Stave River Project Water Use Plan

Fish Biomass Assessment

Implementation Year 8

Reference: SFLMON-3

Abundance and Biomass of Fish in Stave Reservoir in October 2012

Study Period: 2012

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ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR
IN OCTOBER 2012

Final Data Report

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Final Data Report

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Cover photo: Mount Crickmer seen from Stave Reservoir, September 2011. Photo by Brock Stables.

EXECUTIVE SUMMARY

An acoustic survey was conducted on the night of October 9-10, 2012 to determine the abundance, biomass, and spatial distribution of fish in Stave Reservoir. Survey and analysis methods were the same as in previous years. The 2012 survey represents year 8 of a 10 year study conducted under the Stave River Water Use Plan.

As prescribed in the study plan, gill net data from the previous year (collected October 3-6, 2011) were used to apportion the 2012 acoustic estimate of fish ≥100 mm in length among fish species and salmonid age-groups. Fish <100 mm in length were all assumed to be kokanee fry. Abundance and biomass estimates were stratified by slope and pelagic habitat zones, with the slope zone defined as the area shoreward of the 40 m depth contour, and the pelagic zone the remaining deeper portion of the lake. Both the 2012 acoustic survey and 2011 gill netting were limited to the part of the main reservoir basin that was free enough of dead standing timber and debris to be sampled without undue risk to equipment and personnel. Acoustic sampling was performed on six transects within this designated study area.

At the time of the 2012 survey the reservoir was stratified, with well-defined thermal layers. Dissolved oxygen was below saturation over the depth range sampled (0-55 m) at both stations. It exceeded the minimum level considered adequate for protection of fish (>6.5 mg/L, CCME 2003), except below 15 m at the north station, and did not fall below 6.0 mg/l anywhere we sampled. Weather conditions were calm and well suited to acoustic sampling during the 2012 survey.

The 2012 abundance and biomass estimates for all species combined were 319,496 ± 54,343 fish (±17%) and 4,586 kg. These values represent a 64% decrease in abundance and a 75% decrease in biomass since 2011, continuing a declining trend since 2010 when both estimates peaked. Acoustic data suggest that declining kokanee abundance was mainly responsible for these trends.

The 2012 areal density and biomass estimates for individual fish species (ages combined) were 112 kokanee/ha (1.00 kg/ha), 0.0431 cutthroat trout/ha (0.0193 kg/ha), 0.671 bull trout/ha (0.554 kg/ha), 0.176 northern pikeminnow/ha (0.0480 kg/ha), 0.0 peamouth/ha, and 0.162 redside shiner/ha (0.00272 kg/ha), for a total of 113 fish/ha and 1.62 kg/ha for all species combined.

The 2012 total fish abundance estimate is dependable, however, the total biomass estimate and species and cohort specific biomass and abundance estimates are questionable. After the large population decline from 2011 to 2012, the 2011 gill net data could not reliably represented species and age composition in 2012.

ACKNOWLEDGEMENTS

This project was performed under contract to BC Hydro as part of the Stave River Water Use Plan Studies. We are grateful to James Bruce (BC Hydro Research Biologist), and Ian Dodd, Dave Hunter, and Darin Nishi (BC Hydro Natural Resource Specialists), who have assisted with logistics, coordinated this work with related studies of the Stave Water Use Plan, and provided constructive review of reports. Due to their continued interest and active support it has been possible to adapt and improve the study design as our knowledge has grown with each year of the project. We also wish to thank Danusia Dolecki (invertebrate taxonomist), Sylvain Guerin (acoustics boat operator), Bob Hamaguchi (fish aging specialist), Jason Macnair (fisheries biologist), and Bob Secord (gill net boat skipper) for their essential contributions to lab and field work.

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1.0 INTRODUCTION

Stave Reservoir is the major impoundment within BC Hydro's Stave River Hydroelectric Project. Improving fish production in Stave Reservoir is a key goal of the Stave River Water Use Plan (WUP, Failing 1999). Based on limited information that was available for early planning, the WUP Consultative Committee (WCC) hypothesized that a low rate of fish production in the reservoir is due to low nutrient loading that is characteristic of ultra-oligotrophic conditions, a high flushing rate, and extensive drawdown during the growing season. Together these factors were thought to limit primary and secondary production and limit the forage base for fish in both littoral (shoreward of the 6 m depth contour) and pelagic (open water offshore) habitats (Failing 1999).

After considering several alternatives for enhancing fish resources in Stave Reservoir through WUP modifications, the WUP Consultative Committee recommended that primary and secondary production – and ultimately fish production - might be improved by a plan titled Combo 6 (Failing 1999). For reservoir fish, the most significant feature of this plan is a change in the reservoir drawdown regime to stabilize the water level to some degree during the growing season. It was hypothesized that this change might increase fish food resources and improve the sport fishery.

To determine the benefits of Combo 6, studies to monitor primary production and fish biomass in the reservoir were approved by the WCC. Following implementation of Combo 6 in 2004, measurements of fish population size and biomass began in 2005 and will continue for ten years to determine if the anticipated ecological benefits are realized. These studies will also expand general knowledge about the reservoir's ecology to assist with future water management decisions.

Acoustic sampling (scientific echo sounding) with species composition determined from gill netting was the method chosen for estimating total fish abundance and biomass in the lake. The fish population to be assessed was restricted to pelagic and semi-pelagic species that can be sampled effectively with these gears. Specific goals of the ten-year fish population monitoring program are to:

1. Determine if total numbers and biomass of fish in Stave Reservoir (species combined) change over time following implementation of Combo 6;
2. Determine if species and cohort-specific fish abundance and biomass change after the implementation of Combo 6; and
3. Correlate trends and changes in fish abundance and biomass with indicators of littoral and pelagic primary productivity to evaluate the importance of water level management in sustaining fish populations and reservoir health. This experimental design, chosen by the WUP Consultative Committee, is not a before-after design (there is no comparable data from before initiation of Combo 6) that would allow testing the null hypothesis that reduced

variation in water levels does not improve conditions for fish populations (James Bruce, BC Hydro, personal communication).

This report describes findings of the 2012 study, year 8 of this program, in a brief “data report” format. Results of earlier surveys in this series appear in Stables and Perrin (2006-2012). Specific objectives in 2012 were to:

1. Estimate the abundance and biomass of fish during fall 2012 for:
    a. all fish species combined;
    b. individual fish species;
    c. individual age groups of salmonids.
2. Continue to stratify the abundance and biomass data by nearshore and pelagic habitat zones.

2.0 METHODS

2.1 Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen (DO) concentrations were measured over the upper 55 m of the water column at two mid-lake stations on October 9 and 10, 2012, concurrent with the acoustic survey (Figure 1). Measurements were made every 5 m using a YSI model 6920 Sonde that was calibrated on the day of measurement.

2.2 Gill netting

Gill net data used to apportion the 2012 acoustic estimate by species, size, and age were collected one year earlier (October 3-6, 2011) at two nearshore and three mid-lake stations in the main lake basin (Figure 1). Surface, mid-water, and bottom sets were made at each nearshore station, whereas only surface and mid-water sets were made at mid-lake stations. Gill net catch and catch per unit effort (CPUE) were computed for individual gill net panels (fish/panel-hour) to assess spatial abundance patterns of fish species. CPUE was calculated for each species in relation to depth within the water column (depth of capture) and total water column depth where fish were captured (bottom depth) to allow separate species composition estimates for the slope zone (shoreward of the 40 m depth contour) and the pelagic zone (offshore of the 40 m depth contour, Stables and Perrin 2008). A complete description of gill net sampling and analysis methods appears in Stables and Perrin (2010).

2.3 Acoustics

2.3.1 Sampling

A mobile acoustic survey (scientific echo sounding) to measure fish abundance was performed during the night of October 9-10, 2012. Sampling methods were the same as in previous years and followed protocols described in standard fisheries acoustics texts (Thorne 1983, Simmonds and MacLennan 2005, Brandt 1996). Acoustic data were collected along six transects within the debris-free portion of the main lake basin (Figure 1).

Acoustic sampling was performed from a 6.5 m long, covered aluminum skiff at a transecting speed of about 1.5-2.0 m/s. A single transducer was deployed in two configurations from a pole-mount attached to the side of the boat. For coverage of the water column from 2 m deep to the lake bottom, it was aimed vertically with the face 0.8 m beneath the surface (down-looking mode). For increased coverage of the upper 5 m of the water column, it was aimed 7 degrees below the horizontal plane looking sideways from the boat (side-looking mode). Each transect was run twice consecutively, once with each transducer orientation.

The echo sounding system consisted of a 201 kHz BioSonics split-beam scientific echo sounder with a 6.7 degree beam paired with a Garmin model 546s differential GPS. The echo sounder was operated by a laptop computer, which also served as a data logger and allowed monitoring of data quality on echograms during collection. Latitude and longitude from the GPS were added to acoustic data files as they were logged. Additional equipment specifications and data collection settings are shown in Table 1.

2.3.2 Data Processing and Analysis

Fish were counted on electronic echograms according to standard echo-trace counting methods (Thorne 1983, Simmonds and MacLennan 2005). Computer files were processed in the office using Echoview© software to extract fish traces, to measure target strength (TS, the acoustic size of fish), and to determine sampling volumes. Down-looking data were used to compute fish density at depths greater than 5 m, while side-looking data were used to represent the uppermost 5 m of the water column. Fish traces were recognized on echograms by their shape, cohesiveness, TS, and number of echoes. Minimum and maximum acceptance thresholds for trace counts were -65 dB and -25 dB, respectively. Other fish tracking settings are listed in Table 1.

TS was determined by the split-beam method (Simmonds and MacLennan 2005). Accuracy of acoustic measurements was assured by field calibration tests. In-situ TS measurements of a standard sphere during the survey averaged -39.1 dB, within 0.4 dB of the expected value (-39.5 dB), so no calibration correction was applied data during processing. Lengths of individual fish that were observed with acoustics were estimated from down-looking TS using Love's (1977) equation for fish insonified within +/-45 degrees of dorsal aspect:

$$\text{length (mm)} = 10 * 10^{((TS + 1.6 \log (kHz) + 61.6) / 18.4)}$$

It should be noted that this equation provides an estimate of fish length that is less precise than a hands-on physical measurement because TS is affected by factors other than fish length (Simmonds and MacLennan 2005) and Love's (1977) equation is a generalization from many fish species and sizes. The relationship between side-looking TS and fish length is highly variable, so fish length was not estimated from side-looking TS data.

Depth intervals for data analysis were 0-5 m, 5-10 m, 10-15 m, and so forth to 80 m. Data were categorized into slope and pelagic zones using the 40 m depth contour as the boundary between them. Fish densities were summarized as fish/m^3 within depth intervals of transects for the population estimate, and as fish/ha in 50 m long segments of transects for spatial analysis. For each spatial cell of interest, fish density was calculated as the total count of fish divided by the volume sampled. The volume sampled in each spatial cell was calculated using the acoustic beam angle, distance transected, and a correction for bottom intrusion. The wedge model (Keiser and Mulligan 1984) was used for all depth intervals. Processing settings were a -65 dB counting threshold and a 6.7º nominal beam angle. As in previous years, the effective beam angle for each depth interval was modeled considering the nominal beam angle, boat speed, ping rate, and hits required per fish trace, and the sampling volume was adjusted accordingly at ranges where the effective beam angle was less than the nominal beam angle. Under conditions of the survey, the effective beam angle was not <4.9° for any range-bin, and it was >6.0° for all bins >10 meters from the transducer. A complete list of data analysis settings is shown in Table 1.

For population estimates, each transect provided one replicate of each depth interval contained in each habitat zone (shallow transects did not contain all intervals). For each spatial stratum, mean fish density was expanded in proportion to stratum volume, and resulting abundance estimates were summed to obtain the total population estimate. Variance and 95% confidence intervals of this estimate were calculated for a stratified random sample subdivided by habitat zones and depth intervals (Cochran 1977). Total Lake surface area as well as volumes of depth intervals and habitat zones were computed from hydrometric data provided by BC Hydro. Whole-lake fish density (number/ha) and biomass (kg/ha) estimates were computed using a surface area of 2,831 ha, the surface area at elevation 76 m, to facilitate inter-annual comparisons.

Relative abundance of fish captured in gill nets was used to apportion the acoustic estimate among species. Fish and acoustic data from corresponding depths and locations were matched for this analysis (e.g., floating gill net data were matched with side-looking acoustic data from the 0-5 m depth range). Only gill net panels corresponding to the area sampled with acoustics (offshore of the 17 m depth contour on average) were used for species apportionment. Species composition was computed separately for slope and pelagic zones using the 40 m depth contour as the boundary between them.

Mean weights of fish captured in gill nets were used to compute species and cohort biomass for fish over 100 mm long. Fish less than 100 mm in length were detectable with acoustics but were too small to be captured in gill nets. Per Love's (1977) +/- 45 degree model, fish with mean TS <-46.9 dB were considered to be <100 mm long. The biomass of this smaller size group was computed by estimating a mean length per fish from TS and then calculating a corresponding mean weight using the weight-length regression equation that we developed for larger kokanee from the 2011 gill net data (all fish in the acoustic sample less than 100 mm long were assumed to be kokanee).

3.0 RESULTS AND DISCUSSION

Weather conditions were calm and well suited to acoustic sampling during the 2012 survey, resulting in high quality down and side-looking data on all transects. At the time of the survey the reservoir was strongly stratified with well-defined thermal layers (Figure 2). The dissolved oxygen concentration was below saturation with respect to temperature over the depth range sampled (0-55 m) at both stations (Figure 2). Except below 15 m at the north station, it exceeded the minimum level considered adequate for protection of fish (>6.5 mg/L, CCME 2003), and was not <6.0 mg/l anywhere we sampled. Dissolved oxygen below saturation and below levels observed in previous years (e.g., Stables and Perrin 2011) can be attributed to the strong thermal stratification that lasted later than usual into autumn in 2012. Relatively high dissolved oxygen concentrations in the epilimnion (Figure 2) can be ascribed to the production of oxygen by photosynthesis while demand for oxygen by respiration at depths below the euphotic zone may explain lower concentrations in the hypolimnion.

Information used to calculate the abundance and biomass estimates is shown in Tables 2 through 6. Tables 2 and 3 contain species composition from the 2011 gill netting. Counts of fish and fish density by transect and depth layer are shown in Tables 4 and 5. Proportions of fish larger and smaller than 100 mm in length appear in Table 6. Abundance and biomass estimates appear in Tables 7 and 8.

The 2012 abundance and biomass estimates for all species combined were 319,496 ± 54,343 fish (±17%) and 4,586 kg (Tables 7 and 8). These values represent a 64% decrease in abundance and a 75% decrease in biomass since 2011, continuing a decline since 2010 when both estimates peaked (Figure 3). Acoustic data suggest in two ways that declining kokanee abundance was mainly responsible for these trends. First, echograms (Figure 4) show that fish abundance decreased from 2010 to 2012 mainly within the 6-11°C thermal layer preferred by kokanee during autumn at night (D. Sebastian, MOE, personal communication). Second, exclusion from population estimates of the 0-10 m depth range where redside shiners may have been numerous (S. Harris, MOE, personal communication) did not appreciably change the percentage decline in numbers from 2010 to 2012 (81% decline including 0-10 m, 85% excluding 0-10 m).

The 2012 areal density and biomass estimates for individual fish species (ages combined) were 112 kokanee/ha (1.00 kg/ha), 0.0431 cutthroat trout/ha (0.0193 kg/ha), 0.671 bull trout/ha (0.554 kg/ha), 0.176 northern pikeminnow/ha (0.0480 kg/ha), 0.0 peamouth/ha, and 0.162 redside shiner/ha (0.00272 kg/ha), for a total of 113 fish/ha and 1.62 kg/ha for all species combined (Table 8). Cohort specific abundance and biomass estimates for salmonids are shown in Table 8.

Despite the large drop in numbers from 2011 to 2012, the 2012 total fish abundance estimate is dependable: the in situ calibration indicated proper echo sounder operation, survey conditions were excellent, and the observed decline in abundance continued a trend begun in the previous year. However, the accuracy of the 2012 total fish biomass estimate and the abundance and biomass estimates for individual species and age groups are questionable. Considering the large decrease in abundance from 2011 to 2012, population characteristics (species, age, and size composition) may have changed considerably from one year to the next, so apportionment of the 2012 acoustic data using 2011 gill net results is unreliable. For example, target strengths showed that the proportion of small fish in the population was much lower in 2012 than in 2011 or previous years (Figure 5). The next reliable biomass and abundance estimates for individual species and age groups will be available after the 2013 survey, which will include both acoustics and gill netting.

The cause of the recent decline in fish abundance is presently unknown. The study design as stated in the original Terms of Reference (TOR) seeks only to determine if fish biomass changes in response to implementation of Combo 6 ($H_0$1), and whether fish biomass is correlated with indices of littoral and pelagic primary production ($H_0$2). Since the study began, several uncontrolled and potentially important factors have emerged, including: nutrient contributions and kokanee entrainment from Alouette Reservoir, parasitism of kokanee by copepods (observed in 2011), annual variation in water column temperature and dissolved oxygen profiles, egg and fry mortality from winter floods in spawning areas, and potential effects of dams that have recently been constructed on the Upper Stave River. These factors may confound tests of ($H_0$1) and ($H_0$2) and, if feasible, it may be advantageous to include them as part of a multivariate model to evaluate factors affecting fish biomass in the final analysis after all sampling has been completed in 2014. If this additional analysis is to take place it will be necessary to take several preparatory steps, including: identifying all potential factors of interest with available data sources (e.g., Upper Stave River hydrographic data for evaluating flood related egg mortality of stream-spawning kokanee); screening potential factors to choose credible, testable ones; and obtaining data sets for the factors to be tested.

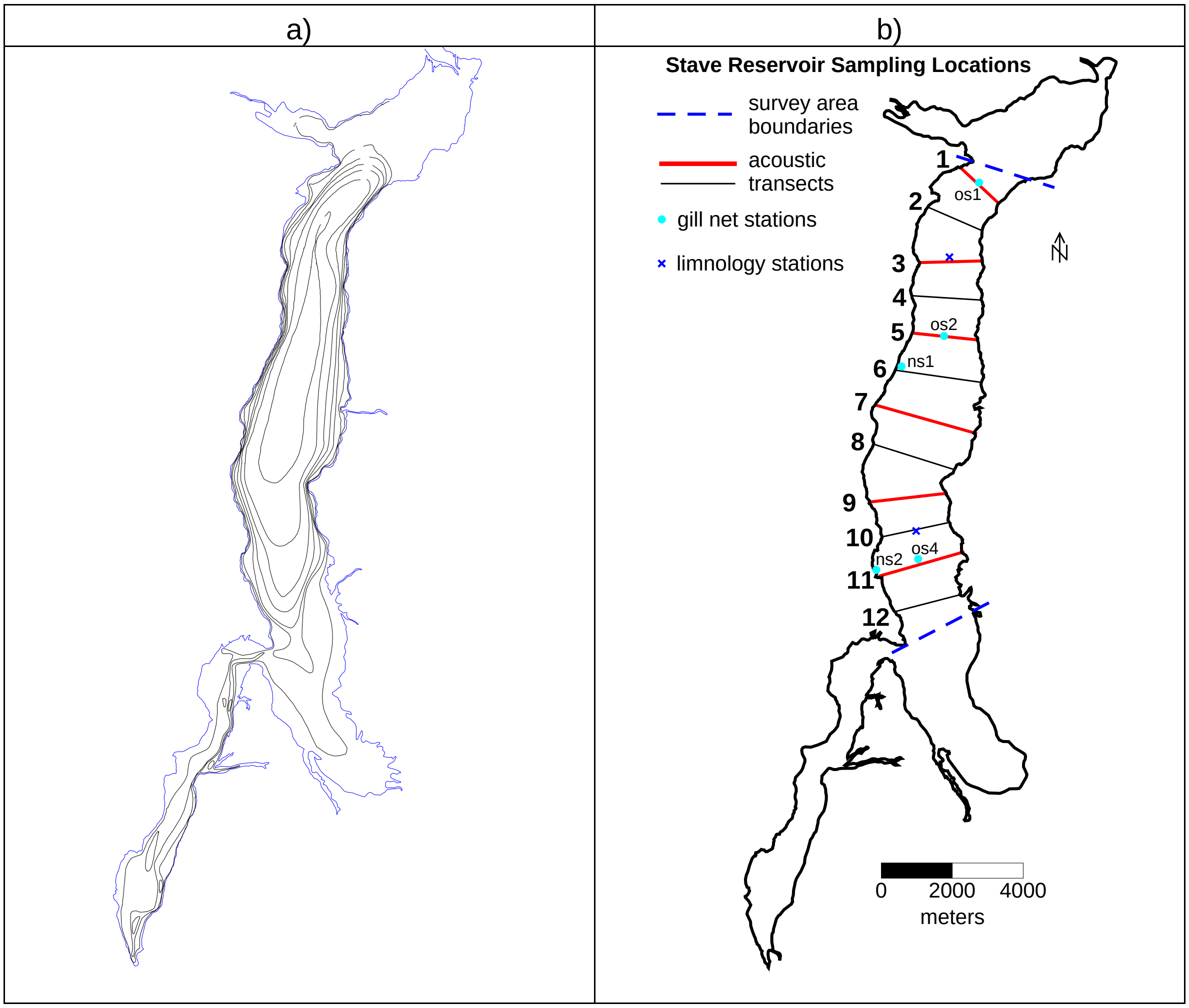

Figure 1. Maps of Stave Reservoir: a) bathymetric map showing the reservoir outline at full pool (82.1 m above sea level) with 10 m depth contours; b) 2012 acoustic survey transects (red lines), 2012 limnology stations, and 2011 gill net stations. Black lines between the red lines indicate optional transects that were not sampled in 2012.

Table 1. Equipment specifications and settings for collection and processing of acoustic data, Stave Reservoir, October 9, 2012 survey. D = down-looking, S = side-looking, unspecified = both.

Project Phase	Category	Parameter	Value
Data collection	Transducer	Type[1]	Split-beam
"	"	Sound frequency (kHz)	201
"	"	Nominal (full) beam angle	6.7°
"	"	Depth below lake surface (m)	0.80 D, 0.50 S
"	Settings	Pulse width	0.4 ms
"	"	Transmit power (dB)	0.0
"	"	Collection threshold (dB)	-100
"	"	Minimum data range[2]	1.0 m
"	"	Time varied threshold	40 log R
"	"	Ping rate (pps)	6 D, 4 S
"	GPS	Type[3]	Differential
"	"	Datum	NAD83
"	Other	Transecting speed (m/s)	1.7-2.0 D, 1.4-1.5 S
Data Analysis	General	Calibration offset (dB)	0.0
"	"	Time varied gain	40 log R
"	"	Minimum threshold (dB)[4]	-65
"	"	Maximum threshold (dB)[4]	-25
"	"	Beam pattern thresh.(dB)	-6
"	"	Beam full angle	6.7°
"	"	Single target filters	0.5-1.5 @ -6 dB
"	Range processed[2]	For fish abundance	5-80 m D, 10-25 m S
"	"	For TS	2-80 m D
"	Fish tracks per fish	Minimum # echoes	2
"	"	Max range change	0.2 m
"	"	Max ping gap	1

[1] BioSonics DT-X split-beam.
[2] range from transducer.
[3] WAAS differential GPS.
[4] Processing threshold after application of calibration offset.

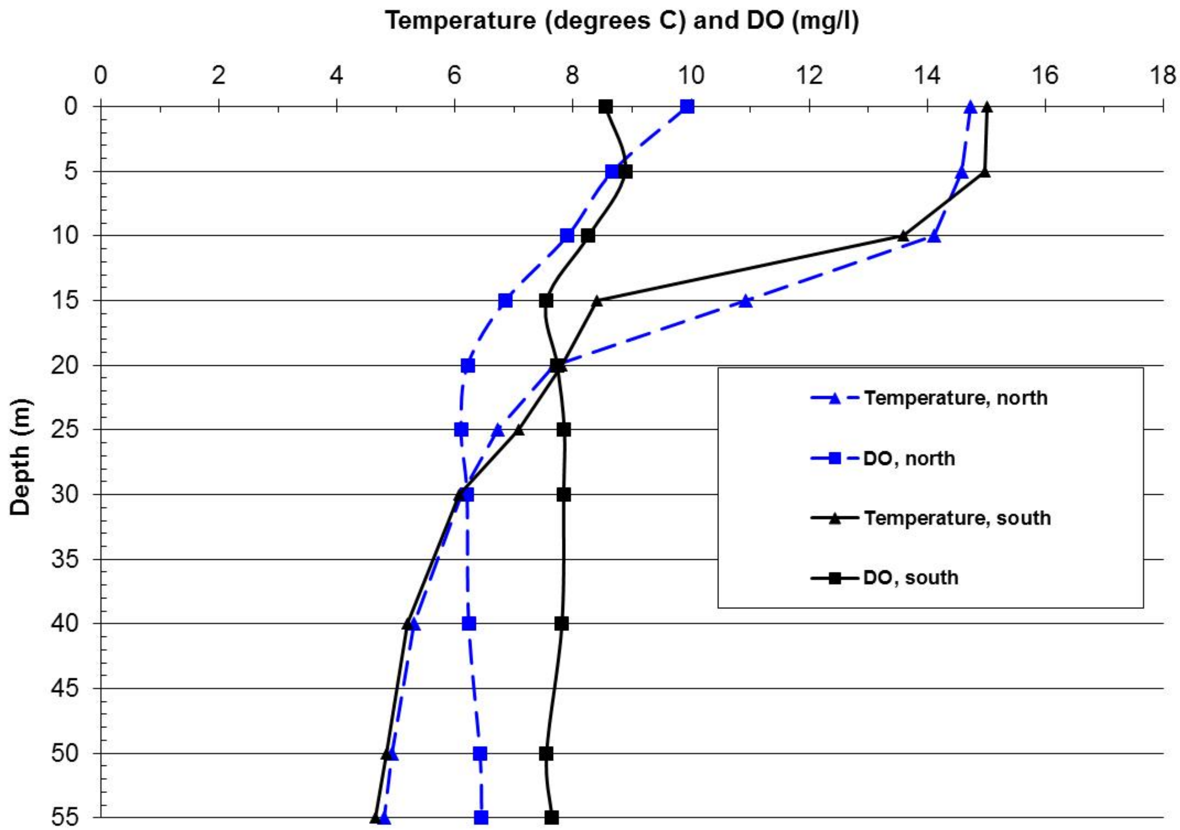

Figure 2. Temperature and dissolved oxygen (DO) profiles from Stave Reservoir on October 9, 2012. The vertical grid with 5 m spacing represents depth intervals used for the acoustic population estimate.

Table 2. Species composition by depth layer of the slope zone. These data, from October 2011 gill netting, were used to apportion the 2012 Stave Reservoir acoustic estimate of fish > 100 mm long.

Depth layer	C. trout	Kokanee	L. sucker	P. sculpin		Peamouth	Pikeminnow	R. shiner	R. trout	Bull trout	Total
Catch by depth layer											
0-5 m	12	4	0	0		1	2	4	0	0	23
5-10 m											
10-15 m											
15-20 m	0	2	2	0		1	2	0	0	0	7
20-25 m	0	5	2	0		0	1	0	0	7	15
25-30 m	0	0	0	0		0	0	0	0	0	0
30-35 m	0	0	1	0		0	0	0	0	2	3
35-40 m	0	1	0	0		1	1	0	0	0	3
Raw percentage of layer total catch											
0-5 m	52.2%	17.4%	0.0%	0.0%		4.3%	8.7%	17.4%	0.0%	0.0%	100.0%
5-10 m											
10-15 m											
15-20 m	0.0%	28.6%	28.6%	0.0%		14.3%	28.6%	0.0%	0.0%	0.0%	100.0%
20-25 m	0.0%	33.3%	13.3%	0.0%		0.0%	6.7%	0.0%	0.0%	46.7%	100.0%
25-30 m	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
30-35 m	0.0%	0.0%	33.3%	0.0%		0.0%	0.0%	0.0%	0.0%	66.7%	100.0%
35-40 m	0.0%	33.3%	0.0%	0.0%		33.3%	33.3%	0.0%	0.0%	0.0%	100.0%
Estimated species composition by layer for the population estimate*											
0-5 m	52.2%	17.4%		0.0%	0.0%	4.3%	8.7%	17.4%	0.0%	0.0%	100.0%
5-10 m	52.2%	17.4%		0.0%	0.0%	4.3%	8.7%	17.4%	0.0%	0.0%	100.0%
10-15 m	26.1%	28.7%		0.0%	0.0%	12.2%	24.3%	8.7%	0.0%	0.0%	100.0%
15-20 m	0.0%	40.0%		0.0%	0.0%	20.0%	40.0%	0.0%	0.0%	0.0%	100.0%
20-25 m	0.0%	38.5%		0.0%	0.0%	0.0%	7.7%	0.0%	0.0%	53.8%	100.0%
25-30 m	0.0%	27.6%		0.0%	0.0%	8.3%	12.2%	0.0%	0.0%	51.9%	100.0%
30-35 m	0.0%	16.7%		0.0%	0.0%	16.7%	16.7%	0.0%	0.0%	50.0%	100.0%
35-40 m	0.0%	16.7%		0.0%	0.0%	16.7%	16.7%	0.0%	0.0%	50.0%	100.0%

* Suckers were likely too close to the bottom to be detected with acoustics, so they were excluded from this species composition estimate. Species composition for layers not sampled was estimated from adjacent layers: 1) the 5-10 m layer was considered the same as the 0-5 m layer because both were in the epilimnion; 2) the 10-15 m layer was interpolated from the layers immediately above and below; 3) due to low catches, the 30-35 m and 35-40 m layers were pooled; and 4) the 25-30 layer was interpolated from layers immediately above and below.

Table 3. Species composition by depth layer of the pelagic zone. These data, from October 2011 gill netting, were used to apportion the 2012 Stave Reservoir acoustic estimate of fish > 100 mm long.

Depth layer	C. trout	Kokanee	L. sucker	P. sculpin	Peamouth	Pikeminnow	R. shiner	R. trout	Bull trout	Total
Catch by depth layer										
0-5 m	3	11	0	0	3	1	2	7	0	27
5-10 m										
10-15 m	0	17	0	0	0	0	0	0	0	17
15-20 m	1	48	0	0	0	0	0	0	2	51
20-25 m	0	11	0	0	0	0	0	0	0	11
25-30 m										
30-35 m										
35-40 m										
40-45 m	0	0	0	0	0	0	0	0	0	0
45-50 m	0	0	0	0	0	0	0	0	0	0
Raw percentage of layer total catch										
0-5 m	11.1%	40.7%	0.0%	0.0%	11.1%	3.7%	7.4%	25.9%	0.0%	100.0%
5-10 m										
10-15 m	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
15-20 m	2.0%	94.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	100.0%
20-25 m	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
25-30 m										
30-35 m										
35-40 m										
40-45 m	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
45-50 m	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Estimated species composition by layer for the population estimate*										
0-5 m	11%	41%	0%	0%	11%	4%	7%	26%	0%	100%
5-10 m	11%	41%	0%	0%	11%	4%	7%	26%	0%	100%
10-15 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
15-20 m	2%	94%	0%	0%	0%	0%	0%	0%	4%	100%
20-25 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
25-30 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
30-35 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
35-40 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
40-45 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
45-50 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
50-55 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
55-60 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
60-65 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
65-70 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
70-75 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%
75-80 m	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%

* Species composition for layers not sampled was estimated from adjacent layers: 1) the 5-10 m layer was considered the same as the 0-5 m layer because both were in the epilimnion; 2) values for the 20-25 m layer were extrapolated to all deeper layers.

Table 4. Counts of fish from echograms by transect and depth interval, Stave Reservoir, October 9-10, 2012. Counts for 0-5 m and >5 m depth ranges were from side and down-looking data, respectively.

Zone	Depth range (m)	Fish Count by Transect 1	2	3	4	5	6	7	8	9	10	11	12	Total
slope	0-5	14		3		21		3		11		5		57
"	5-10	0		0		1		0		0		1		2
"	10-15	0		0		2		1		1		0		4
"	15-20	0		1		2		1		0		2		6
"	20-25	0		1		2		2		0		0		5
"	25-30	0		0		1		3		0		2		6
"	30-35	0		0		1		5		0		0		6
"	35-40	0		0		0		1		0		0		1
"	0-40	14		5		30		16		12		10		87
pelagic	0-5	42		20		18		20		35		16		151
"	5-10	3		1		1		0		2		1		8
"	10-15	5		2		1		6		4		2		20
"	15-20	3		10		8		8		6		1		36
"	20-25	2		7		6		9		9		4		37
"	25-30	4		10		10		20		18		6		68
"	30-35	7		2		2		13		10		3		37
"	35-40	6		2		3		2		0		1		14
"	40-45	1		0		0		0		0		0		1
"	45-50	1		0		0		0		0		1		2
"	50-55	0		0		0		0		0		0		0
"	55-60	2		0		0		0		0		0		2
"	60-65	2		0		0		0		1		1		4
"	65-70	2		2		0		0		1				5
"	70-75	0		0		0		0		1				1
"	75-80			0		0		0		0				0
"	0-80	80		56		49		78		87		36		386

Table 5. Fish density (fish/m^3) for all species combined by transect and depth interval from the October 9, 2012 acoustic survey. Densities for 0-5 m and >5 m depth ranges were from side and down-looking data, respectively.

	Depth	Fish density by transect (fish/m^3)												Total		
Zone	**range (m)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**n**	**Mean**	**Var**
slope	0-5	0.00245		0.00069		0.00320		0.00031		0.00182		0.00089		6	0.001558	1.262E-06
"	5-10	0.00000		0.00000		0.00167		0.00000		0.00000		0.00077		6	0.000407	4.771E-07
"	10-15	0.00000		0.00000		0.00127		0.00050		0.00129		0.00000		6	0.000511	3.936E-07
"	15-20	0.00000		0.00114		0.00090		0.00037		0.00000		0.00058		6	0.000498	2.178E-07
"	20-25	0.00000		0.00078		0.00080		0.00067		0.00000		0.00000		6	0.000375	1.710E-07
"	25-30	0.00000		0.00000		0.00042		0.00119		0.00000		0.00047		6	0.000346	2.170E-07
"	30-35	0.00000		0.00000		0.00060		0.00334		0.00000		0.00000		6	0.000657	1.785E-06
"	35-40	0.00000		0.00000		0.00000		0.00370		0.00000		0.00000		6	0.000616	2.279E-06
"	0-40	0.00031		0.00033		0.00111		0.00126		0.00039		0.00034		48		
pelagic	0-5	0.00134		0.00043		0.00041		0.00031		0.00067		0.00033		6	0.000582	1.531E-07
"	5-10	0.00073		0.00020		0.00026		0.00000		0.00032		0.00018		6	0.000283	5.960E-08
"	10-15	0.00058		0.00019		0.00010		0.00035		0.00031		0.00017		6	0.000284	2.962E-08
"	15-20	0.00024		0.00066		0.00053		0.00032		0.00032		0.00006		6	0.000354	4.638E-08
"	20-25	0.00012		0.00035		0.00030		0.00027		0.00036		0.00017		6	0.000265	9.572E-09
"	25-30	0.00020		0.00041		0.00041		0.00050		0.00059		0.00021		6	0.000385	2.419E-08
"	30-35	0.00029		0.00007		0.00007		0.00027		0.00028		0.00009		6	0.000178	1.262E-08
"	35-40	0.00021		0.00006		0.00009		0.00004		0.00000		0.00003		6	0.000071	5.878E-09
"	40-45	0.00003		0.00000		0.00000		0.00000		0.00000		0.00000		6	0.000005	1.748E-10
"	45-50	0.00003		0.00000		0.00000		0.00000		0.00000		0.00002		6	0.000009	1.922E-10
"	50-55	0.00000		0.00000		0.00000		0.00000		0.00000		0.00000		6	0.000000	0.000E+00
"	55-60	0.00006		0.00000		0.00000		0.00000		0.00000		0.00000		6	0.000010	5.946E-10
"	60-65	0.00006		0.00000		0.00000		0.00000		0.00002		0.00004		6	0.000021	7.232E-10
"	65-70	0.00008		0.00006		0.00000		0.00000		0.00002				5	0.000030	1.190E-09
"	70-75	0.00000		0.00000		0.00000		0.00000		0.00002				5	0.000003	5.480E-11
"	75-80			0.00000		0.00000		0.00000		0.00000				4	0.000000	0.000E+00
"	0-80	0.00026		0.00015		0.00014		0.00013		0.00018		0.00010		92		

Table 6. Counts and percentages of fish with estimated fork lengths <100 mm and ⩾100 mm, Stave Reservoir, October 2012. Lengths were estimated from acoustic data (TS of tracked fish) using Love's (1977) +/- 45 degree relationship. Percentages for layers with an insufficient count were adjusted using data from adjacent layers.

Zone	Depth interval (m)	Count			Percentages for size-groups	
		<100 mm	⩾100 mm	Total	<100 mm	⩾100 mm
slope	0-5	0	0	0	100.00%	0.00%
"	5-10	2	0	2	100.00%	0.00%
"	10-15	4	0	4	100.00%	0.00%
"	15-20	6	0	6	100.00%	0.00%
"	20-25	5	0	5	100.00%	0.00%
"	25-30	4	2	6	66.67%	33.33%
"	30-35	3	3	6	50.00%	50.00%
"	35-40	1	1	2	50.00%	50.00%
pelagic	0-5	5	0	5	100.00%	0.00%
"	5-10	8	0	8	100.00%	0.00%
"	10-15	20	0	20	100.00%	0.00%
"	15-20	30	6	36	83.33%	16.67%
"	20-25	23	14	37	62.16%	37.84%
"	25-30	39	29	68	57.35%	42.65%
"	30-35	22	15	37	59.46%	40.54%
"	35-40	7	7	14	50.00%	50.00%
"	40-45	0	1	1	0.00%	100.00%
"	45-50	1	1	2	50.00%	50.00%
"	50-55	0	0	0	0.00%	0.00%
"	55-60	2	0	2	100.00%	0.00%
"	60-65	4	0	4	100.00%	0.00%
"	65-70	4	1	5	80.00%	20.00%
"	70-75	0	1	1	0.00%	100.00%
"	75-80	0	0	0	0.00%	0.00%

Table 7. Total fish abundance (species combined) by habitat zone of Stave Reservoir, from the October 9-10, 2012 acoustic survey. The reservoir surface elevation was 76.6 m above sea level at the time of the survey.

Zone	Depth range (m)	Mean no. per m³	Variance	Sample size *	Stratum Volume (cubic m)	Pop est	SE of pop est	95% CL lower	95% CL upper
slope	0-5	0.00156	1.3E-06	6	1.6E+07	25,451	7,491	6,195	44,708
"	5-10	0.00041	4.8E-07	6	1.6E+07	6,644	4,605	-5,193	18,482
"	10-15	0.00051	3.9E-07	6	1.6E+07	8,338	4,183	-2,414	19,091
"	15-20	0.00050	2.2E-07	6	1.6E+07	7,813	2,990	127	15,499
"	20-25	0.00038	1.7E-07	6	1.3E+07	4,696	2,112	-733	10,125
"	25-30	0.00035	2.2E-07	6	8.9E+06	3,091	1,701	-1,283	7,465
"	30-35	0.00066	1.8E-06	6	5.2E+06	3,431	2,850	-3,896	10,757
"	35-40	0.00062	2.3E-06	6	1.7E+06	1,047	1,047	-1,645	3,740
"	0-40			48	9.3E+07	60,513	10,970	38,359	82,666
pelagic	0-5	0.00058	1.5E-07	6	1.1E+08	61,291	16,813	18,072	104,510
"	5-10	0.00028	6.0E-08	6	1.1E+08	29,736	10,490	2,771	56,701
"	10-15	0.00028	3.0E-08	6	1.1E+08	29,913	7,395	10,903	48,923
"	15-20	0.00035	4.6E-08	6	1.1E+08	37,305	9,253	13,520	61,090
"	20-25	0.00026	9.6E-09	6	1.1E+08	27,867	4,204	17,061	38,673
"	25-30	0.00039	2.4E-08	6	1.1E+08	40,548	6,682	23,371	57,725
"	30-35	0.00018	1.3E-08	6	1.1E+08	18,721	4,827	6,313	31,129
"	35-40	0.00007	5.9E-09	6	1.1E+08	7,514	3,294	-954	15,981
"	40-45	0.00001	1.7E-10	6	1.0E+08	556	556	-873	1,985
"	45-50	0.00001	1.9E-10	6	9.8E+07	861	554	-564	2,286
"	50-55	0.00000	0.0E+00	6	9.3E+07	0	0	0	0
"	55-60	0.00001	5.9E-10	6	8.5E+07	849	849	-1,333	3,031
"	60-65	0.00002	7.2E-10	6	7.7E+07	1,580	845	-592	3,751
"	65-70	0.00003	1.2E-09	5	7.0E+07	2,061	1,073	-919	5,041
"	70-75	0.00000	5.5E-11	5	5.5E+07	181	181	-322	685
"	75-80	0.00000	0.0E+00	4	4.1E+07	0	0	0	0
"	0-80			92	1.5E+09	258,983	25,154	208,895	309,071
Combined						319,496	27,442	265,153	373,838

Table 8. Abundance and biomass of individual fish species within the study area in Stave Reservoir, from the October 2012 acoustic survey results apportioned using species, size, and age composition data from fall 2011 gill netting.

			Species							
Size group	**Estimate**	**Age**	**C. trout**	**R. trout**	**Kokanee**	**B. trout**	**Peamouth**	**Pikeminnow**	**R. shiner**	**Total**
< 100 mm	abundance	0	0	0	269,243	0	0	0	0	269,243
"	biomass (kg)	0	0	0	94	0	0	0	0	94
≥ 100 mm	percentage	1	11.1%	-	9.7%	-	-	-	-	
"	"	2	38.9%	-	19.4%	-	-	-	-	
"	"	3	22.2%	-	71.0%	7.1%	-	-	-	
"	"	4	5.6%	-	-	42.9%	-	-	-	
"	"	5	16.7%	-	-	28.6%	-	-	-	
"	"	10	5.6%	-	-	7.1%	-	-	-	
"	"	12	-	-	-	14.3%	-	-	-	
"	"	total	100.0%	-	100.0%	100.0%	-	-	-	
"	abundance	1	14	-	4,575	-	-	-	-	
"	"	2	47	-	9,150	-	-	-	-	
"	"	3	27	-	33,550	135	-	-	-	
"	"	4	7	-	-	814	-	-	-	
"	"	5	20	-	-	543	-	-	-	
"	"	10	7	-	-	135	-	-	-	
"	"	12	-	-	-	271	-	-	-	
"	"	total	122	0	47,275	1,898	0	499	459	50,253
"	biomass (kg)	1	1	-	101	-	-	-	-	102
"	"	2	10	-	412	-	-	-	-	421
"	"	3	7	-	2,214	15	-	-	-	2,237
"	"	4	3	-	-	279	-	-	-	283
"	"	5	23	-	-	551	-	-	-	574
"	"	10	10	-	-	105	-	-	-	115
"	"	12	-	-	-	617	-	-	-	617
"	"	total	54	0	2,727	1,567	0	136	8	4,492
Combined	abundance	total	122	0	316,518	1,898	0	499	459	319,496
"	biomass (kg)	"	54.5	0.000	2,821	1,567	0.000	136	7.71	4,586
"	number/ha	"	0.0431	0.000	112	0.671	0.000	0.176	0.162	113
"	kg/ha	"	0.0193	0.000	1.00	0.554	0.000	0.0480	0.00272	1.62
	% of tot kg		1.19%	0.00%	61.5%	34.2%	0.00%	2.97%	0.168%	100%

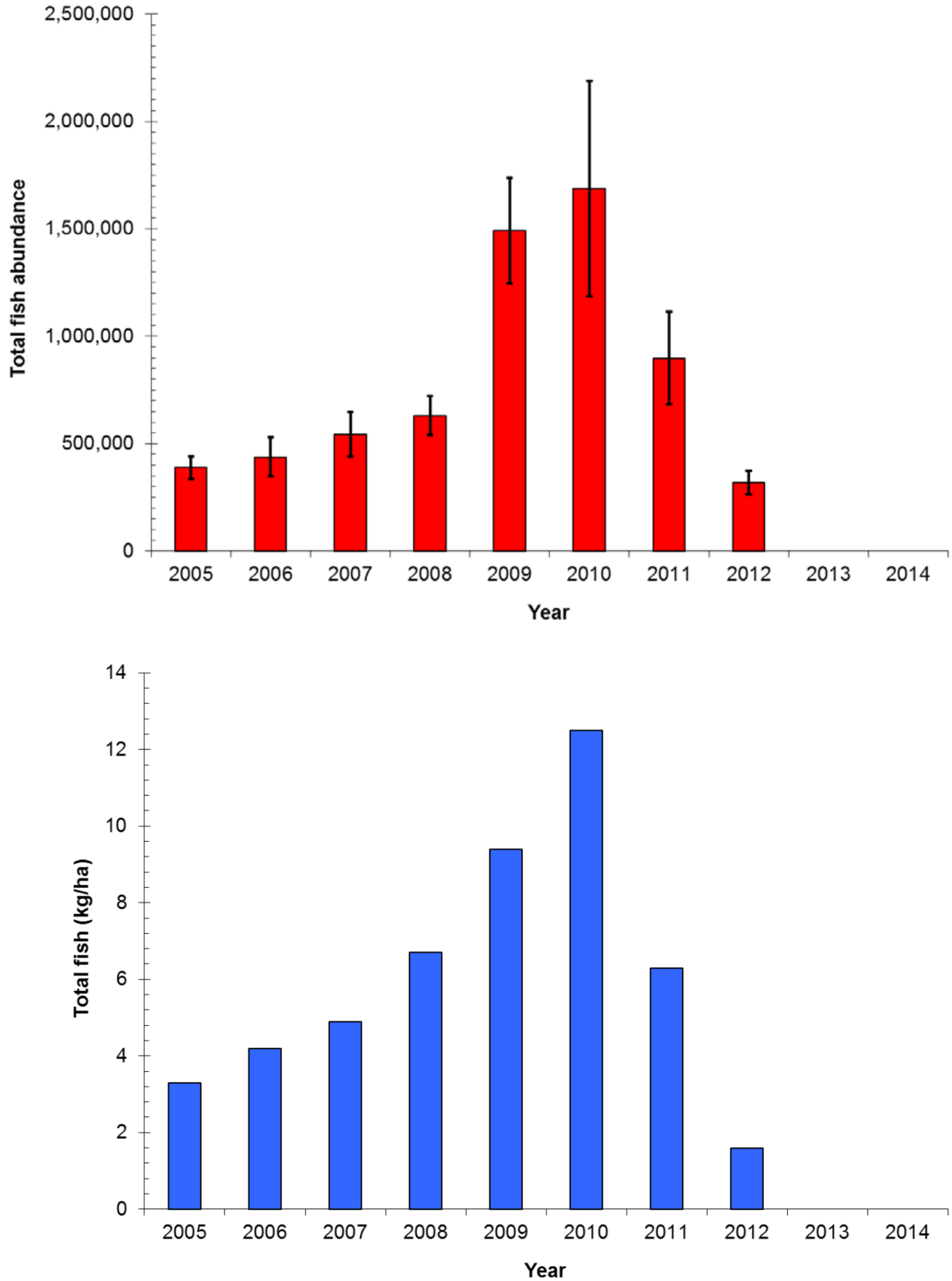

Figure 3. Total fish abundance (upper) and biomass (lower) in Stave Reservoir for species combined from study inception to the most recent survey. Error bars on abundance estimates are 95% confidence limits.

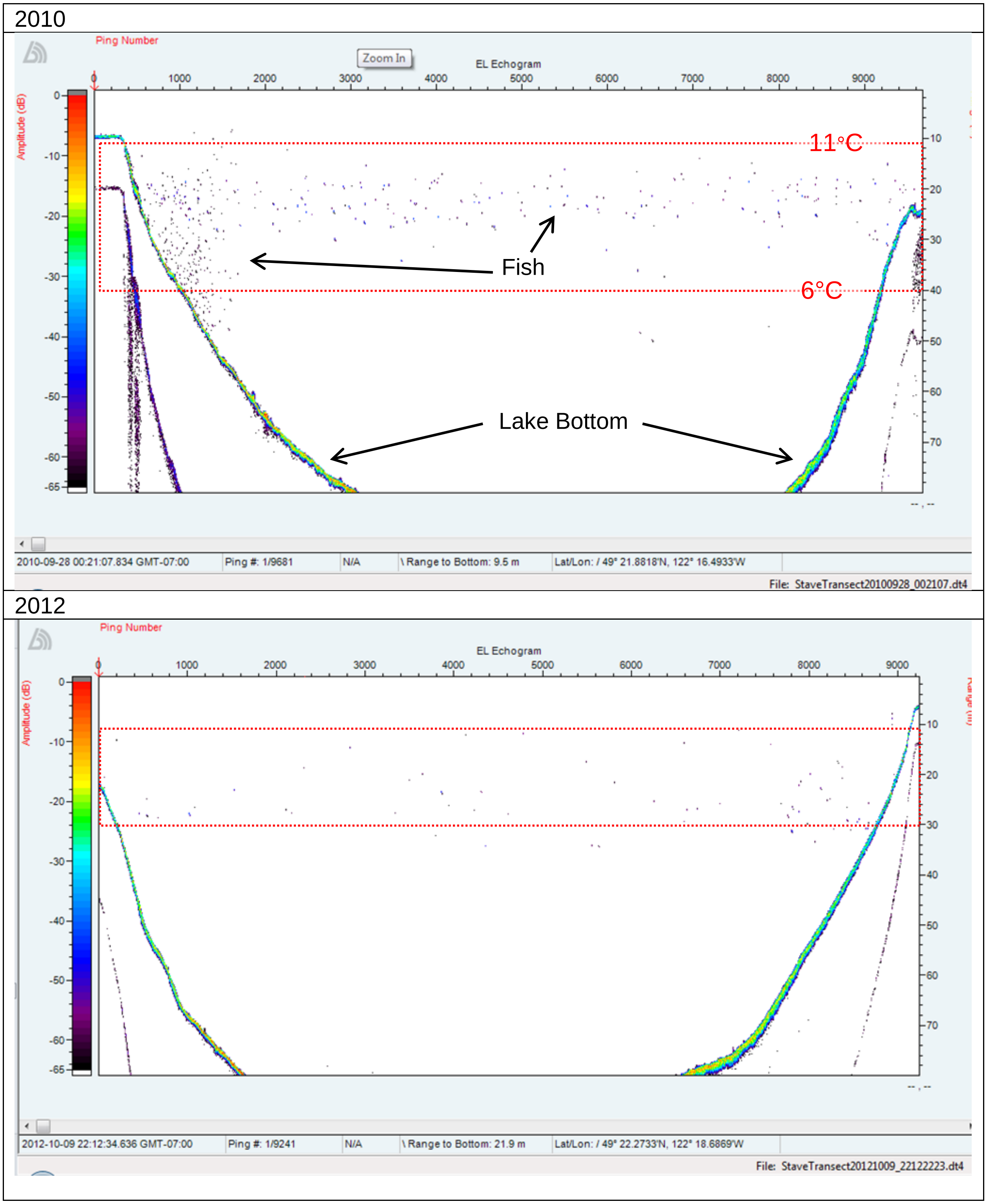

Figure 4. Down-looking echograms from Stave Reservoir acoustic Transect 7, showing the decline in fish abundance from 2010 to 2012 within the 6-11°C layer preferred by kokanee during autumn at night (between red lines).

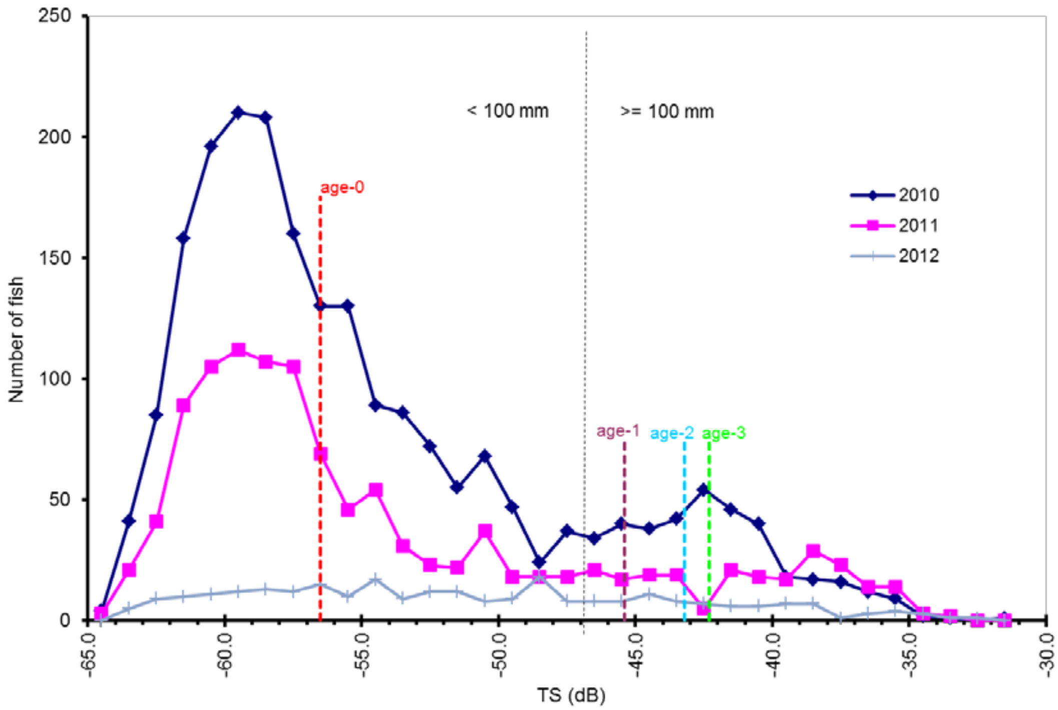

Figure 5. Frequency distributions of fish target strength (TS, the acoustic size of fish) in Stave Reservoir, fall 2010-2012. Data are from the slope and pelagic zones combined. Dashed lines indicate the mean TS of each kokanee age-group as estimated by Love's (1977) ±45° TS versus length model using 2011 gill net data. A TS of -46.9 dB corresponds to a 100 mm long fish. The sample size (number of fish tracked on echograms) was 2,170 in 2010, 1,141 in 2011, and 271 in 2012.

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5.0 DATA APPENDICES

Raw data appendices are available from BC Hydro.