Stave River Water Use Plan

Fish Biomass Assessment

Implementation Year 9

Reference: SFLMON-3

Abundance and Biomass of Fish in Stave Reservoir in October 2013

Study Period: 2013

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ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR IN FALL 2013

Draft Report

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Draft Report

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Cover photo: Gill netting on Stave Reservoir, October 2013. Photo by Brock Stables.

EXECUTIVE SUMMARY

An acoustic survey and gill netting were conducted between September 17 and October 4, 2013 to determine the abundance, biomass, and spatial distribution of fish in Stave Reservoir. Acoustic sampling was performed during the night of September 17-18 and gill netting was conducted October 1-4. Survey and analysis methods were the same as in previous years. As in the past, standard RISC gill nets were used to estimate fish species composition. In addition, a pilot-test was conducted using small-mesh gill nets to sample fish <100 mm in length for non-quantitative descriptive purposes. The 2013 survey represents year 9 of a 10 year study conducted under the Stave River Water Use Plan.

Stormy weather during the gill net survey reduced sampling from three nights to two, and cut the number of RISC gill net sets from the target of 21 to 17. Even so, all gill net stations and most depth layers of interest were sampled, although coverage was less thorough than planned. Conditions on the night of the acoustic survey were not ideal, with winds exceeding 10 knots on some transects, particularly in the middle of the lake. Despite these difficulties, most side-looking data were usable, except from transects 3 and 7 which were too rough other than near shore, and all down-looking data were usable.

Thermal stratification was strong on September 17, 2013, during the acoustic survey, with temperatures in the epilimnion (0-5 m) exceeding 18°C at both the north and south limnology stations. By October 3, during the gill net survey, surface water temperatures had declined to 12-13°C, and the epilimnion extended to a depth of 10-15 m. Dissolved oxygen concentrations exceeded 9 mg/l at all depths on both sampling dates, well above the minimum level considered adequate for protection of fish (>6.5 mg/L).

A total of 302 fish of eight species were captured in 17 RISC gill net sets (339 set-hours) at nearshore and mid-lake stations. The species captured were cutthroat trout, rainbow trout, bull trout, kokanee, largescale sucker, northern pikeminnow, peamouth, and redside shiner. Prickly sculpins, an uncommon species in some previous years, were not captured in 2013. It is noteworthy that no cutthroat trout or bull trout older than age 4 were caught in 2013, since small numbers of older fish were captured in previous years.

Fish spatial distribution patterns from RISC gill netting were similar to previous years, with most fish of all species found in the upper 30 m of the water column and distinct species-specific habitat preferences within that depth range. Compared to other years, the 2013 overall catch rates in RISC nets (fish $\cdot$ 100 m^{-2} $\cdot$ 24 $hours^{-1}$) were relatively low in both nearshore and offshore zones for all species combined and for most individual species. Kokanee catch per unit effort (CPUE) was the lowest on record for the nearshore zone (except day sampling), and second lowest for the offshore zone. Small-mesh gill nets only captured fish at the lake surface (0-5 m range) and only at the northern gill net station, and 88% of their limited catch (8 fish) was redside shiner. These patterns, along with those of RISC gill net catches, suggest that redside shiners made up a considerable fraction of the fish <100 mm in length in the 0-5 m or 0-10 m depth range of the pelagic zone, especially in the northern part of the lake.

Many kokanee had parasitic copepods or “gill lice”, probably *Salmincola californiensis*, attached near the base of fins and in the gill cavity. They occurred on a high percentage of the kokanee captured (67%) and on some cutthroat trout (8%), and the mean number of gill lice per fish was higher for kokanee (8) than for cutthroat trout (1.5). No gill lice were found on bull trout or rainbow trout, although few fish of these species were available for examination.

The 2013 abundance and biomass estimates for all species combined in the study area were 461,184 ± 75,675 fish (±16%) and 10,354 kg. These values represent a 44% increase in abundance and a 131% increase in biomass since 2012, reversing the trend of decline that began in 2011. However, 2013 abundance and biomass values remained, respectively, 73% and 70% below peak values observed in 2010. The 2013 areal density and biomass estimates for individual fish species (ages combined) were 157 kokanee/ha (2.4 kg/ha), 1.2 cutthroat trout/ha (0.26 kg/ha), 0.1 rainbow trout/ha (0.006 kg/ha), 1.4 bull trout/ha (0.6 kg/ha), 1.0 northern pikeminnow/ha (0.4 kg/ha), 1.2 peamouth/ha (0.03 kg/ha), and 1.1 redside shiner/ha (0.02 kg/ha), for a total of 163 fish/ha and 3.75 kg/ha for all species combined. Small-mesh gill net catches suggest that to some extent kokanee fry abundance was overestimated and redside shiner abundance was underestimated in 2013, mainly in the upper 5 or 10 m of the pelagic zone, due to our assumption that all fish <100 mm long are kokanee. This was probably the case in prior years as well.

Trends in total abundance and biomass were strongly influenced by kokanee, which were again the dominant species in the study area, comprising 96% of numbers and 65% of biomass. Although kokanee were still much less numerous in 2013 than in 2010, abundance and biomass of kokanee fry (age 0) and older age groups increased markedly from 2012 to 2013. These results indicate that the kokanee population has rebounded somewhat from a low in 2012, but remains well below the high point reached in 2010. The causes underlying these population trends are unclear from the limited analysis possible for this annual report. Gill lice infesting kokanee remain a factor of interest that we will continue to investigate.

ACKNOWLEDGEMENTS

This project was performed under contract to BC Hydro as part of the Stave River Water Use Plan Studies. We are grateful to Darin Nishi (BC Hydro Natural Resource Specialist) and Jeff Sneep (BC Hydro Research Biologist) for management of the project, assistance with logistics, and constructive review of reports. 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.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

1.0 INTRODUCTION

Stave Reservoir is the major impoundment within BC Hydro's Stave River Hydroelectric Project. Improving fish production in this 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 severely 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 the resulting reduction in desiccation of the littoral zone might increase fish food production and thereby 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 controlled 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 2013 study, year 9 of this program. Results of earlier surveys in this series appear in Stables and Perrin (2006-2012b). Specific objectives in 2013 were to:

1. Conduct coordinated acoustic and gill net sampling of the reservoir in late September and early October using a sampling and analysis design stratified by nearshore and pelagic habitat zones;
2. Estimate the abundance and biomass of fish during that period for:
    a. all fish species combined
    b. individual fish species
    c. individual age groups of salmonids;
3. Examine fish for gill lice to determine the extent of infestation and to obtain samples of the parasite for accurate identification;
4. In addition to the usual sampling with standard RISC gill nets as in previous years, use small-mesh gill nets to sample fish <100 mm in length as a pilot-test if time allowed;
5. Collect DNA samples from 50 kokanee for unspecified analysis by DFO;
6. Summarize the data and present the results in a brief “data report” format.

2.0 METHODS

2.1 Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen (DO) concentrations were measured over the upper 60 m of the water column at two mid-lake stations (Figure 1) on September 17 and October 3, 2013 using a calibrated YSI model 6920 Sonde.

2.2 Gill netting

2.2.1 Sampling

Gill netting took place on three nights from October 1-4, 2013 at two nearshore and three mid-lake stations in the main lake basin (Figure 1). Surface, midwater, and bottom sets were made at each nearshore station, whereas only surface and midwater sets were made at mid-lake stations. Nearshore sets sampled the 0-50 m depth range, while mid-lake sets sampled the 0-30 m depth range. All nets were set in late afternoon and pulled the next morning, and in this report a “set” is defined as one net fished overnight.

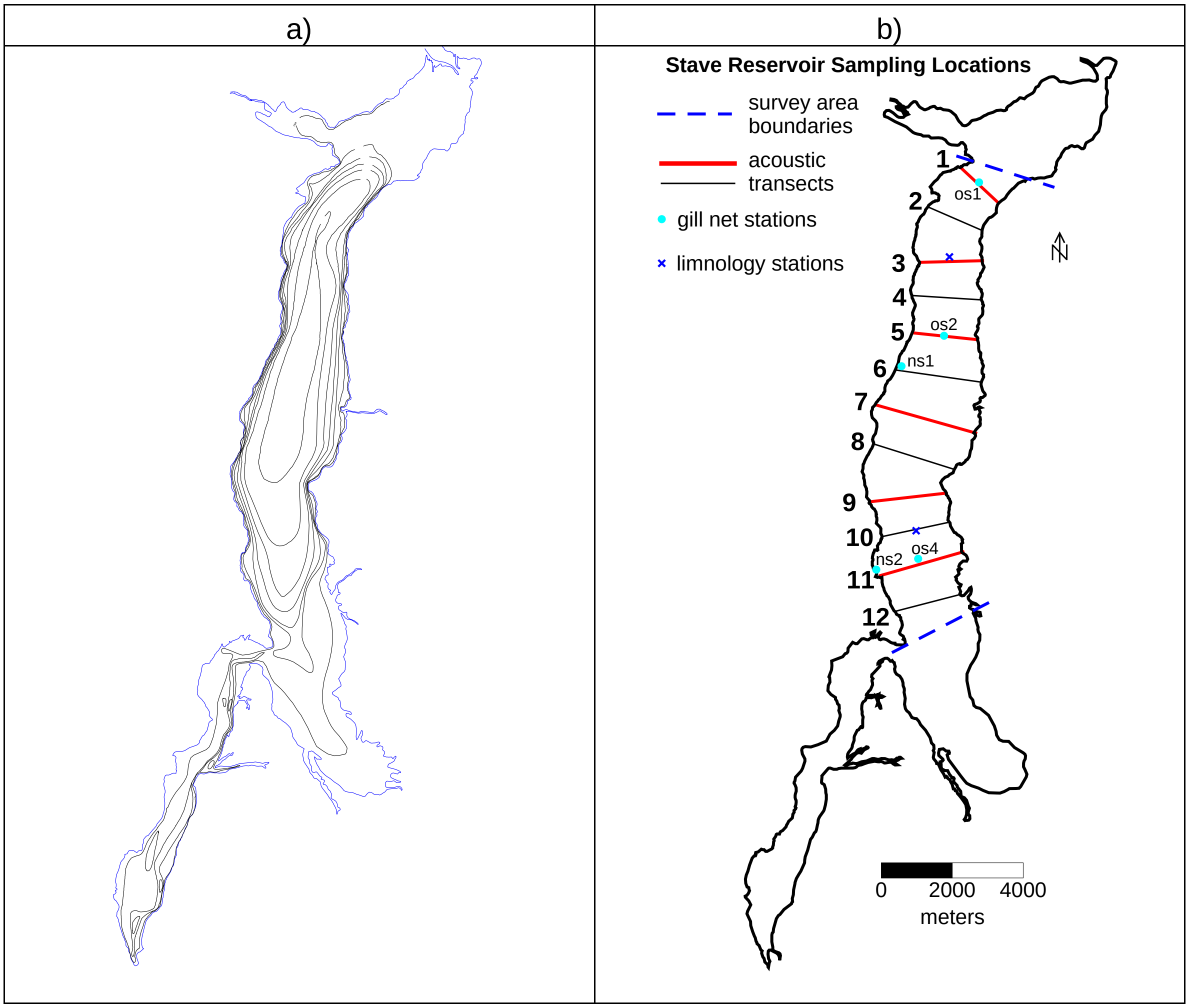


Figure 1. Maps of Stave Reservoir: a) bathymetric map showing the reservoir outline at full pool (82.1 m above sea level) with 10 m depth contours; b) 2013 sampling locations for water quality, gill netting, and acoustics. Acoustic transects that were actually sampled are shown in red; transects in black were unsampled in 2013.

Most nets used for the study were standard RISC 91.2 x 2.4 m floating or sinking variable mesh gill nets (RIC 1997) consisting of 6 panels, each of a different mesh size (25, 89, 51, 76, 38, and 64 mm stretched mesh), which were fished at all nearshore and mid-lake stations. Mid-lake stations were also sampled with small-mesh gill nets targeting fish as small as 70 mm in length. These nets were 15.8 m long by 1.5 or 3.7 m tall, with four panels of stretched mesh sizes of 12.5, 20, 16, and 25 mm in that order. Surface and midwater sets with small-mesh nets supplemented RISC nets at the northern and southern mid-lake stations (OS1 and OS4, Figure 1).

In the field, all fish were identified to species, counted, measured to the nearest mm (fork length), and weighed to the nearest gram on an Ohaus Scout Pro SP4001 top loading balance. Structures for aging were taken from salmonids only. Smears of scales were removed from preferred body areas of all trout and kokanee and stored in plastic paper sleeves in labeled envelopes. Otoliths were obtained from all char sacrificed for biological sampling. Stomachs were excised from a target of seven fish of each salmonid species and preserved in 70% isopropyl alcohol for later examination. Tissue samples (fin clips) for DNA analysis were taken from 50 kokanee and stored individually in glass vials filled with non-denatured ethanol for storage until analysis. These tissue samples were sent to Dr. Lyse Godbout of DFO for processing (their results are outside the scope of this report). Collection of tissue samples from char for DNA analysis was discontinued in 2013. Previous year's tests showed that all char sampled from the reservoir were bull trout (Stables and Perrin 2012a), which is consistent with similar situations in BC (E. Taylor, UBC, personal communication), so for the duration of this study it will be assumed that all char in the reservoir are bull trout.

A more detailed description of our gill net sampling and analysis methods appears in Stables and Perrin (2010). The 2013 methods were identical to those of 2009-2011 and comparable to those of previous study years (Stables and Perrin 2010).

2.2.2 Processing and Analysis

In the lab, scales or otoliths from trout, kokanee, and char were read by a qualified expert. A subsample of each species catch was aged because more fish were captured than were budgeted for aging (60 fish budgeted). The list of fish to be aged was sorted by length and samples to process were chosen systematically from 25 mm size bins for kokanee or 50 mm size bins for trout (e.g., 100-125 mm or 100-150 mm). For each species, the number of samples from a size bin was proportional to the fraction of the total catch of that species represented by that size bin.

Organisms from fish stomachs were identified to the lowest reliable taxon (usually family) and counted by a qualified analyst. Heads or other unambiguous body parts were used for enumeration of organisms that were partly digested. Stomach contents of salmonids were summarized as percent of composition by numbers for broad diet categories (terrestrial invertebrates, benthic invertebrates, zooplankton, and fish).

Catch and catch per unit effort (CPUE) from RISC gill nets 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 of capture and total water column depth to support separate calculation of 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 composite standardized catch rate (catch x 100 m^{-2} of net x 24 hr^{-1}) was also computed for each species for nearshore and mid-lake sets for comparison to catch rates in previous years. CPUE from small-mesh nets was simply computed per set for each depth layer in which sets were made.

Other biological statistics computed from gill net samples included mean and standard deviation of length and weight, length-frequency and age distributions, weight-length regressions, and Fulton's condition factor ($100 \cdot g/cm^3$, Ricker 1975).

2.3 Acoustics

2.3.1 Sampling

A mobile acoustic survey (scientific echo sounding) was performed during the night of September 17-18, 2013 to measure fish abundance in the reservoir. Sampling methods were the same as in previous years and generally followed protocols described in standard fisheries acoustics texts (Thorne 1983, Brandt 1996, Simmonds and MacLennan 2005, Parker-Stetter et al. 2009). The survey took place on the usual six transects perpendicular to the lake shore within the debris-free portion of the main lake basin (Figure 1).

Acoustic sampling was performed from a 6 m long, covered aluminum skiff at a transecting speed of 1.5-1.7 m/s. The 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, the transducer 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, the transducer was aimed 7 degrees below the horizontal plane looking sideways from the boat on a second pass of each transect line (side-looking mode). Both down-looking and side-looking scans were made on each transect.

The echo sounding system consisted of a 206 kHz BioSonics split-beam scientific echo sounder with a 6.7 degree beam paired with a Garmin model 546 differential GPS. The echo sounder was operated by a 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 merged with acoustic data they were logged. Additional equipment specifications and data collection settings are shown in Table 1.

2.3.2 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 track echoes forming fish traces, to measure target strength (TS, the acoustic size of fish), and to determine sampling volumes. 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.

Table 1. Equipment specifications and settings for collection and processing of acoustic data, Stave Reservoir, September 17-18, 2013 survey. D = down-looking, S = side-looking, unspecified = both.

Project Phase	Category	Parameter	Value
Data collection	Transducer	Type[1]	Split-beam
"	"	Sound frequency (kHz)	206
"	"	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
"	"	Ping rate (pps)	6 D, 4 S
"	GPS	Type[3]	Differential
"	"	Datum	NAD83
"	Other	Transecting speed (m/s)	1.7 D, 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.

TS was determined by the split-beam method (Simmonds and MacLennan 2005). Accuracy of acoustic data was assured by an in-situ calibration test in which the TS of a standard sphere was measured during the survey (BioSonics 2004). Measured and expected TS were -39.6 dB and -39.5 dB, so no calibration correction was necessary during data processing. Lengths of individual fish that were observed with down-looking acoustics were estimated from TS using Love's (1977) equation for fish insonified within +/-45 degrees of dorsal aspect:

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

Because TS is affected by factors other than fish size (Simmonds and MacLennan 2005) and Love's (1977) equation is a generalization from many fish species and sizes, this equation provides an estimate of fish length that is less precise than a hands-on physical measurement. 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 habitat 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 number of fish counted 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 the conditions of the survey, the effective beam angle was not less than 5.1°, and was >6.0° except within 10 meters of the transducer. A complete list of data analysis settings appears 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 spatial strata, 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). Volumes of depth intervals and habitat zones were computed from lake volume data provided by BC Hydro. Whole-lake fish density (number/ha) and biomass (kg/ha) estimates were standardized to a surface area of 2,831 ha, the surface area at elevation 76 m, to facilitate inter-annual comparisons. The reservoir surface elevation was 77.9 m during the 2013 acoustic survey.

Relative abundance of fish captured in RISC gill nets was used to apportion the acoustic estimate of fish >100 mm long 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 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. Data from small-mesh gill nets were excluded from this analysis.

Mean weights of fish captured in RISC gill nets were used to compute species and cohort biomass for fish over 100 mm long. Fish <100 mm in length were detectable with acoustics but were too small to be captured in RISC 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 developed for larger kokanee from the 2013 gill net data (all fish in the acoustic sample less than 100 mm long were assumed to be kokanee). This estimate of biomass for the smaller size group is only approximate considering the several sources of uncertainty it contains (uncertain species composition, fish length estimated from TS, and the weight length relationship extrapolated beyond the actual data range).

3.0 RESULTS AND DISCUSSION

Thermal stratification was strong on September 17, 2013, during the acoustic survey, with temperatures in the epilimnion (0-5 m) exceeding 18°C at both the north and south limnology stations (Figure 2). By October 3, during the gill net survey, surface water temperatures had declined to 12-13°C, and the epilimnion extended to a depth of 10-15 m. Dissolved oxygen concentrations exceeded 9 mg/l at all depths on both sampling dates, well above the minimum level considered adequate for protection of fish (>6.5 mg/L, CCME 2003).

Stormy weather during the gill net survey reduced sampling from three nights to two, and cut the number of RISC gill net sets from the target of 21 to 17. Even so, all gill net stations and most depth layers of interest were sampled, although coverage was less thorough than planned. A total of 302 fish of eight species were captured in the 17 RISC gill net sets (339 set-hours) at nearshore and mid-lake stations (Table 2). The species captured were cutthroat trout, rainbow trout, bull trout, kokanee, largescale sucker, northern pikeminnow, peamouth, and redside shiner. Prickly sculpins, an uncommon species in some previous years, were not captured in 2013.

Small-mesh gill nets captured 8 fish of two species (1 cutthroat trout and 7 redside shiners) in 4 sets and 84 set-hours at the mid-lake gill net stations (Table 3). The redside shiners were 55-110 mm in length, and the cutthroat trout was 249 mm long. Small-mesh nets only captured fish at the lake surface (0-5 m range) and only at the northern station. These patterns, along with those of RISC gill net catches (Table 2, Figure 4), suggest that redside shiners made up a considerable fraction of the fish <100 mm in length in the 0-5 m or 0-10 m depth range of the pelagic zone, especially in the northern part of the lake. This small amount of information is a valuable addition to our knowledge about small fish in Stave Reservoir, but it was insufficient for an estimate of species composition. An assessment with small-mesh nets to obtain data suitable for estimating species composition would require more sets and better spatial coverage than in the 2013 test. It would also call for the availability of several small-mesh nets so they could be deployed simultaneously in a number of locations, and the additional net handling and fish processing involved with fishing more nets would require additional field time. In pelagic areas a practical approach might be to fish a small-mesh net and a RISC net at each depth layer of interest, with most small-mesh effort directed at the 0-10 m depth range. The benefit of such sampling would be good species composition data for fish in the 70-100 mm size range, such as redside shiners and age 1 kokanee, but smaller fish including kokanee fry would remain unsampled.

Many kokanee had parasitic copepods or "gill lice", probably *Salmincola californiensis*, attached near the base of fins and in the gill cavity (Figure 3). They occurred on a high percentage of the kokanee captured (67%) and on some cutthroat trout (8%), and the mean number of gill lice per fish was higher for kokanee (8) than for cutthroat trout (1.5, Table 4). No gill lice were found on bull trout or rainbow trout, although few fish of these species were available for examination. The true taxonomic classification of the gill lice in Stave Reservoir is not yet known. Results from specimens sent to an expert for identification are not yet available but are expected early in 2014.

Figure 4 shows catch rates in RISC nets (fish per panel-hour) for individual species in relation to depth of capture and bottom depth at location of capture. Fish distribution patterns were similar to previous years, with most fish of all species found in the upper 30 m of the water column and distinct species-specific habitat preferences within that depth range. Compared to other years, the 2013 overall catch rates in RISC nets (fish $\cdot$ 100 m^{-2} $\cdot$ 24 $hours^{-1}$) were relatively low in both nearshore and offshore zones for all species combined and for most individual species (Table 5). Kokanee CPUE was the lowest on record for the nearshore zone (except day sampling), and second lowest for the offshore zone (Table 5).

Other information from gill netting used to describe the fish community and to calculate the 2013 abundance and biomass estimates is compiled in Tables 6-10 and Figures 5-8. Tables 6 and 7 contain species composition data by depth layer; Tables 8 and 9 describe mean length, weight, and condition factor by species; Table 10 shows age and size composition of salmonids. It is noteworthy that no cutthroat trout or bull trout older than age 4 were caught in 2013 (Table 10) since small numbers of older fish were captured in previous years. Figure 5 shows weight-length regression plots for all species; Figure 6 contains length-frequency distributions for all species; Figure 7 plots length versus age for salmonids; Figure 8 shows length versus age for kokanee in all years of gill netting. Figure 9 shows mean percent (by numbers) of food items in the stomachs of salmonids. Information about fish <100 mm long from small-mesh gill nets was not used in the 2013 species composition estimates due to small sample size and incomplete spatial coverage with small-mesh nets in 2013, and because there was no comparable sampling in previous years. This means it is likely that to some extent kokanee fry abundance was overestimated and redside shiner abundance was underestimated in 2013, mainly in the upper 5 or 10 m of the water column. This was probably the case in prior years as well.

Conditions on the night of the acoustic survey were not ideal, with winds exceeding 10 knots on some transects, particularly in the middle of the lake. Even so, most side-looking data were usable, except from transects 3 and 7 which were too rough other than near shore, and all down-looking data were usable. Results of acoustic sampling used to calculate the 2013 abundance and biomass estimates appear in Tables 11-13. Acoustic counts of fish and fish density by transect and depth layer appear in Tables 11 and 12. Proportions of fish larger and smaller than 100 mm in length are shown in Table 13. Figure 10 compares the frequency distributions of target strengths (TS, the acoustic size of fish) from 2010-2013 acoustic surveys.

The 2013 abundance and biomass estimates for all species combined in the study area were 461,184 ± 75,675 fish (±16%) and 10,354 kg (Tables 14 and 15). These values represent a 44% increase in abundance and a 131% increase in biomass since 2012, reversing the trend of decline that began in 2011 (Figure 11). However, 2013 abundance and biomass values remained, respectively, 73% and 70% below peak values observed in 2010.

The 2013 areal density and biomass estimates for individual fish species (ages combined) were 157 kokanee/ha (2.4 kg/ha), 1.2 cutthroat trout/ha (0.26 kg/ha), 0.1 rainbow trout/ha (0.006 kg/ha), 1.4 bull trout/ha (0.6 kg/ha), 1.0 northern pikeminnow/ha (0.4 kg/ha), 1.2 peamouth/ha (0.03 kg/ha), and 1.1 redside shiner/ha (0.02 kg/ha), for a total of 163 fish/ha and 3.75 kg/ha for all species combined (Table 15).

Trends in total abundance and biomass were strongly influenced by kokanee, which were again the dominant species in the study area, comprising 96% of numbers and 65% of biomass (Table 15). Although kokanee were still much less numerous in 2013 than in 2010, abundance and biomass of kokanee fry (age 0) and older age groups increased markedly from 2012 to 2013. Target strength data from acoustics show that the abundance of kokanee fry relative to other age groups was higher in 2013 than in 2012, but still much lower than in a typical population where young fish greatly outnumber older ones, such as in 2010 (Figure 10). The 2013 age distribution of kokanee from gill netting was typical of most years of the study, with age 2 fish more abundant than age 3 (46% and 37% of total, respectively), unlike 2012 when age 3 fish made up 71% of the catch (Table 10). The mean lengths of kokanee age groups 1-3 were considerably greater in 2013 than in 2012, and were similar to most other study years (Figure 8). All these results indicate that the kokanee population has rebounded somewhat from a low in 2012, but remains well below the high point reached in 2010.

The causes underlying these population trends are unclear. Analysis of food supply limitations (bottom up control) and the influence of predation (top down control) are beyond the scope of this annual report. Parasitism by gill lice that appeared in 2011 and remained present in 2013 could have had some negative affect on kokanee. Severe infestations of this parasite can reduce growth, survival, stamina, fecundity, and tolerance of stress in salmonids (Gall et al. 1972, Kabata and Cousens 1977, Pawaputanon 1980), and researchers in Colorado are currently attempting to establish a link between gill lice infestations and collapse of wild kokanee populations (S. Harris, BCMOE, personal communication). However, infections heavy enough to cause noticeable harm are undocumented in wild populations to date and are only known from crowded environments such as hatcheries (LaCross Fish Health Center 2012). Also, the high condition factor of kokanee in Stave Reservoir in 2011 and 2013 (1.18 and 1.26) is uncharacteristic of severe Salmincola infestations (Pawaputanon 1980) and was no worse than in earlier years of this study (range 1.17-1.20). Although it is uncertain at this time whether gill lice played a part in the decline of kokanee in Stave Reservoir they remain a factor of interest that we will continue to investigate.

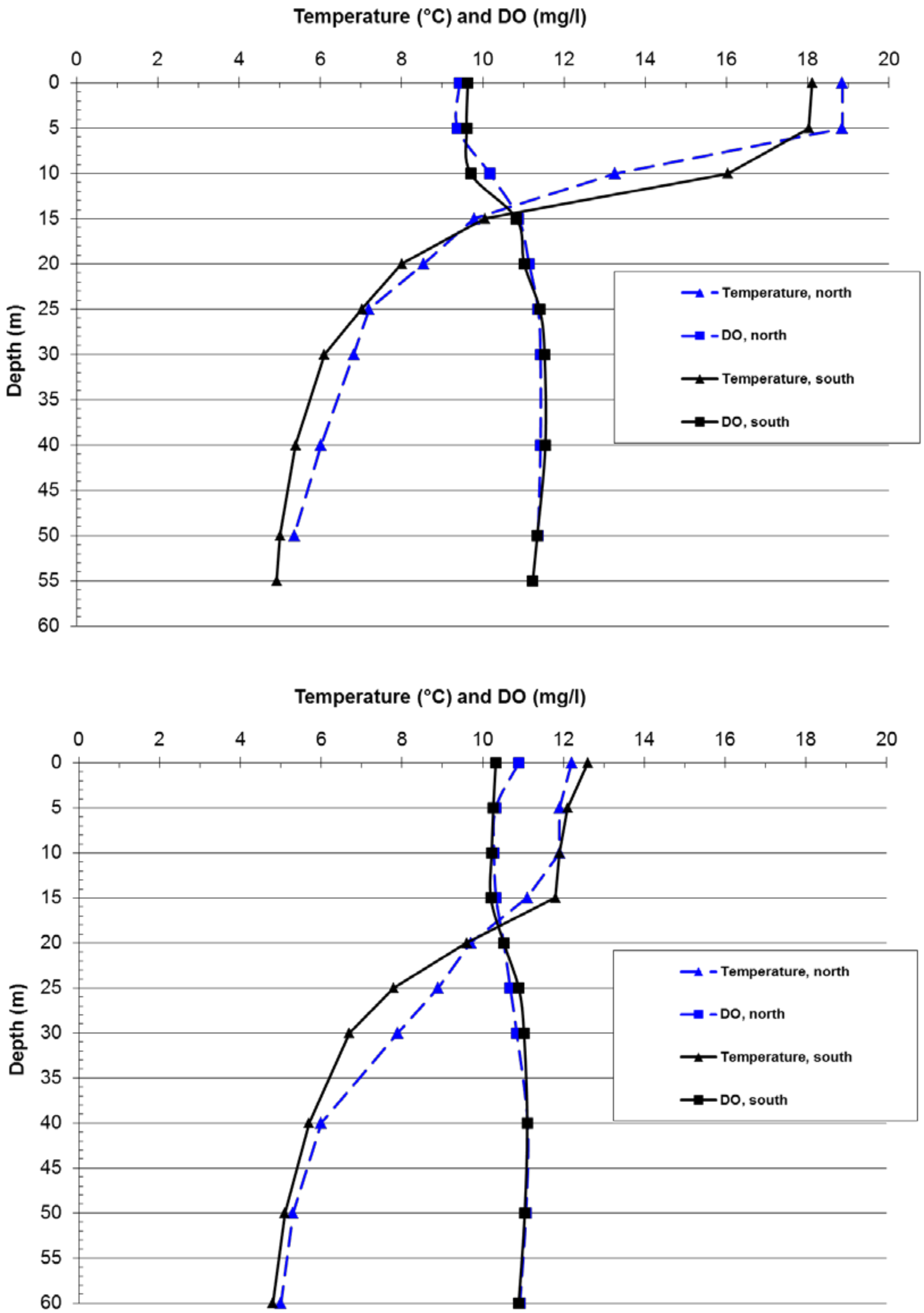


Figure 2. Temperature and dissolved oxygen (DO) profiles of Stave Reservoir on September 17 and October 3, 2013, corresponding to times of acoustic and gill net surveys, respectively. The vertical grid with 5 m spacing represents depth intervals used for the acoustic population estimate.

Table 2. Catch and CPUE (catch per panel-hour) of fish in RISC gill nets, categorized by species and station, Stave Reservoir, October 1-4, 2013. Data from surface, bottom, and midwater sets were pooled within stations. All sets were overnight.

					Species																	
	Station	No of	Set-	Panel-	C. trout		R. trout		Kokanee		B. trout		L. sucker		Pikeminnow		Peamouth		R. shiner		Total	
Set zone	location	sets	hours	hours	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
nearshore	central	4	77	463	12	0.026	1	0.002	5	0.011	1	0.002	21	0.045	17	0.037	27	0.058	48	0.104	132	0.285
"	south	4	78	471	1	0.002	0	0.000	11	0.023	4	0.008	32	0.068	10	0.021	23	0.049	12	0.025	93	0.197
"	combined	8	156	934	13	0.014	1	0.001	16	0.017	5	0.005	53	0.057	27	0.029	50	0.054	60	0.064	225	0.241
offshore	north	3	60	362	6	0.017	0	0.000	40	0.111	0	0.000	0	0.000	1	0.003	0	0.000	4	0.011	51	0.141
"	central	3	61	368	0	0.000	0	0.000	6	0.016	0	0.000	0	0.000	0	0.000	0	0.000	2	0.005	8	0.022
"	south	3	62	371	5	0.013	0	0.000	10	0.027	2	0.005	0	0.000	0	0.000	0	0.000	1	0.003	18	0.049
"	combined	9	183	1,100	11	0.010	0	0.000	56	0.051	2	0.002	0	0.000	1	0.001	0	0.000	7	0.006	77	0.070
All stations	combined	17	339	2,034	24	0.012	1	0.0005	72	0.035	7	0.003	53	0.026	28	0.014	50	0.025	67	0.033	302	0.148

Table 3. Catch and CPUE (catch·hours^{-1}·m^{-2}) of fish in small-mesh gill nets Stave Reservoir, October 1-4, 2013. Data are categorized by species, depth range, and station. All sets were overnight.

							C. trout		R. shiner		Total	
Period	Zone	Station	Layer	No. of sets	Set-hrs	Hrs·m^2	Catch	CPUE	Catch	CPUE	Catch	CPUE
overnight	offshore	north	0-5 m	1	21	1,219	1	0.0008	7	0.0057	8	0.0066
"	"	south	0-5 m	2	43	1,010	0	0.0000	0	0.0000	0	0.0000
"	"	"	20-25 m	1	20	1,179	0	0.0000	0	0.0000	0	0.0000
			Combined	4	84	3,407	1	0.0003	7	0.0021	8	0.0023

Table 4. Frequency and severity of gill lice infestations of salmonids in the gill net catch from Stave Reservoir, October 1-4, 2013. Non-salmonids were not examined for gill lice.

	Species			
Metric	C. trout	Kokanee	B. trout	R. trout
% with gill lice*	8%	67%	0%	0%
mean gill lice/fish	1.5	8	0	0
min gill lice/fish	1	3	0	0
max gill lice/fish	2	20	0	0
Sample size	2	23	7	1

* All salmonids captured were examined for gill lice.

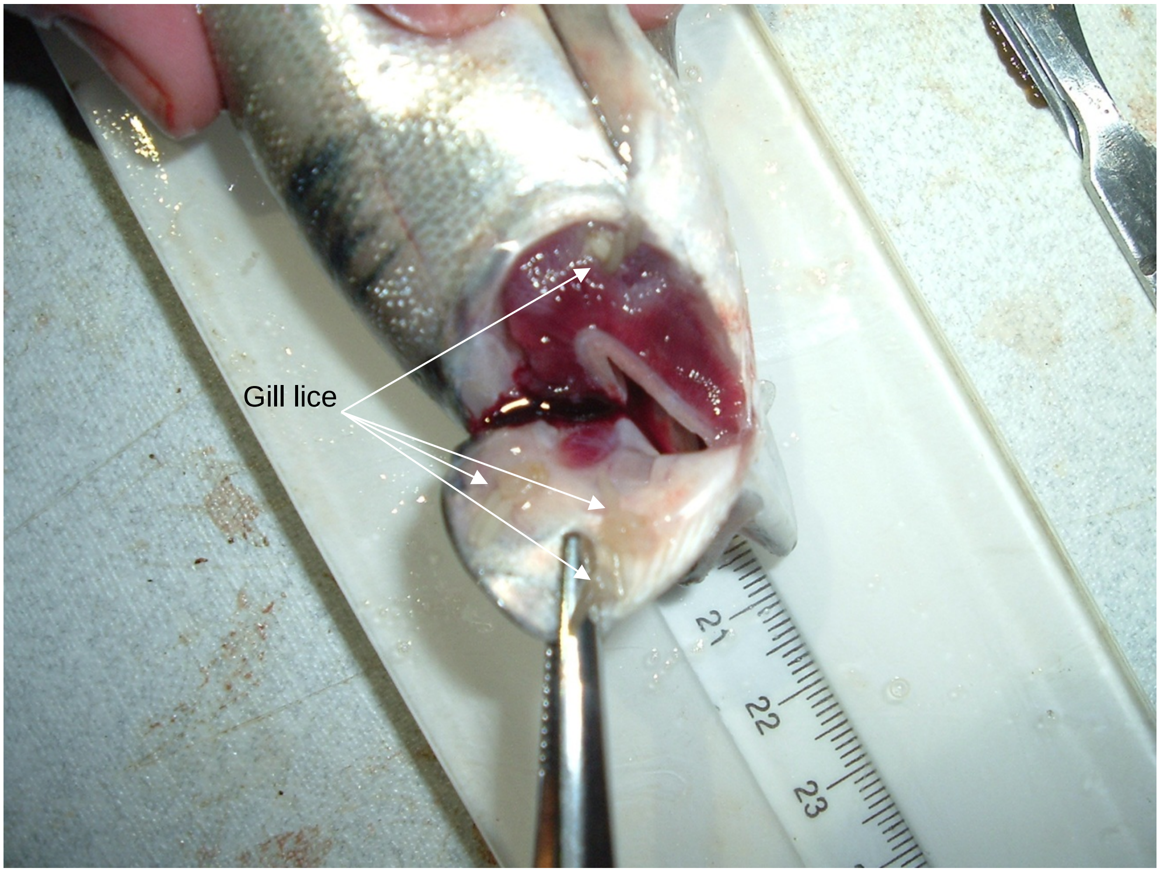


Figure 3. A kokanee from Stave Reservoir with several parasitic copepods, tentatively *Salmincola californiensis,* in its gill cavity (photo from October 2011).

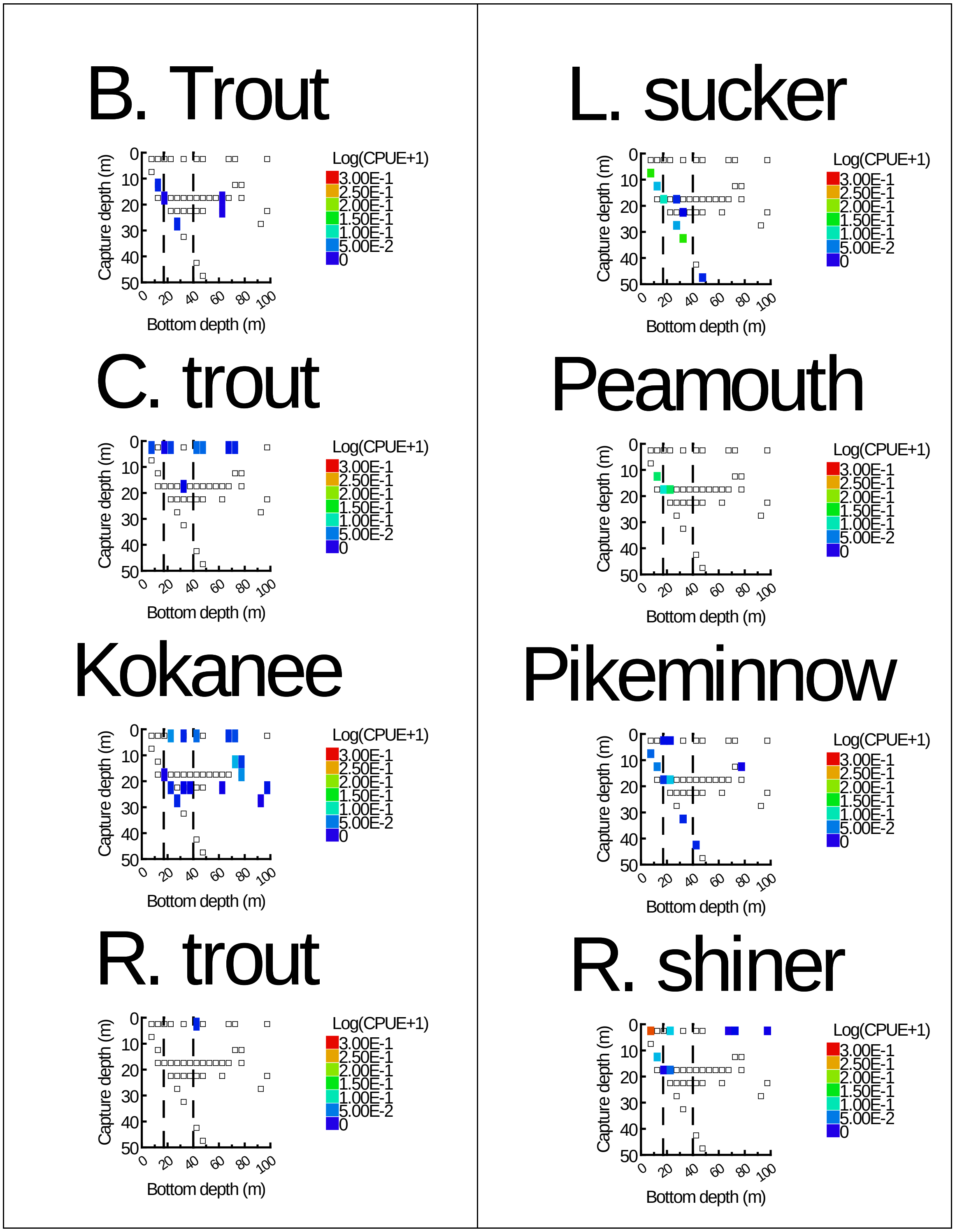


Figure 4. Horizontal and vertical distribution patterns of fish captured in RISC gill nets, Stave Reservoir October 1-4, 2013. Fish density, represented by CPUE, is categorized by depth of capture and bottom depth at location of capture for all set types and stations combined. Empty boxes indicate panels with no catch. Vertical dashed lines indicate the average shoreward limit of acoustic coverage (17 m) and the boundary between slope and pelagic zones (40 m).

Table 5. Comparison of gill net CPUE from all years of sampling in Stave Reservoir. CPUE was standardized to Fish • 100 m^{-2} • 24 $hours^{-1}$ and the general location and period of sets are noted when known.

Survey details	Fish · 100 m^{-2} · 24 $hours^{-1}$									
	C. trout	R. trout	Kokanee	B. Trout	L. sucker	Pikeminnow	Peamouth	R. shiner	B. bullhead	Total
July-1987[a]	1.74	0.15	3.63	1.16	1.16	12.50	0.00	9.58	0.00	29.92
July-1988[b]	0.15	0.10	1.49	0.36	0.00	1.08	0.00	0.05	0.00	3.23
Sept-1993[c]	0.32	1.28	1.61	0.32	11.08	60.35	0.00	2.89	0.96	78.81
Sept-2005 day, nearshore[d]	1.00	0.00	1.00	1.00	0.25	2.49	0.25	0.75	0.00	6.74
Sept-2005 overnight, nearshore[d]	1.06	0.19	2.13	1.06	6.95	11.59	2.61	10.63	0.00	36.22
Oct-2007 night, nearshore[d]	1.13	0.16	4.68	0.65	5.33	8.56	1.45	10.66	0.00	32.62
Oct-2007 night, mid-lake[d]	0.76	0.00	3.31	0.00	0.00	0.25	0.00	0.00	0.00	6.37
Sept-2009 overnight, nearshore[d]	0.79	0.00	4.41	0.21	2.05	4.98	3.10	3.88	0.00	19.41
Sept-2009 overnight, mid-lake[d]	1.16	0.00	5.05	0.07	0.00	0.55	0.00	0.55	0.00	7.37
Sept-2011 overnight, nearshore[d]	1.04	0.05	1.79	0.66	0.80	2.82	2.45	3.81	0.00	13.89
Sept-2011 overnight, mid-lake[d]	0.26	0.45	5.11	0.13	0.00	0.06	0.19	0.65	0.00	6.85
Oct-2013 overnight, nearshore[d]	0.92	0.07	1.13	0.35	3.73	1.90	3.52	4.23	0.00	15.86
Oct-2013 overnight, mid-lake[d]	0.66	0.00	3.35	0.12	0.00	0.06	0.00	0.42	0.00	4.60

[a] Source: Norris and Balkwill 1987 in Bruce et al. 1994.
[b] Source: B. Gadbois, B.C. Hydro, personnel communication in Bruce et al. 1994. Targeted open water areas.
[c] Source: Bruce et al. 1994. Targeted timber and debris choked areas.
[d] Source: This study. Sampling was in the main lake basin, away from debris choked areas. Nearshore means all sets that were not in the middle of the lake, including gangs of midwater nets that extended up to 3 net lengths out from a point of contact with the lake bottom.

Table 6. Catch, species composition, and CPUE by depth layer of the slope zone, Stave Reservoir RISC gill netting, October 1-4, 2013*. This table was used to apportion the acoustic estimate of fish >100 mm long.

Depth layer	Species							
	C. trout	**R. trout**	**Kokanee**	**B. Trout**	**Pikeminnow**	**Peamouth**	**R. shiner**	**Total**
A) Catch of fish > 100 mm in length by depth layer								
0-5 m	5	0	9	0	4	0	11	29
5-10 m								
10-15 m								
15-20 m	1	0	1	1	12	31	5	51
20-25 m	0	0	3	0	0	0	0	3
25-30 m	0	0	1	1	0	0	0	2
30-35 m	0	0	0	0	1	0	0	1
35-40 m								
Combined	6	0	14	2	17	31	16	86
B) Raw % of catch by depth layer								
0-5 m	17%	0%	31%	0%	14%	0%	38%	100%
5-10 m								
10-15 m								
15-20 m	2%	0%	2%	2%	24%	61%	10%	100%
20-25 m	0%	0%	100%	0%	0%	0%	0%	100%
25-30 m	0%	0%	50%	50%	0%	0%	0%	100%
30-35 m	0%	0%	0%	0%	100%	0%	0%	100%
35-40 m								
C) Estimated species composition by depth layer for apportioning the acoustic estimate								
0-5 m	17%	0%	31%	0%	14%	0%	38%	100%
5-10 m	9%	0%	18%	0%	18%	29%	26%	100%
10-15 m	2%	0%	7%	2%	22%	49%	17%	100%
15-20 m	2%	0%	2%	2%	24%	61%	10%	100%
20-25 m	0%	0%	100%	0%	0%	0%	0%	100%
25-30 m	0%	0%	50%	50%	0%	0%	0%	100%
30-35 m	0%	0%	0%	0%	100%	0%	0%	100%
35-40 m	0%	0%	0%	0%	100%	0%	0%	100%
D) CPUE by depth layer (catch per panel-hour)								
0-5 m	0.037	0.000	0.067	0.000	0.030	0.000	0.082	0.215
5-10 m								
10-15 m								
15-20 m	0.005	0.000	0.005	0.005	0.062	0.160	0.026	0.263
20-25 m	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.025
25-30 m	0.000	0.000	0.052	0.052	0.000	0.000	0.000	0.104
30-35 m	0.000	0.000	0.000	0.000	0.052	0.000	0.000	0.052
35-40 m								

* Suckers and sculpins, which were likely too close to the bottom for detection with acoustics, were excluded from this species composition estimate.

Table 7. Catch, species composition, and CPUE by depth layer of the pelagic zone, Stave Reservoir RISC gill netting, October 1-4, 2013*. This table was used to apportion the acoustic estimate of fish >100 mm long.

Depth layer	Species							
	C. trout	R. trout	Kokanee	B. Trout	Pikeminnow	Peamouth	R. shiner	Total
A) Catch of fish > 100 mm in length by depth layer								
0-5 m	15	1	20	0	0	0	7	43
5-10 m								
10-15 m	0	0	14	0	1	0	0	15
15-20 m	0	0	16	1	0	0	0	17
20-25 m	0	0	7	1	0	0	0	8
25-30 m	0	0	1	0	0	0	0	1
30-35 m								
35-40 m								
40-45 m	0	0	0	0	1	0	0	1
50-55 m	0	0	0	0	0	0	0	0
Combined	15	1	58	2	2	0	7	85
B) Raw % of catch by depth layer								
0-5 m	35%	2%	47%	0%	0%	0%	16%	100%
5-10 m								
10-15 m	0%	0%	93%	0%	7%	0%	0%	100%
15-20 m	0%	0%	94%	6%	0%	0%	0%	100%
20-25 m	0%	0%	88%	13%	0%	0%	0%	100%
25-30 m	0%	0%	100%	0%	0%	0%	0%	100%
30-35 m								
35-40 m								
40-45 m	0%	0%	0%	0%	100%	0%	0%	100%
50-55 m								
C) Estimated species composition by depth layer for apportioning the acoustic estimate								
0-5 m	35%	2%	47%	0%	0%	0%	16%	100%
5-10 m	19%	0%	65%	0%	4%	0%	12%	100%
10-15 m	0%	0%	93%	0%	7%	0%	0%	100%
15-20 m	0%	0%	94%	6%	0%	0%	0%	100%
20-25 m	0%	0%	88%	13%	0%	0%	0%	100%
25-30 m	0%	0%	100%	0%	0%	0%	0%	100%
30-35 m	0%	0%	100%	0%	0%	0%	0%	100%
35-40 m	0%	0%	50%	0%	50%	0%	0%	100%
40-45 m	0%	0%	100%	0%	0%	0%	0%	100%
45-50 m	0%	0%	100%	0%	0%	0%	0%	100%
50-55 m	0%	0%	100%	0%	0%	0%	0%	100%
55-60 m	0%	0%	100%	0%	0%	0%	0%	100%
60-65 m	0%	0%	100%	0%	0%	0%	0%	100%
65-70 m	0%	0%	100%	0%	0%	0%	0%	100%
70-75 m	0%	0%	100%	0%	0%	0%	0%	100%
75-80 m	0%	0%	100%	0%	0%	0%	0%	100%
D) CPUE by depth layer (catch per panel-hour)								
0-5 m	0.036	0.002	0.049	0.000	0.000	0.000	0.017	0.104
5-10 m								
10-15 m	0.000	0.000	0.116	0.000	0.008	0.000	0.000	0.124
15-20 m	0.000	0.000	0.047	0.003	0.000	0.000	0.000	0.050
20-25 m	0.000	0.000	0.019	0.003	0.000	0.000	0.000	0.022
25-30 m	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.008
30-35 m								
35-40 m								
40-45 m	0.000	0.000	0.000	0.000	0.052	0.000	0.000	0.052
45-50 m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

* Suckers and sculpins, which were likely too close to the bottom for detection with acoustics, were excluded from this species composition estimate.

Table 8. Length, weight, and condition factor of fish captured in gill nets in Stave Lake, October 1-4, 2013. Types of nets were RISC and small-mesh (SM). Fish from all depth intervals and habitat zones were pooled.

		Length (mm)					Weight (g)					
Species	**Net type**	**Mean**	**Min**	**Max**	**SD**	**n**	**Mean**	**Min**	**Max**	**SD**	**n**	**CF**
C. trout	RISC	277.2	168.0	356.0	45.9	24	229.6	51.0	417.0	100.0	24	1.01
"	SM	249.0	249.0	249.0	-	1	163.0	163.0	163.0	-	1	1.06
"	Combined	276.1	168.0	356.0	45.3	25	227.0	51.0	417.0	98.8	25	1.01
R. trout	RISC	216.0	216.0	216.0	-	1	107.0	107.0	107.0	-	1	1.06
Kokanee	RISC	190.6	104.0	260.0	39.1	72	97.8	16.0	180.0	49.2	72	1.26
B. Trout	RISC	323.1	210.0	414.0	60.7	7	463.2	269.0	801.0	177.8	6	1.11
L. sucker	RISC	296.7	115.0	420.0	64.5	53	379.9	18.0	895.0	195.6	44	1.17
Pikeminnow	RISC	270.2	125.0	455.0	124.9	26	384.3	20.0	1089.0	370.6	26	1.13
Peamouth	RISC	127.1	102.0	165.0	15.4	46	25.3	15.0	54.0	10.9	45	1.17
R. shiner	RISC	107.1	95.0	122.0	5.7	55	16.0	12.0	23.0	2.9	39	1.28
"	SM	89.7	55.0	110.0	19.9	7	9.4	2.0	15.0	5.0	7	1.17
"	Combined	105.1	55.0	122.0	9.9	62	15.0	2.0	23.0	4.0	46	1.27

Table 9. Weight versus length regression equations from the October 1-4, 2013 RISC and small-mesh gill net catch from Stave Reservoir.

Species	**Weight versus length equation**				**Sample size**	**r^2**
cutthroat trout	Log(g) =	2.890	· log(mm) +	-4.73	25	0.978
rainbow trout	Log(g) =	-	· log(mm) +	-	1	-
kokanee	Log(g) =	3.070	· log(mm) +	-5.06	72	0.989
bull trout	Log(g) =	3.278	· log(mm) +	-5.66	6	0.978
largescale sucker	Log(g) =	3.026	· log(mm) +	-5.00	44	0.995
pikeminnow	Log(g) =	3.150	· log(mm) +	-5.31	26	0.998
peamouth	Log(g) =	3.054	· log(mm) +	-5.05	45	0.954
redside shiner	Log(g) =	3.085	· log(mm) +	-5.07	43	0.929

Table 10. Age composition and mean size-at-age of salmonids in a subsample of the October 1-4, 2013 RISC and small-mesh gill net catch. Catches from all depths and habitat zones were pooled.

Metric	**Age**	**Salmonid species**			
		C. trout	**R. trout**	**Kokanee**	**B. Trout**
Number of fish aged	1	3		6	
"	2	4	1	16	
"	3	8		13	3
"	4				1
"	Combined	15	1	35	4
Percentage of species catch	1	20.0%		17.1%	
"	2	26.7%	100.0%	45.7%	
"	3	53.3%		37.1%	75.0%
"	4				25.0%
"	Combined	100.0%	100.0%	100.0%	100.0%
Mean fork length (mm)	1	208.3		124.7	
"	2	268.5	216.0	187.4	
"	3	296.4		220.2	334.0
"	4				335.0
"	Combined	271.3	216.0	188.8	334.3
Mean weight (g)	1	97.3		24.3	
"	2	205.5	107.0	86.0	
"	3	278.9		137.7	427.3
"	4				427.0
"	Combined	223.0	107.0	94.6	427.3

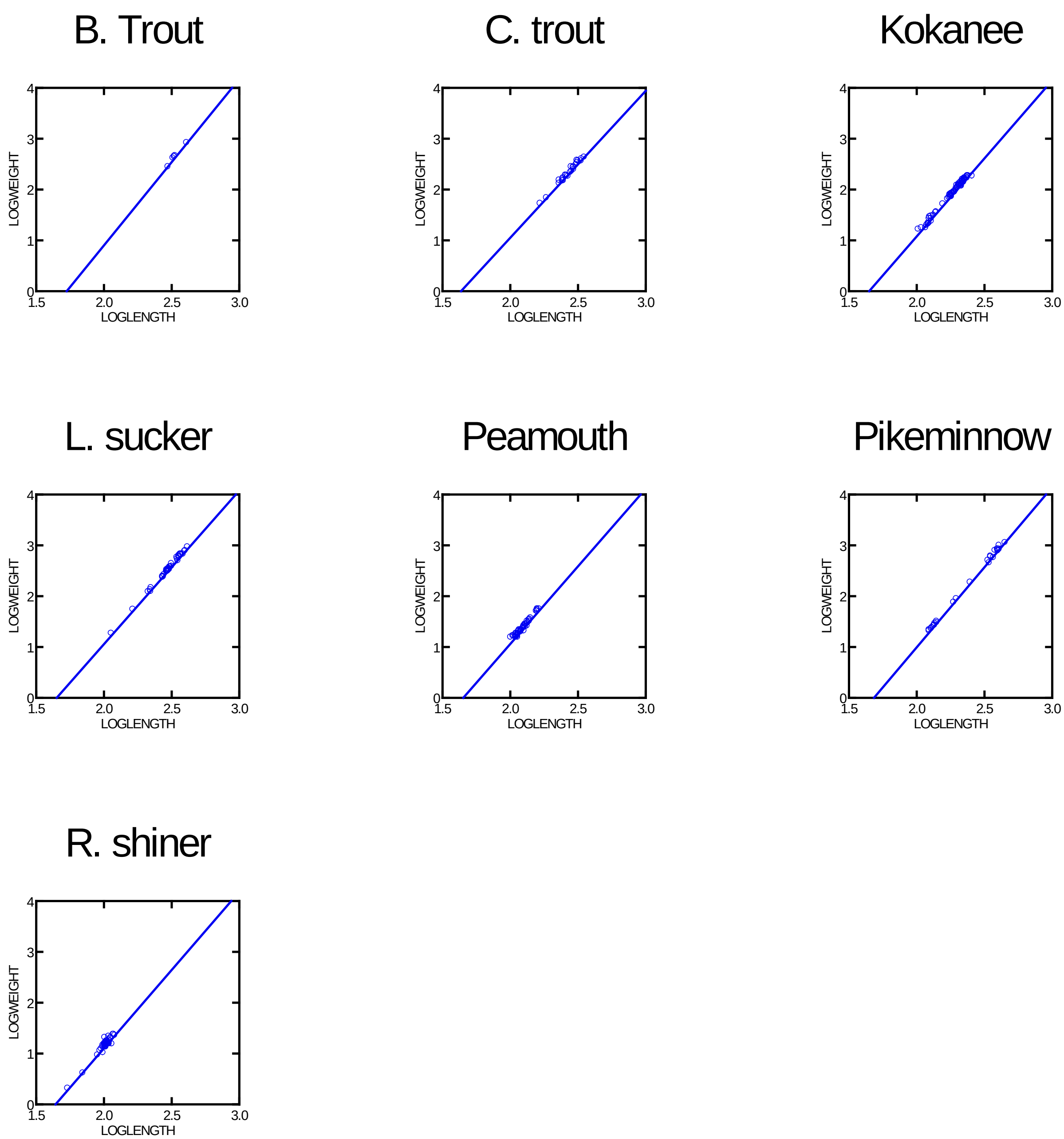


Figure 5. Log(weight) versus log(length) scatter plots for fish captured in RISC and small-mesh gill nets, Stave Reservoir, October 1-4, 2013.

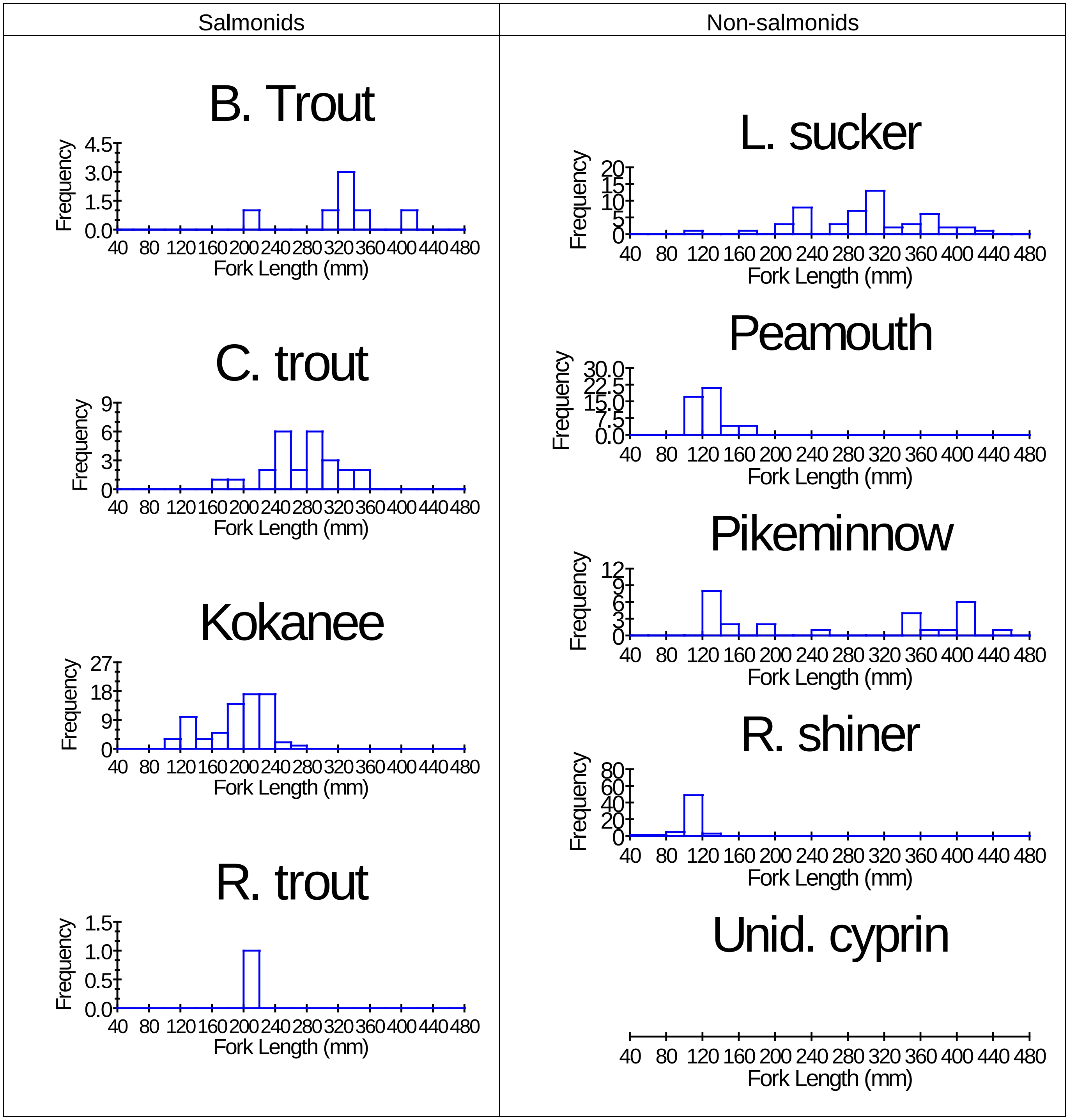


Figure 6. Length-frequency distributions of fish captured in RISC and small-mesh gill nets, Stave Reservoir, October 1-4, 2013.

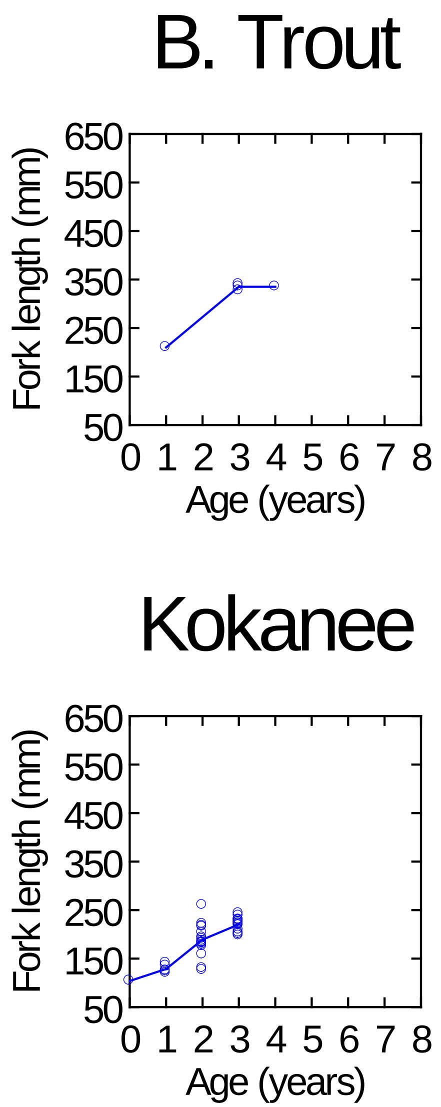


Figure 7. Length versus age of salmonids captured in RISC and small-mesh gill nets, Stave Reservoir, October 1-4. 2013. Lines connect mean lengths of age-groups.

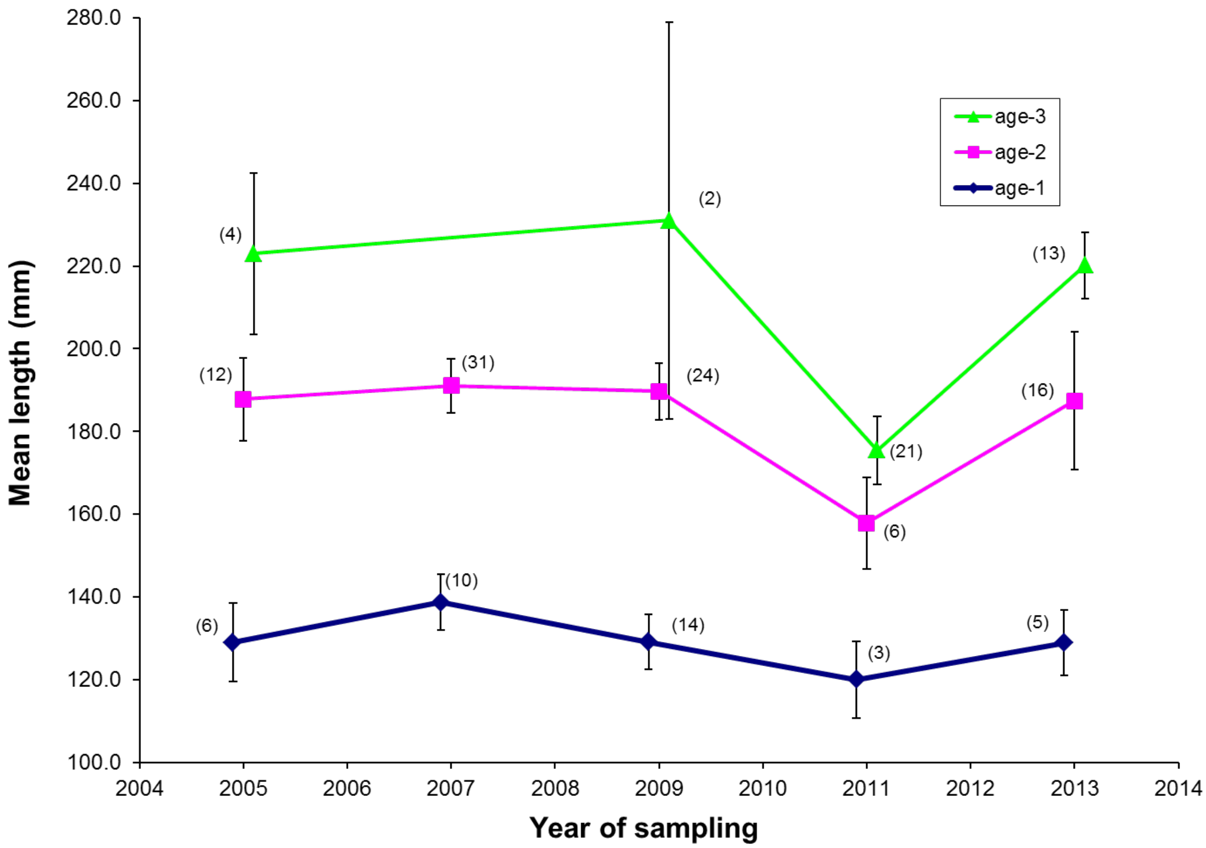
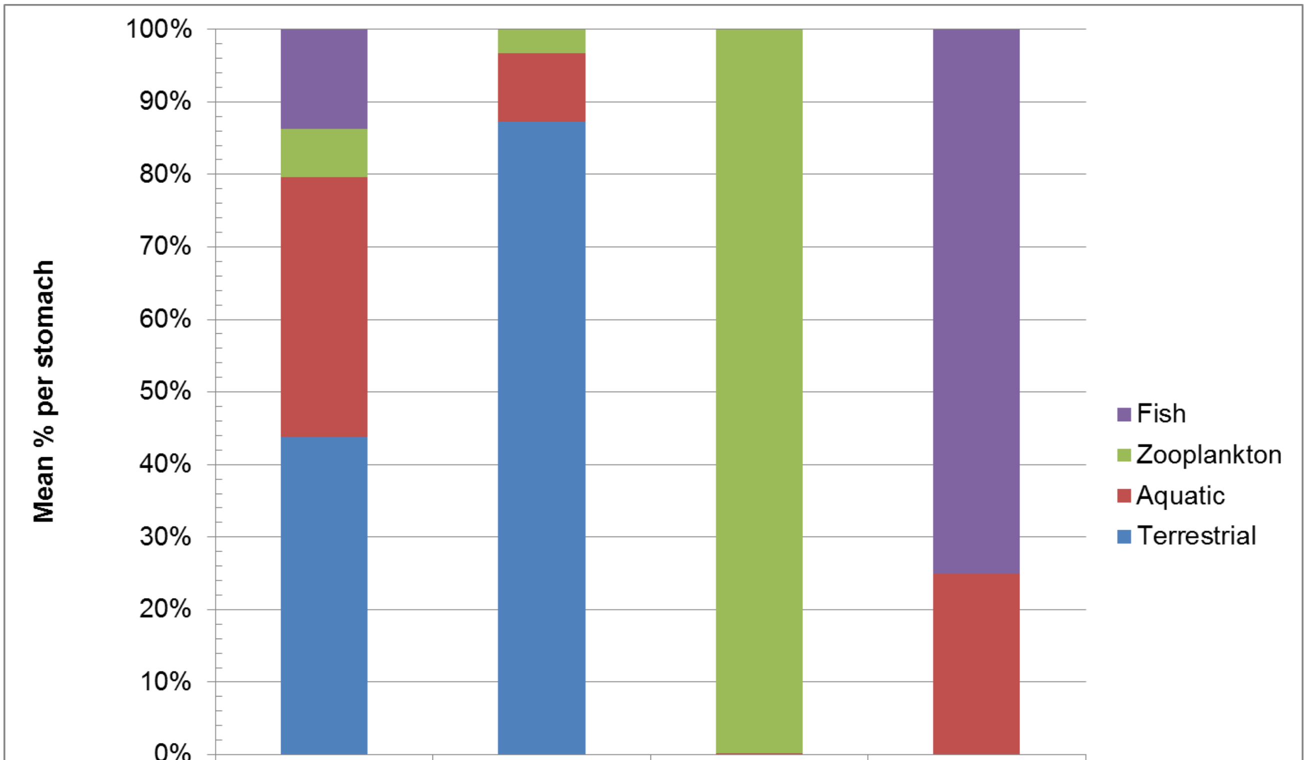


Figure 8. Mean length of kokanee age-groups in 2005-2013 fall gill net catches from Stave Reservoir. Error bars show 95% CI and sample sizes are in parentheses. Sampling was during the first half of October in all years.



	C. trout	R. trout	Kokanee	B. trout
Fish	14%	0%	0%	75%
Zooplankton	7%	3%	100%	0%
Aquatic	36%	9%	0%	25%
Terrestrial	44%	87%	0%	0%

Figure 9. Contents of salmonid stomachs expressed as mean percentage of composition by numbers. Stomachs were from fish captured in gill nets in Stave Reservoir, October 1-4, 2013.

Table 11. Counts of fish (species combined) from echograms grouped by transect and depth interval, Stave Reservoir, September 17-18, 2013 acoustic survey. Data for 0-5 m and 5-80 m layers are from side-looking and down-looking transducers, 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	4		21		31		9		4		3		72
"	5-10	4		0		0		1		0		0		5
"	10-15	6		2		2		1		1		3		15
"	15-20	1		0		2		2		2		1		8
"	20-25	0		1		1		1		0		3		6
"	25-30	1		0		1		2		1		0		5
"	30-35	0		1		0		0		0		1		2
"	35-40	0		0		0		0		0		0		0
"	0-40	16		25		37		16		8		11		113
pelagic	0-5	12		7		24		4		9		9		65
"	5-10	1		1		0		1		0		0		3
"	10-15	11		9		8		8		6		5		47
"	15-20	7		17		13		25		18		23		103
"	20-25	9		11		8		20		10		26		84
"	25-30	2		25		8		8		4		10		57
"	30-35	0		14		1		4		2		0		21
"	35-40	3		1		1		4		0		0		9
"	40-45	0		3		0		1		0		0		4
"	45-50	0		1		2		0		0		0		3
"	50-55	0		2		0		0		0		0		2
"	55-60	0		1		0		0		1		1		3
"	60-65	1		0		0		0		0		1		2
"	65-70	0		1		0		0		0		0		1
"	70-75	1		1		4		0		0				6
"	75-80	0		0		0		0		0				0
"	0-80	47		94		69		75		50		75		410
Zones combined		63		119		106		91		58		86		523

Table 12. Fish density (fish/m^3 for species combined) by transect and depth interval, Stave Reservoir, September 17-18, 2013 acoustic survey. Data for 0-5 m and 5-80 m layers are from side-looking and down-looking transducers, 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	0.00199		0.00603		0.00445		0.00093		0.00065		0.00024		6	0.002383	5.481E-06
"	5-10	0.00560		0.00000		0.00000		0.00069		0.00000		0.00000		6	0.001049	5.058E-06
"	10-15	0.00424		0.00205		0.00112		0.00036		0.00074		0.00183		6	0.001724	1.934E-06
"	15-20	0.00061		0.00000		0.00083		0.00054		0.00107		0.00045		6	0.000583	1.310E-07
"	20-25	0.00000		0.00054		0.00035		0.00024		0.00000		0.00111		6	0.000373	1.727E-07
"	25-30	0.00067		0.00000		0.00033		0.00049		0.00041		0.00000		6	0.000317	7.249E-08
"	30-35	0.00000		0.00053		0.00000		0.00000		0.00000		0.00038		6	0.000153	5.846E-08
"	35-40	0.00000		0.00000		0.00000		0.00000		0.00000		0.00000		6	0.000000	0.000E+00
"	0-40	0.00164		0.00114		0.00089		0.00041		0.00036		0.00050		48		
pelagic	0-5	0.00050		0.00087		0.00058		0.00014		0.00028		0.00027		6	0.000442	7.049E-08
"	5-10	0.00024		0.00019		0.00000		0.00012		0.00000		0.00000		6	0.000093	1.173E-08
"	10-15	0.00131		0.00087		0.00074		0.00050		0.00046		0.00039		6	0.000710	1.192E-07
"	15-20	0.00057		0.00112		0.00082		0.00106		0.00094		0.00124		6	0.000959	5.659E-08
"	20-25	0.00056		0.00055		0.00039		0.00065		0.00040		0.00107		6	0.000605	6.240E-08
"	25-30	0.00010		0.00102		0.00031		0.00021		0.00013		0.00033		6	0.000352	1.166E-07
"	30-35	0.00000		0.00049		0.00003		0.00009		0.00005		0.00000		6	0.000111	3.500E-08
"	35-40	0.00012		0.00003		0.00003		0.00008		0.00000		0.00000		6	0.000042	2.094E-09
"	40-45	0.00000		0.00009		0.00000		0.00002		0.00000		0.00000		6	0.000017	1.204E-09
"	45-50	0.00000		0.00003		0.00005		0.00000		0.00000		0.00000		6	0.000014	4.922E-10
"	50-55	0.00000		0.00005		0.00000		0.00000		0.00000		0.00000		6	0.000008	4.190E-10
"	55-60	0.00000		0.00002		0.00000		0.00000		0.00002		0.00002		6	0.000011	1.380E-10
"	60-65	0.00003		0.00000		0.00000		0.00000		0.00000		0.00003		6	0.000010	2.637E-10
"	65-70	0.00000		0.00003		0.00000		0.00000		0.00000		0.00000		6	0.000004	1.103E-10
"	70-75	0.00005		0.00003		0.00011		0.00000		0.00000				5	0.000037	1.964E-09
"	75-80	0.00000		0.00000		0.00000		0.00000		0.00000				5	0.000000	0.000E+00
"	0-80	0.00022		0.00034		0.00019		0.00018		0.00014		0.00024		94		

Table 13. Counts and adjusted percentages of fish with estimated fork lengths <100 mm and ⩾ 100 mm, Stave Reservoir, September 17-18 2013 acoustic survey. Lengths were estimated from down-looking data (TS of tracked fish) using Love's (1977) +/- 45 degree relationship. Percentages for layers with insufficient counts were adjusted using data from adjacent layers.

Zone	Depth interval (m)	Raw counts			Adjusted percentage	
		<100 mm	⩾100 mm	Total	<100 mm	⩾100 mm
slope	0-5	0	0	0	91.67%	8.33%
"	5-10	2	0	2	91.67%	8.33%
"	10-15	9	1	10	90.00%	10.00%
"	15-20	7	0	7	78.33%	21.67%
"	20-25	4	2	6	66.67%	33.33%
"	25-30	4	1	5	80.00%	20.00%
"	30-35	2	0	2	85.71%	14.29%
"	35-40	0	0	0	85.71%	14.29%
pelagic	0-5	0	0	0	86.00%	14.00%
"	5-10	3	0	3	86.00%	14.00%
"	10-15	40	7	47	85.11%	14.89%
"	15-20	87	15	102	85.29%	14.71%
"	20-25	55	28	83	66.27%	33.73%
"	25-30	35	22	57	61.40%	38.60%
"	30-35	16	5	21	76.19%	23.81%
"	35-40	8	1	9	88.89%	11.11%
"	40-45	4	0	4	80.00%	20.00%
"	45-50	3	0	3	80.00%	20.00%
"	50-55	2	0	2	80.00%	20.00%
"	55-60	2	0	2	80.00%	20.00%
"	60-65	0	2	2	80.00%	20.00%
"	65-70	0	1	1	80.00%	20.00%
"	70-75	5	1	6	80.00%	20.00%
"	75-80	0	0	0	80.00%	20.00%

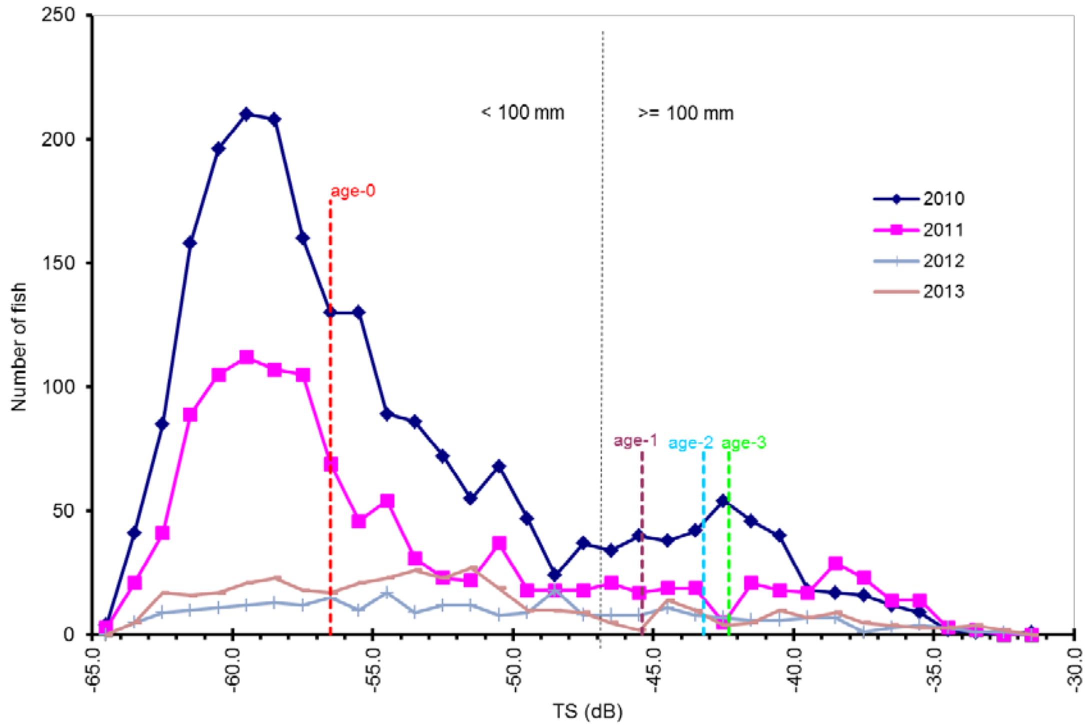


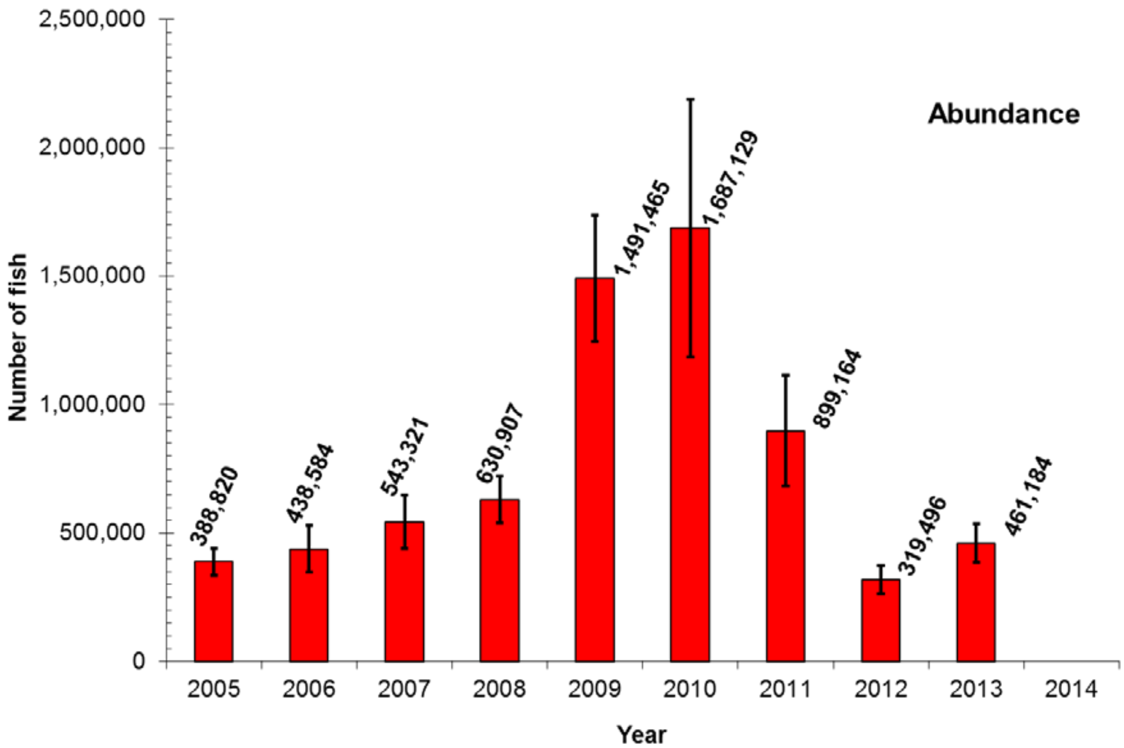
Figure 10. Frequency distributions of fish target strength (TS) from 2010-2013 fall acoustic surveys of Stave Reservoir. Data are from slope and pelagic zones combined, down-looking data only. Dashed lines indicate the approximate mean TS of kokanee age-groups estimated using Love's (1977) ±45° TS versus length model applied to mean lengths from 2011 gill net data.

Table 14. Total fish abundance (species combined) by habitat zone, Stave Reservoir, September 17-18, 2013 acoustic survey.

Zone	Depth range (m)	Mean no. per m^3	Variance	Sample size *	Stratum Volume (cubic m)	Abundance estimate	SE of estimate	95% CL lower	95% CL upper
slope	0-5	0.00238	5.5E-06	6	1.6E+07	39,039	15,658	-1,211	79,289
"	5-10	0.00105	5.1E-06	6	1.6E+07	17,187	15,041	-21,477	55,851
"	10-15	0.00172	1.9E-06	6	1.6E+07	28,246	9,301	4,336	52,156
"	15-20	0.00058	1.3E-07	6	1.6E+07	9,180	2,325	3,204	15,155
"	20-25	0.00037	1.7E-07	6	1.3E+07	4,663	2,123	-794	10,121
"	25-30	0.00032	7.2E-08	6	9.0E+06	2,858	992	309	5,408
"	30-35	0.00015	5.8E-08	6	5.3E+06	808	521	-532	2,148
"	35-40	0.00000	0.0E+00	6	1.7E+06	0	0	0	0
"	0-40			48	9.3E+07	101,981	23,856	53,804	150,158
pelagic	0-5	0.00044	7.0E-08	6	1.1E+08	46,792	11,480	17,281	76,304
"	5-10	0.00009	1.2E-08	6	1.1E+08	9,859	4,684	-2,182	21,899
"	10-15	0.00071	1.2E-07	6	1.1E+08	75,232	14,926	36,863	113,601
"	15-20	0.00096	5.7E-08	6	1.1E+08	101,617	10,286	75,175	128,059
"	20-25	0.00060	6.2E-08	6	1.1E+08	64,049	10,802	36,282	91,815
"	25-30	0.00035	1.2E-07	6	1.1E+08	37,309	14,762	-638	75,257
"	30-35	0.00011	3.5E-08	6	1.1E+08	11,705	8,090	-9,090	32,501
"	35-40	0.00004	2.1E-09	6	1.1E+08	4,466	1,979	-620	9,553
"	40-45	0.00002	1.2E-09	6	1.0E+08	1,807	1,472	-1,976	5,590
"	45-50	0.00001	4.9E-10	6	9.9E+07	1,341	896	-963	3,645
"	50-55	0.00001	4.2E-10	6	9.4E+07	786	786	-1,234	2,805
"	55-60	0.00001	1.4E-10	6	8.7E+07	926	418	-149	2,001
"	60-65	0.00001	2.6E-10	6	7.8E+07	823	520	-515	2,160
"	65-70	0.00000	1.1E-10	6	7.1E+07	304	304	-478	1,087
"	70-75	0.00004	2.0E-09	5	5.8E+07	2,186	1,156	-1,024	5,397
"	75-80	0.00000	0.0E+00	5	4.4E+07	0	0	0	0
"	0-80			94	1.5E+09	359,203	29,862	299,763	418,642
Combined						461,184	38,221	385,509	536,859

Table 15. Abundance and biomass of individual fish species within the Stave Reservoir study area during fall 2013; from September 17-18, 2013 acoustic survey results apportioned using October 1-4, 2013 gill net data.

			Species							
Size group	**Estimate**	**Age**	**C. trout**	**R. Trout**	**Kokanee**	**Bull trout**	**Pikeminnow**	**Peamouth**	**R. shiner**	**Total**
< 100 mm	abundance	0	0	0	374,439	0	0	0	0	374,439
"	biomass (kg)	0	0	0	250	0	0	0	0	250
≥ 100 mm	percentage	1	20.0%	-	17.1%	-	-	-	-	
"	"	2	26.7%	100.0%	45.7%	-	-	-	-	
"	"	3	53.3%	-	37.1%	75.0%	-	-	-	
"	"	4	-	-	-	25.0%	-	-	-	
"	"	total	100.0%	100.0%	100.0%	100.0%	-	-	-	
"	abundance	1	669	-	11,965	-	-	-	-	12,634
"	"	2	892	152	31,907	-	-	-	-	32,951
"	"	3	1,784	-	25,924	2,980	-	-	-	30,689
"	"	4	-	-	-	993	-	-	-	993
"	"	total	3,346	152	69,796	3,974	2,953	3,516	3,008	86,745
"	biomass (kg)	1	65	-	311	-	-	-	-	376
"	"	2	183	16	2,744	-	-	-	-	2,944
"	"	3	498	-	3,570	1,273	-	-	-	5,340
"	"	4	-	-	-	424	-	-	-	424
"	"	total	746	16	6,625	1,697	1,134	88	48	10,354
Combined	abundance	total	3,346	152	444,235	3,974	2,953	3,516	3,008	461,184
"	biomass (kg)	"	746	16	6,875	1,697	1,134	88	48	10,604
"	number/ha	"	1.2	0.1	156.9	1.4	1.0	1.2	1.1	162.9
"	kg/ha	"	0.264	0.006	2.43	0.599	0.401	0.031	0.017	3.75
	% of total no.		0.73%	0.033%	96.3%	0.86%	0.64%	0.76%	0.65%	100.0%
	% of total kg		7.0%	0.15%	64.8%	16.0%	10.7%	0.83%	0.45%	100.0%



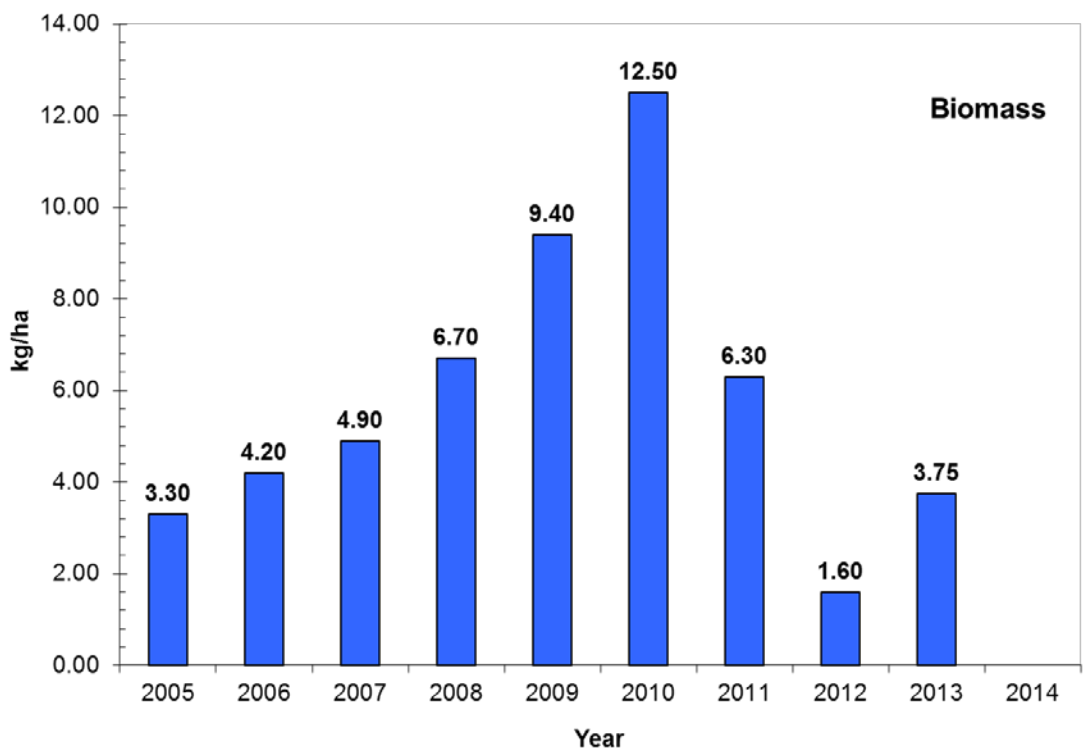


Figure 11. Total fish abundance and biomass (all species combined) in the Stave Reservoir study area, from 2005-2013 fall acoustic surveys. Error bars on abundance estimates are 95% confidence intervals.

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5.0 DATA APPENDICES

Raw data appendices are available from BC Hydro.