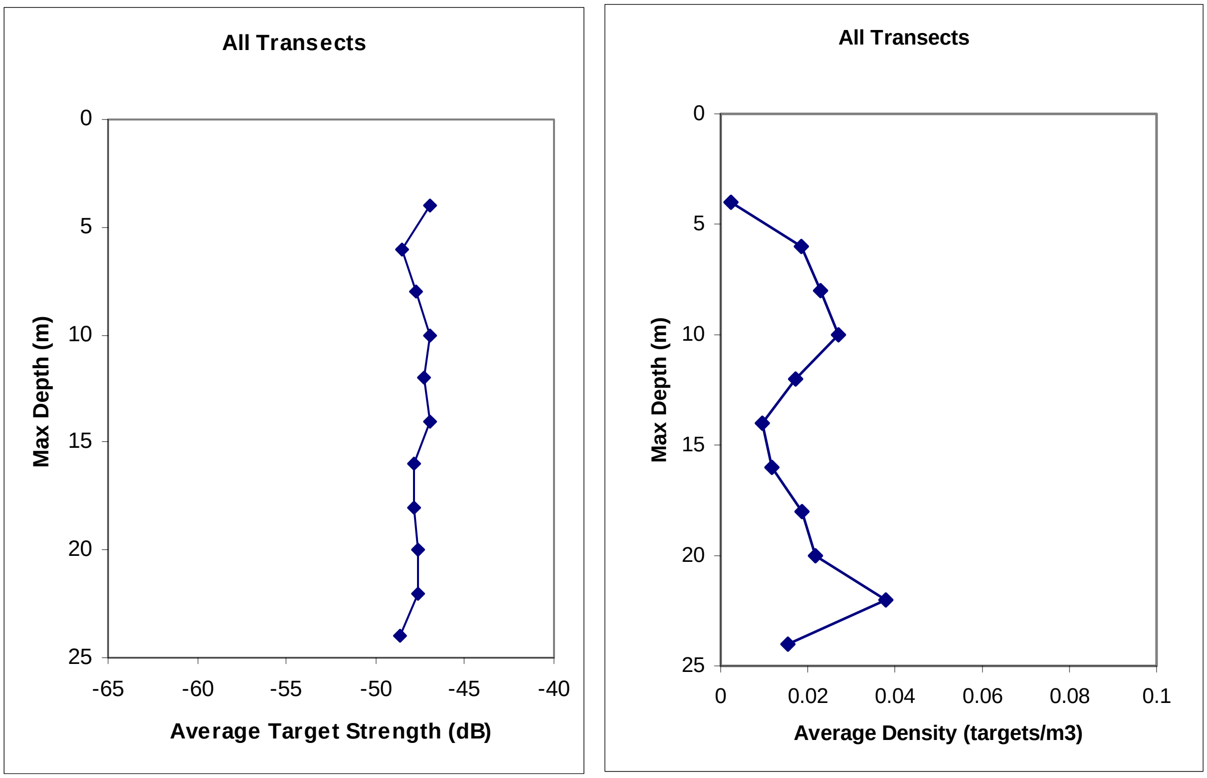

Figure 14. **Average target strength and fish density profiles of Stephens Lake**

APPENDIX 1: McDonell Lake Transect Echograms

Note: All echograms are vertically exaggerated by varying amounts based on transect length.

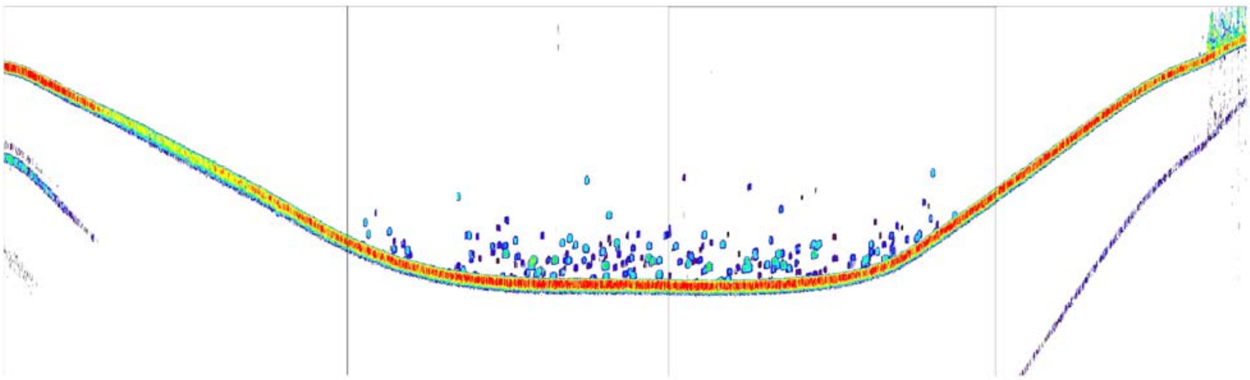

Figure 15. **McDonell Lake transect 2 echogram**

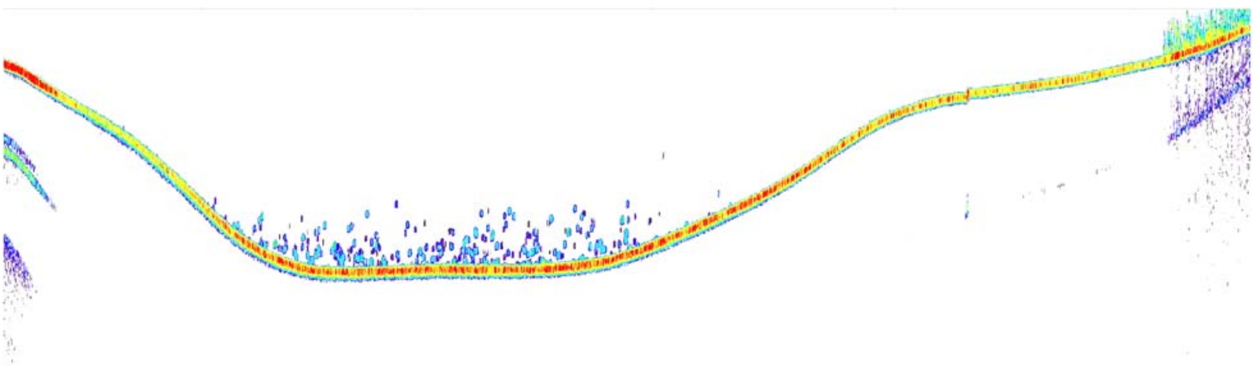

Figure 16. **McDonell Lake transect 3 echogram**

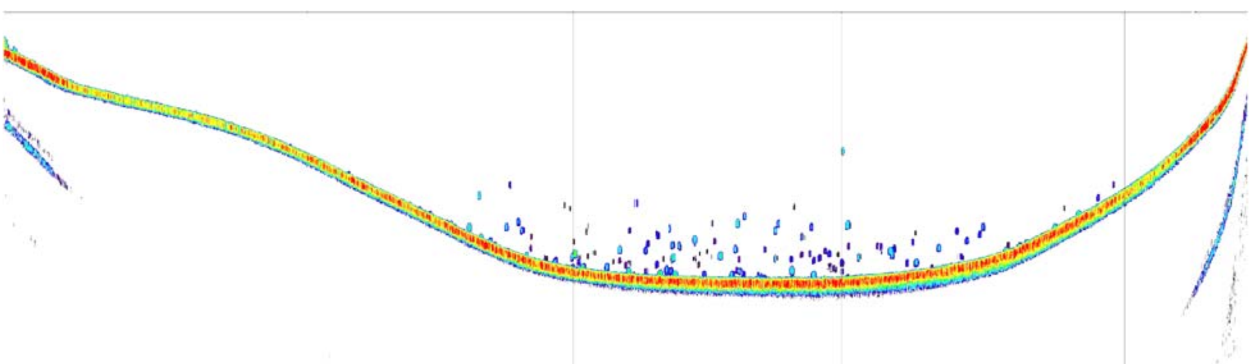

Figure 17. **McDonell Lake transect 4 echogram**

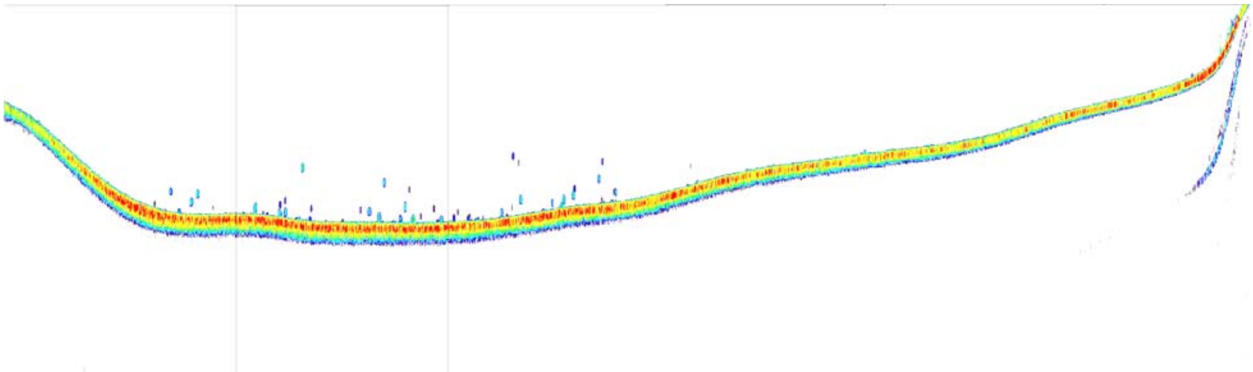

Figure 18. **McDonell Lake transect 5 echogram**

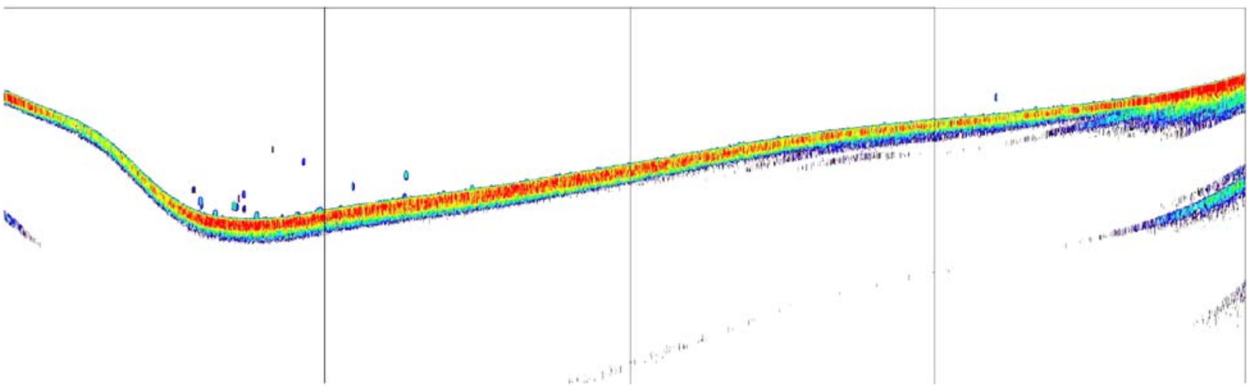

Figure 19. **McDonell Lake transect 6 echogram**

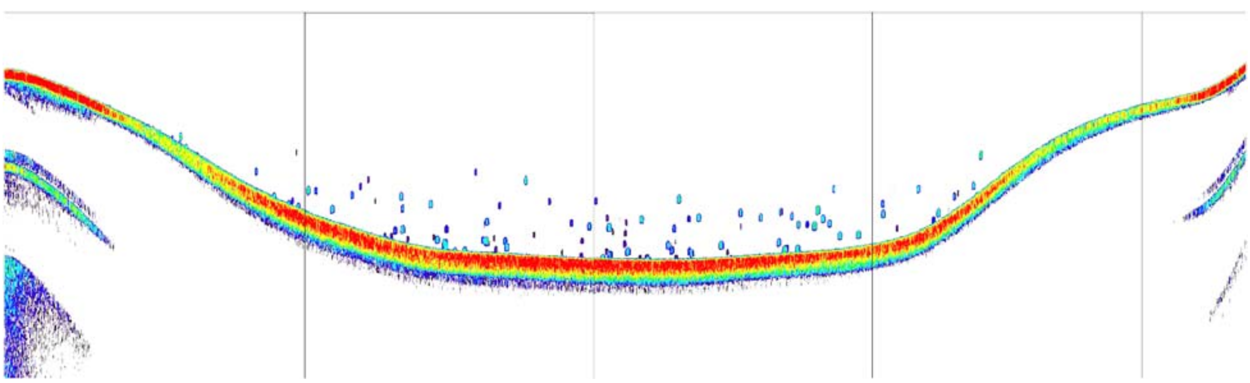

Figure 20. **McDonell Lake transect 7 echogram**

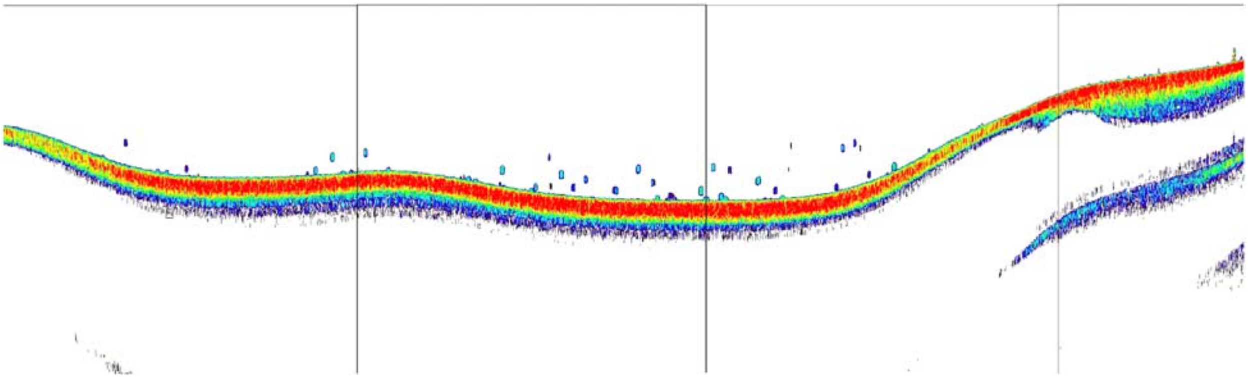

Figure 21. McDonell Lake transect 8 echogram

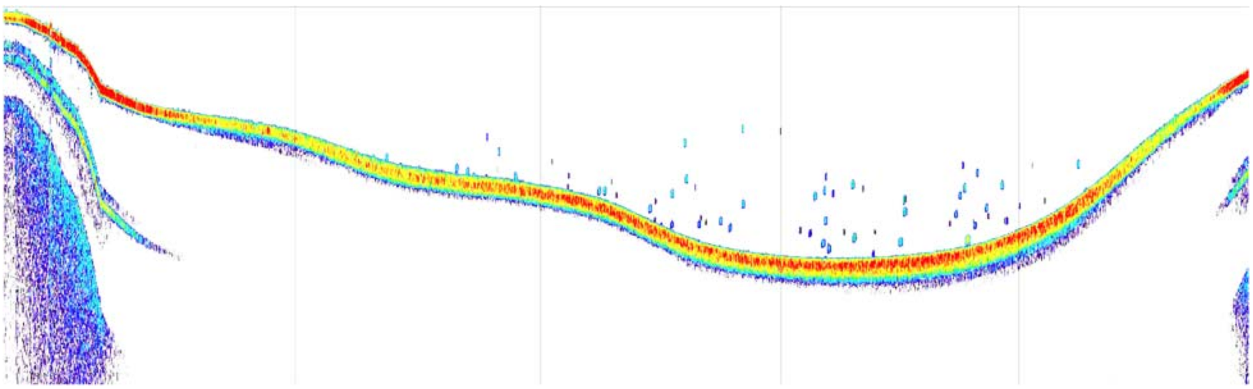

Figure 22. McDonell Lake transect 9 echogram

APPENDIX 2: Stephens Lake Transect Echograms

Note: All echograms are vertically exaggerated by varying amounts.

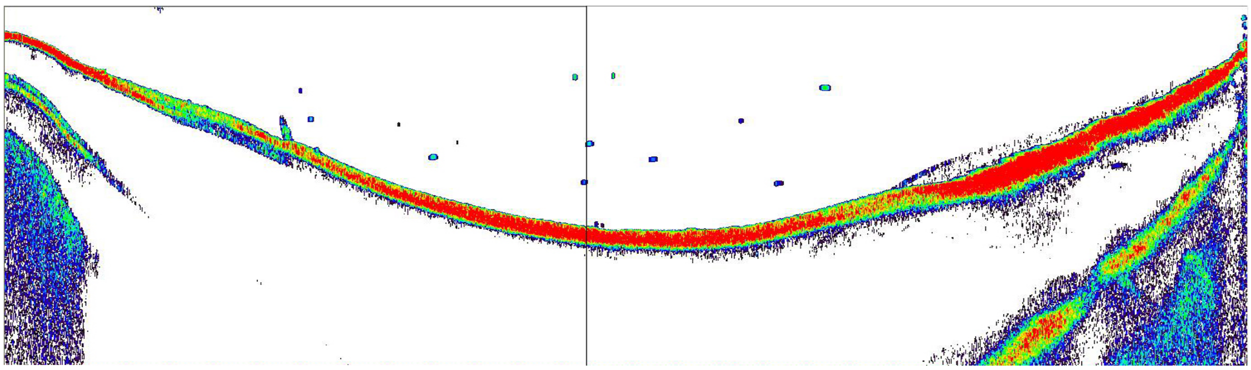

Figure 23. Stephens Lake transect 1 echogram

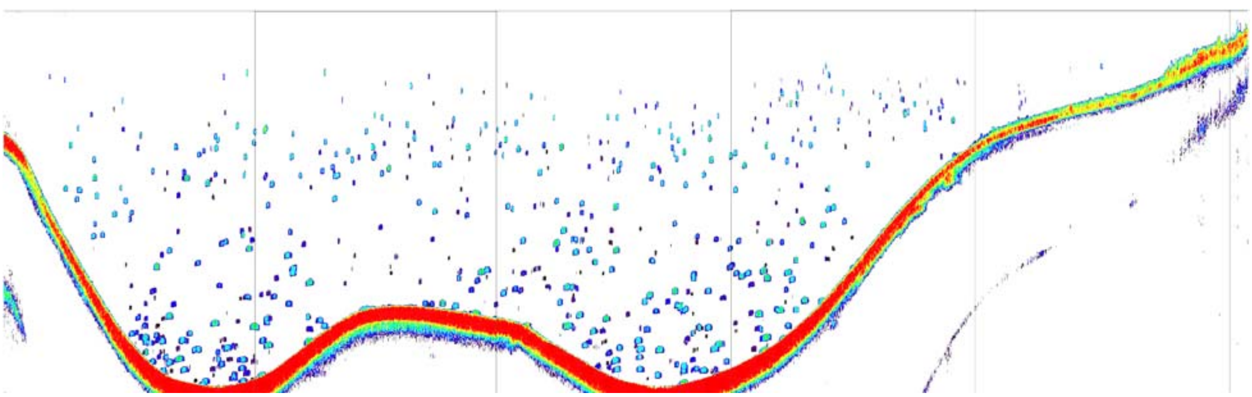

Figure 24. Stephens Lake transect 2 echogram

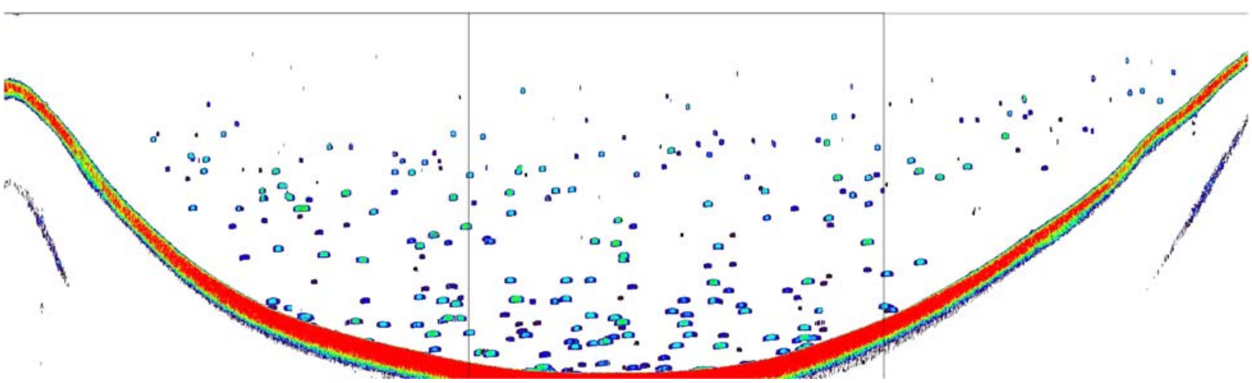

Figure 25. Stephens Lake transect 3 echogram

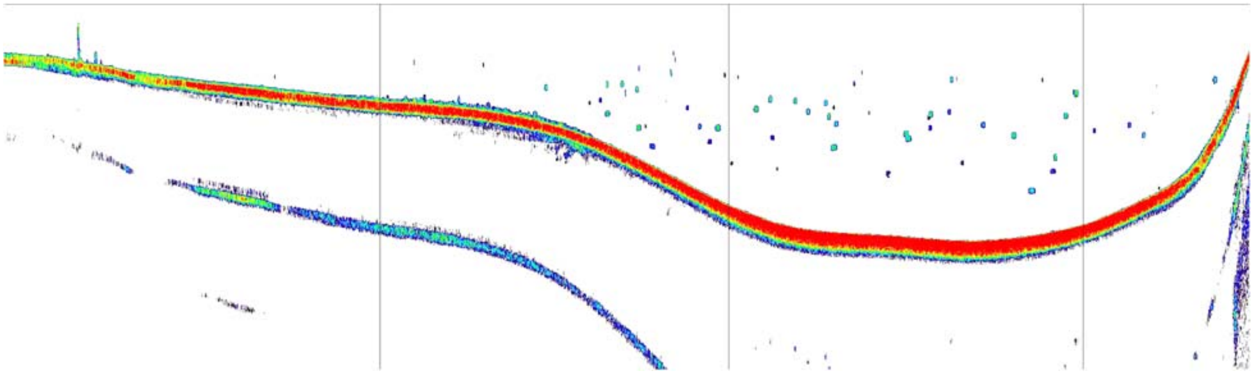

Figure 26. Stephens Lake transect 4 echogram

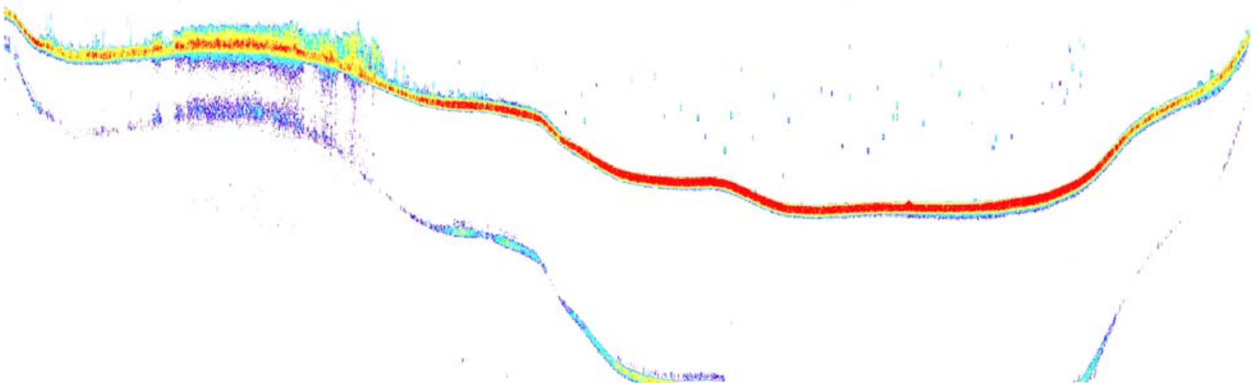

Figure 27. Stephens Lake transect 5 echogram

APPENDIX 3: McDonell Lake Fish Catch

#	Trawl #	Species	Lgth.(mm)	Wt. (g)	Comments	Scale Bk	Scale #
1	3	Sockeye	67	3.58		76974	1
2	3	Sockeye	57	1.92		76974	2
3	3	Sockeye	79	5.38		76974	3
4	3	Sockeye	64	2.53		76974	4
5	3	Sockeye	56	1.84		76974	5
6	3	Sockeye	63	2		76974	6
7	3	Sockeye	57	1.92		76974	7
8	3	Sockeye	64	2.59		76974	8
9	3	Sockeye	59	1.94		76974	9
10	3	Sockeye	60	2.15		76974	10
11	3	Sockeye	64	2.49		76974	11
12	3	Sockeye	59	2.04		76974	12
13	3	Sockeye	59	2.2		76974	13
14	3	Sockeye	50	1.19		76974	14
15	3	Sockeye	69	3.22		76974	15
16	3	Sockeye	55	1.66		76974	16
17	3	Sockeye	56	1.67		76974	17
18	3	Sockeye	54	1.54		76974	18
19	3	Sockeye	50	1.2		76974	19
20	3	Sockeye	64	2.45		76974	20
21	3	Sockeye	53	1.25		76974	21
22	3	Sockeye	57	1.83		76974	22
23	3	Sockeye	55	1.58		76974	23
24	3	Sockeye	58	2.18		76974	24
25	3	Sockeye	53	1.36		76974	25
26	3	Sockeye	45	0.89		76974	26
27	3	Sculpin	44	0.74			
28	4	Sockeye	69	3.22		76974	27
29	4	Sockeye	74	3.86		76974	28
30	4	Sockeye	69	3.48		76974	29
31	4	Sockeye	70	3.5		76974	30
32	4	Sculpin	92	10.8			
33	4	Sockeye	56	1.71		76974	31
34	4	Sockeye	51	1.14		76974	32
35	4	Sculpin	79	6.02			
36	4	Sockeye	53	1.47		76974	33
37	4	Sockeye	50	1.12		76974	34
38	4	Sculpin	25	0.12			
39	4	Sockeye	60	2		76974	35
40	4	Sockeye	64	2.7		76974	36
41	4	Sockeye	77	4.46		76974	37
42	4	Sockeye	67	3.45		76974	38
43	4	Sockeye	69	3.58		76974	39
44	4	Sockeye	71	3.95		76974	40
45	4	Sockeye	68	3.15		76974	41

46	4	Sockeye	67	2.34		76974	42
47	4	Sockeye	66	2.46		76974	43
48	4	Sockeye	69	3.56		76974	44
49	4	Sockeye	65	2.88		76974	45
50	4	Sockeye	67	3.23		76974	46
51	4	Sockeye	68	3.72		76974	47
52	4	Sockeye	68	3.52		76974	48
53	4	Sockeye	67	2.56		76974	49
54	4	Sockeye	54	1.59		76974	50
55	4	Sockeye	54	1.8		76995	1
56	4	Sockeye	60	2.03		76995	2
57	4	Sockeye	57	1.87		76995	3
58	4	Sockeye	57	1.69		76995	4
59	4	Sockeye	54	1.42		76995	5
60	4	Sockeye	59	1.9		76995	6
61	4	Sockeye	58	1.03		76995	7
62	4	Sockeye	52	1.19		76995	8
63	4	Sockeye	57	1		76995	9
64	5	Sockeye	71	3.49		76995	10
65	5	Sockeye	74	4.07		76995	11
66	5	Sockeye	69	3.28		76995	12
67	5	Sockeye	67	2.83		76995	13
68	5	Sockeye	68	3.24		76995	14
69	5	Sockeye	68	2.98		76995	15
70	5	Sockeye	72	3.9		76995	16
71	5	Sockeye	70	3.31		76995	17
72	5	Sockeye	63	2.31		76995	18
73	5	Sockeye	57	1.64		76995	19
74	5	Sockeye	52	1.3		76995	20
75	5	Sockeye	54	1.47		76995	21
76	5	Sockeye	80	5.58		76995	22
77	5	Sockeye	83	5.61		76995	23
78	5	Sockeye	66	3.03		76995	24
79	5	Sockeye	63	2.45		76995	25
80	5	Sockeye	68	3.41		76995	26
81	5	Sockeye	73	3.88		76995	27
82	5	Sockeye	70	3.64		76995	28
83	5	Sockeye	67	2.47		76995	29
84	5	Sockeye	74	4.71		76995	30
85	5	Sockeye	64	2.74		76995	31
86	5	Sockeye	68	3.16		76995	32
87	5	Sockeye	64	2.3		76995	33
88	5	Sockeye	68	2.86		76995	34
89	5	Sockeye	64	2.41		76995	35
90	5	Sockeye	63	2.54		76995	36
91	5	Sockeye	61	2.28		76995	37
92	5	Sockeye	60	2.09		76995	38
93	5	Sockeye	59	1.96		76995	39

94	5	Sockeye	59	1.53		76995	40
95	5	Sockeye	57	1.68		76995	41
96	5	Sockeye	51	1.16		76995	42
97	5	Sockeye	50	1.17		76995	43
98	5	Sockeye	69	3.35		76995	44
99	5	Sockeye	63	2.39		76995	45
100	5	Sockeye	66	3		76995	46
101	5	Sockeye	63	2.28		76995	47
102	5	Sockeye	61	2.21		76995	48
103	5	Sockeye	58	1.99		76995	49
104	5	Sockeye	70	3.63		76995	50
105	5	Sockeye	67	2.92			
106	5	Sockeye	75	4.39			
107	5	Sockeye	64	2.85			
108	5	Sockeye	46	0.91			
109	5	Sockeye	53	1.37			
110	5	Sockeye	54	1.68			
111	5	Sockeye	55	1.58			
112	5	Sockeye	68	2.93			
113	5	Sockeye	59	2.16			
114	5	Sockeye	62	2.33			
115	5	Sockeye	53	1.34			
116	5	Sockeye	57	1.86			
117	5	Sockeye	55	1.52			
118	5	Sockeye	54	1.43			
119	5	Sockeye	64	2.64			
120	5	Sockeye	57	1.84			
121	5	Sockeye	54	1.62			
122	5	Sockeye	38	0.57			
123	5	Sockeye	72	3.93			
124	5	Sockeye	55	1.65			
125	5	Sockeye	69	3.58			
126	5	Sockeye	67	2.96			
127	5	Sockeye	69	3.5			
128	5	Sockeye	68	3.36			
129	5	Sockeye	54	1.55			
130	5	Sockeye	60	2.11			
131	5	Sockeye	54	1.6			
132	5	Sockeye	50	1.16			
133	5	Sockeye	69	3.64			
134	5	Sockeye	67	2.79			
135	5	Sockeye	64	2.57			
136	5	Sockeye	56	1.12			
137	5	Sockeye	58	1.62			
138	5	Sockeye	58	1.7			
139	5	Sockeye	59	1.81			
140	5	Sockeye	54	1.57			
141		Sockeye	94	9.43	gillnet	77000	1-2

142		Cutthrout	184	77.09	gillnet		
143	5	Sockeye	65		released		
144	5	Sockeye	65		released		
145	5	Sockeye	68		released		
146	5	Sockeye	70		released		
147	5	Sockeye	75		released		
148	5	Sockeye	63		released		
149	5	Sockeye	76		released		
150	5	Sockeye	60		released		
151	5	Sockeye	56		released		
152	5	Sockeye	50		released		
153	5	Sockeye	60		released		
154	5	Sockeye	63		released		
155	5	Sockeye	68		released		
156	5	Sockeye	68		released		
157	5	Sockeye	56		released		
158	5	Sockeye	70		released		
159	5	Sockeye	61		released		
160	5	Sockeye	75		released		
161	5	Sockeye	60		released		
162	5	Sockeye	63		released		
163	5	Sockeye	72		released		
164	5	Sockeye	71		released		
165	5	Sockeye	76		released		
166	5	Sockeye	71		released		
167	5	Sockeye	46		released		
168	5	Sockeye	66		released		
169	5	Sockeye	55		released		
170	5	Sockeye	61		released		
171	5	Sockeye	79		released		
172	5	Sockeye	76		released		
173	5	Sockeye	68		released		
174	5	Sockeye	61		released		
175	5	Sockeye	47		released		
176	5	Sockeye	55		released		
177	5	Sockeye	81		released		
178	5	Sockeye	60		released		
179	5	Sockeye	51		released		
180	5	Sockeye	66		released		
181	5	Sockeye	63		released		
182	5	Sockeye	60		released		
183	5	Sockeye	56		released		
184	5	Sockeye	56		released		
185	5	Sockeye	58		released		
186	5	Sockeye	55		released		
187	5	Sockeye	66		released		
188	5	Sockeye	55		released		
189	5	Sockeye	70		released		

190	5	Sockeye	56		released		
191	5	Sockeye	65		released		
192	5	Sockeye	60		released		
193	5	Sockeye	60		released		
194	5	Sockeye	63		released		
195	5	Sockeye	50		released		
196	5	Sockeye	68		released		
197	5	Sockeye	51		released		
198	5	Sockeye	78		released		
199	5	Sockeye	63		released		
200	5	Sockeye	68		released		
201	5	Sockeye	78		released		
202	5	Sockeye	48		released		
203	5	Sockeye	68		released		
204	5	Sockeye	62		released		
205	5	Sockeye	63		released		
206	5	Sockeye	53		released		
207		Whitefish			Gillnet – release live		
208		Whitefish			Gillnet – release live		
209		Cutthroat			Gillnet – release live		
210		Cutthroat			Gillnet – release live		
211		Cutthroat			Gillnet – release live		

APPENDIX 4: Stephens Lake Fish Catch

#	Trawl #	Species	Lgth.(mm)	Wt. (g)	Comments	Scale Bk	Scale #
1	1	Sockeye	80	4.41		76996	1
2	1	Sockeye	79	5.51		76996	2
3	1	Sockeye	76	3.87		76996	3
4	1	Sockeye	75	4.38		76996	4
5	1	Sockeye	69	3.19		76996	5
6	1	Sockeye	52	1.45		76996	6
7	1	Sockeye	56	1.82		76996	7
8	1	Sockeye	73	3.94		76996	8
9	2	Sockeye	82	5.32		76996	9
10	2	Sockeye	69	3.11		76996	10
11	2	Sockeye	72	3.47		76996	11
12	2	Sockeye	74	3.94		76996	12
13	2	Sockeye	67	3.2		76996	13
14	2	Sockeye	81	4.93		76996	14
15	2	Sockeye	74	3.94		76996	15
16	2	Sockeye	73	3.53		76996	16
17	2	Sockeye	73	3.55		76996	17
18	2	Sockeye	67	2.92		76996	18
19	3	Sockeye	71	3.67		76996	19
20	3	Sockeye	76	3.99		76996	20
21	3	Sockeye	78	4.54		76996	21
22	3	Sockeye	74	4.09		76996	22
23	3	Sockeye	75	4.25		76996	23
24	3	Sockeye	74	3.86		76996	24
25	3	Sockeye	80	5.42		76996	25
26	3	Sculpin	56	1.6			
27	4	Sockeye	71	3.61		76996	26
28	4	Sockeye	75	4.06		76996	27
29	4	Sockeye	71	3.8		76996	28
30	4	Sockeye	76	4.22		76996	29
31	4	Sockeye	77	4.62		76996	30
32	4	Sockeye	75	3.98		76996	31
33	4	Sockeye	73	3.78		76996	32
34	4	Sockeye	72	3.39		76996	33
35	4	Sockeye	67	2.77		76996	34
36	4	Sockeye	76	4.45		76996	35
37	4	Sockeye	72	3.77		76996	36
38	4	Sockeye	70	3.3		76996	37
39	4	Sockeye	74	4.02		76996	38
40	4	Sockeye	61	2.39		76996	39
41	5	Sockeye	72	4.5		76996	40
42	5	Sockeye	70	3.5		76996	41
43	5	Sockeye	72	3.68		76996	42
44	5	Sockeye	75	4.23		76996	43
45	5	Sockeye	77	4.06		76996	44

46	5	Sockeye	64	2.53		76996	45
47	5	Sockeye	61	2.35		76996	46
48	5	Sockeye	76	4.5		76996	47
49	5	Sockeye	74	4,06		76996	48
50	5	Sockeye	77	4.72		76996	49
51	5	Sockeye	77	4.65		76996	50
52	5	Sockeye	66	2.86		76993	1
53	5	Sockeye	71	3.53		76993	2
54	5	Sockeye	72	3.79		76993	3
55	5	Sockeye	71	3.53		76993	4
56	5	Sockeye	68	3.13		76993	5
57	5	Sockeye	71	3.55		76993	6
58	5	Sockeye	74	3.97		76993	7
59	5	Sockeye	72	3.5		76993	8
60	5	Sockeye	67	2.97		76993	9
61		Sockeye	82	5.13	gill net	76993	10

APPENDIX 5: Hydroacoustic Data By Transect

Table 10. McDonell Lake age-0 sockeye fry estimates by transect and analysis method

Transect	Surface Area (ha)	Population (N)			Density (N/ha)		
		NTG	ST	TT	NTG	ST	TT
2	18.3	2.75×10^4	2.46×10^4	3.44×10^4	1,502	1,346	1,883
3	21.6	4.36×10^4	2.91×10^4	5.08×10^4	2,013	1,345	2,350
4	23.8	1.59×10^4	1.56×10^4	2.49×10^4	669	657	1,047
5	33.7	1.50×10^4	1.19×10^4	1.62×10^4	446	353	481
6	29.6	2.09×10^4	1.36×10^4	1.38×10^4	707	458	466
7	27.5	2.20×10^4	2.06×10^4	2.81×10^4	801	749	1,022
8	26.0	1.79×10^4	2.01×10^4	2.24×10^4	689	774	863
9	34.0	7.92×10^3	8.95×10^3	1.32×10^4	233	263	388
Total	214.4	1.71×10^5	1.44×10^5	2.04×10^5	796	674	951

NTG = Integration ST = Single Target TT = Tracked Target

Table 11. McDonell Lake large fish estimates by transect and analysis method

Transect	Surface Area (ha)	Population (N)			Density (N/ha)		
		NTG	ST	TT	NTG	ST	TT
2	18.3	1.79×10^3	1.72×10^3	2.34×10^3	98	94	128
3	21.6	9.40×10^2	5.99×10^2	1.06×10^3	43	28	49
4	23.8	4.60×10^2	4.08×10^2	7.05×10^2	19	17	30
5	33.7	2.32×10^3	1.73×10^3	2.46×10^3	69	51	73
6	29.6	1.51×10^3	8.02×10^2	8.54×10^2	51	27	29
7	27.5	2.87×10^3	3.21×10^3	3.05×10^3	105	117	111
8	26.0	7.78×10^2	8.75×10^2	9.74×10^2	30	34	38
9	34.0	1.18×10^3	1.34×10^3	2.02×10^3	35	40	59
Total	214.4	1.19×10^4	1.07×10^4	1.35×10^4	55	50	63

NTG = Integration ST = Single Target TT = Tracked Target

Table 12. Stephens Lake age-0 sockeye fry estimates by transect and analysis method

Transect	Surface Area (ha)	Population (N)			Density (N/ha)		
		NTG	ST	TT	NTG	ST	TT
1	19.2	2.56 x10^3	3.10 x10^3	3.60 x10^3	133	161	187
2	56.5	1.46 x10^5	1.54 x10^5	2.17 x10^5	2,594	2,729	3,852
3	23.5	5.22 x10^4	4.63 x10^4	6.01 x10^4	2,220	1,970	2,556
4	43.1	2.65 x10^4	3.09 x10^4	5.03 x10^4	616	718	1,168
5	54.3	1.70 x10^4	2.03 x10^4	2.96 x10^4	313	373	545
Total	196.6	2.45 x10^5	2.55 x10^5	3.61 x10^5	1,245	1,296	1,837

NTG = Integration ST = Single Target TT = Tracked Target

Table 13. Stephens Lake large fish estimates by transect and analysis method

Transect	Surface Area (ha)	Population (N)			Density (N/ha)		
		NTG	ST	TT	NTG	ST	TT
1	19.2	5.16 x10^2	8.28 x10^2	9.27 x10^2	27	43	48
2	56.5	3.58 x10^4	3.90 x10^4	5.47 x10^4	635	690	969
3	23.5	6.67 x10^3	6.63 x10^3	8.47 x10^3	284	282	360
4	43.1	1.14 x10^4	1.32 x10^4	2.06 x10^4	264	307	479
5	54.3	6.84 x10^3	8.40 x10^3	1.22 x10^4	126	155	225
Total	196.6	6.12 x10^4	6.80 x10^4	9.69 x10^4	311	346	493

NTG = Integration ST = Single Target TT = Tracked Target