Stave River Project Water Use Plan

Fish Biomass Assessment

Implementation Year 7

Reference: SFLMON#3

Report on the 2011 Fish Biomass Assessment

Study Period: 2011

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February 2012

ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR
IN FALL 2011

Final Report

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SHUKSAN

LIMNOTEK

ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR IN FALL 2011

Final Report

Submitted to

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Cover photo: A kokanee from Stave Reservoir, October 2011. Photo by Brock Stables.

EXECUTIVE SUMMARY

An acoustic survey and gill netting were conducted between September 28 and October 6, 2011 to determine the abundance, biomass, and spatial distribution of fish in Stave Reservoir. Acoustic sampling was performed during the night of September 28-29 and gill netting was conducted October 3-6. The reservoir was thermally stratified at the time of the survey. The 2011 survey represents year 7 of a 10 year study conducted under the Stave River Water Use Plan.

Gill net data were used to apportion the 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 acoustic survey and 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, however, rough conditions during the survey required deviation from the usual transect lines that have been used in the past. Rough conditions also rendered side-looking acoustic data unusable, which required estimation of fish density in the 0-5 m depth range from density in deeper layers.

A total of 396 fish of nine species were captured in 20 gill net sets (402.6 set-hours) at nearshore and mid-lake sampling stations. The species captured were cutthroat trout, rainbow trout, bull trout, kokanee, largescale sucker, sculpin *sp.*, peamouth, northern pikeminnow, and redside shiner. Analysis of DNA confirmed that all 16 char tested were bull trout. Many kokanee had parasitic copepods or “gill lice”, probably *Salmincola californiensis*, attached near the base of fins and in the gill cavity.

The 2011 gill net catch rates (CPUE) for individual species were all within the range of values seen in previous years, however, in nearshore sets, kokanee CPUE was the lowest since the beginning of this study (2005), and total CPUE (all species combined) was the lowest on record in Stave reservoir for overnight sampling.

The 2011 abundance and biomass estimates for all species combined were 899,164 ± 214,517 fish (±24%) and 17,950 kg. These estimates represent a 47% decrease in abundance and a 50% decrease in biomass since 2010. The 2011 areal density and biomass estimates for individual fish species (ages combined) were 309 kokanee/ha (3.4 kg/ha), 1.8 cutthroat trout/ha (0.81 kg/ha), 1.7 rainbow trout/ha (0.40 kg/ha), 1.5 bull trout/ha (1.3 kg/ha), 1.5 northern pikeminnow/ha (0.40 kg/ha), 0.67 peamouth/ha (0.015 kg/ha), and 1.4 redside shiner/ha (0.023 kg/ha), for a total of 318 fish/ha and 6.4 kg/ha for all species combined.

Kokanee abundance and biomass were down 47% and 38%, respectively, from 2010 to 2011, and the proportion of kokanee caught in gill nets that were age 1 and 2 decreased from 95% to 29% in the same period. Although the overall mean length of

kokanee was about the same in 2010 and 2011, mean lengths of 1, 2, and 3 year old kokanee were smaller than ever before in 2011.

The causes underlying this sudden population decline are unclear at this time. Parasitism of kokanee by gill lice was probably not a major contributing factor and uncertainties in the population estimate caused by rough weather during the acoustic survey are not sufficient to explain such a large decline.

ACKNOWLEDGEMENTS

This project was performed under contract to BC Hydro as part of the Stave River Water Use Plan Studies. We are grateful to Ian Dodd and Dave Hunter (BC Hydro Natural Resource Specialists) and James Bruce (BC Hydro Research Biologist) who have assisted with logistics, coordinated this work with related studies of the Stave Water Use Plan, and provided constructive review of reports. We 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 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 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 2011 study, year 7 of this program. Results of earlier surveys in this series appear in Stables and Perrin (2006-2011). Specific objectives in 2011 were to:

1. Conduct coordinated acoustic and gill net sampling of the reservoir in late September and early October;
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. Use a sampling and analysis design stratified by nearshore and pelagic habitat zones;
4. Collect tissue samples from native char for DNA analysis to determine their species (Dolly Varden or bull trout);
5. Collect tissue samples from kokanee for DNA analysis to determine their degree of relation to kokanee in Alouette Reservoir; and
6. 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 October 18, 2011 using a calibrated YSI model 6920 Sonde.

2.2 Gill netting

2.2.1 Sampling

Gill netting took place on three nights from 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. Nearshore sets sampled the 0-50 m depth range, while mid-lake sets sampled the 0-30 m depth range.

All nets were standard 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). All nets were set in late afternoon and pulled the next morning, and in this report a "set" is defined as one 6-panel net fished overnight.

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. When necessary, fish were anaesthetized with clove oil prior to handling. Structures for aging were taken from salmonids only. Scales were removed from preferred body areas of all trout and kokanee and stored 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 for DNA analysis were taken from all char and from over 50 kokanee. A paper punch was used to obtain a sample from the operculum of each char, and a fin clip was taken from each kokanee. DNA samples were individually stored in glass vials filled with ethanol (not denatured) prior to analysis.

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

2.2.2 Processing and Analysis

In the lab, scales and otoliths were read by a qualified expert. Otoliths from all char were read, however, only a subsample of trout and kokanee were aged because more of them were captured than were budgeted for scale reading (60 fish budgeted). Fish to be aged were chosen randomly 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. Age-length keys constructed from the resulting data (Isely and Grabowski 2007) were then used to compute the age composition of trout and kokanee.

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).

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 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 each habitat zone (slope and pelagic) for comparison to catch rates in previous years.

Other biological statistics computed from fish samples included mean and standard deviation of length and weight, length-frequency and age distributions, weight-length regressions, and condition factor (weight in grams/length in cm^3, Ricker 1975).

Char tissue samples were sent to Dr. Eric Taylor of UBC for DNA analysis. Tissue samples from kokanee were sent to Dr. Lyse Godbout of DFO for processing (their results are outside the scope of this report).

2.3 Acoustics

2.3.1 Sampling

A mobile acoustic survey (scientific echo sounding) was performed during the night of September 28-29, 2011 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 was planned for six transects perpendicular to the lake shore within the debris-free portion of the main lake basin (the usual transect layout), however, rough conditions caused by a steady north wind required the southern four transects to be run diagonally down-lake to reduce rolling of the boat, resulting in a zigzag survey pattern in the southern two thirds of the survey area (Figure 1).

Acoustic sampling was performed from a 6 m long, covered aluminum skiff at a transecting speed of about 1.5-2.2 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 0.5 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 (side-looking mode). Both down-looking and side-looking scans were made on each transect.

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 182 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.

For down-looking data, we evaluated the effect of transducer instability from boat pitch and roll on counts of fish traces by visual comparison of fish traces in transect segments with and without appreciable transducer movement. The shape of the bottom signal on echograms was used to identify the two stability categories. Echogram segments with a smooth bottom line indicated no appreciable transducer movement. A regularly undulating bottom line indicated appreciable transducer movement. The rates at which traces were counted as fish with and without appreciable transducer movement were compared on an ordinal scale (less, same, more) during the visual inspection. The degree to which traces were fragmented by transducer instability and how this affected fish counts was examined at the same time. The proportion of each transect in each stability category was also evaluated.

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 -39.4 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:

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

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 seldom less than 4.9°, and was seldom less than 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 computed using a surface area of 2,831 ha, the surface area at elevation 76 m, to facilitate inter-annual comparisons. The reservoir surface elevation was 78.6 m during the acoustic survey on September 28-29, 2011.

Down-looking data were used to compute fish density at depths greater than 5 m, while side-looking data were intended to represent the uppermost 5 m of the water column. However, rough conditions during the survey rendered the side-looking data unusable, so abundance of fish in the 0-5 m range of the water column was estimated based on fish abundance in the deeper layers. In previous years the abundance of fish in the 0-5 m depth range was 11% to 42% of abundance in the 5-80 m depth range, with a median of 17.5%. This median value was applied to the 2011 estimate of abundance in the 5-80 m layer to derive the "best" estimate of fish abundance in the 0-5 m layer. The extremes (11% and 42%) were used in the same way to estimate the credible range of abundance estimates by this method. Variance of the "best" estimate was approximated from the relationship between fish density in the 0-5 m range and its own variance in previous years of this survey (2005-2010). The resulting equation from linear regression was:

$$\log[\text{variance(fish density)}] = 2.0897 \times \log[\text{fish density}], \quad (n=12, R^2=0.94)$$

The 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 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 <100 mm in length were detectable with acoustics but were too small to be captured in gill nets. The biomass of this smaller size group (those with a length estimated from TS to be less than 100 mm) 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). 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

We assumed that water temperatures during the fish survey (September 25 through October 6) were similar to those of September 17 when the reservoir was strongly stratified with temperatures ≥14° to a depth of 10 m (Figure 2). By October 18, 12 days after gill netting and 20 days after the acoustic survey, thermal stratification had weakened greatly, but the upper 10 m of the water column remained warm (10-11°C) relative to deeper water (Figure 2). On October 18, dissolved oxygen (DO) levels were ample for fish throughout the water column (Figure 2). DO was not sampled earlier in the season, but was no doubt sufficient then too based on recent historical trends (Stables and Perrin 2006-2011).

A total of 396 fish of nine species were captured in 20 gill net sets (402.6 set-hours) at nearshore and mid-lake sampling stations (Table 2). The species captured were cutthroat trout, rainbow trout, bull trout, kokanee, largescale sucker, sculpin *sp.*, peamouth, northern pikeminnow, and redside shiner. Analysis of DNA confirmed that all 16 char tested were bull trout. Many kokanee had parasitic copepods or “gill lice”, probably *Salmincola californiensis*, attached near the base of fins and in the gill cavity (Figure 3).

Figure 4 shows catch rates (CPUE) for individual species in relation to depth of capture and bottom depth. The 2011 catch rates for individual species were all within the range of values seen in previous years (Table 3). However, in nearshore sets kokanee CPUE was the lowest since the beginning of this study (2005), and total CPUE (species combined) was the lowest on record in Stave reservoir for overnight sampling (Table 3). Compared to the most recent gill net sample (2009), the 2011 catch rates were generally higher for rainbow trout and bull trout, lower for northern pikeminnow and largescale sucker, and inconsistent among set zones (mid-lake and nearshore) for other species (Table 3).

Other information from gill netting used to describe the fish community and to calculate the 2011 abundance and biomass estimates is compiled in Tables 4-13 and Figures 5-8.

Tables 4 and 5 contain species composition data by depth layer; Tables 6 and 7 describe mean length, weight, and condition factor by species; Table 8 shows age and size composition of salmonids. Figure 5 shows weight-length regressions for all species; Figure 6 contains length-frequency distributions for all species, showing mean length at age for salmonids; Figure 7 plots length versus age for salmonids; Figure 8 shows length versus age for kokanee in all years of sampling. Figure 9 shows percent (by numbers) of food items in the stomachs of salmonids.

Acoustic data used to calculate the 2011 abundance and biomass estimates appear in Tables 9-11. Acoustic counts of fish and fish density by transect and depth layer appear in Tables 9 and 10. Proportions of fish larger and smaller than 100 mm in length are shown in Table 11. Figure 10 compares the frequency distributions of target strengths (TS, the acoustic size of fish) in 2010 and 2011.

The “best” estimates of abundance and biomass for all species combined in 2011 were 899,164 ± 214,517 fish (±24%) and 17,950 kg (Tables 12 and 13). Considering the uncertainty about fish abundance in the 0-5 m depth range, the credible range for abundance estimates for 2011 was 859,364 to 1,322,532 fish (see Methods for explanation of credible range). The “best” estimates represent a 47% decrease in abundance and a 50% decrease in biomass since 2010. The 2011 data are the first since the study began in 2005 to show a decline in these population metrics (Figure 11). The 2011 areal density and biomass estimates for individual fish species (ages combined) were 309 kokanee/ha (3.4 kg/ha), 1.8 cutthroat trout/ha (0.81 kg/ha), 1.7 rainbow trout/ha (0.40 kg/ha), 1.5 bull trout/ha (1.3 kg/ha), 1.5 northern pikeminnow/ha (0.40 kg/ha), 0.67 peamouth/ha (0.015 kg/ha), and 1.4 redside shiner/ha (0.023 kg/ha), for a total of 318 fish/ha and 6.3 kg/ha for all species combined (Table 13). Cohort specific abundance and biomass estimates for salmonids appear in Table 13.

The observed declines in fish abundance and biomass were strongly influenced by population trends for kokanee, the dominant species in the study area (97% of numbers and 54% of biomass in 2011). Kokanee abundance and biomass were down 47% and 38%, respectively, from 2010 to 2011, and the proportion of kokanee caught in gill nets that were age 1 and 2 decreased from 95% to 29% in the same period. Target strength (TS) data from acoustic sampling also suggests a decline in kokanee abundance. Whereas the 2010 TS frequency distribution had a peak in the expected TS range for age 1-3 kokanee, the 2011 distribution showed a flat spot in the same TS range (Figure 10), indicating reduced abundance of fish of that size. In addition, the gill net data suggest that kokanee growth rates were lower in 2011. Although the overall mean length of kokanee was about the same in 2010 and 2011, mean lengths of 1, 2, and 3 year old kokanee were smaller than ever before in 2011 (Figure 8). An unusually high proportion of sexually mature kokanee in 2011 (80% of those examined internally) made scale reading difficult, which raises the possibility that some older kokanee were aged incorrectly. If all the fish in question were age 2 rather than 3, their mean length would be 177 mm, which is 15 mm smaller than age 2 kokanee in any other year. Age 1 scales were unambiguous, so the low catch of this age group in 2011 is not in doubt. An alternative explanation (besides low abundance) is that most age 1 kokanee were too small to be captured in gill nets, which would also indicate slower growth in 2011 than in the past.

The causes underlying this sudden population decline are unclear. Analysis of food supply limitations (bottom up control) and the influence of predation (top down control) are beyond the scope of this report. Parasitism by gill lice that appeared in 2011 and not in earlier years may 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). However, infections heavy enough to cause noticeable harm are rare in wild populations and are only typical of crowded environments such as hatcheries (LaCross Fish Health Center 2012). Also, the high condition factor of kokanee in 2011 (1.18) is uncharacteristic of severe Salmincola infestations (Pawaputanon 1980) and was no different from other years of this study (range 1.17-1.20). These observations indicate that parasitism by gill lice was probably not a major factor in the decline of kokanee.

Rough conditions during acoustic sampling can cause error in abundance and fish size estimates due to boat rolling and consequent swinging of the transducer, usually causing a negative bias (Furusawa and Sawada 1991, Simmonds and MacLennan 2005, Parker-Stetter et al. 2009). Detailed inspection of the 2011 acoustic survey results indicated that down-looking data remained reliable. Altering the transect lines to quarter down-wind minimized and slowed boat rolling, which maintained data quality and gave adequate coverage of the whole study area. Although down-looking echograms indicated some swinging movement of the transducer during much of the survey (through an undulating bottom line), spot checks of echograms showed that fish trace counting performance was similar whether or not the transducer was steady. The fact that most fish were in the upper 30 m of the water column aided fish tracking when the boat was rolling because of the short time between sound transmission from the transducer and return of fish echoes (Furusawa and Sawada 1991). Furusawa and Sawada's (1991) findings also suggest that when the boat was rolling, mean target strength estimates for fish traces and for the population as a whole should have remained reasonably accurate, although TS of individual echoes within traces would have fluctuated more than if the transducer had been stable. The loss of side-looking data for the 0-5 m depth range was a more serious problem that greatly increased the uncertainty of the abundance and biomass estimates. Even so, the largest credible abundance estimate for 2011 (1,322,532 fish) would still constitute a 22% decline from the previous high of 1,687,129 fish in 2010. The conclusion is that despite some uncertainty as to its magnitude, the decline in fish abundance and biomass in 2011 compared to earlier years is real and not an artifact of unique sampling conditions.

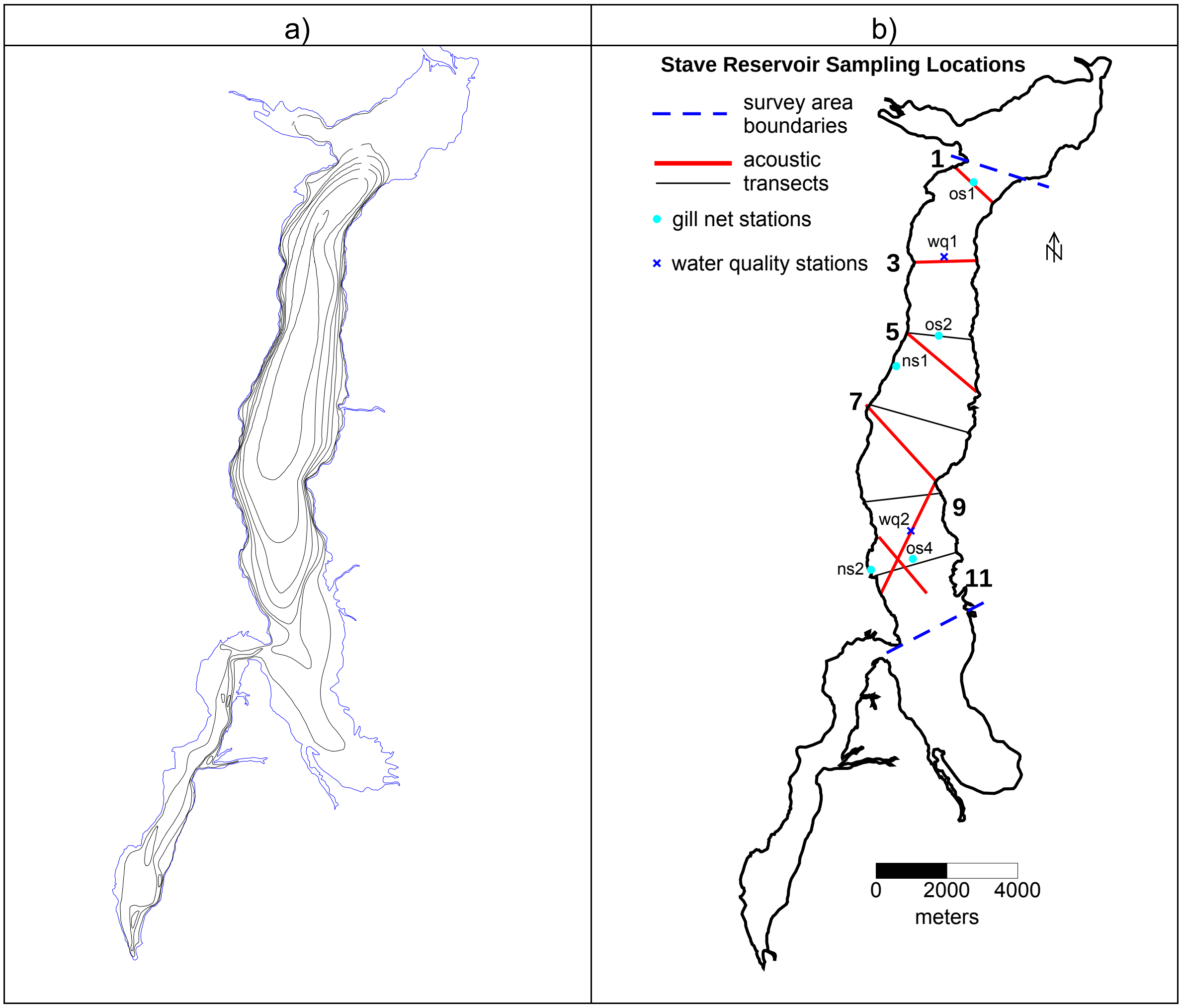


Figure 1. Maps of Stave Reservoir: a) bathymetric map showing the reservoir outline at full pool (82.1 m above sea level) with 10 m depth contours; b) 2011 sampling locations for water quality, gill netting, and acoustics. Acoustic transects that were actually sampled are shown in red; planned transects that were not sampled due to rough conditions are show in black.

Table 1. Equipment specifications and settings for collection and processing of acoustic data, Stave Reservoir, September 28-29, 2011 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)	0.75 D, 0.45 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)	1.5-2.2 D&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.

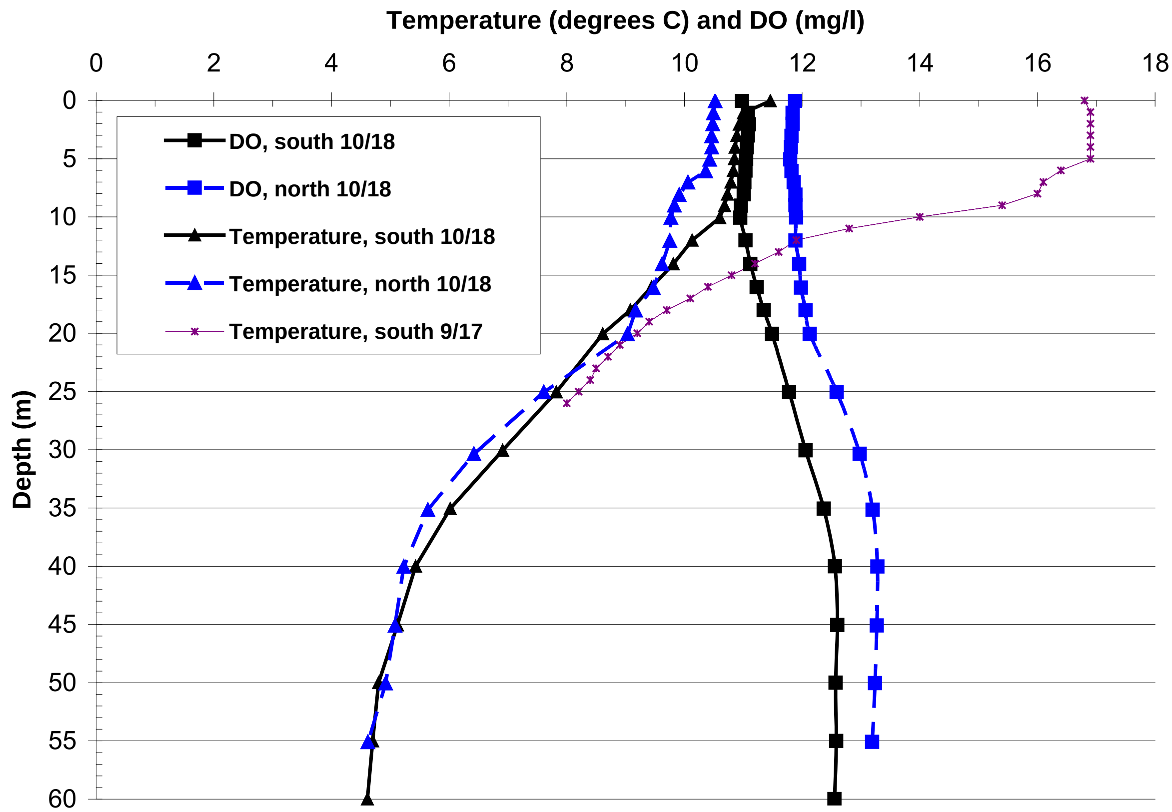


Figure 2. Temperature and dissolved oxygen (DO) profiles from Stave Reservoir on September 17 and October 18, 2011. The vertical grid with 5 m spacing represents depth intervals used for the acoustic population estimate. September 17 data courtesy of J. Beer, Ness Environmental Sciences.

Table 2. Catch (C) and CPUE (catch per panel-hour) by species at individual gill net stations, Stave Lake, October 3-6, 2011*. Data from surface, bottom, and mid-water sets were pooled within stations. All sets were overnight.

					Species																	
					C. trout		Bull trout		Kokanee		L. sucker		P. sculpin		Peamouth		Pikeminnow		R. shiner		R. trout	
Set zone	Station location	No of sets	Set-hours	Panel-hours	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
nearshore	central	5	103.5	621.2	9	0.014	12	0.019	30	0.048	8	0.013	3	0.005	29	0.047	25	0.040	33	0.053	0	0.000
"	south	6	129.4	776.5	13	0.017	2	0.003	8	0.010	9	0.012	2	0.003	23	0.030	35	0.045	48	0.062	1	0.001
"	combined	11	233.0	1397.7	22	0.016	14	0.010	38	0.027	17	0.012	5	0.004	52	0.037	60	0.043	81	0.058	1	0.001
offshore	north	3	55.3	332.1	0	0.000	1	0.003	60	0.181	0	0	0	0	1	0.003	1	0.003	9	0.027	2	0.006
"	central	3	56.7	340.1	3	0.009	1	0.003	14	0.041	0	0	0	0	1	0.003	0	0.000	0	0.000	1	0.003
"	south	3	57.6	345.4	1	0.003	0	0.000	5	0.014	0	0	0	0	1	0.003	0	0.000	1	0.003	4	0.012
"	combined	9	169.6	1017.6	4	0.004	2	0.002	79	0.078	0	0	0	0	3	0.003	1	0.001	10	0.010	7	0.007
All stations	combined	20	402.6	2415.3	26	0.011	16	0.007	117	0.048	17	0.007	5	0.002	55	0.023	61	0.025	91	0.038	8	0.003

* An additional set at the central nearshore station (ns1) was not included in this analysis because the net was badly tangled so effort could not be estimated. It captured 7 cutthroat trout, 1 kokanee, 2 northern pikeminnow, and 2 redside shiners that were used in length and weight analysis..

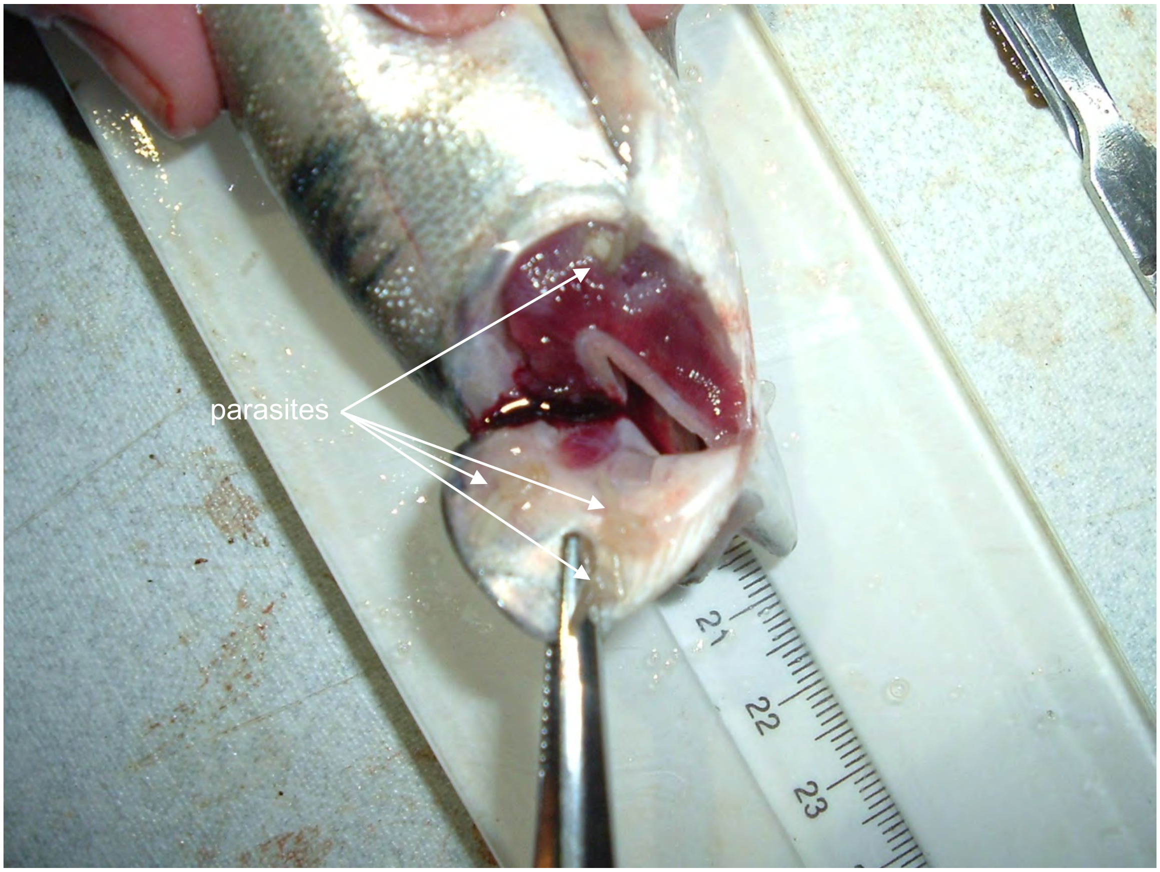


Figure 3. A kokanee from Stave Reservoir in October 2011 with several parasitic copepods, probably *Salmincola californiensis,* in its gill cavity.

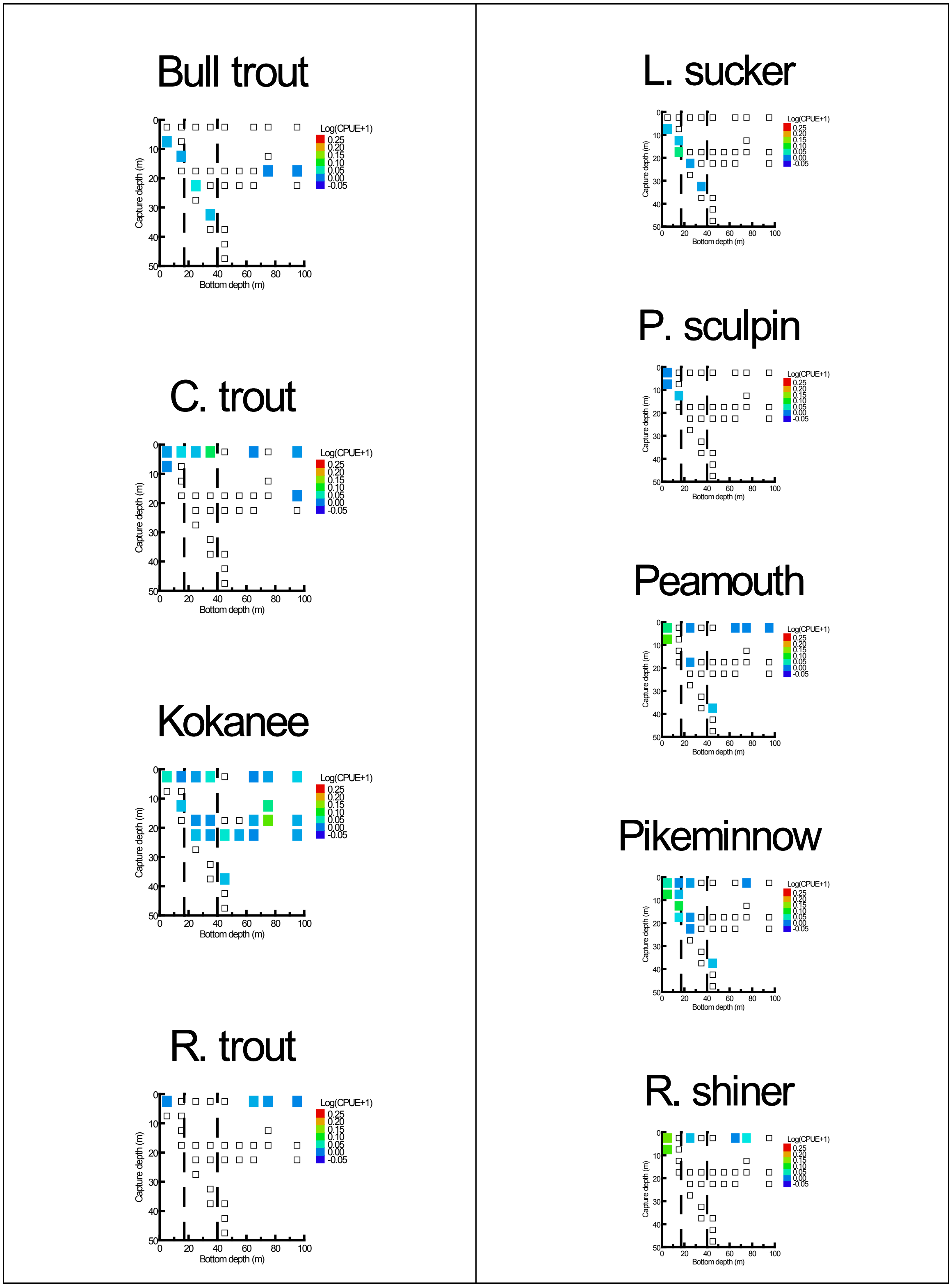


Figure 4. CPUE (log of catch per panel-hour) for fish species captured during Stave Reservoir fall 2011 gill netting, categorized by depth of capture and bottom depth for all set types and stations combined. Empty boxes indicate panels with no catch. Vertical dashed lines indicate the average shoreward limit of acoustic coverage (17 m) and the boundary between slope and pelagic zones (40 m).

Table 3. A comparison of gill net CPUE from all years of sampling in Stave Reservoir. CPUE was standardized to fish captured x 100 m^{-2} x 24 hr^{-1}. The general location and period of sets is noted when known.

Survey date	Fish x 100m^{-2} x 24 hr^{-1}									
	Rainbow trout	**Cutthroat trout**	**Kokanee**	**Bull trout**	**Pike Minnow**	**Redside shiner**	**Large-scale sucker**	**Brown bullhead**	**Pea-mouth**	**Total**
July-1987[a]	0.15	1.74	3.63	1.16	12.5	9.58	1.16	0.00	0.00	29.92
July-1988[b]	0.10	0.15	1.49	0.36	1.08	0.05	0.00	0.00	0.00	3.23
Sept-1993[c]	1.28	0.32	1.61	0.32	60.35	2.89	11.08	0.96	0.00	78.81
Sept-2005 day, nearshore[d]	0.00	1.00	1.00	1.00	2.49	0.75	0.25	0.00	0.25	6.74
Sept-2005 overnight, nearshore[d]	0.19	1.06	2.13	1.06	11.59	10.63	6.95	0.00	2.61	36.22
Oct-2007 night, nearshore[d]	0.16	1.13	4.68	0.65	8.56	10.66	5.33	0.00	1.45	32.62
Oct-2007 night, mid-lake[d]	0.00	0.76	3.31	0.00	0.25	0.00	0.00	0.00	0.00	6.37
Sept-2009 overnight, nearshore[d]	0.00	0.79	4.41	0.21	4.98	3.88	2.05	0.00	3.10	19.41
Sept-2009 overnight, mid-lake[d]	0.00	1.16	5.05	0.07	0.55	0.55	0.00	0.00	0.00	7.37
Sept-2011 overnight, nearshore[d]	0.05	1.04	1.79	0.66	2.82	3.81	0.80	0.00	2.45	13.89
Sept-2011 overnight, mid-lake[d]	0.45	0.26	5.11	0.13	0.06	0.65	0.00	0.00	0.19	6.85

[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 mid-water nets that extended up to 3 net lengths out from a point of contact with the lake bottom.

Table 4. Species composition in the slope zone of Stave Reservoir, partitioned by depth layer, from October 2011 gill netting. This table was used to apportion the 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 and sculpins were likely too close to the bottom for detection with acoustics, so they were excluded from the species composition estimate used to apportion the acoustic estimate of fish abundance.

Table 5. Species composition in the pelagic zone of Stave Reservoir, partitioned by depth layer, from October 2011 gill netting. This table was used to apportion the 2011 acoustic estimate of fish > 100 mm long.

Depth layer	Species: 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%

Table 6. Length, weight, and condition factor of fish captured in gill nets in Stave Lake, October 2011. Fish from all depth intervals and habitat zones are pooled.

Species	Length (mm)					Weight (g)					
	Sample size	Min	Max	Mean	SD	Sample size	Min	Max	Mean	SD	CF
C. trout	33	197	510	306	85	33	77	1,603	395	415	1.05
R. trout	8	184	430	254	76	8	70	946	236	291	1.09
Kokanee	114	112	208	170	21	114	16	120	61	21	1.18
Bull trout	16	228	595	379	110	16	113	2,527	789	747	1.11
L. sucker	17	156	410	322	70	17	45	792	448	236	1.19
N. pikeminnow	63	106	480	232	110	63	13	1,401	273	352	1.18
Peamouth	54	106	162	122	11	54	14	53	22	8	1.19
R. shiner	83	92	124	107	8	83	10	24	17	4	1.36
P. sculpin	5	105	145	121	17	5	11	33	20	9	1.06

Table 7. Weight versus length regression equations for salmonids and non-salmonids in the October 2011 gill net catch.

Species	Weight versus length equation				Sample size	R^2
C. trout	Log(g) =	3.130	x log(mm)	-5.303	33	0.985
R. trout	Log(g) =	3.162	x log(mm)	-5.351	8	0.993
Kokanee	Log(g) =	2.974	x log(mm)	-4.872	114	0.958
Bull trout	Log(g) =	3.198	x log(mm)	-5.463	16	0.994
L. sucker	Log(g) =	2.984	x log(mm)	-4.887	17	0.994
N. pikeminnow	Log(g) =	3.135	x log(mm)	-5.245	63	0.995
Peamouth	Log(g) =	3.149	x log(mm)	-5.239	54	0.906
R. shiner	Log(g) =	2.760	x log(mm)	-4.382	83	0.864
P. sculpin	Log(g) =	3.308	x log(mm)	-5.619	5	0.977

Table 8. Age composition and mean size by age group for salmonids in October 2011, estimated from a subsample of the gill net catch. Catches from all depths and habitat zones were pooled to obtain the maximum possible sample size.

Metric	Age	Species		
		Cutthroat trout	Kokanee	Bull trout
Count of fish aged	1	2	3	
	2	7	6	
	3	4	22	1
	4	1		6
	5	3		4
	6	1		1
	7			2
	Combined	18	31	14
Percentage of catch	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%
	6	5.6%		7.1%
	7			14.3%
	Combined	100.0%	100.0%	100.0%
Mean fork length (mm)	1	208	120	
	2	264	158	
	3	295	175	228
	4	370		302
	5	456		432
	6	480		405
	7			574
	Combined	315	167	380
Mean weight (g)	1	89	22	
	2	201	45	
	3	265	66	113
	4	510		343
	5	1,130		1,015
	6	1,500		777
	7			2,272
	Combined	447	57	825

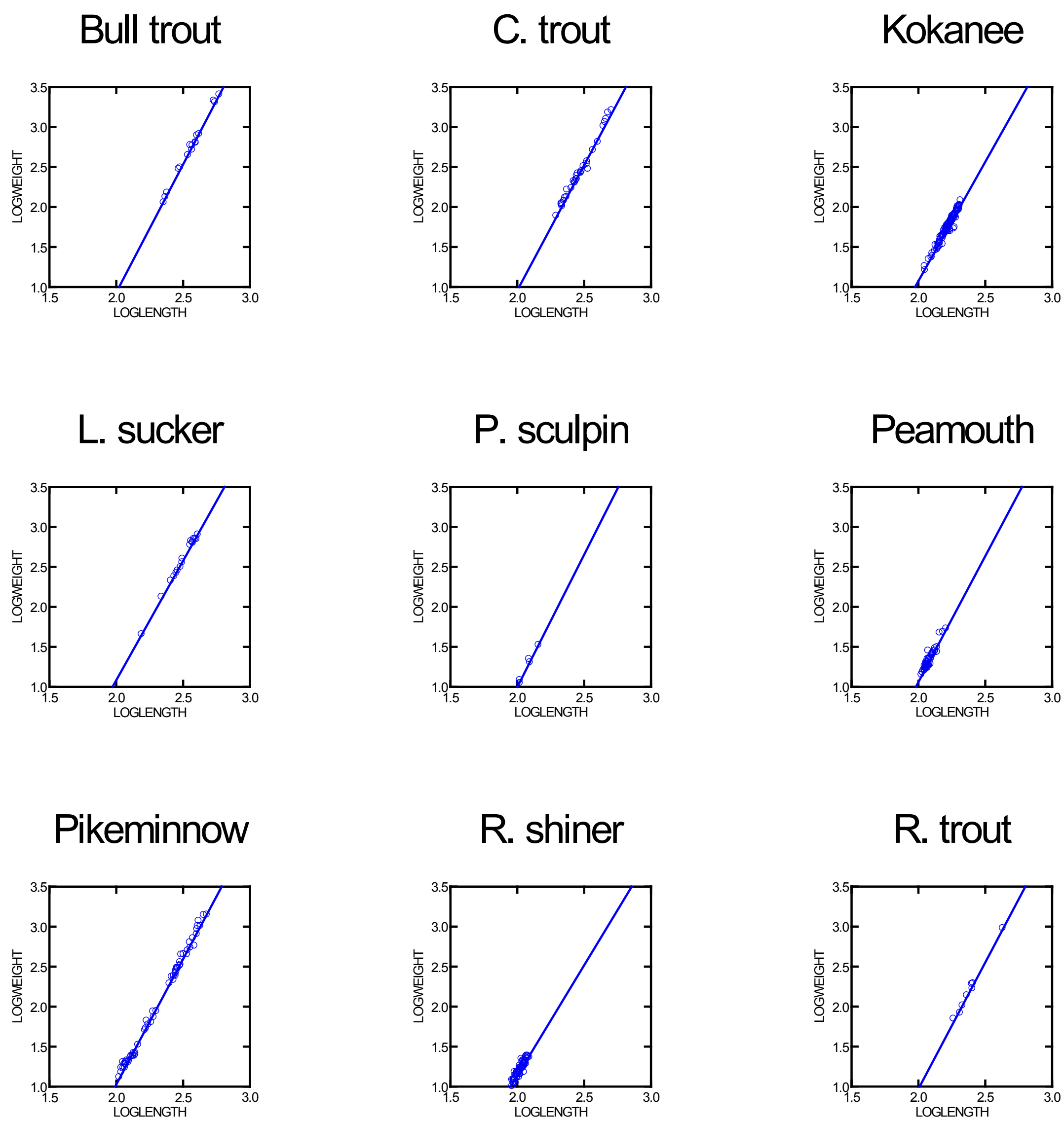


Figure 5. Log(weight) versus log(length) scatter plots for salmonids and non-salmonids captured in gill nets, Stave Reservoir, October 2011.

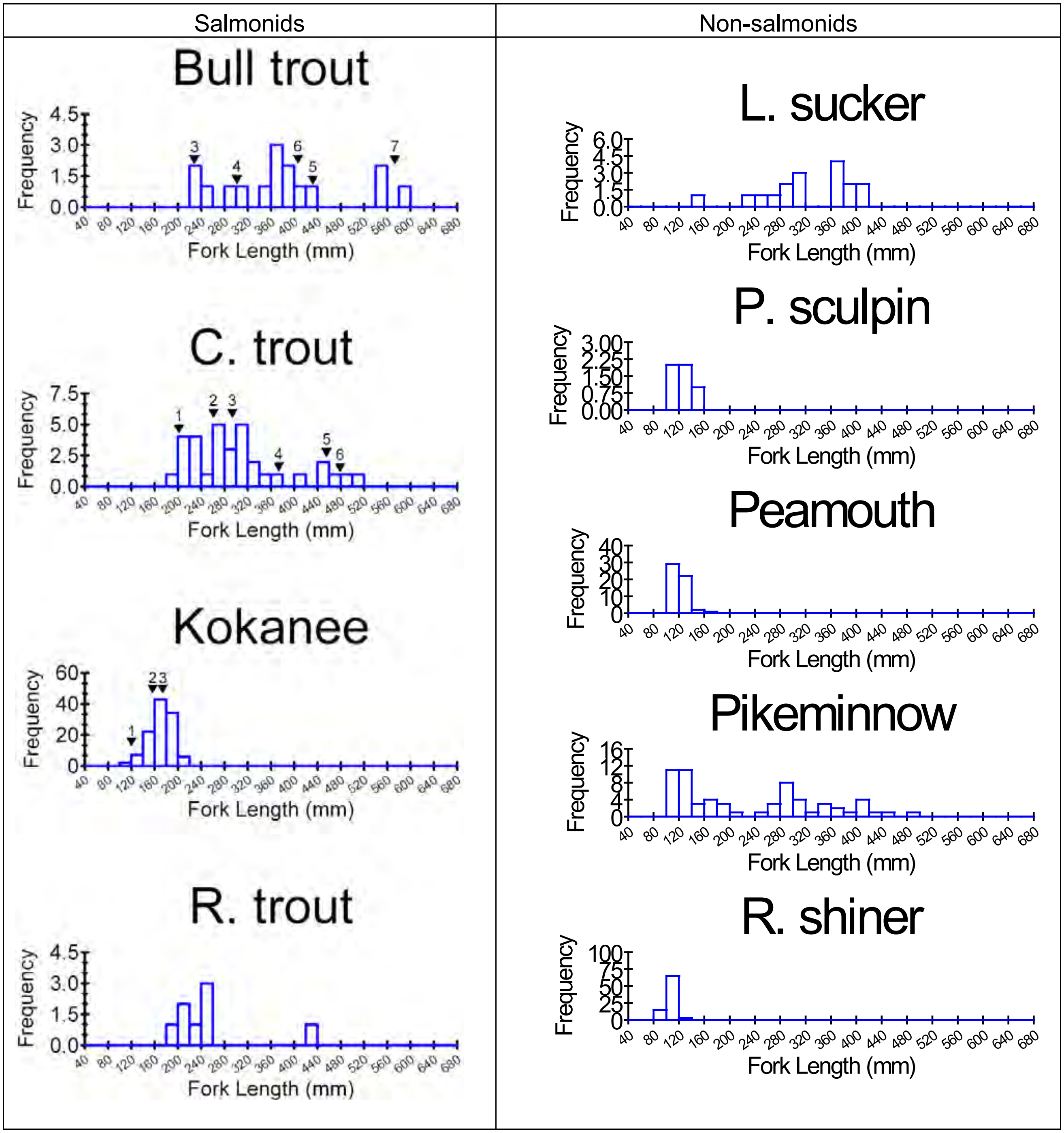


Figure 6. Length-frequency distributions of fish captured in gill nets in Stave Reservoir, October 2011. Numbered arrows indicate mean lengths of designated age groups of salmonids.

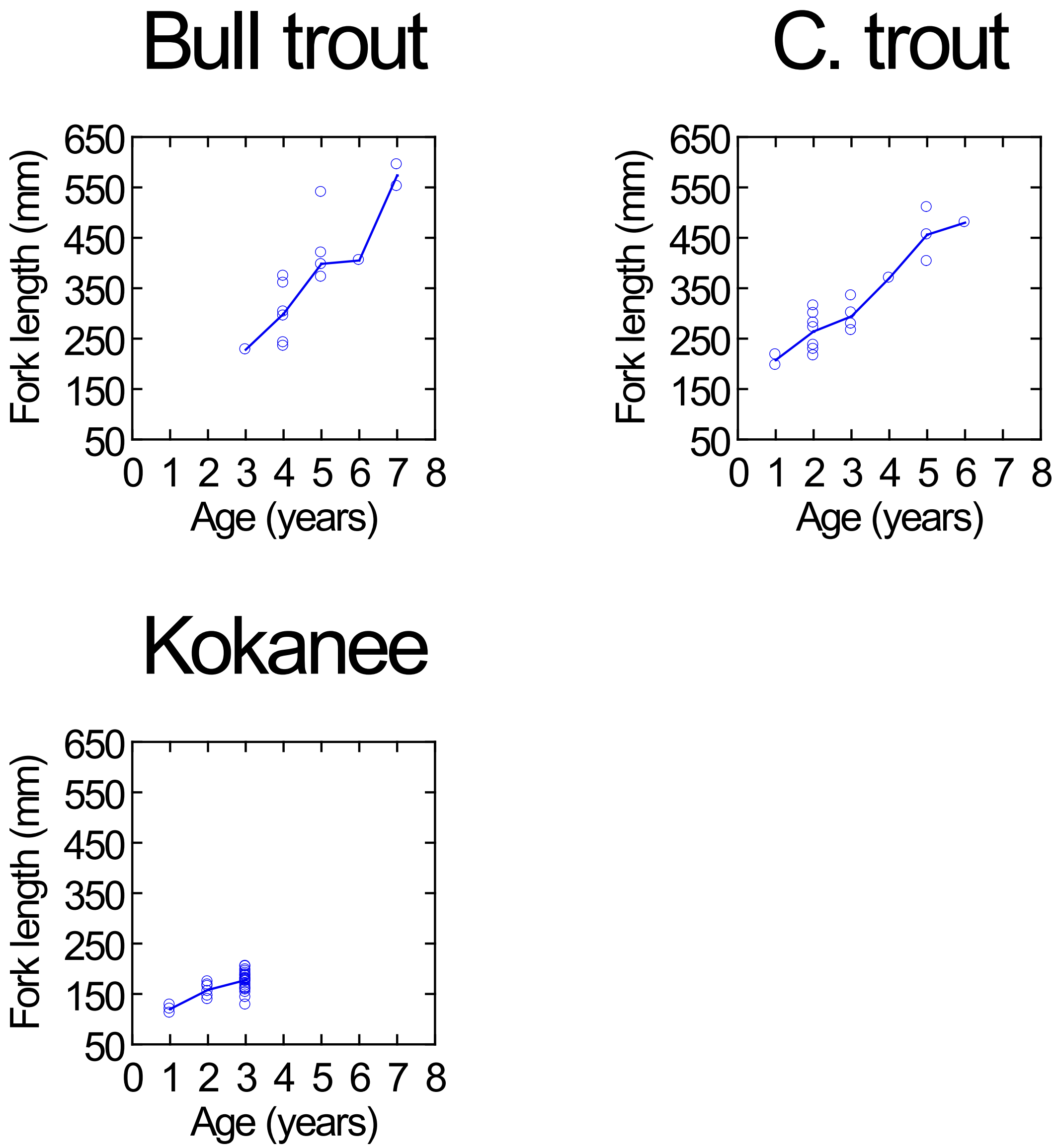


Figure 7. Length versus age of salmonids captured in gill nets in Stave Reservoir, October 2011. Lines connect mean lengths of age groups.

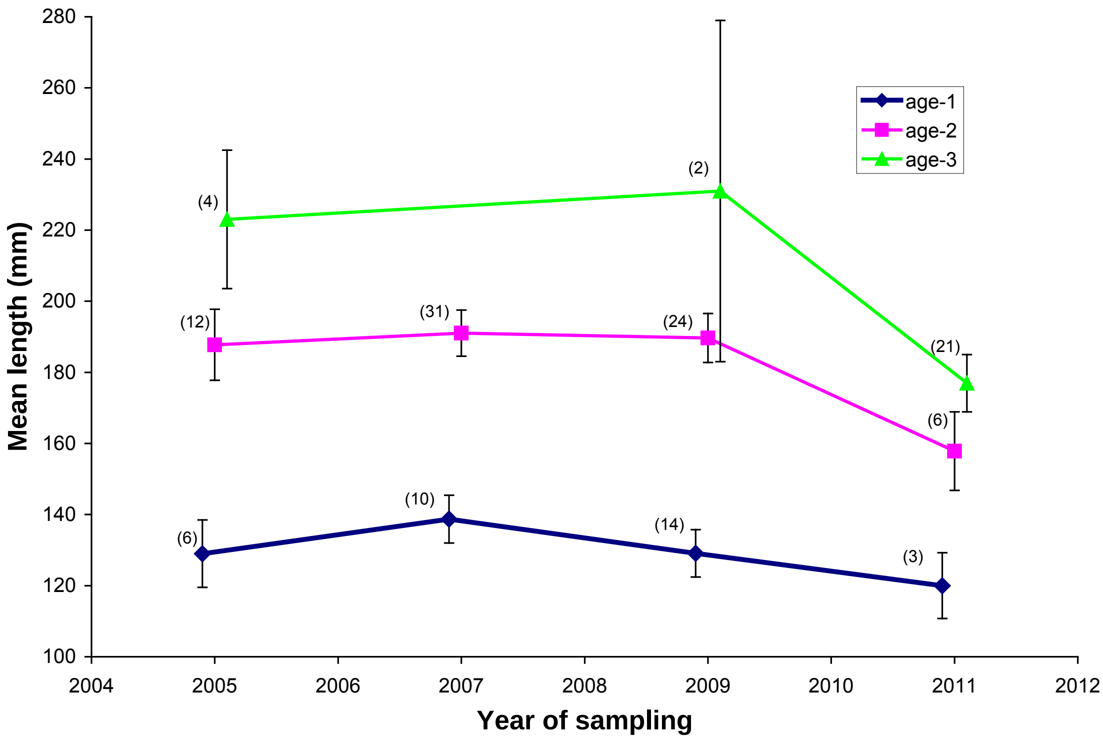


Figure 8. Mean length of kokanee age-groups in 2005-2011 fall gill netting of Stave Reservoir. Error bars show 95% CI and sample sizes are in parentheses. Sampling was during the first half of October in all years.

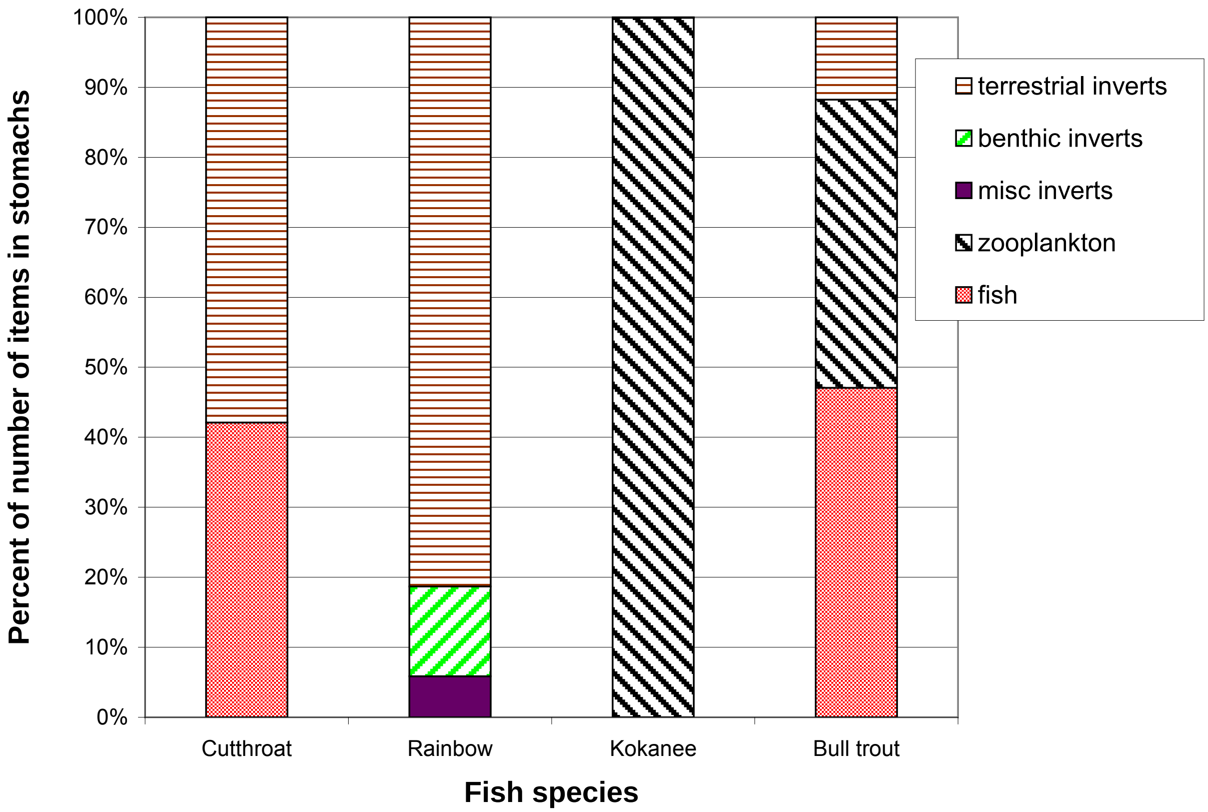


Figure 9. Contents of salmonid stomachs expressed as percentage of composition by numbers. Stomachs were from fish captured in gill nets in Stave Reservoir, October 2011.

Table 9. Counts of fish from echograms by transect and depth interval, Stave Reservoir, September 28-29, 2011. Counts from side-looking sampling of the 0-5 m range are missing due to rough conditions during the survey. Counts for depth ranges >0-5 m are from down-looking data.

Zone	Depth range (m)	Fish Count by Transect												Total
		1	2	3	4	5	6	7	8	9	10	11	12	
slope	0-5	-		-		-		-		-		-		-
"	5-10	0		0		1		0		0		2		3
"	10-15	3		0		3		1		0		0		7
"	15-20	2		0		0		6		1		0		9
"	20-25	0		0		2		1		4		2		9
"	25-30	0		0		1		1		2		3		7
"	30-35	0		0		0		1		1		0		2
"	35-40	0		0		0		1		0		0		1
"	5-40	5		0		7		11		8		7		38
pelagic	0-5	-		-		-		-		-		-		-
"	5-10	2		10		2		4		0		2		20
"	10-15	5		15		10		1		9		5		45
"	15-20	21		31		45		48		25		25		195
"	20-25	16		3		40		69		20		80		228
"	25-30	20		6		4		13		7		58		108
"	30-35	17		8		8		2		3		58		96
"	35-40	16		6		6		3		0		76		107
"	40-45	13		3		6		6		4		61		93
"	45-50	13		1		6		3		0		41		64
"	50-55	7		3		3		3		0		43		59
"	55-60	9		2		3		1		0		19		34
"	60-65	8		1		7		1		1		8		26
"	65-70	6		0		3		0		1				10
"	70-75	3		0		0		3		0				6
"	75-80	3		0		2		4						9
"	5-80	159		89		145		161		70		476		1,100

Table 10. Fish density (fish/m^3) for all species combined by transect and depth interval from the September 28-29, 2011 acoustic survey. Densities from side-looking sampling of the 0-5 m range are missing due to rough conditions during the survey. Densities for depth ranges >0-5 m are from down-looking data.

	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	-		-		-		-		-		-		-	-	-
"	5-10	0.00000		0.00000		0.00123		0.00000		0.00000		0.00246		6	0.000616	1.062E-06
"	10-15	0.00191		0.00000		0.00181		0.00023		0.00000		0.00000		6	0.000660	8.779E-07
"	15-20	0.00139		0.00000		0.00000		0.00101		0.00054		0.00000		6	0.000489	3.613E-07
"	20-25	0.00000		0.00000		0.00092		0.00015		0.00169		0.00082		6	0.000598	4.535E-07
"	25-30	0.00000		0.00000		0.00045		0.00027		0.00082		0.00107		6	0.000436	1.916E-07
"	30-35	0.00000		0.00000		0.00000		0.00037		0.00054		0.00000		6	0.000151	5.799E-08
"	35-40	0.00000		0.00000		0.00000		0.00069		0.00000		0.00000		6	0.000115	7.958E-08
"	0-40	0.00047		0.00000		0.00063		0.00039		0.00051		0.00062		42		
pelagic	0-5	-		-		-		-		-		-		-	-	-
"	5-10	0.00044		0.00186		0.00039		0.00045		0.00000		0.00035		6	0.000580	4.181E-07
"	10-15	0.00052		0.00133		0.00074		0.00005		0.00042		0.00042		6	0.000580	1.844E-07
"	15-20	0.00149		0.00187		0.00220		0.00176		0.00079		0.00143		6	0.001591	2.323E-07
"	20-25	0.00087		0.00014		0.00148		0.00193		0.00048		0.00348		6	0.001398	1.469E-06
"	25-30	0.00088		0.00023		0.00012		0.00030		0.00014		0.00205		6	0.000618	5.692E-07
"	30-35	0.00063		0.00026		0.00020		0.00004		0.00005		0.00172		6	0.000483	4.153E-07
"	35-40	0.00051		0.00017		0.00013		0.00005		0.00000		0.00195		6	0.000468	5.601E-07
"	40-45	0.00037		0.00008		0.00012		0.00009		0.00005		0.00145		6	0.000360	2.987E-07
"	45-50	0.00034		0.00002		0.00011		0.00004		0.00000		0.00097		6	0.000248	1.400E-07
"	50-55	0.00018		0.00008		0.00005		0.00004		0.00000		0.00108		6	0.000238	1.719E-07
"	55-60	0.00023		0.00004		0.00005		0.00002		0.00000		0.00058		6	0.000154	5.101E-08
"	60-65	0.00020		0.00002		0.00015		0.00001		0.00001		0.00054		6	0.000157	4.233E-08
"	65-70	0.00016		0.00000		0.00008		0.00000		0.00004				5	0.000057	4.766E-09
"	70-75	0.00010		0.00000		0.00000		0.00004		0.00000				5	0.000028	1.867E-09
"	75-80	0.00018		0.00000		0.00004		0.00005						4	0.000066	6.314E-09
"	5-80	0.00047		0.00041		0.00039		0.00033		0.00014		0.00133		86		

Table 11. Counts and percentages of fish with estimated fork lengths <100 mm and ⩾100 mm, Stave Reservoir, September 28-29, 2011. Lengths were estimated from down-looking 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	1	0	1	100.00%	0.00%
"	5-10	2	0	2	100.00%	0.00%
"	10-15	0	0	0	44.44%	55.56%
"	15-20	4	5	9	44.44%	55.56%
"	20-25	8	1	9	88.89%	11.11%
"	25-30	4	3	7	57.14%	42.86%
"	30-35	2	0	2	85.71%	14.29%
"	35-40	1	0	1	100.00%	0.00%
pelagic	0-5	3	0	3	92.50%	7.50%
"	5-10	17	3	20	85.00%	15.00%
"	10-15	34	11	45	75.56%	24.44%
"	15-20	107	88	195	54.87%	45.13%
"	20-25	148	80	228	64.91%	35.09%
"	25-30	96	12	108	88.89%	11.11%
"	30-35	95	1	96	98.96%	1.04%
"	35-40	107	0	107	100.00%	0.00%
"	40-45	92	1	93	98.92%	1.08%
"	45-50	64	0	64	100.00%	0.00%
"	50-55	57	2	59	96.61%	3.39%
"	55-60	33	1	34	97.06%	2.94%
"	60-65	21	5	26	80.77%	19.23%
"	65-70	8	2	10	80.00%	20.00%
"	70-75	6	0	6	100.00%	0.00%
"	75-80	8	1	9	88.89%	11.11%

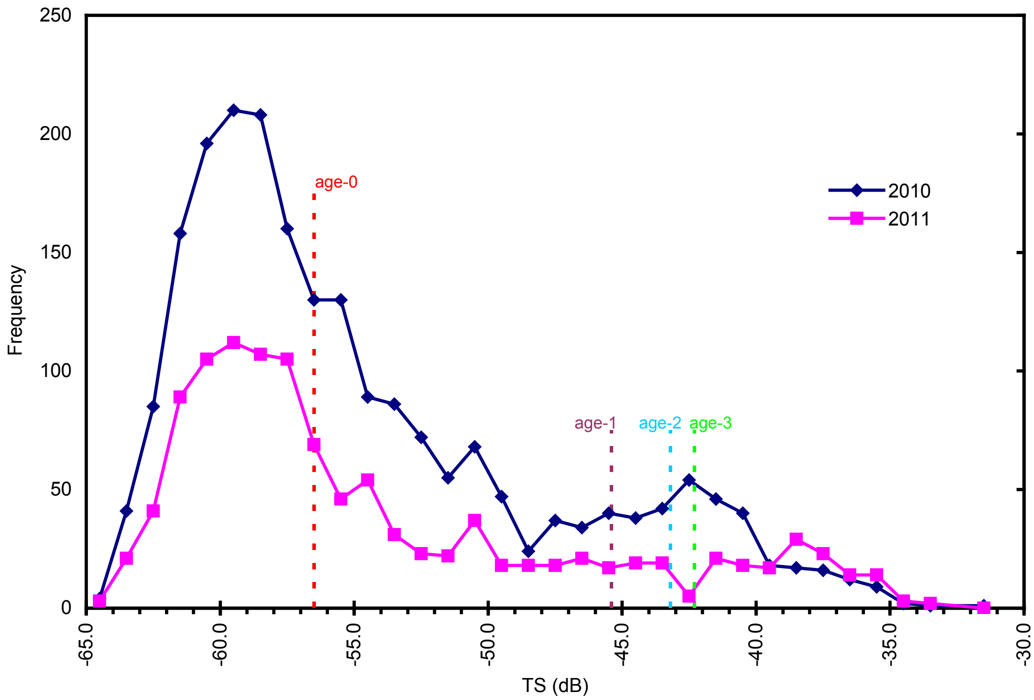


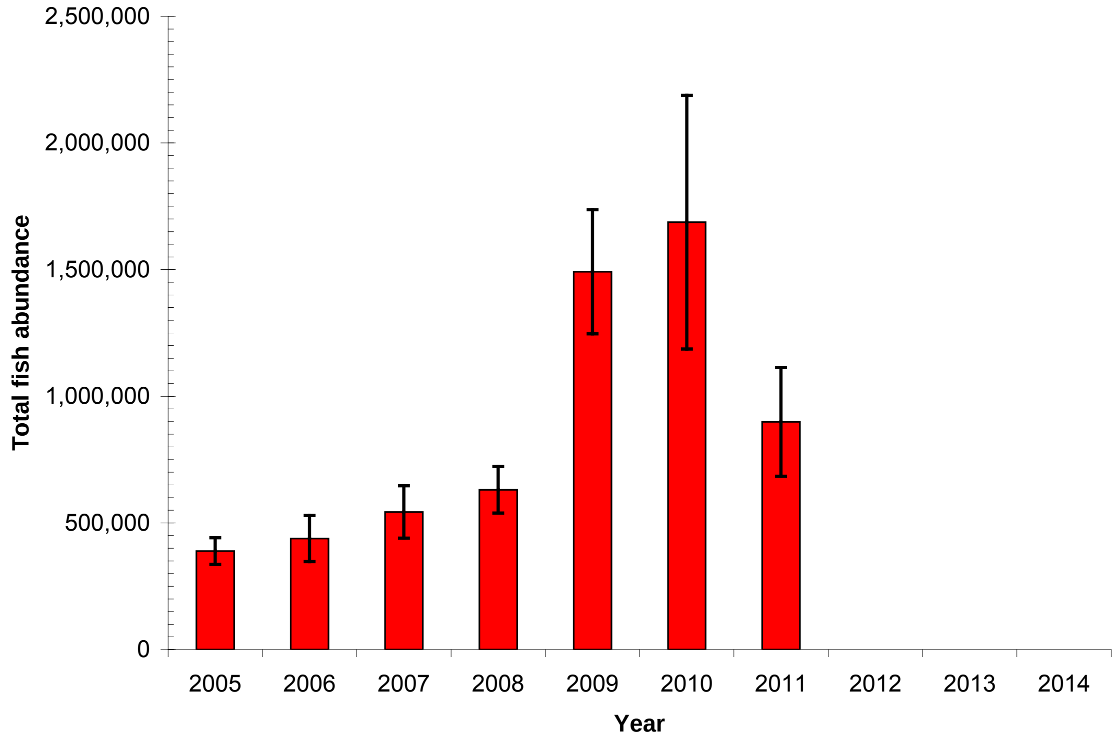
Figure 10. Frequency distributions of target strength (TS) from fish in Stave Reservoir during late September 2010 and 2011. Data are from both the slope and pelagic zones in both years. Dashed lines indicate the mean TS of each kokanee age-group as estimated by Love's (1977) ±45° TS versus length model using 2011 gill net data. The sample size (number of fish tracked on echograms) was 2,170 in 2010 and 1,141 in 2011.

Table 12. Total fish abundance (species combined) by habitat zone of Stave Reservoir, from the September 28-29, 2011 acoustic survey. The reservoir surface elevation was 78.6 m above sea level at the time of the survey.

Zone	Depth range (m)	Mean no. per m^3	Variance	Sample size *	Stratum Volume (cubic m)	Pop est	SE of pop est	95% CL lower	95% CL upper
slope	0-5	0.00044	9.6E-08	6	1.6E+07	7,179	2,072	1,853	12,504
"	5-10	0.00062	1.1E-06	6	1.6E+07	10,091	6,892	-7,625	27,807
"	10-15	0.00066	8.8E-07	6	1.6E+07	10,807	6,266	-5,301	26,916
"	15-20	0.00049	3.6E-07	6	1.6E+07	7,701	3,861	-2,224	17,626
"	20-25	0.00060	4.5E-07	6	1.3E+07	7,489	3,441	-1,356	16,335
"	25-30	0.00044	1.9E-07	6	9.0E+06	3,930	1,612	-215	8,075
"	30-35	0.00015	5.8E-08	6	5.3E+06	800	519	-535	2,135
"	35-40	0.00012	8.0E-08	6	1.7E+06	198	198	-311	707
"	0-40			42	9.3E+07	48,195	10,987	25,890	70,500
pelagic	0-5	0.00120	1.7E-06	6	1.1E+08	126,752	57,049	-19,897	273,400
"	5-10	0.00058	4.2E-07	6	1.1E+08	61,445	27,961	-10,431	133,321
"	10-15	0.00058	1.8E-07	6	1.1E+08	61,468	18,570	13,732	109,204
"	15-20	0.00159	2.3E-07	6	1.1E+08	168,527	20,839	114,959	222,095
"	20-25	0.00140	1.5E-06	6	1.1E+08	148,067	52,409	13,346	282,789
"	25-30	0.00062	5.7E-07	6	1.1E+08	65,433	32,622	-18,425	149,291
"	30-35	0.00048	4.2E-07	6	1.1E+08	51,106	27,867	-20,529	122,741
"	35-40	0.00047	5.6E-07	6	1.1E+08	49,544	32,362	-33,645	132,732
"	40-45	0.00036	3.0E-07	6	1.0E+08	37,379	23,183	-22,214	96,973
"	45-50	0.00025	1.4E-07	6	9.9E+07	24,551	15,113	-14,298	63,400
"	50-55	0.00024	1.7E-07	6	9.4E+07	22,414	15,913	-18,492	63,320
"	55-60	0.00015	5.1E-08	6	8.7E+07	13,390	8,039	-7,275	34,054
"	60-65	0.00016	4.2E-08	6	7.8E+07	12,312	6,591	-4,631	29,255
"	65-70	0.00006	4.8E-09	5	7.1E+07	4,021	2,192	-2,065	10,107
"	70-75	0.00003	1.9E-09	5	5.8E+07	1,644	1,127	-1,486	4,774
"	75-80	0.00007	6.3E-09	4	4.4E+07	2,917	1,751	-2,656	8,490
"	0-80			86	1.5E+09	850,970	107,641	636,340	1,065,599
Combined						899,164	108,200	684,647	1,113,682

Table 13. Abundance and biomass of individual fish species within the study area in Stave Reservoir from the fall 2011 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**	**Bull trout**	**Peamouth**	**Pikeminnow**	**R. shiner**	**Total**
< 100 mm	abundance	0	0	0	711,642	0	0	0	0	711,642
"	biomass (kg)	0	0	0	249	0	0	0	0	249
≥ 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%	-	-	-	
"	"	6	5.6%	-	-	7.1%	-	-	-	
"	"	7	-	-	-	14.3%	-	-	-	
"	"	total	100.0%	-	100.0%	100.0%	-	-	-	
"	abundance	1	571	-	15,801	-	-	-	-	
"	"	2	1,998	-	31,602	-	-	-	-	
"	"	3	1,142	-	115,875	310	-	-	-	
"	"	4	285	-	-	1,871	-	-	-	
"	"	5	856	-	-	1,248	-	-	-	
"	"	6	285	-	-	310	-	-	-	
"	"	7	-	-	-	624	-	-	-	
"	"	total	5,138	4,854	163,278	4,362	1,909	4,155	3,826	187,523
"	biomass (kg)	1	51	-	348	-	-	-	-	398
"	"	2	402	-	1,422	-	-	-	-	1,824
"	"	3	303	-	7,648	35	-	-	-	7,985
"	"	4	146	-	-	642	-	-	-	787
"	"	5	968	-	-	1,266	-	-	-	2,234
"	"	6	428	-	-	241	-	-	-	669
"	"	7	-	-	-	1,417	-	-	-	1,417
"	"	total	2,296	1,146	9,417	3,601	42	1,133	64	17,701
Combined	abundance	total	5,138	4,854	874,920	4,362	1,909	4,155	3,826	899,164
"	biomass (kg)	"	2,296	1,146	9,667	3,601	42	1,133	64	17,950
"	number/ha	"	1.8	1.7	309.0	1.5	0.67	1.5	1.4	317.6
"	kg/ha	"	0.81	0.40	3.4	1.3	0.015	0.40	0.023	6.3
	% of tot kg		12.8%	6.4%	53.9%	20.1%	0.23%	6.3%	0.36%	100.0%



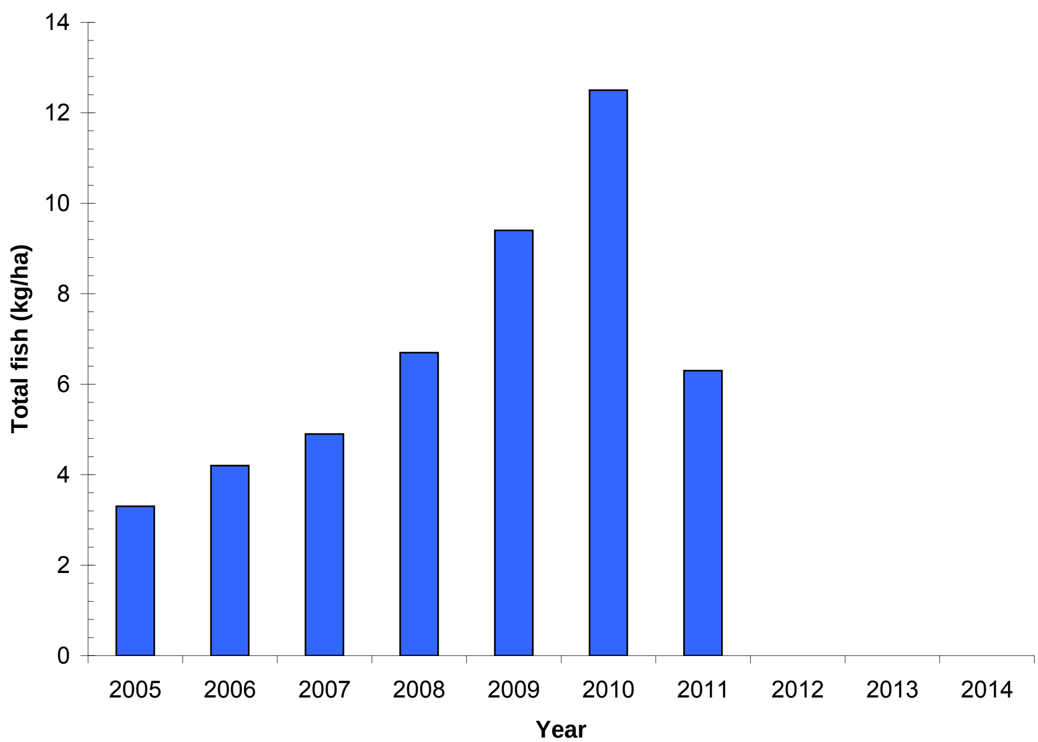


Figure 11. Total fish abundance (upper) and biomass (lower) in Stave Reservoir for all species combined from study inception through 2011. Error bars on abundance estimates are 95% confidence limits.

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5.0 DATA APPENDICES

Raw data appendices are available from BC Hydro.