Stave River Project Water Use Plan

Fish Biomass Assessment (Year 4)

Reference: SFLMON#3

Stave River Project Water Use Plan: Fish Biomass Assessment

Study Period: October 2008

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BC hydro

ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR IN SEPTEMBER 2008

Final Report

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SHUKSAN

LIMNOTEK

ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR IN SEPTEMBER 2008

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Cover photo: Kiyo Masuda recording data during gill netting on Stave Reservoir, October 2005. Photo by Bruce Probert.

EXECUTIVE SUMMARY

An acoustic survey was conducted on the night of September 23, 2008 to determine abundance, biomass, and spatial distribution of fish in Stave Reservoir. Nearshore and mid-lake gill net data collected in early October 2007 were used to apportion the acoustic estimate among fish species and salmonid age groups. The 2008 abundance and biomass estimates were computed using stratification by slope (< 40 m deep) and pelagic (>40 m deep) habitat zones, as in 2007. Both the acoustic survey and gill netting were limited to portions of the main reservoir basin that were free enough of dead standing timber and debris to be sampled without undue risk to equipment and personnel. The 2008 survey represents year 4 of a 10 year study conducted under the Stave River Water Use Plan.

Temperature profiles of the water column indicated that thermal stratification was strong during the 2008 survey. Temperature ranged from 14.5-15.5 ºC in the epilimnion (0-10 m) to 5 ºC at 60 m. The 6-13 ºC temperature range typically preferred by kokanee extended from just below the epilimnion to 30-40 m. Dissolved oxygen exceeded 9 mg/l at all depths measured (0-50 m).

Most fish were found in the upper 30 m of both the slope and pelagic zones during the 2008 acoustic survey. Peak densities tended to be shallower (5-25 m) in the slope zone than in the pelagic zone (15-25 m). In both cases, average density for combined transects approached 0.0014 fish/m^3 in the most concentrated layers. Fish densities were very low in the upper 5 meters of both zones, except in the pelagic zone on transects 1 and 9.

Target strength (TS) of fish ranged from -64.0 to -30.4 dB. In the slope zone there was a single major peak between -56 and -50 dB, whereas there were two major peaks in the pelagic zone: between -60 and -55 dB and between -40 and -35 dB. The proportion of large TS values (>-45 dB) was much higher in the pelagic zone than in the slope zone. When TS values were converted to fork length, estimated lengths of fish ranged from 18 to 424 mm in the slope zone and 12 to 785 mm in the pelagic zone. Fish longer than 100 mm were much more numerous in the pelagic zone (45% of total) than in the slope zone (14% of total).

The 2008 population estimate for the entire study area was 630,907 ± 91,573 fish of all species combined. Of these, 94,315 were in the slope zone and 536,593 were in the pelagic zone. In the slope zone, 96% of all fish occurred in the 0-25 m depth range. In the pelagic zone, 96% of all fish were in the 0-30 m range.

For both habitat zones combined, the population estimate of fish less than 100 mm long was 421,968 fish (biomass 312 kg), all of which were assumed to be age 0 kokanee. Also for both zones, the estimated numbers and biomass of larger fish (⩾100 mm in length) were 7,895 cutthroat trout (2,628 kg), 1,066 native char (965 kg), 190,490 kokanee (14,392 kg), 227 rainbow trout (28 kg), 6,233 peamouth chub (243 kg), and 3,028 northern pikeminnow (375 kg). Numbers and biomass of salmonids were further broken down by cohorts based on age structure of the 2007 gill net catch. Considering cutthroat trout, age-2 was by far most abundant but age-3 had the largest biomass. For native char, all ages (3, 5, 8, and 10) were equally abundant, while their contribution to

biomass increased with age. This estimate was based on just one fish of each age. Age 1-3 kokanee were present in the population, with age-2 strongly dominant both numerically and in terms of biomass. The only cohort of rainbow trout present was age-2.

Areal density and biomass of individual species with all ages combined was 216.3 kokanee/ha (5.2 kg/ha), 2.8 cutthroat trout/ha (0.9 kg/ha), 0.4 native char/ha (0.3 kg/ha), 1.1 northern pikeminnow/ha (0.1 kg/ha), 2.2 peamouth chub/ha (0.09 kg/ha), and 0.1 rainbow trout/ha (0.01 kg/ha), for a combined total of 222.9 fish/ha (6.7 kg/ha).

Discrepancies between fish length frequency distributions from the 2007 gill net data and estimated from the 2008 acoustic data (TS) suggest that use of 2007 gill net data to apportion the 2008 acoustic estimate may have caused error in kokanee age composition estimates. The net effect of this error on the 2008 biomass estimates of kokanee and of all species combined is estimated to be less than 10%.

The 2008 population estimate was stratified by slope and pelagic habitat zones to improve accuracy over the analysis of 2005 and 2006 data in which no stratification was used (Stables and Perrin 2008). The 2008 results are fully comparable to 2007 results (which had the same stratification), but are only partially comparable to 2005 and 2006 results. The 2005 and 2006 abundance and biomass estimates will be recalculated using stratification once 2009 gill net sampling has provided another year of data for assessing the consistency of nearshore versus offshore fish distribution patterns.

The 2008 native char biomass estimate for Stave Reservoir agreed closely with the 2007 estimate and with char biomass estimates from other western lakes and reservoirs, whereas 2005 and 2006 estimates (without stratification) were much higher. The 2008 biomass of char in Stave Reservoir (0.3 kg/ha) was higher than in Ross Lake (0.04-0.08 kg/ha), however, the combined biomass of char and trout in Stave Reservoir (1.2 kg/ha) was intermediate among values from Ross Lake (2.8-5.7 kg/ha) and Lake Pend Oreille (0.8-1.9 kg/ha).

The total 2008 fish biomass estimate for Stave Reservoir (6.7 kg/ha of all species combined) and estimates for individual species other than char were also similar to the 2007 estimate (4.9 kg/ha for all species) and in line with several other lakes and reservoirs. Total biomass in Ross Lake, a northern Washington reservoir that mainly supports rainbow trout, was slightly less (2.8-5.7 kg/ha), while biomass in Coquitlam Reservoir, which is dominated by non-salmonids, was much higher (31.2 kg/ha). Biomass of kokanee was lower in Stave Reservoir than in other lakes except Williston Reservoir, which is dominated by lake whitefish. Trout densities and biomass in Stave Reservoir (2.82 fish/ha and 0.91 kg/ha for rainbow and cutthroat combined) were also lower than those reported for Ross Lake (8-15 trout/ha, 3-6 kg/ha).

DEDICATION AND ACKNOWLEDGEMENTS

This project was performed under contract to BC Hydro as part of the Stave River Water Use Plan Studies. We are grateful to Dave Hunter, BC Hydro Natural Resource Specialist, and James Bruce, BC Hydro Research Biologist, who assisted with logistics and coordinated this work with related studies for the Stave Water Use Plan. Due to their continued interest and active support it has been possible to adapt and improve the study design as our knowledge has grown with each year of the project. We also thank Sylvain Guerin (boat operator) for his part in the 2008 acoustic survey. We dedicate this report to the memory of Kiyo Masuda (1950-2008), who's tireless efforts as coordinator of Limnotek field activities contributed immeasurably to the success of this and many other BC Hydro projects.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

1.0 INTRODUCTION

Stave Reservoir is the major impoundment within BC Hydro's Stave River Hydroelectric Project (Figure 1). Improving fish production in Stave Reservoir is a key goal of the Stave River Water Use Plan (WUP, Failing 1999a). Based on limited information that was available for early planning (e.g., Bruce et al. 1994, Slaney 1989), 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 1999a). Indeed, monitoring of primary production since the WCC report has determined that the reservoir is ultra-oligotrophic with one of the lowest rates of carbon fixation so far observed in any lake or reservoir ecosystem in British Columbia (Stockner and Beer 2004).

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 1999a). For reservoir fish, the most significant feature of this plan is a change in the reservoir drawdown regime to stabilize the water level to some degree during the growing season. It was hypothesized that this change might increase fish food resources and improve the sport fishery.

Preliminary estimates predicted that Combo 6 would increase primary production in the reservoir by 21% and increase the "effective littoral zone" area by 830 ha, with production increasing mainly in the littoral zone (Failing 1999 a & b). However, it was uncertain that these gains would be realized and unclear in what way and to what extent they would affect fish production. For example, even if primary production increases, will fish biomass in the reservoir increase appreciably? If so, will sport fish (trout and kokanee) or other fish benefit most? If sport fish populations are enhanced, will the main beneficiaries be trout, which rely heavily on benthic and terrestrial food sources (e.g., Stables et al. 1990, Johnston et al. 1999, Perrin et al. 2006), or kokanee, which mainly exploit the pelagic food chain (Burgner 1991, Quinn 2005).

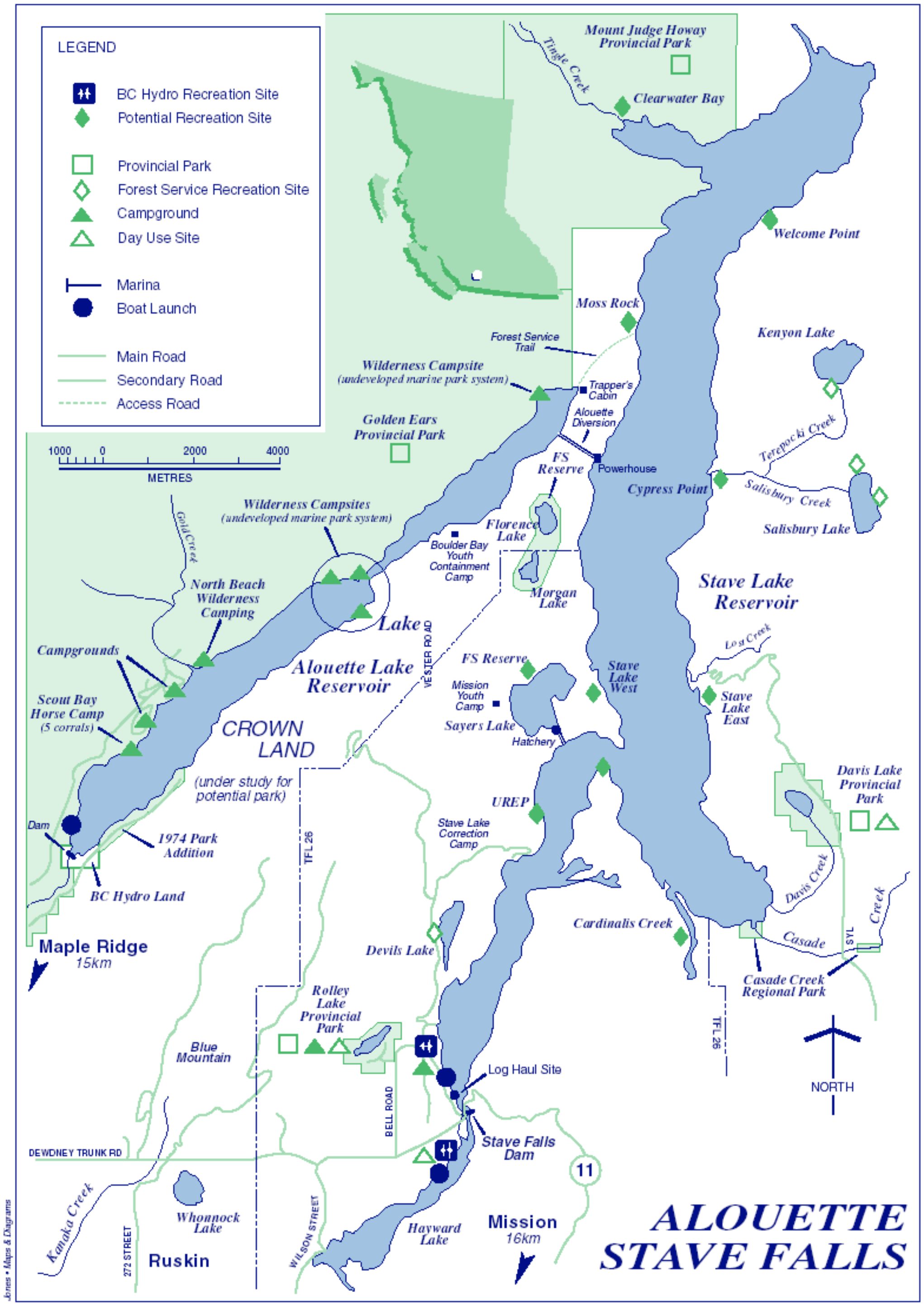

Figure 1. Stave Reservoir and the Stave River Hydroelectric Project.

Fish sampling prior to the present study found that Stave Reservoir supported several salmonid species (rainbow trout, *Oncorhynchus mykiss*; coastal cutthroat trout, *O. clarki clarki*; kokanee, *O. nerka*; and native char, *Salvelinus malma* or *S. confluentus*) and non-salmonid species (northern pikeminnow, *Ptychocheilus oregonensis*; peamouth chub, *Mylocheilus caurinus*; three-spine stickleback, *Gasterosteus aculeatus*; largescale sucker, *Catostomus macrocheilus*; and redside shiner *Richardsonius balteatus*, Norris and Balkwill 1987, Bruce et al. 1994). Many of these fish species can compete for food and space and interact as predators and prey to some degree. Since non-salmonids were the more abundant group in the littoral zone where the benefits of Combo 6 are expected to accrue, they may be the fish most likely to benefit. However, the species of trout and char present in Stave Reservoir often utilize littoral habitats opportunistically (Andrusak and Northcote 1971, Nilsson and Northcote 1981, Stables and Thomas 1992), and littoral foraging can be especially important to them in oligotrophic water bodies like Stave Reservoir (Stables and Perrin 2004).

To help resolve these uncertainties and 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 (Stables and Perrin 2006) 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.

In 2008, as in previous years, an acoustic survey (scientific echo sounding) was used to estimate fish abundance in the lake. The fish population to be assessed was restricted to pelagic and semi-pelagic species that can be sampled effectively with acoustics. Specific goals of the ten-year fish population monitoring program are to:

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

In 2008, as in 2007, abundance and biomass estimates were computed using an analysis design that stratified the lake into nearshore and pelagic zones.

This report describes findings of the 2008 study, year four of this program, in which only acoustic data were collected. Specific objectives were to:

1. Estimate the abundance and biomass of fish during fall 2008 for:
    a. all fish species combined
    b. individual fish species
    c. individual age groups of salmonids;
2. Estimate species composition, age composition, and size composition of the fish community by applying 2007 gill net data to the 2008 acoustic data;
3. Evaluate sampling and analysis methods with regard to study goals and make recommendations for future years.

2.0 STUDY SITE DESCRIPTION

Stave Reservoir is located 65 km east of Vancouver in the Fraser River watershed (Figure 1). The reservoir is 25 km long, it has a surface area of 5,860 ha and a mean depth of 36 m at full pool (Norris and Balkwill 1987, Stockner and Beer 2004). The Stave watershed (1,150 km^2), includes Alouette Lake, which drains into Stave Reservoir through a BC Hydro diversion tunnel and power plant. Stave Reservoir is composed of a main basin that contains the original natural lake, plus a 9.5 km long outlet arm that was formerly part of the Stave River. The present outlet of the reservoir is at the Stave Falls Dam. The central and largest portion of the reservoir that includes the original lake is steep sided and deep, reaching a maximum measured depth of 101 m. The north and south ends of the main basin contain several km of shallows outside the natural lake basin that are densely covered with dead standing timber from the forest that existed before the water surface elevation was raised to create the reservoir. Extensive shallows at the ends of the lake become dewatered at drawdown. The outlet arm is similarly shallow and timbered, with large areas subject to dewatering during drawdown. Timbered areas are extremely difficult to access and sample, so in this study acoustic and fish sampling were limited to the portion of the main basin that is relatively free of shoreline obstructions (Figure 2). The area of this selected portion of the reservoir is 2,962 ha at full pool (elevation 82.1 m above sea level).

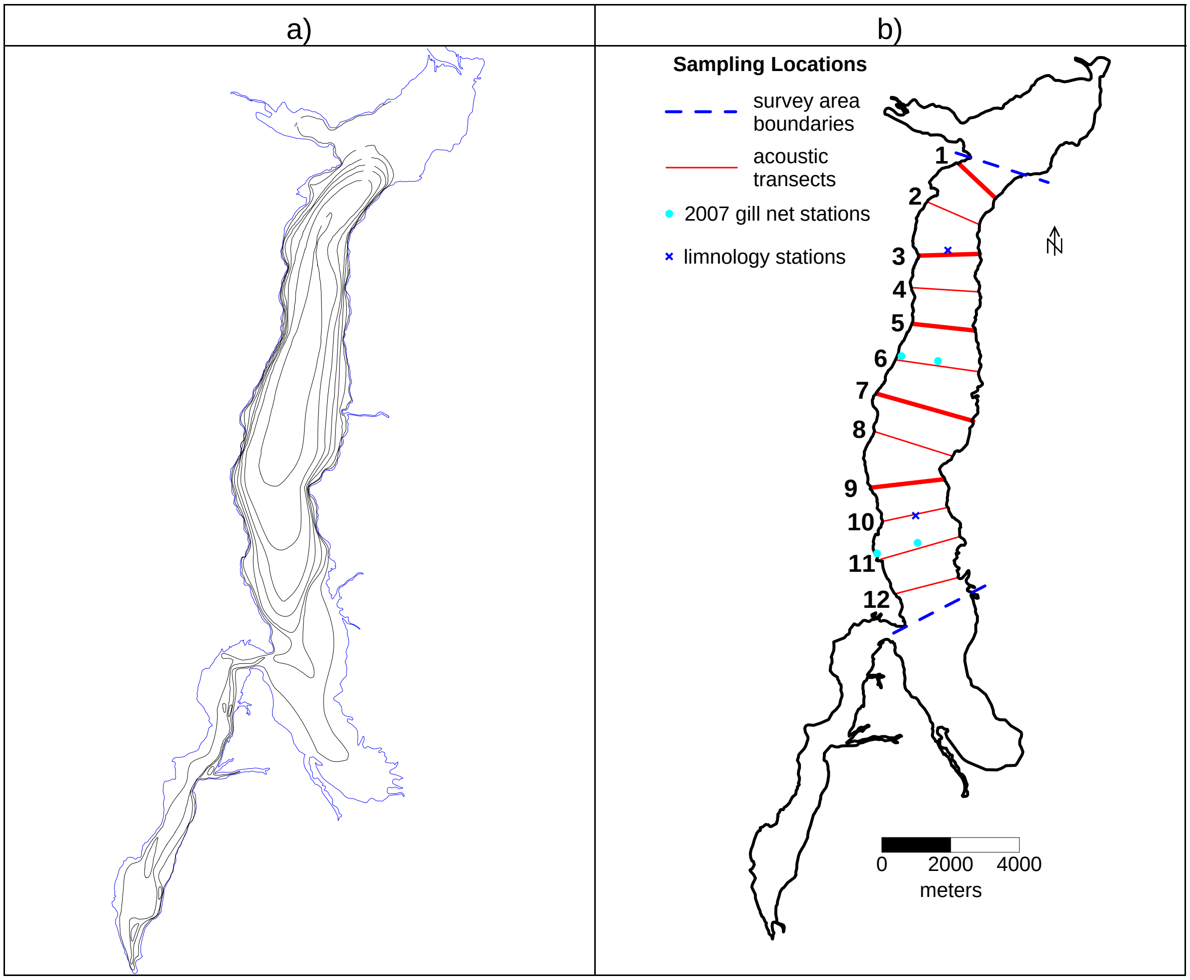

Figure 2. Maps of Stave Reservoir: a) bathymetric map showing the reservoir outline at full pool (82.1 m above sea level) with 10 m depth contours; b) 2008 acoustic survey transects (bold red lines), limnology stations, and 2007 gill net and Gee trap sampling sites. Light red lines are optional acoustic transects that were not sampled in 2008.

Stave Reservoir is an ultra-oligotrophic ecosystem characterized by extremely low dissolved phosphorus concentration, very low algal biomass, very low littoral and pelagic primary production, and low zooplankton standing crop (Stockner and Beer 2004). During summer stratification, the average depth of the epilimnion (the uppermost and warmest layer of water) is approximately 7 m. Epilimnetic temperature often reaches 20ºC in summer. Dissolved oxygen concentration remains close to saturation with respect to temperature throughout the water column at all times (Bruce et al. 1994, Stockner and Beer 2004).

The shoreline of the main basin where the survey was conducted is variously composed of bedrock, gravel, and finer sediments, with dead standing timber and decomposing woody debris present in many places. The bottom drops off steeply from shore in most places, leaving little littoral habitat over most of the study area (Figure 2). Rooted aquatic plants are rare in

Stave Reservoir and are absent from the study area (J. Bruce, BC Hydro, personal communication). Under Combo 6, the typical annual drawdown will be approximately 4.5 m, with seasonally different target elevations. The surface elevation target will be a 77-79 m above sea level, except from May 15 to September 7 when it will increase to 80-81.5 m. The surface elevation was 77.5 m at the time of the 2008 survey.

3.0 METHODS

An acoustic survey (scientific echo sounding) was conducted the night of September 23-24, 2008 to estimate the abundance of fish in Stave Reservoir. Gill netting that was used to apportion the acoustic data was conducted during the previous fall, from October 8-13, 2007. Temperature profiles were made during both sampling events for comparison. Dissolved oxygen (DO) was also profiled in 2008. All sampling took place within the debris-free portion of the main lake basin shown in Figure 2.

3.1 Limnological Sampling and Analysis

Temperature and dissolved oxygen (DO) concentrations were measured over the upper 60 m of the water column at two locations in the main lake basin (Figure 2). Measurements were made every 5 m using a calibrated YSI model 51B temperature-DO meter. These water-column profiles were taken to aid interpretation of vertical distributions of fish that were observed during acoustics and gill netting.

3.2 Fish Sampling

3.2.1 Field Activities

Collection of gill net data in 2007 that were used to apportion the 2008 acoustic estimate is described in this section. The 2007 gill net sampling was mostly the same as that in 2005 to insure comparability among years, with a few changes to better meet study needs. Soak time was shortened in 2007 to avoid inflation of char capture rates that would occur if char are attracted to nets containing prey species. All nets were set in late afternoon or early evening and pulled before daylight; there were no overnight sets in 2007. Mid-lake as well as nearshore sets were made for the first time in 2007 to allow comparison of species composition in the two areas.

Gill netting took place on four nights from October 8-13, 2007. Nearshore sets were made near the ends of acoustic transects 6 and 11 at the same northern and southern stations sampled in 2005 (Figure 2). Mid-lake sets were made at adjacent stations 1,100-1,300 m from shore. All nets were standard 91.2 x 2.4 m floating and 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).

Surface, mid-water, and bottom sets were made at each nearshore station. All nearshore sets were perpendicular to the shoreline. Large and small mesh ends of nets were placed toward shore on alternate nights. Surface and bottom sets were attached to shore and anchored at the offshore end, buoyed and marked with a light to minimize the hazard to boat traffic. Bottom sets fished from shore to deep water below the thermocline. Floating nets sampled the upper 2.4 m of the water column from the littoral zone (shoreward of the 6 m depth contour) to the pelagic zone (offshore open water). Nearshore, mid-water sets sampled horizontally from bottom out into the pelagic zone within the thermocline where fish were observed on echograms. They were suspended from floats on dropper lines to the desired depth and marked with buoys. In 2007, mid-water nets fished the 23-30 m depth range. Up to three mid-water nets were strung end-to-end on a single placement to extend coverage farther from shore. Four surface, four bottom, and eight mid-water nets were set at nearshore stations, sampling the 0-45 m range of the water column from shore to 270 m offshore of the 25 m depth contour.

Surface and mid-water sets were made at each mid-lake station. Mid-lake nets were set parallel to shore to facilitate placement and retrieval in rough, windy conditions. Mid-water sets were deployed in the same way and at the same depths as near shore, however, mid-lake nets were at least 35 m above the bottom over their entire length. Mid-water nets were strung end-to-end in pairs to facilitate deployment. Four surface and four mid-water nets were fished at mid-lake stations in the 0-2.4 m (epilimnion) and 23-30 m (thermocline) depth ranges.

For each set, the depth of water at the inshore and offshore ends was measured with an echo sounder and depths of intermediate panels were estimated by linear interpolation. Geographical coordinates of each set were recorded on a GPS. Set and retrieval times were recorded to the nearest minute. The mesh size and position of each panel relative to shore was noted and catches were recorded by individual net panel.

In the field, all fish were identified to species, counted, measured to the nearest mm (fork length), and weighed to the nearest gram. Fish were anaesthetized with clove oil prior to handling when necessary. Structures for aging were taken from salmonids only. Scales were removed from preferred body areas and stored in labeled envelopes. Otoliths were also obtained from any char that were sacrificed for biological sampling. Tissue samples were taken from char using a paper punch to obtain a small piece of the operculum for DNA analysis. DNA samples were individually stored in glass vials filled with ethanol (not denatured) prior to analysis. An effort was made to return all live fish to the reservoir quickly, without harm.

3.2.2 Processing and Analysis

The 2007 gillnet data were analyzed with respect to several factors. Catch and catch per unit effort (CPUE) were computed for individual gill net panels (fish/panel-hour) to allow assessment of spatial abundance patterns. CPUE was calculated for each species in relation to depth in the water column and lateral distance from shore or from the point where a net met the lake bottom. It was also calculated with respect to total water column depth to define the boundary between slope zone and pelagic zone fish assemblages as recommended by Beauchamp et al. (in preparation).

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.

3.3 Acoustic Surveys

3.3.1 Sampling

Acoustic sampling methods were the same in 2008 as in previous years. Only night sampling was performed in 2008 (as in 2006 and 2007), based on 2005 results indicating that night was the best time to estimate abundance and biomass of all species of interest (Stables and Perrin 2006). A mobile acoustic survey was conducted on September 23-24 from 2058-0216 hours. Survey methods generally followed protocols described in standard fisheries acoustics texts (Thorne 1983, MacLennan and Simmonds 1992, Brandt 1996).

Acoustic sampling was performed from a 6 m long, covered aluminum skiff at a transecting speed of 1.5-2 m/s (Table 1). 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, it 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). The collection of side-looking data was deemed necessary because trout are often surface oriented (Johnston 1981, Yule 2000, Stables and Thomas 1992, Stables and Perrin 2006). Both down-looking and side-looking scans were made on all acoustic transects.

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 at the time of collection. Latitude and longitude from the GPS were added to acoustic data files as they were logged. Additional equipment specifications and data collection settings are shown in Table 1.

Table 1. Equipment specifications and settings for collection and processing of acoustic data collected from Stave Lake, September 23, 2008.

Project Phase	Category	Parameter	Value
Data collection	transducer	type[1]	split-beam
"	"	sound frequency	201 kHz
"	"	nominal beam angle	6.7 deg
"	"	depth of face	0.5 m
"	settings	pulse width	0.4 ms
"	"	data collection threshold	-70 dB
"	"	minimum data range[2]	1.0 m
"	"	Time Varied Threshold	40 log R
"	"	ping rate[3]	4-6 pps
"	GPS	type[4]	differential
"	"	Datum	NAD83
"	Other	Transecting speed[3]	1.5-2 m/s
Data Analysis	general	calibration offset	0.0 dB
"	"	Time Varied Gain	40 log R
"	"	minimum threshold[5]	-65 dB
"	"	maximum threshold[5]	-25 dB
"	"	beam pattern threshold	-6 dB
"	"	beam full angle	6.7 deg
"	"	Single target filters	0.5-1.5 @ -6 dB
"	range processed[2]	down-looking	2-80 m
"	"	side-looking	10-25 m
"	fish tracking, per fish	minimum # echoes	2
"	"	max range change[6]	0.2 m
"	"	max ping gap	1

[1] BioSonics DT-X split-beam digital scientific echo sounder.
[2] range from transducer.
[3] slower transect speeds were used with slower ping rates so pings/m traveled were constant.
[4] WAAS differential GPS.
[5] Processing threshold after application of calibration offset.
[6] maximum allowable range change in x, y, or z dimension.

Due to deteriorating weather during the survey, only five of six planned transects were completed before the lake became too rough for sampling (Figure 2). Of these transects, three were in the north half of the lake and two were in the south half. Transects were approximately perpendicular to the longitudinal axis of the lake, spaced at 2.2 km intervals, and they extended shoreward as close as safety allowed. Because of steep drop-offs and standing timber along the shoreline, transects ended at the 17 m depth contour on average. Each transect was sampled twice in immediate succession, first in side-looking mode, then in down-looking mode.

3.3.2 Processing and Analysis

Fish were counted on electronic echograms according to standard echo-trace counting methods (Thorne 1983, MacLennan and Simmonds 1992). Computer files were processed in the office using Echoview© software to extract fish traces, to measure target strength (TS, the acoustic size of fish), and to determine sampling volumes. Down-looking data were used to compute fish density at depths greater than 5 m, while side-looking data were used to represent the uppermost 5 m of the water column. Fish traces were recognized on echograms by their shape, cohesiveness, TS, and number of echoes. Minimum and maximum acceptance thresholds for trace counts were -65 dB and -25 dB, respectively. Other fish tracking settings are listed in Table 1.

Excessive noise from sporadic rough, windy conditions made it necessary to exclude some of the sidelooking data from analysis. Usable sidelooking data were collected on transects 1, 7, and 9 (Figure 2). Bubbles were nearly absent and required no correction in 2008.

TS was determined by the split-beam method (MacLennan and Simmonds 1992). Accuracy of acoustic measurements was assured by field calibration tests. In-situ TS measurements of a standard sphere were made during the survey. Results of the field test were within 0.3 dB of the expected value (-39.5 dB), so no calibration correction was necessary. Lengths of individual fish that were observed with acoustics were estimated from down-looking TS using Love's (1977) equation for fish insonified within +/-45 degrees of dorsal aspect:

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

Because TS is affected by factors other than fish size (MacLennan and Simmonds 1992) 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 zones, functional habitat zones defined by fish species composition determined from gill netting (see explanation below). 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 full beam angle. 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 each spatial stratum, mean fish density was expanded in proportion to stratum volume, and resulting abundance estimates were summed to obtain the total population estimate. Variance and 95% confidence intervals of this estimate were calculated for a stratified random sample subdivided by habitat zones and depth intervals (Cochran 1977). 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.

Relative abundance of fish captured in 2007 gill net sets was used to apportion the acoustic estimate among species. Fish and acoustic data from corresponding depths and locations were compared for this analysis (e.g., floating gill net data were matched with side-looking acoustic data from the 0-5 m depth range). Only gill net panels corresponding to the area sampled with acoustics (offshore of the 17 m depth contour on average) were used for species apportionment. Additionally, fish species composition in relation to total water column depth was used to differentiate slope and pelagic habitat zones as recommended by Beauchamp et al (in preparation). For apportionment of 2008 data, the 40 m depth contour was used as the boundary between zones as in 2007. Species composition, zone volume, and an acoustic population estimate were computed separately for each zone.

Mean weights of fish captured in gill nets were used to compute species and cohort biomass for fish over 100 mm long. Fish smaller than this size 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 2007 gill net data (all fish in the acoustic sample less than 100 mm long were assumed to be kokanee).

4.0 RESULTS

4.1 Limnology

Temperature profiles at the two stations indicated that thermal stratification was strong during the 2008 survey (Figure 3). Temperature ranged from 14.5-15.5 ºC in the epilimnion (0-10 m) to 5 ºC at 60 m. The 6-13 ºC temperature range typically preferred by kokanee extended from just below the epilimnion to 30-40 m. DO exceeded 9 mg/l at all depths measured.

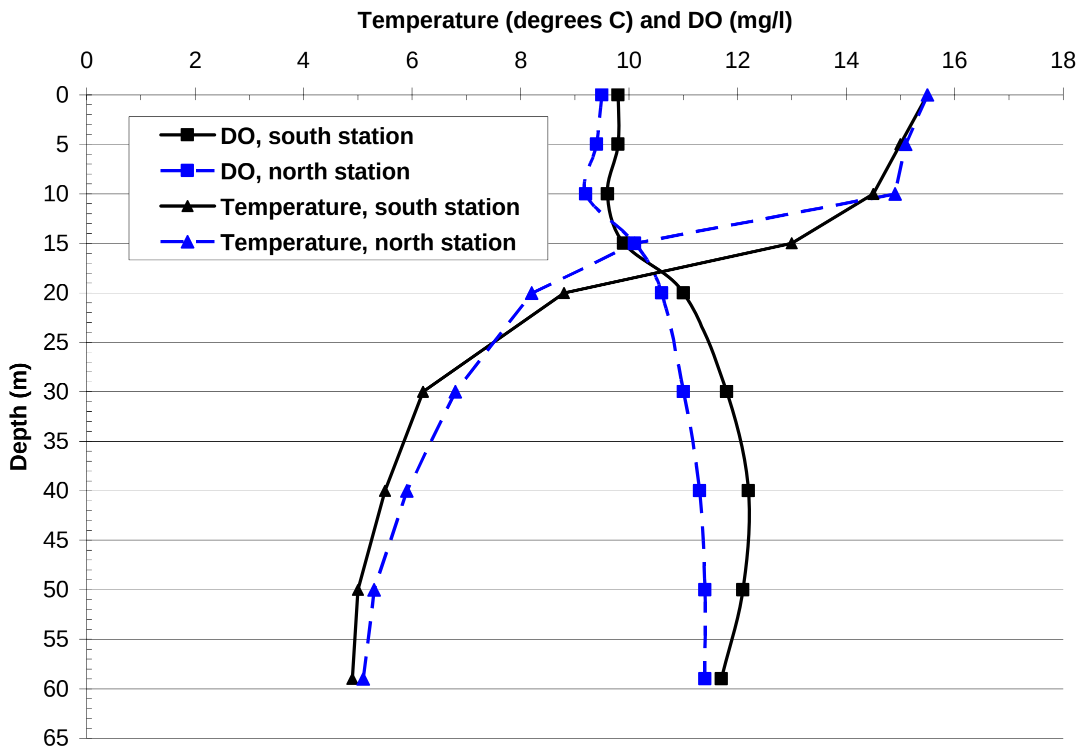

Figure 3. Temperature and DO profiles during the September 23, 2008 acoustic survey. The horizontal grid with 5 m spacing represents depth intervals used for the acoustic population estimate.

4.2 Fish Sampling

4.2.1 Gee Traps

A total of 34 fish were captured in the 12 traps that were set in 2007 (Table 2). Northern pikeminnow dominated the catch at both stations and made up 56% of the total catch in traps. Sculpins (*Cottus sp.*) and redside shiners were also captured at both stations. A single unidentified juvenile salmonid was captured at the south station. Catch per unit effort was highest at the south station for all species combined and for all individual species, except redside shiner.

4.2.2 Gill Nets

4.2.2.1 Catch and CPUE

A total of 22 surface, bottom, and mid-water gill net sets were made in nearshore and mid-lake areas in 2007. These sets captured 219 fish in 665 panel-hours of sampling (111 net-hours), with non-salmonids accounting for 74% of all fish captured (Table 3). Redside shiner (30% of total), Northern pikeminnow (25%), and kokanee (19%) were the predominant species captured in gill nets.

Four native char were captured in 2007, three at the north station and one at the south station. DNA analysis from three of them showed all were bull trout, *Salvelinus confluentus*. Considering the small sample size, it is possible that both bull trout and Dolly Varden inhabit in the reservoir, so char are referred to as “native char” throughout this report.

Catch composition of nearshore and mid-lake sets was distinctly different. Mid-lake sets (surface and mid-water, depth range 0-30 m) captured mainly kokanee, plus a few cutthroat trout and one northern pikeminnow (Table 3). Effort in this zone was considerable; a total of 401 panel-hours were expended at the surface and mid-water at depths where fish were numerous on echograms. Nearshore sets (surface, mid-water, and bottom, depth range 0-45 m) captured all species encountered in the study (Table 3). Native char, largescale sucker, peamouth chub, redside shiner, and rainbow trout were captured only in nearshore sets, and northern pikeminnow were captured mainly in nearshore sets.

Some differences in species abundance were apparent between the north and south stations (Table 3). Cutthroat trout, peamouth chub, and redside shiner were most abundant at the south station. Rainbow trout were only captured at the north station (a single fish) and mean CPUE was highest there for native char. Other species (kokanee, largescale sucker, and northern pikeminnow) were about equally abundant at both stations.

The distribution of fish species varied markedly in relation to depth in the water column and lateral distance from shore or bottom (Figure 4). Within 100 m laterally of shore or bottom, the fish assemblage was dominated by redside shiner in the upper water column (0-5 m deep) and by largescale sucker, northern pikeminnow, and peamouth chub in deeper strata from 5 to 35 m. Farther offshore, the fish community was dominated by kokanee, with some trout and pikeminnow also present. Cutthroat trout occurred nearshore and mid-lake mainly 0-5 m deep, however, one large cutthroat trout was captured mid-lake 25-30 m deep. The highest CPUE for cutthroat was 25-100 m from shore. Native char were only found within 25 m of shore and in the 5-30 m depth range, with highest CPUE 5-10 m deep. Kokanee were very widespread, occurring from shore to mid-lake 0-40 m deep in the water column, with highest densities 150-250 m laterally from bottom in mid-water sets (at a depth of 25-30 m). In contrast, the single rainbow trout that was captured in 2007 was taken 50-75 m from shore in the upper 5 m of the water column.

Similar differences in species distribution patterns were apparent in plots of CPUE versus total water column depth (Figure 5). Beyond the 40 m depth contour most fish were kokanee, with cutthroat trout, northern pikeminnow, and redside shiner present in much lower abundance. Of these less common offshore species, cutthroat and pikeminnow were captured in mid-lake sets, whereas redside shiner was not. Native char were captured at a water column depth no greater than 30 m. A depth of 40 m was chosen as the boundary between slope and pelagic zone habitats.

Using this definition, 82% of fish in the pelagic zone were kokanee, while the dominant species in the portion of the slope zone sampled with acoustics (offshore of the 17 m depth contour on average) were largescale sucker (27%) and northern pikeminnow (23%, Table 4). Native char comprised 8% of the slope zone fish and 0% of pelagic fish.

Species composition tables that were used for apportionment of the acoustic estimate showed similar relative species abundance with some exceptions (Tables 5 and 6). Suckers were excluded from slope zone species based on the assumption that they are usually found too close to the bottom for detection with acoustics. This assumption was also made for 2005 and 2006 population estimates. Redside shiners were not included in pelagic zone species composition because although a small number (two) were captured in surface sets with a water column depth of 45 m, none were captured in extensive mid-lake sampling. Species composition in depth intervals for which there was no data (e.g., 5-10 m) or low catches was estimated using data from adjacent intervals.

Table 2. Catch and CPUE (fish/trap-hour) in Gee-traps, summarized by station, period, and species. Stave Lake, October 8-13, 2007.

Station	Depth Range (m)	Trap-hours	Number of traps	Species Name									
				juv. salmonids		pikeminnow		prickly sculpin		redside shiner		Total	
				Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
North	1.0-6.0	74.7	12	0	0.000	6	0.080	3	0.040	5	0.067	14	0.187
South	0.5-6.3	35.3	12	1	0.028	13	0.368	5	0.142	1	0.028	20	0.567
Combined	0.5-6.3	110.0	24	1	0.009	19	0.173	8	0.073	6	0.055	34	0.309

Table 3. Catch and CPUE (catch per panel-hour) in gill nets at north and south stations from nearshore and mid-lake sets, Stave Lake, October 8-13, 2007. Data from surface, bottom, and mid-water sets within zones were combined. All sets were put out in the afternoon or evening and retrieved before daylight.

			Species																	
		Panel	cutthroat trout		native char		kokanee		largescale sucker		peamouth chub		pikeminnow		rainbow trout		redside shiner		Total Catch	
Station	Zone	hours	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
North	Nearshore	254.5	3	0.012	3	0.012	4	0.016	15	0.059	1	0.004	24	0.094	1	0.004	26	0.102	77	0.303
	Mid-lake	53.9	0	0.000	0	0.000	15	0.278	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	15	0.278
	Combined	308.4	3	0.010	3	0.010	19	0.062	15	0.049	1	0.003	24	0.078	1	0.003	26	0.084	92	0.298
South	Nearshore	152.9	4	0.026	1	0.007	17	0.111	18	0.118	8	0.052	29	0.190	0	0.000	40	0.262	117	0.765
	Mid-lake	204.1	3	0.015	0	0.000	6	0.029	0	0.000	0	0.000	1	0.005	0	0.000	0	0.000	10	0.049
	Combined	357.0	7	0.020	1	0.003	23	0.064	18	0.050	8	0.022	30	0.084	0	0.000	40	0.112	127	0.356
North & south	Both zones	665.4	10	0.015	4	0.006	42	0.063	33	0.050	9	0.014	54	0.081	1	0.002	66	0.099	219	0.329

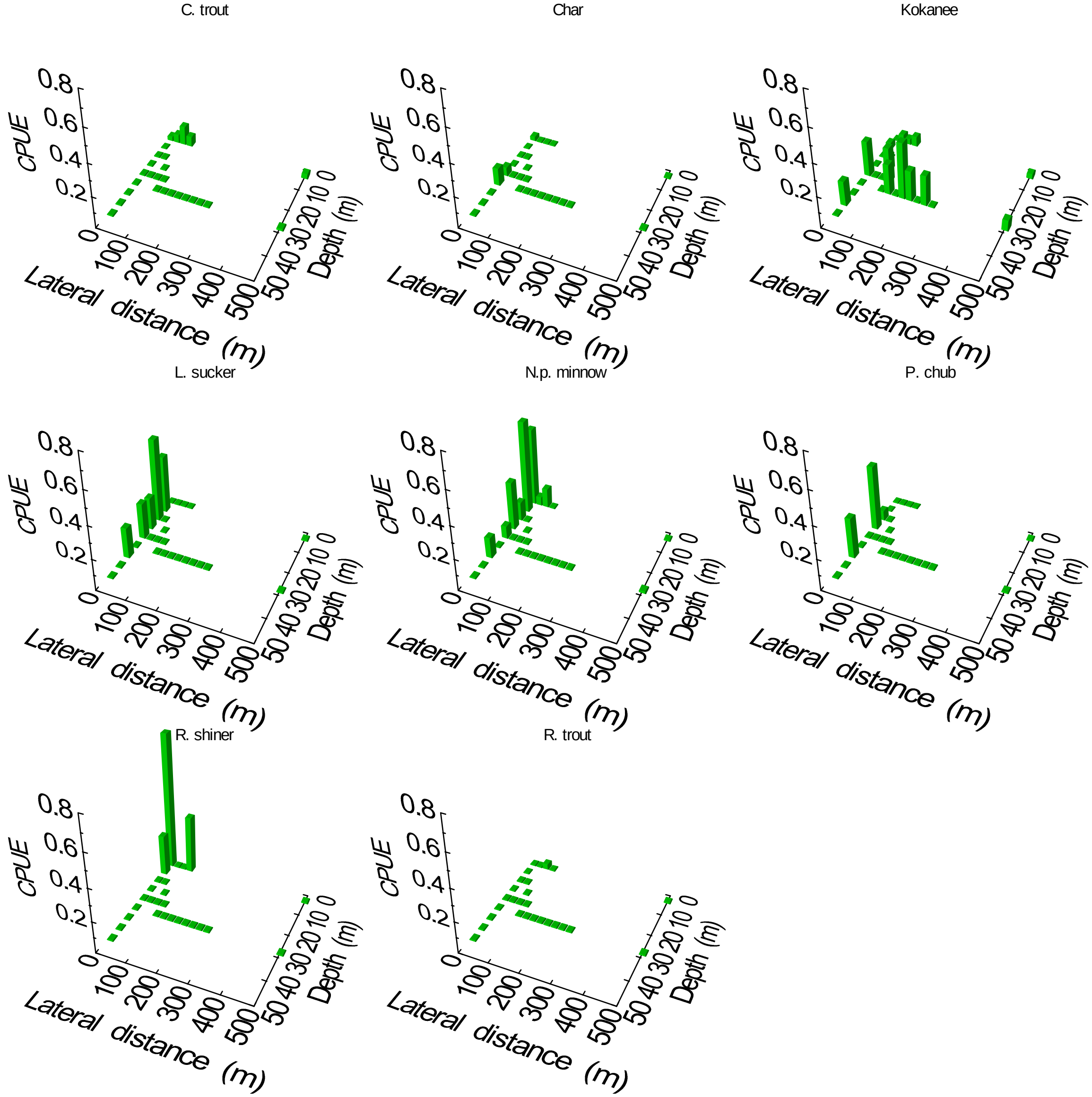

Figure 4. CPUE (catch per panel-hour) for each species captured in gill nets in 2007, categorized by depth and lateral distance from bottom. Surface, mid-water, and bottom sets from both stations were pooled for these graphs. Mid-lake sets are plotted at a lateral distance of 500 m; their actual distance from shore was 1,100-1,300 m.

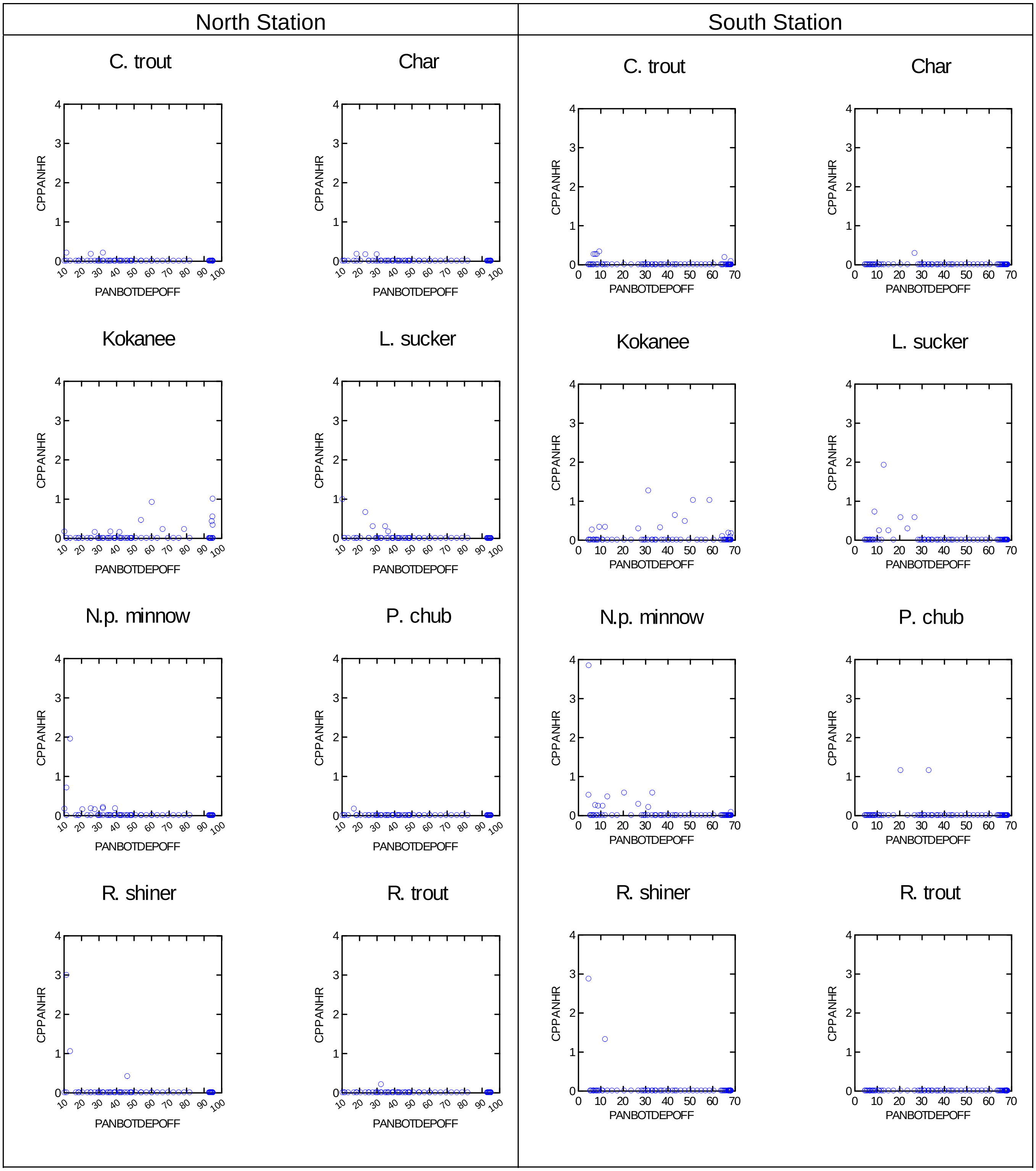

Figure 5. CPUE (Catch per panel-hour) of each species versus total water column depth, Stave Lake north and south gill net stations, October 2007.

Table 4. Gill net catch (upper table) and species composition (lower table) by analysis zones, Stave Lake, October 8-13, 2007. All types of sets were combined within each zone. Acoustics only sampled the slope and pelagic zones.

	Catch by zone		
Species	**Shallows (<17 m)**	**Slope (17-40 m)**	**Pelagic (>40 m)**
cutthroat trout	5	2	3
kokanee	4	10	28
largescale sucker	19	14	0
native char	0	4	0
northern pikeminnow	41	12	1
peamouth chub	0	9	0
rainbow trout	0	1	0
redside shiner	64	0	2
Combined	133	52	34

	Percent of catch within zone		
Species	Shallows (<17 m)	Slope (17-40 m)	Pelagic (>40 m)
cutthroat trout	4%	4%	9%
kokanee	3%	19%	82%
largescale sucker	14%	27%	0%
native char	0%	8%	0%
northern pikeminnow	31%	23%	3%
peamouth chub	0%	17%	0%
rainbow trout	0%	2%	0%
redside shiner	48%	0%	6%
Grand Total	100%	100%	100%

Table 5. Catch, raw percentage of catch within layer, and estimated species composition by depth layer in the portion of the slope zone sampled with acoustics (between 17 m and 40 m depth contours), Stave Lake, October 2007. This table was used to apportion the 2008 acoustic estimate of fish > 100 mm long in the slope zone.

Depth layer	Species								Total
	C. trout	Char	Kokanee	L. sucker	N.p. minnow	P. chub	R. shiner	R. trout	
Catch by depth layer									
0-5 m	2	1	0	0	4	0	0	1	8
5-10 m	0	0	0	0	0	0	0	0	0
10-15 m	0	0	0	0	0	1	0	0	1
15-20 m	0	0	1	2	3	4	0	0	10
20-25 m	0	2	9	9	3	0	0	0	23
25-30 m	0	1	0	0	0	0	0	0	1
30-35 m	0	0	0	3	2	4	0	0	9
35-40 m	-	-	-	-	-	-	-	-	-
Raw percentage within layer									
0-5 m	25%	13%	0%	0%	50%	0%	0%	13%	100%
5-10 m	0%	0%	0%	0%	0%	0%	0%	0%	100%
10-15 m	0%	0%	0%	0%	0%	100%	0%	0%	100%
15-20 m	0%	0%	10%	20%	30%	40%	0%	0%	100%
20-25 m	0%	9%	39%	39%	13%	0%	0%	0%	100%
25-30 m	0%	100%	0%	0%	0%	0%	0%	0%	100%
30-35 m	0%	0%	0%	33%	22%	44%	0%	0%	100%
35-40 m	-	-	-	-	-	-	-	-	-
Estimated species composition by layer									
0-5 m	25%	13%	0%	0%	50%	0%	0%	13%	100%
5-10 m	13%	6%	0%	0%	25%	50%	0%	6%	100%
10-15 m	0%	0%	6%	0%	19%	75%	0%	0%	100%
15-20 m	0%	0%	13%	0%	38%	50%	0%	0%	100%
20-25 m	0%	14%	64%	0%	21%	0%	0%	0%	100%
25-30 m	0%	38%	21%	0%	18%	22%	0%	0%	100%
30-35 m	0%	0%	0%	0%	33%	67%	0%	0%	100%
35-40 m	0%	0%	0%	0%	33%	67%	0%	0%	100%

* Numerous suckers were captured in bottom set gill nets in the slope zone, however, they were likely too close to the bottom to be detected with acoustics. Therefore, they were excluded from species composition estimates for acoustics in the slope zone.

Table 6. Catch, raw percentage of catch within layer, and estimated species composition by depth layer in the pelagic zone (offshore of the 40 m depth contour), Stave Lake, October 2007. This table was used to apportion the 2008 acoustic estimate of fish > 100 mm long in the pelagic zone.

Depth layer	C. trout	Char	Kokanee	L. sucker	N.p. minnow	P. chub	R. shiner	R. trout	Total
Catch by depth layer									
0-5 m	2	0	2	0	0	0	2	0	6
5-10 m									
10-15 m									
15-20 m									
20-25 m	0	0	3	0	0	0	0	0	3
25-30 m	1	0	22	0	1	0	0	0	24
30-35 m									
35-40 m	0	0	1	0	0	0	0	0	1
40-45 m	0	0	0	0	0	0	0	0	0
Raw percentage within layer									
0-5 m	33%	0%	33%	0%	0%	0%	33%	0%	100%
5-10 m									
10-15 m									
15-20 m									
20-25 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
25-30 m	4%	0%	92%	0%	4%	0%	0%	0%	100%
30-35 m									
35-40 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
40-45 m	0%	0%	0%	0%	0%	0%	0%	0%	100%
*Estimated species composition by layer**									
0-5 m	50%	0%	50%	0%	0%	0%	0%	0%	100%
5-10 m	25%	0%	75%	0%	0%	0%	0%	0%	100%
10-15 m	13%	0%	87%	0%	0%	0%	0%	0%	100%
15-20 m	2%	0%	96%	0%	2%	0%	0%	0%	100%
20-25 m	2%	0%	96%	0%	2%	0%	0%	0%	100%
25-30 m	2%	0%	96%	0%	2%	0%	0%	0%	100%
30-35 m	2%	0%	96%	0%	2%	0%	0%	0%	100%
35-40 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
40-45 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
45-50 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
50-55 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
55-60 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
60-65 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
65-70 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
70-75 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
75-80 m	0%	0%	100%	0%	0%	0%	0%	0%	100%
80-85 m	0%	0%	100%	0%	0%	0%	0%	0%	100%

* Two redside shiners were caught in surface sets with bottom depth about 45 m, however, none were caught in extensive mid-lake sampling. They were therefore assumed to be very uncommon offshore and were not included in the species composition estimate for apportionment of acoustics in the pelagic zone.

4.2.3 Size and Age of Fish

Mean lengths and weights of cutthroat trout, rainbow trout, kokanee, and native char caught in gill nets in 2007 (none were captured in traps) were 305 mm (333 g), 223 mm (124 g), 180 mm (72 g), and 418 mm (557 g), respectively (Table 7). Mean condition factors of all salmonid species were greater than 1.0, ranging from 1.07 for native char to 1.19 for kokanee, indicating that these species were in good condition (Table 7). Weight versus length regressions were highly significant *(P*<0.001) for all salmonids, with r^2 values exceeding 0.97 (Figure 6 and Table 8). Length frequency distributions of salmonids exhibited one clear mode, that of age 2 kokanee at 180-200 mm (Figure 7). Sample sizes of other species were too small for modes to be apparent. Age-length plots showed that all salmonid species increased in size with age for the few age groups that were captured (Figure 8).

Salmonid age composition and weight data that were used for the 2008 biomass estimate appear in Table 9. Age ranges were 1-4 years for cutthroat trout and 1-3 years for kokanee. The single rainbow trout captured in 2007 was 2 years old. Native char that were aged from otoliths ranged from 4 to 5 years old, while two larger un-aged char were estimated to be 8 and 10 years old from plots of age versus length. Due to small sample sizes for individual depth intervals, catches from all depths were pooled for age composition and age specific mean weight estimates. Mean weights of salmonids and non-salmonids for all ages combined are listed in Table 9.

Mean lengths and weights of non-salmonids caught in gill nets and traps were 252 mm and 217 g for largescale sucker, 147 mm and 39 g for peamouth chub, 175 mm and 124 g for northern pikeminnow, and 106 mm and 15 g for redside shiner (Table 7). The mean condition factors of all non-salmonids were greater than or equal to 1.0, ranging from 1.05 for pikeminnow to 1.26 for redside shiner (Table 7). Weight versus length regressions were highly significant (*P*<0.001) for all non-salmonids, with all r^2 values exceeding 0.97 (Figure 6 and Table 8). Length-frequency distributions of largescale sucker and northern pikeminnow suggested the presence of several age groups. Largescale sucker had several indistinct modes from 160-380 mm. Northern pikeminnow had a major peak at 120-140 mm and low numbers of other size groups up to 440 mm. Redside shiners showed a single major peak at 100-120 mm, while the sample size for peamouth chub and unidentified sculpins was too small for clear definition of modes.

Table 7. Length, weight, and condition factor of fish captured in gill nets in Stave Lake, October 2007

	Length (mm)					Weight (g)					
Species	**Sample size**	**Min**	**Max**	**Mean**	**SD**	**Sample size**	**Min**	**Max**	**Mean**	**SD**	**CF**
Cutthroat trout	10	233	402	305	59	10	134	707	333	189	1.08
Rainbow trout	1	223	223	223		1	124	124	124		1.12
Kokanee	42	123	264	180	31	40	20	145	72	31	1.19
Native char	4	257	586	418	144	3	187	1040	577	431	1.07
Largescale sucker	33	160	364	252	69	33	42	535	217	163	1.09
Peamouth chub	9	114	173	147	25	9	14	60	39	19	1.11
Northern pikeminnow	54	108	426	175	73	41	17	905	124	196	1.05
Redside shiner	65	93	126	106	6	57	11	26	15	2	1.26

Table 8. Weight versus length regression equations for salmonids and non-salmonids in the 2007 gill net catch.

Species	**Weight versus length equation**				**Sample size**	**r^2**
Cutthroat trout	Log(g) =	2.920	x log(mm)	-4.769	10	0.995
Rainbow trout	Log(g) =	-	x log(mm)	-	1	-
Kokanee	Log(g) =	3.068	x log(mm)	-5.079	40	0.974
Native char	Log(g) =	2.745	x log(mm)	-4.322	3	0.991
Largescale sucker	Log(g) =	3.050	x log(mm)	-5.081	33	0.998
Peamouth chub	Log(g) =	3.242	x log(mm)	-5.480	9	0.972
N. pikeminnow	Log(g) =	3.182	x log(mm)	-5.389	41	0.990
Redside shiner	Log(g) =	2.262	x log(mm)	-3.410	9	0.972

Table 9. Age and size of salmonids, from October 2007 gill net sampling. Age of oldest char (8 and 10) was estimated from 2005 and 2007 age-length relationships. Catches from slope and pelagic zones were pooled

	Age	Species: Cutthroat trout	Native char	Kokanee	Rainbow trout
Number captured	1	0	0	10	0
	2	5	0	31	1
	3	3	1	0	0
	4	2	0	0	0
	5	0	1	0	0
	8	0	1	0	0
	10	0	1	0	0
	Combined	10	4	42	1
Percentage of catch	1	0.0%	0.0%	23.8%	0.0%
	2	50.0%	0.0%	73.8%	100.0%
	3	30.0%	25.0%	2.4%	0.0%
	4	20.0%	0.0%	0.0%	0.0%
	5	0.0%	25.0%	0.0%	0.0%
	8	0.0%	25.0%	0.0%	0.0%
	10	0.0%	25.0%	0.0%	0.0%
	Combined	100%	100%	100%	100%
Mean fork length (mm)	1			139	
	2	266		191	223
	3	330	257	264	
	4	363			
	5		350		
	8		480		
	10		586		
Mean weight (g)	1			38	
	2	208		86	124
	3	422	187	224*	
	4	510			
	5		504		
	8		1,040		
	10		1,887*		

* Weight was unrecorded. It was estimated using the 2007 length-weight regression equation.

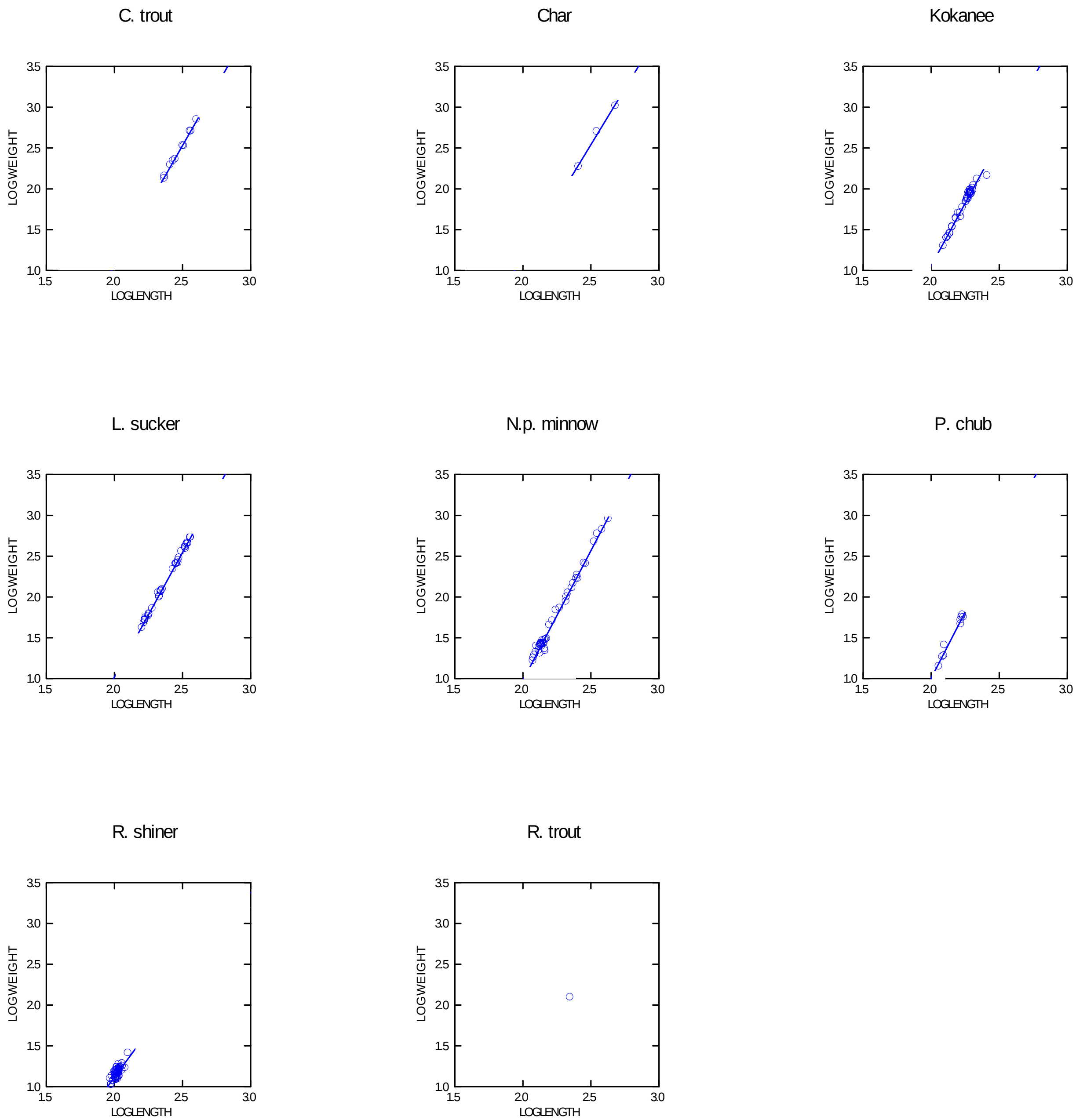

Figure 6. Weight versus length scatter plots for salmonids and non-salmonids from gill net and trap catches, Stave Lake October 2007.

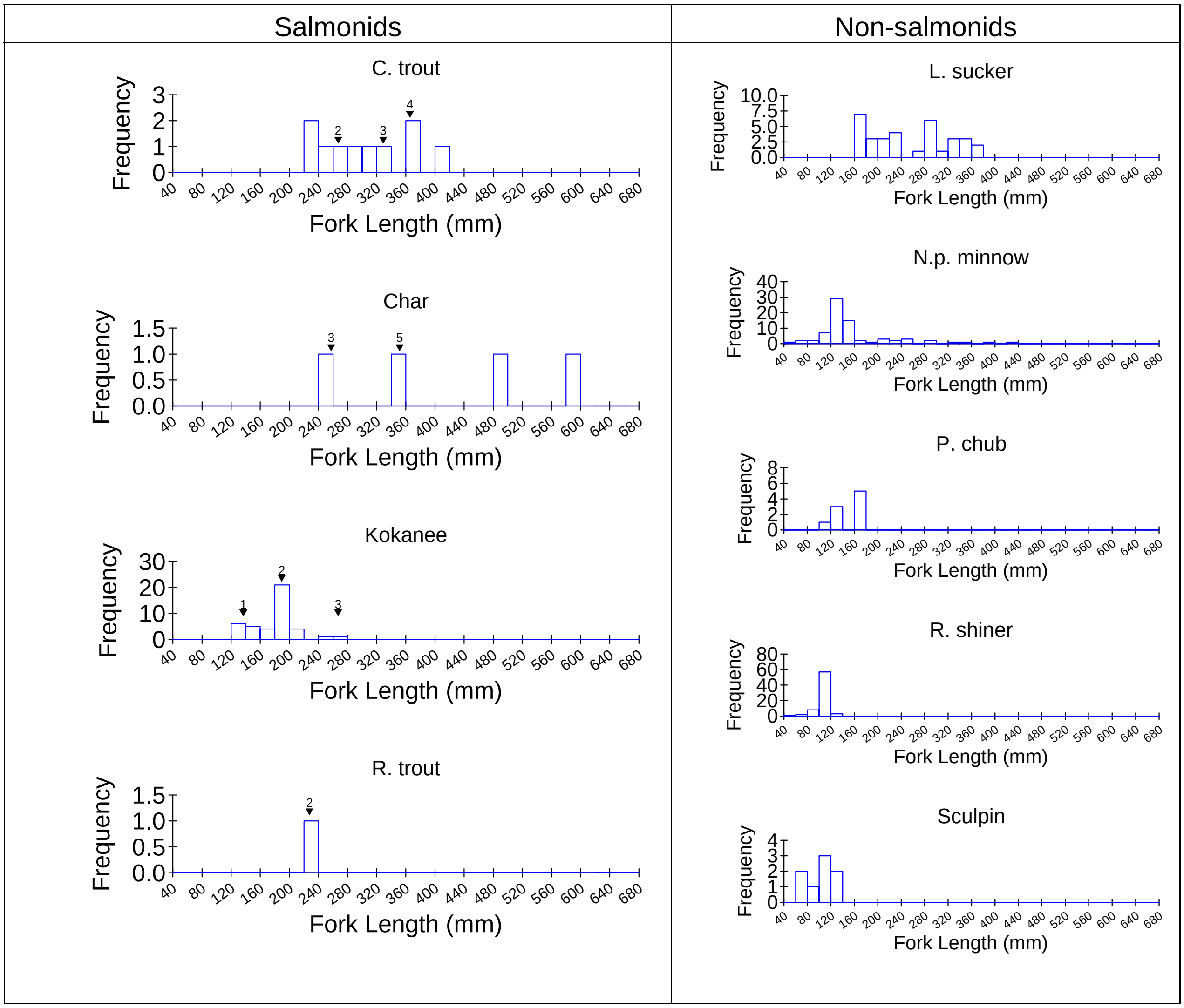

Figure 7. Length-frequency distributions of fish captured in gill nets and traps in Stave Lake, October 2007. Numbered arrows indicate mean lengths of designated age groups.

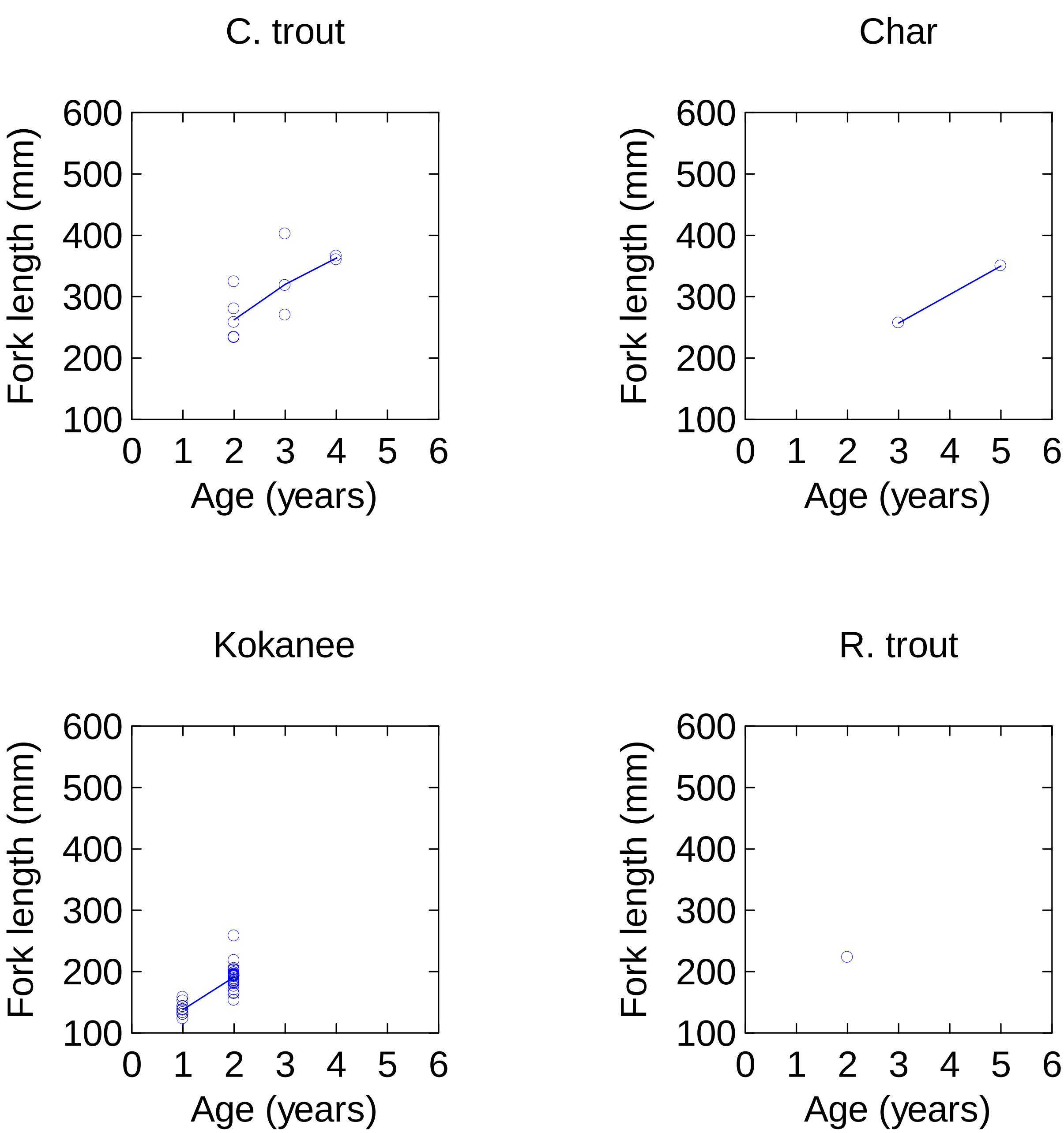

Figure 8. Length versus age of salmonids captured in gill nets in Stave Reservoir, October 2007. Lines connect mean lengths of age groups.

4.2.4 Salmonid Stomachs Contents

Stomachs were examined from 6 cutthroat trout, 11 kokanee, and 2 native char in 2007. All contained food items. General prey categories were terrestrial invertebrates (insects and other arthropods), benthic invertebrates (mainly insects), zooplankton, and fish. Cutthroat trout stomach contents (% of counts) were 66% benthic invertebrates, 30% terrestrial invertebrates, and 1% fish. Fish (sticklebacks or unidentified species) were present in three of six cutthroat stomachs (Figure 9). Kokanee stomach contents were 95% zooplankton, 4% terrestrial invertebrates, and 1% benthic invertebrates. Native char stomachs mostly contained fish (88%), plus some benthic (6%) and terrestrial (6%) invertebrates. The larger of the two char sampled, a 350 mm fish, contained 15 sticklebacks. The smaller one (257 mm) contained terrestrial and benthic insects.

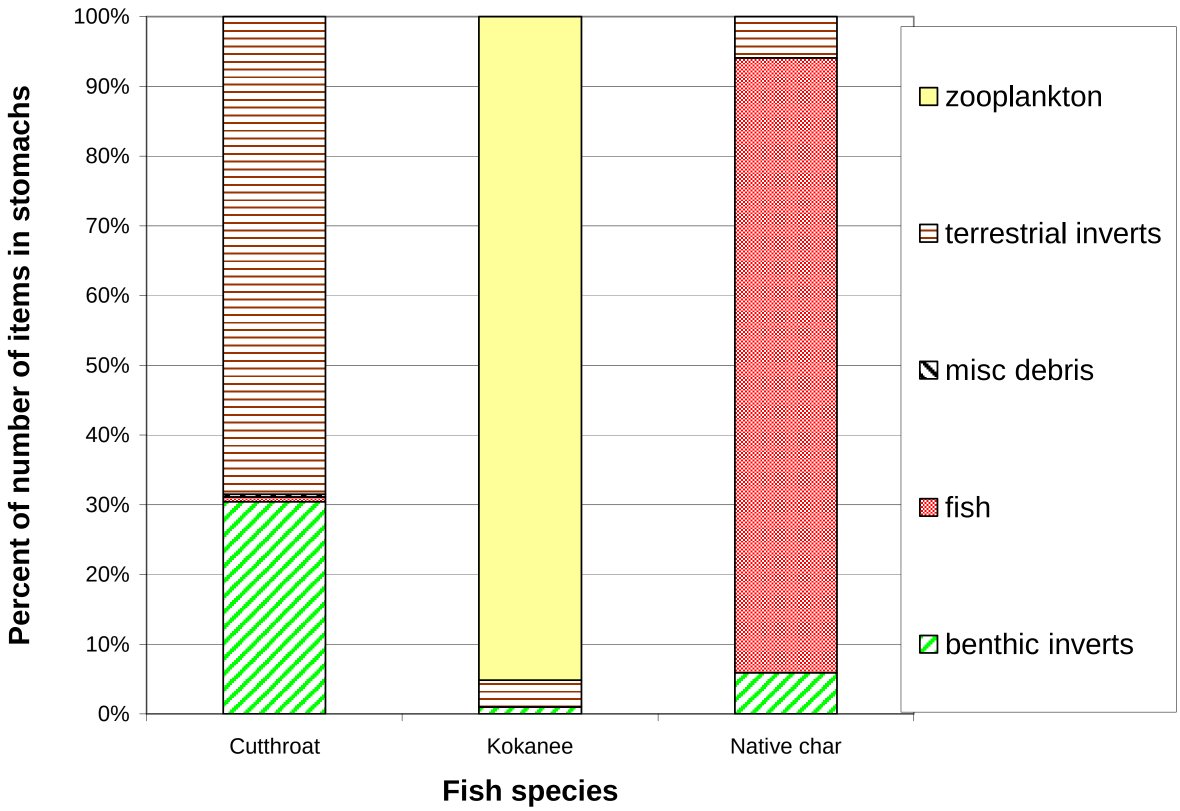

Figure 9. Contents of salmonid stomachs, expressed as percentage of composition by numbers. Stomachs were from fish captured in gill nets in Stave Reservoir, October 2007.

4.3 Acoustics

4.3.1 Spatial Distribution of Fish

Most fish were found in the upper 30 m of both the slope and pelagic zones during the 2008 acoustic survey (Figures 10-12). Peak densities tended to be shallower (5-25 m) in the slope zone than in the pelagic zone (15-25 m, Figures 11 and 12). In both cases, average density for transects combined approached 0.0014 fish/m^3 in the most concentrated layers. Fish densities were very low in the upper 5 meters of both zones, except in the pelagic zone on transects 1 and 9.

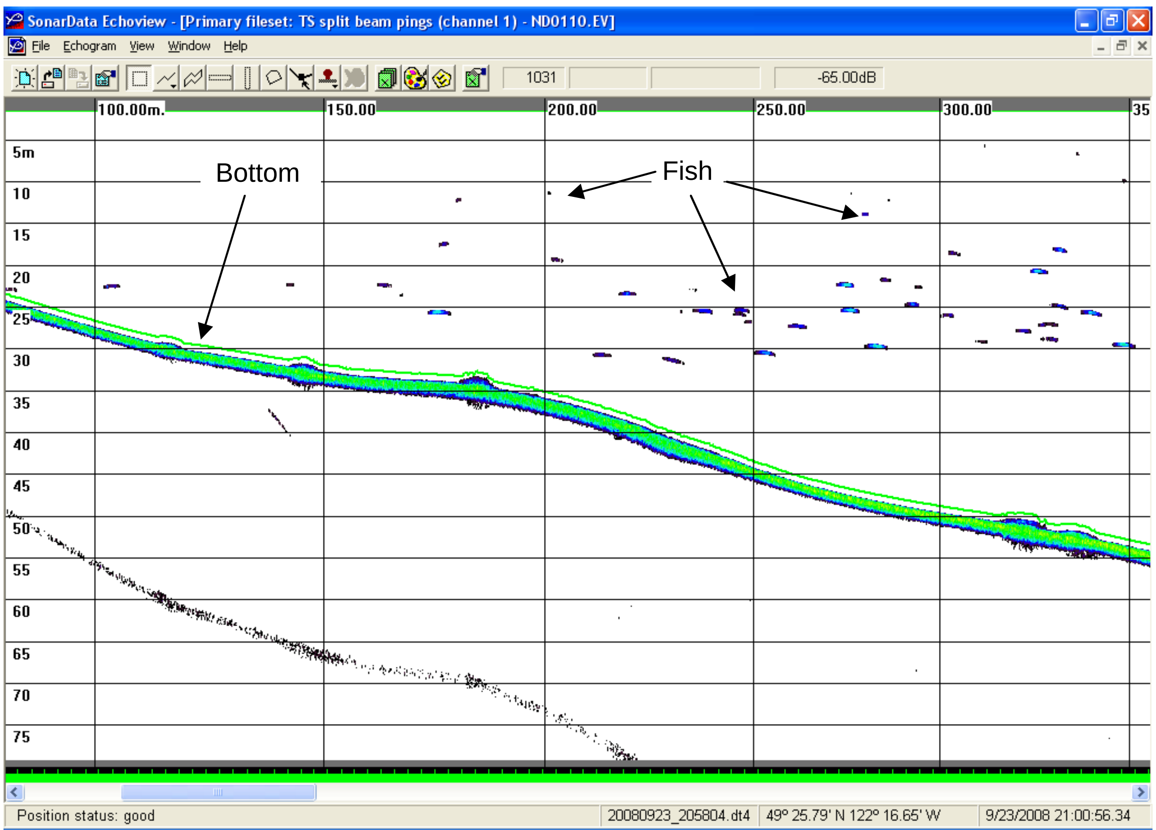

Figure 10. A down-looking echogram from the west side of Transect 1 on the night of September 23, 2008, showing fish between 5 and 35 m in the slope and pelagic zones. Zones were defined in terms of surface to bottom water column depth: slope ≤ 40 m, pelagic > 40 m.

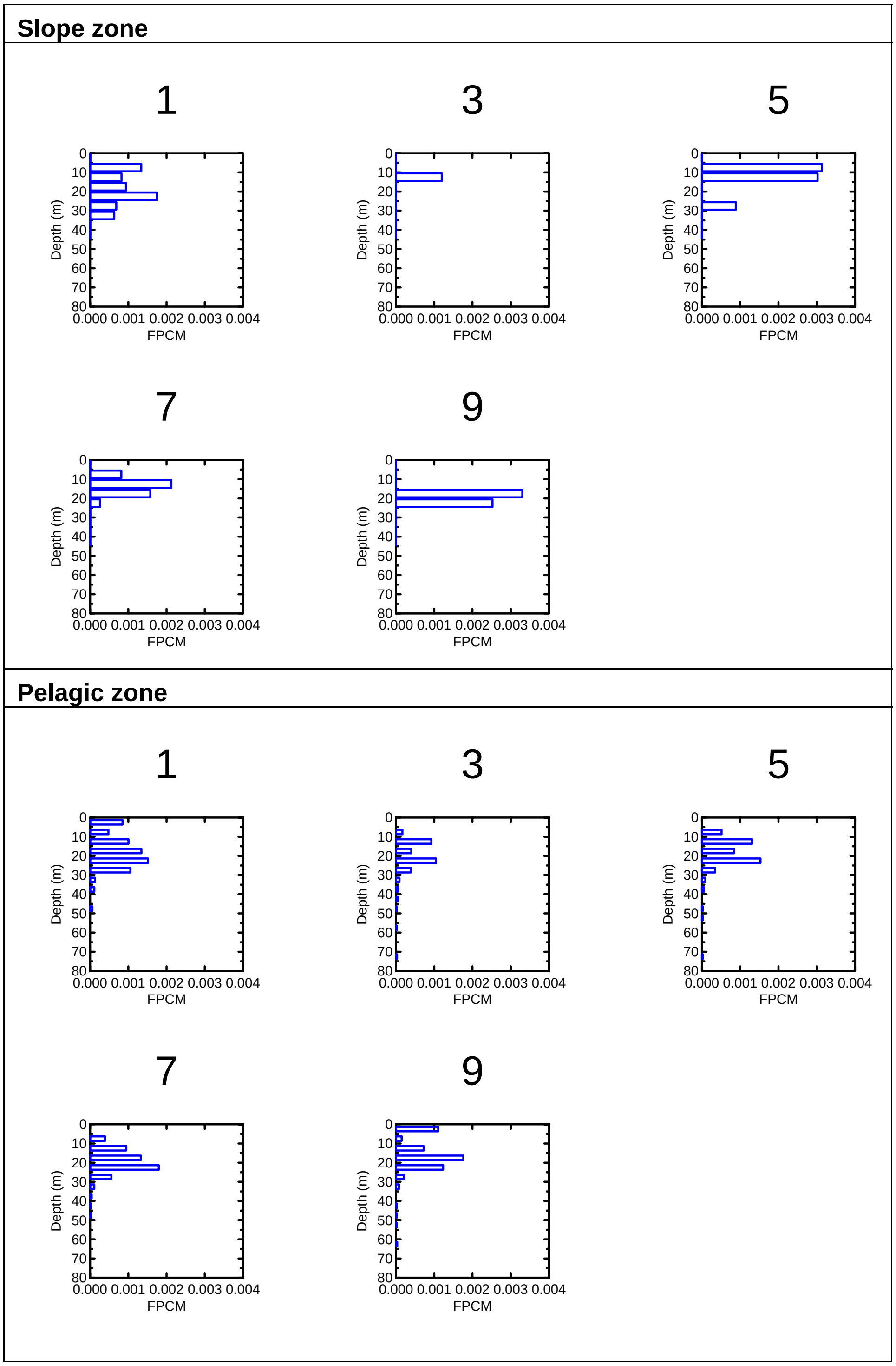

Figure 11. Vertical distribution of fish in Stave Reservoir by transect on the night of September 23, 2008. Units are fish/m^3 for all species combined (X-axis) by 5 m depth intervals (Y-axis). The 0-5 m interval is from side-looking acoustic data; others are from down-looking data.

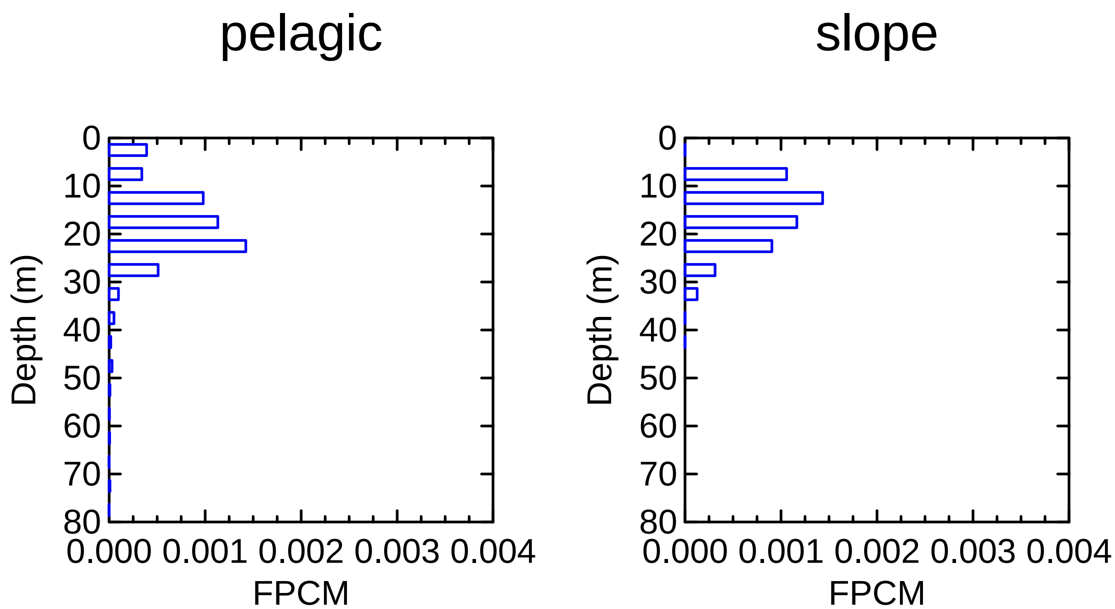

Figure 12. Mean vertical distribution of fish (all species combined) on all acoustic transects sampled September 23, 2008. Data are from down-looking sampling only.

4.3.2 Target Strength and Estimated Size of Fish

Target strength (TS) of fish measured with down-looking acoustics ranged from -64.0 to -30.4 dB. In the slope zone there was a single major peak between -56 and -50 dB, whereas there were two major peaks in the pelagic zone: between -60 and -55 dB and between -40 and -35 dB (Figure 13). The proportion of large TS values (>-45 dB) was much higher in the pelagic zone than in the slope zone. When TS values were converted to fork lengths using Love's (1977) relationship, estimated lengths of fish ranged from 18 to 424 mm in the slope zone and 12 to 785 mm in the pelagic zone (Figure 13). Fish longer than 100 mm were much more numerous in the pelagic zone (45% of total) than in the slope zone (14% of total).

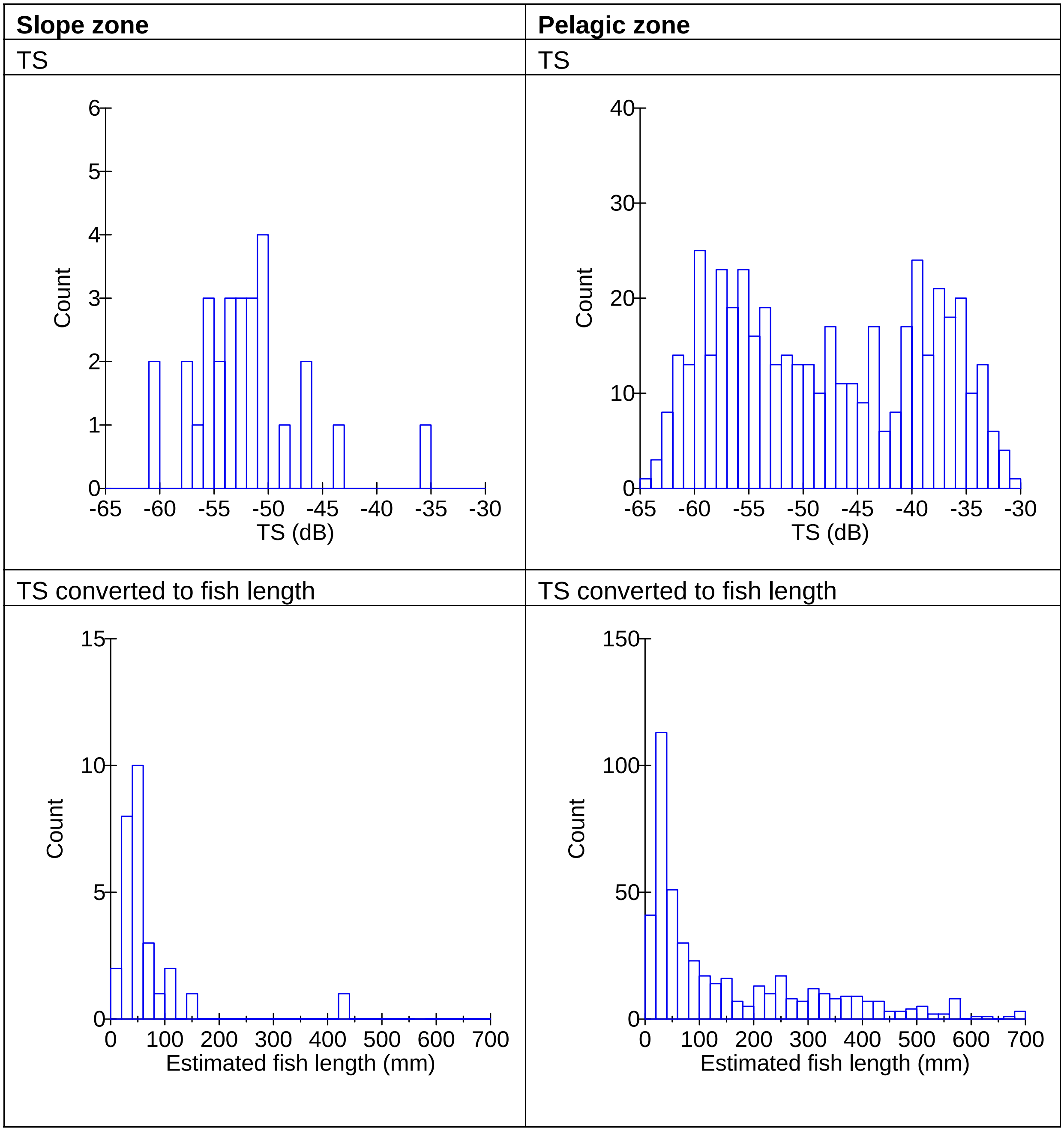

Figure 13. Frequency distributions of TS (upper) and TS converted to fish length (lower), from September 2008 down-looking acoustic data. Lengths were estimated from TS using Love's (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect using down-looking acoustic data only.

For fish >100 mm long, the size captured by gill nets, length frequency distributions estimated from 2008 TS values poorly matched those from 2007 gill net catches. In the slope zone, the TS sample size was too small for valid comparison to gill net results (Figure 14). In the pelagic zone, the single dominant mode in the 2007 gill net data at 200 mm was due to age-2 kokanee, whereas 2008 TS estimates showed high abundance of fish the size of age-1 and age-3 kokanee (modes at 150 and 225 mm). This pattern suggests that the dominant cohort of age-0 kokanee in 2007 (Stables and Perrin 2008) was again abundant as age-1 fish in 2008, and that the abundant cohort of age-2 kokanee in 2007 was again numerous at age-3 in 2008. The 2008 TS data also indicated a much higher abundance of fish over 300 mm long in the pelagic zone than did the 2007 gill net data (Figure 14). Based on 2007 habitat use patterns, these large fish were probably trout and northern pikeminnow. Exclusion of suckers from gill net results did not appreciably change the size distribution of the slope zone (Figure 14) and it had no affect on the pelagic zone where suckers were not captured in gill nets.

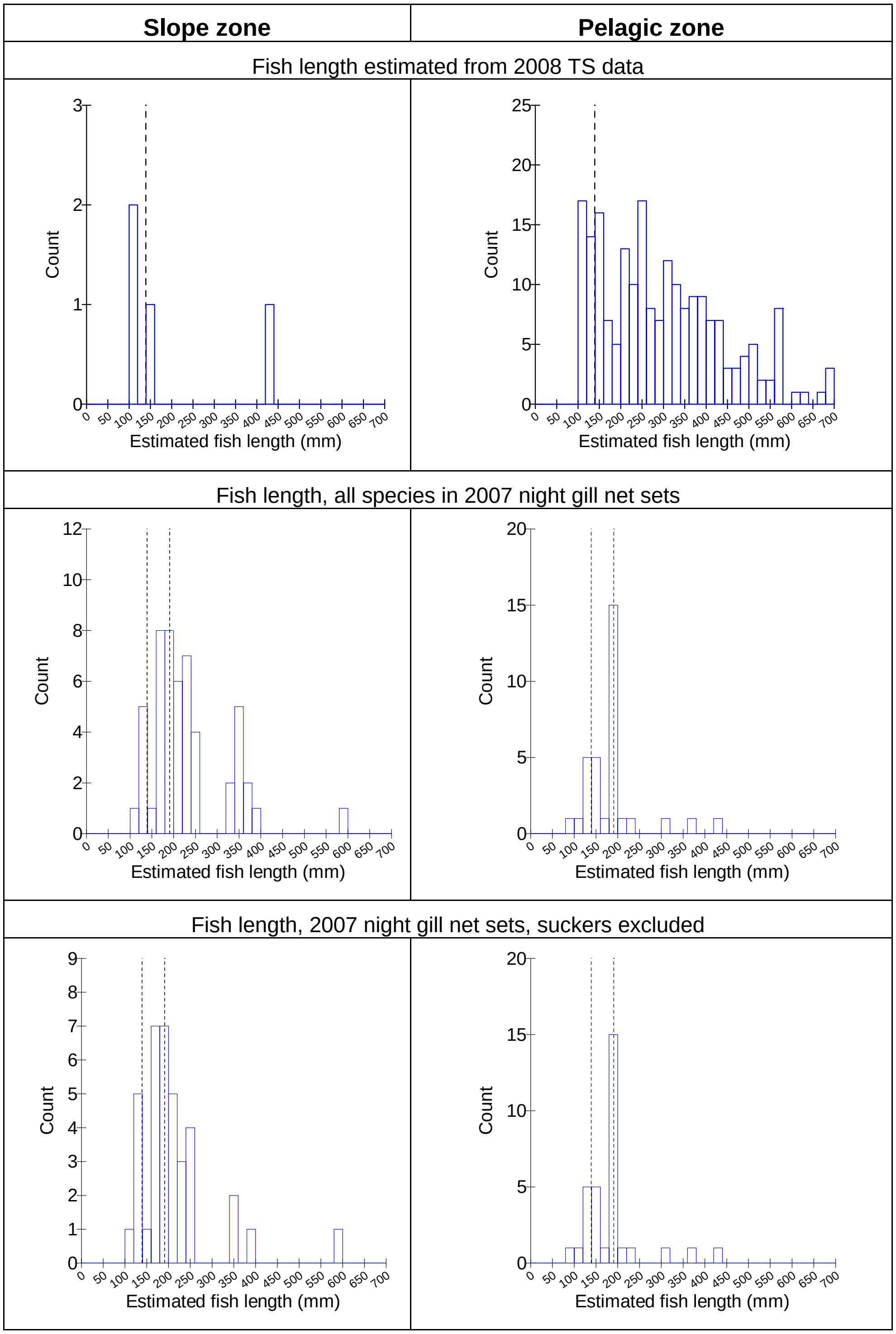

Figure 14. Length-frequency distributions of fish >100 mm long estimated from 2008 acoustic data compared to gill net results from the slope and pelagic zones in October 2007. Lengths were estimated from TS using Love's (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect using down-looking acoustic data only. The vertical dashed lines indicate mean length of age 1 and 2 kokanee.

Close inspection of length-frequency distributions of small fish estimated from TS showed main peaks at 32.5 mm and 57.5 mm in the slope zones and at 22.5 mm in the pelagic zone (Figure 15). These fish were much smaller than the age 1 kokanee we captured in Stave Reservoir in 2007 (length 123-158 mm, mean = 139 mm). Age-0 kokanee should be about 40 mm long in Stave Reservoir in the fall.

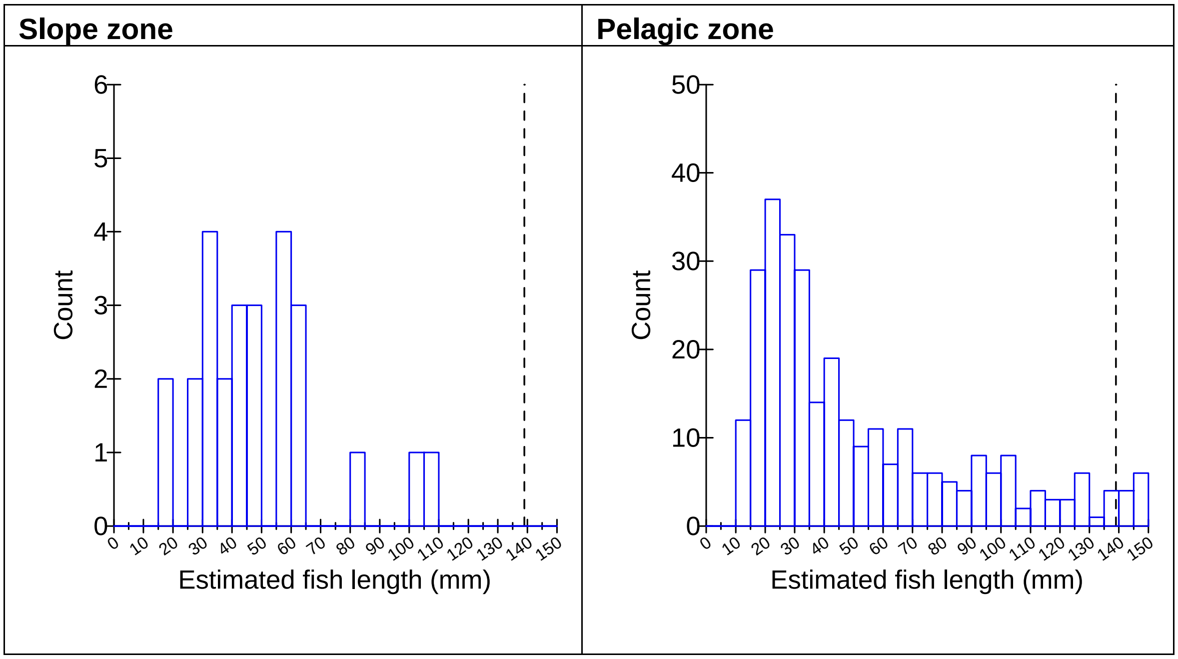

Figure 15. Length-frequency distributions for small fish from the September 2008 acoustic survey. Lengths were estimated from TS using Love's (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect using down-looking acoustic data only. The vertical dashed line indicates the mean length of age 1 kokanee.

TS data indicated that in the slope zone fish of all sizes occurred mainly between 10 and 30 m (Figure 16). In the pelagic zone, fish under 100 mm long were found from near the surface to over 70 m, with high numbers 15-30 m. Fish over 100 mm long were concentrated between 15 and 30 m in the pelagic zone. Fish less than 100 mm long were more numerous than larger ones at all depths in the slope zone, but larger fish predominated between 20 and 30 m in the pelagic zone (Table 10).

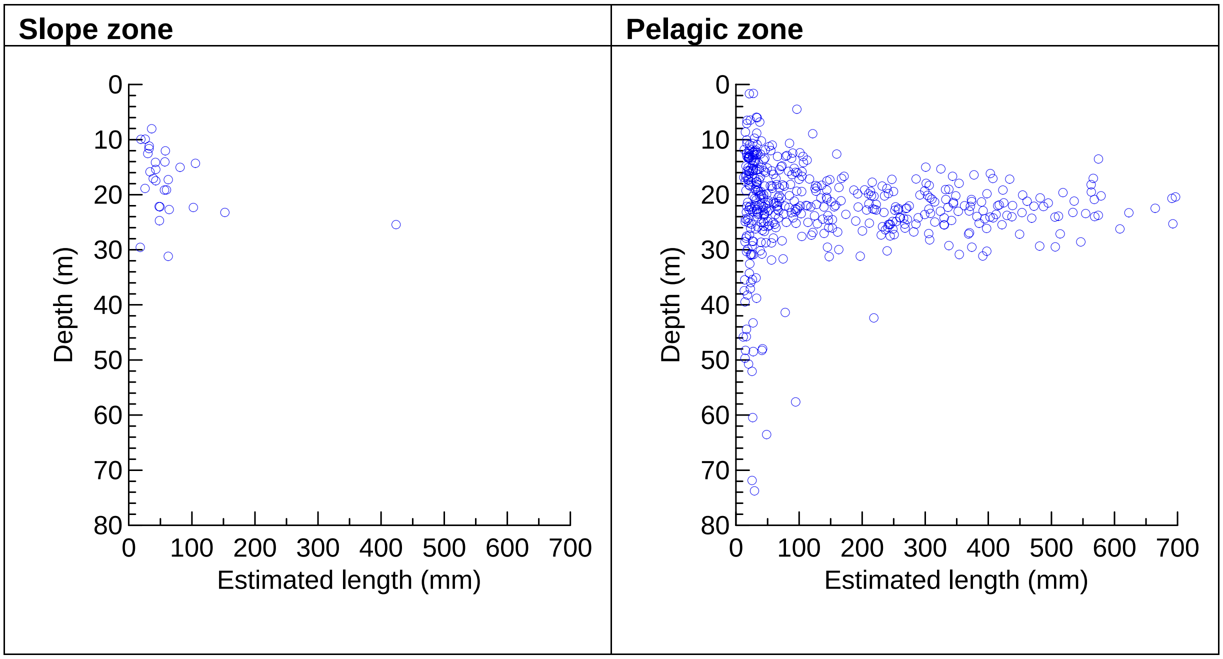

Figure 16. Fish length (mm) versus depth by habitat zone during the September 2008 acoustic survey of Stave Reservoir. Fish lengths were estimated from TS using Love’s (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect. Down-looking data from all transects combined were used for this figure.

Table 10. Percentages of fish in the September 23, 2008 acoustic estimate with estimated fork lengths <100 mm and ⩾100 mm. Percentages in depth intervals with low counts were estimated by averaging with surrounding layers. Length estimates were from Love's (1977) +/- 45 degree relationship.

Zone	Depth interval (m)	Count			Raw Percentage		Adjusted Percentage	
		<100 mm	⩾100 mm	Total	<100 mm	⩾100 mm	<100 mm	⩾100 mm
Slope	0-5	0	0	0	0.00%	0.00%	93.75%	6.25%
"	5-10	3	0	3	100.00%	0.00%	93.75%	6.25%
"	10-15	7	1	8	87.50%	12.50%	87.50%	12.50%
"	15-20	8	0	8	100.00%	0.00%	100.00%	0.00%
"	20-25	4	2	6	66.67%	33.33%	66.67%	33.33%
"	25-30	1	1	2	50.00%	50.00%	72.22%	27.78%
"	30-35	1	0	1	100.00%	0.00%	75.00%	25.00%
"	35-40	0	0	0	0.00%	0.00%	0.00%	0.00%
Pelagic	0-5	3	0	3	100.00%	0.00%	95.00%	5.00%
"	5-10	9	1	10	90.00%	10.00%	90.00%	10.00%
"	10-15	54	7	61	88.52%	11.48%	88.52%	11.48%
"	15-20	60	46	106	56.60%	43.40%	56.60%	43.40%
"	20-25	68	105	173	39.31%	60.69%	39.31%	60.69%
"	25-30	27	44	71	38.03%	61.97%	38.03%	61.97%
"	30-35	11	6	17	64.71%	35.29%	64.71%	35.29%
"	35-40	9	0	9	100.00%	0.00%	100.00%	0.00%
"	40-45	3	1	4	75.00%	25.00%	91.67%	8.33%
"	45-50	7	0	7	100.00%	0.00%	100.00%	0.00%
"	50-55	2	0	2	100.00%	0.00%	100.00%	0.00%
"	55-60	1	0	1	100.00%	0.00%	100.00%	0.00%
"	60-65	2	0	2	100.00%	0.00%	100.00%	0.00%
"	65-70	2	0	2	100.00%	0.00%	100.00%	0.00%
"	70-75	0	0	0	0.00%	0.00%	0.00%	0.00%
"	75-80	0	0	0	0.00%	0.00%	0.00%	0.00%

4.3.3 Fish Abundance and Biomass

A total of 539 fish were counted with acoustics on the 5 transects sampled in 2008 (Table 11). Of this total, 46 were in the slope zone and 493 were in the pelagic zone. Volumetric fish densities of individual transect layers ranged from 0 to 0.0033 fish/m^3 in the slope zone and from 0 to 0.0018 fish/m^3 in the pelagic zone (Table 12). Fish densities were extremely low below 25 m in the slope zone and below 30 m in the pelagic zone.

The 2008 population estimate for the entire study area was 630,907 ± 91,573 fish of all species combined (Table 13). Of these, 94,315 were in the slope zone and 536,593 were in the pelagic zone. In the slope zone, 96% of all fish occurred in the 0-25 m depth range. In the pelagic zone, 96% of all fish were in the 0-30 m range.

Table 11. Counts of fish from echograms, by transect and depth interval, from night time acoustic surveys of Stave Reservoir, September 23, 2008. Counts for 0-5 m and 5-80 m depth ranges were from side and down-looking data, respectively.

Zone	Depth range (m)	Fish Count by Transect												Total
		1	2	3	4	5	6	7	8	9	10	11	12	
Slope	0-5	7						2		8				17
“	5-10	1		0		1		1		0				3
“	10-15	1		1		2		5		0				9
“	15-20	2		0		0		5		1				8
“	20-25	4		0		0		1		1				6
“	25-30	1		0		1		0		0				2
“	30-35	1		0		0		0		0				1
“	35-40	0		0		0		0		0				0
“	0-40	17		1		4		14		10				46
Pelagic	0-5	7						3		18				28
“	5-10	2		1		3		3		1				10
“	10-15	9		11		16		15		10				61
“	15-20	17		7		15		31		36				106
“	20-25	25		24		36		55		33				173
“	25-30	22		11		10		21		7				71
“	30-35	3		3		3		5		3				17
“	35-40	3		2		2		2		0				9
“	40-45	0		2		0		1		1				4
“	45-50	2		1		1		2		1				7
“	50-55	0		0		1		0		1				2
“	55-60	0		1		0		0		0				1
“	60-65	0		0		0		0		2				2
“	65-70	0		0		0		0		0				0
“	70-75	0		1		1		0		0				2
“	75-80	90		64		88		138		113				493

Table 12. Fish density (fish/m^3) for all species combined by transect and depth interval from the September 23, 2008 acoustic survey when 5 transects were sampled. Densities for 0-5 m and 5-80 m depth ranges were from side and down-looking data, respectively.

Zone	Depth range (m)	Fish density by transect (fish/m^3)												Total		
		1	2	3	4	5	6	7	8	9	10	11	12	n	Mean	Var
Slope	0-5	0.00183						0.00022		0.00167				3	0.0012433	7.841E-07
	5-10	0.00134		0.00000		0.00313		0.00082		0.00000				5	0.0010582	1.669E-06
	10-15	0.00082		0.00120		0.00302		0.00212		0.00000				5	0.0014324	1.370E-06
	15-20	0.00094		0.00000		0.00000		0.00158		0.00330				5	0.0011635	1.876E-06
	20-25	0.00175		0.00000		0.00000		0.00026		0.00252				5	0.0009057	1.345E-06
	25-30	0.00069		0.00000		0.00088		0.00000		0.00000				5	0.0003138	1.894E-07
	30-35	0.00063		0.00000		0.00000		0.00000		0.00000				5	0.0001263	7.978E-08
	35-40	0.00000		0.00000		0.00000		0.00000		0.00000				5	0.0000000	0.000E+00
	0-40	0.00100		0.00017		0.00101		0.00063		0.00094				38		
Pelagic	0-5	0.00046						0.00009		0.00084				3	0.0004618	1.431E-07
	5-10	0.00048		0.00017		0.00051		0.00039		0.00015				5	0.0003405	2.926E-08
	10-15	0.00101		0.00092		0.00131		0.00095		0.00072				5	0.0009815	4.535E-08
	15-20	0.00134		0.00040		0.00083		0.00133		0.00176				5	0.0011328	2.758E-07
	20-25	0.00151		0.00105		0.00153		0.00180		0.00123				5	0.0014234	8.438E-08
	25-30	0.00105		0.00039		0.00034		0.00056		0.00021				5	0.0005111	1.071E-07
	30-35	0.00013		0.00009		0.00009		0.00011		0.00008				5	0.0000982	3.969E-10
	35-40	0.00011		0.00005		0.00005		0.00004		0.00000				5	0.0000503	1.565E-09
	40-45	0.00000		0.00005		0.00000		0.00002		0.00002				5	0.0000172	3.688E-10
	45-50	0.00006		0.00002		0.00002		0.00003		0.00002				5	0.0000317	2.810E-10
	50-55	0.00000		0.00000		0.00002		0.00000		0.00002				5	0.0000081	1.225E-10
	55-60	0.00000		0.00002		0.00000		0.00000		0.00000				5	0.0000039	7.651E-11
	60-65	0.00000		0.00000		0.00000		0.00000		0.00003				5	0.0000062	1.936E-10
	65-70	0.00000		0.00000		0.00000		0.00000		0.00000				5	0.0000000	0.000E+00
	70-75	0.00000		0.00003		0.00002		0.00000		0.00000				5	0.0000094	1.691E-10
	75-80	0.00000		0.00000		0.00000		0.00000		0.00000				5	0.0000000	0.000E+00
	0-80	0.00038		0.00021		0.00032		0.00033		0.00032				78		

Table 13. The 2008 population estimate for fish of all species combined in areas sampled by acoustics (slope and pelagic zone of main lake basin, offshore of the 17.0 m depth contour on average).

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	0.00124	7.8E-07	3	1.6E+07	20,369	8,376	-15,668	56,406
"	5-10	0.00106	1.7E-06	5	1.6E+07	17,337	9,466	-8,944	43,618
"	10-15	0.00143	1.4E-06	5	1.6E+07	23,467	8,575	-343	47,276
"	15-20	0.00116	1.9E-06	5	1.6E+07	18,308	9,639	-8,455	45,071
"	20-25	0.00091	1.3E-06	5	1.3E+07	11,335	6,492	-6,688	29,359
"	25-30	0.00031	1.9E-07	5	9.0E+06	2,831	1,756	-2,045	7,708
"	30-35	0.00013	8.0E-08	5	5.3E+06	667	667	-1,185	2,519
"	35-40	0.00000	0.0E+00	5	1.7E+06	0	0	0	0
"	0-40	0.00124	7.8E-07	3	9.3E+07	94,315	19,284	54,984	133,645
Pelagic	0-5	0.00046	1.4E-07	3	1.1E+08	48,914	23,131	-50,612	148,440
"	5-10	0.00034	2.9E-08	5	1.1E+08	36,064	8,102	13,568	58,559
"	10-15	0.00098	4.5E-08	5	1.1E+08	103,962	10,087	75,956	131,967
"	15-20	0.00113	2.8E-07	5	1.1E+08	119,986	24,875	50,922	189,050
"	20-25	0.00142	8.4E-08	5	1.1E+08	150,759	13,759	112,557	188,961
"	25-30	0.00051	1.1E-07	5	1.1E+08	54,131	15,501	11,093	97,168
"	30-35	0.00010	4.0E-10	5	1.1E+08	10,399	944	7,779	13,019
"	35-40	0.00005	1.6E-09	5	1.1E+08	5,323	1,874	119	10,526
"	40-45	0.00002	3.7E-10	5	1.0E+08	1,782	892	-695	4,260
"	45-50	0.00003	2.8E-10	5	9.9E+07	3,134	742	1,075	5,194
"	50-55	0.00001	1.2E-10	5	9.4E+07	760	465	-532	2,052
"	55-60	0.00000	7.7E-11	5	8.7E+07	341	341	-606	1,288
"	60-65	0.00001	1.9E-10	5	7.8E+07	488	488	-867	1,844
"	65-70	0.00000	0.0E+00	5	7.1E+07	0	0	0	0
"	70-75	0.00001	1.7E-10	5	5.8E+07	550	339	-392	1,492
"	75-80	0.00000	0.0E+00	5	4.4E+07	0	0	0	0
"	0-80			78	1.5E+09	536,593	41,895	452,872	620,314
Combined						630,907	46,120	539,334	722,480

* Number of transects with corresponding depth interval.

The population estimate of fish less than 100 mm long was 421,968 fish (biomass 312 kg), all of which were assumed to be age 0 kokanee (Table 14). Estimated numbers and biomass of larger fish (⩾100 mm in length) were 7,895 cutthroat trout (2,628 kg), 1,066 native char (965 kg), 190,490 kokanee (14,392 kg), 227 rainbow trout (28 kg), 6,233 peamouth chub (243 kg), and 3,028 northern pikeminnow (375 kg). Numbers and biomass of salmonids were further broken down by cohorts based on age structure of the 2007 gill net catch. Considering cutthroat trout, age-2 was by far most abundant but age-3 had the largest biomass (Table 14). For native char, all ages (3, 5, 8, and 10) were equally abundant, while their contribution to biomass increased with age. This estimate was based on just one fish of each age, however. Age 1-3 kokanee were present in the population, with age-2 strongly dominant both numerically and in terms of biomass. The only cohort of rainbow trout present was age-2.

Areal density and biomass of individual species with all ages combined was 216.3 kokanee/ha (5.2 kg/ha), 2.8 cutthroat trout/ha (0.9 kg/ha), 0.4 native char/ha (0.3 kg/ha), 1.1 northern pikeminnow/ha (0.1 kg/ha), 2.2 peamouth chub/ha (0.09 kg/ha), and 0.1 rainbow trout/ha (0.01 kg/ha), for a combined total of 222.9 fish/ha (6.7 kg/ha, Table 14).

Due to the poor match between length frequency distributions from 2007 gill net data and 2008 TS data, the effect of uncertainty about the relative abundance of age 1-3 kokanee on kokanee biomass and total fish biomass was examined. Alternative biomass estimates were computed using two other estimates of kokanee age 1-3 relative abundance: 1) age composition from 2005 gill netting; and 2) the 2008 frequency distribution of TS converted to fish length (pelagic zone only, Figure 14). For the latter method, the relative heights of bars coinciding with the mean length of kokanee age groups represented age group relative abundance. Despite considerable variation in age composition among the default age composition (2007 gill net data) and the alternates, kokanee biomass varied only 9.6% (5.2-5.7 kg/ha) and total fish biomass varied only 6.0% (6.7-7.1 kg/ha, Table 15). These computations rely on the assumption that most fish in the pelagic zone in the 100-250 mm size range were kokanee, which 2007 gill net data supports.

Table 14. September 23, 2008 population estimate for all fish species and age groups in the area sampled with acoustics (slope & pelagic zones of the main lake basin, offshore of the 17 m depth contour). This table incorporates results from species composition, age structure, size composition, and population estimate tables.

		Species						
Estimate	**Age**	**C. trout**	**Char**	**kokanee**	**R. trout**	**P. chub**	**N.p. minnow**	**Total**
Abundance	0	0	0	421,968	0	0	0	421,968
Biomass (kg)	"	0	0	312	0	0	0	312
Percentage	1	0.0%	0.0%	23.8%	0.0%	-	-	
"	2	50.0%	0.0%	73.8%	100.0%	-	-	
"	3	30.0%	25.0%	2.4%	0.0%	-	-	
"	4	20.0%	0.0%	0.0%	0.0%	-	-	
"	5	0.0%	25.0%	0.0%	0.0%	-	-	
"	8	0.0%	25.0%	0.0%	0.0%	-	-	
"	10	0.0%	25.0%	0.0%	0.0%	-	-	
"	11	0.0%	0.0%	0.0%	0.0%	-	-	
"	total	100.0%	100.0%	100.0%	100.0%	-	-	
Abundance	1	0	0	45,355	0	-	-	
"	2	3,948	0	140,600	227	-	-	
"	3	2,369	267	4,535	0	-	-	
"	4	1,579	0	0	0	-	-	
"	5	0	267	0	0	-	-	
"	8	0	267	0	0	-	-	
"	10	0	267	0	0	-	-	
"	11	0	0	0	0	-	-	
"	total	7,895	1,066	190,490	227	6,233	3,028	208,939
Biomass (kg)	1	0	0	1,704	0	-	-	1,704
"	2	823	0	12,084	28	-	-	12,935
"	3	999	50	603	0	-	-	1,652
"	4	806	0	0	0	-	-	806
"	5	0	134	0	0	-	-	134
"	8	0	277	0	0	-	-	277
"	10	0	503	0	0	-	-	503
"	11	0	0	0	0	-	-	0
"	total	2,628	965	14,392	28	243	375	18,631
Abundance	total	7,895	1,066	612,458	227	6,233	3,028	630,907
Biomass (kg)	"	2,628	965	14,704	28	243	375	18,943
Number/ha	"	2.8	0.4	216.3	0.1	2.2	1.1	222.9
kg/ha	"	0.9	0.3	5.2	0.01	0.09	0.1	6.7

Table 15. The effect of alternative kokanee age composition estimates on kokanee biomass and total fish biomass estimates from the 2008 acoustic survey. Age composition estimates were from three sources: 2007 GN = 2007 gill net data; 2005 GN = 2005 gill net data; and 2008 TS = the 2008 frequency distribution of TS converted to fish length (pelagic zone only). 2007 GN was the default method.

	Kokanee	Age composition source		
Estimate	**age group**	**2007 GN**	**2005 GN**	**2008 TS**
percentage of fish > 100 mm	1	23.8%	25.0%	48.0%
	2	73.8%	54.2%	11.0%
	3	2.4%	20.8%	41.0%
	Combined	100.0%	100.0%	100.0%
age 1-3 kokanee abundance	1	45,355	47,115	90,460
	2	140,600	102,144	20,730
	3	4,535	39,199	77,268
	Combined	190,490	190,490	190,490
age 1-3 kokanee biomass (kg)	1	1,704	1,771	3,399
	2	12,084	8,779	1,782
	3	603	5,214	10,277
	Combined	14,392	15,763	15,458
total kokanee biomass (age 0-3)				
total kg		14,704	16,075	15,770
kg/ha		5.2	5.7	5.6
total fish biomass (species combined)				
total kg		18,943	20,172	19,867
kg/ha		6.7	7.1	7.0

5.0 DISCUSSION

5.1 Comparison of 2007 Biological Data with Previous Studies of Stave Reservoir

Results of gill netting and Gee trapping in 2007 were similar to those of previous studies at Stave Reservoir (Table 16). The assemblage of fish species captured in nets and traps in 2007 was much the same as in other years of sampling (1987, 1988, 1993, and 2005). In 2007, we did not capture river lamprey or brown bullhead catfish that were reported by Bruce et al. (1994) who targeted debris-choked areas of the lake. We captured peamouth chub in significant numbers in 2007, as in 2005, whereas this species was previously unreported from Stave Reservoir. In 2007, the relative abundance of fish species in nearshore sets was similar to that of 1987, 1993, and 2005 (i.e., pikeminnow and redside shiner were most numerous). Relative abundance in 2007 mid-lake sets was similar to that of 1988 (i.e., kokanee were predominant) when "open water areas" were targeted. Total CPUE from 2007 nearshore sets was intermediate among all years of sampling. In 2007, length statistics (mean and range) were similar to those reported in previous years for all salmonid species (Table 17).

Table 16. 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}. No mid-lake sets were made before 2007. In 2007, sets were placed by dusk and retrieved before daylight. The 2007 nearshore category includes all nets in three-net midwater gangs that extended out from shore.

	Fish x 100m^{-2} x 24 hr^{-1}									
Survey date	Rainbow trout	Cutthroat trout	Kokanee	Native char	Pike Minnow	Redside shiner	Large-scale sucker	Brown bullhead	Pea-mouth chub	Total
July-1987[a]	0.15	1.74	3.63	1.16	12.5	9.58	1.16	0	0	29.92
July-1988[b]	0.10	0.15	1.49	0.36	1.08	0.05	0	0	0	3.23
Sept-1993[c]	1.28	0.32	1.61	0.32	60.35	2.89	11.08	0.96	0	78.81
Sept-2005 day, nearshore[d]	0.00	1.00	1.00	1.00	2.49	0.75	0.25	0	0.25	6.74
Sept-2005 overnight, nearshore[d]	0.19	1.06	2.13	1.06	11.59	10.63	6.95	0	2.61	36.22
Oct-2007 night, nearshore[d]	0.16	1.13	4.68	0.65	8.56	10.66	5.33	0	1.45	32.62
Oct-2007 night, mid-lake[d]	0	0.76	3.31	0	0.25	0	0	0	0	6.37

[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 report. Sampling was in the main lake basin, away from debris choked areas. The 2007 nearshore category in this table means all sets that were not in the middle of the lake, including gangs of three midwater nets that extended 270 m out from the point of contact with lake bottom.

Table 17. Size of salmonids in 2007 compared to previous years.

Survey date	Fork Length (mm)											
	Rainbow trout			Cutthroat trout			Kokanee			Native char		
	Mean	Range	n	Mean	Range	n	Mean	Range	n	Mean	Range	n
July-1987[a]	241	178-330	8	290	284-296	2	207	188-219	10	347	295-398	2
Sept-1993[b]	231	-	1	276	185-332	12	172	110-200	25	376	289-533	8
Sept-2005[c]	220	220-220	2	312	220-430	14	181	120-240	23	457	320-640	15
Oct-2007[c]	223	-	1	305	233-402	10	180	123-264	42	418	257-586	4

[a] Norris and Balkwill 1987 in Bruce et al. 1994.
[b] Bruce et al. 1994. Targeted timber and debris choked areas.
[c] This report. Targeted main lake basin, littoral and pelagic.

Age groups of salmonids present in 2007 were generally similar to previous years (Table 18). The range of cutthroat year-classes was narrower in 2007 (2-4) than in 2005 (1-7). Some of the observed differences between years may have been because rare age groups were not detected when sample sizes were small.

Table 18. Age of salmonids in 2007 compared to previous years.

Survey date	Range of ages captured							
	Rainbow trout		Cutthroat trout		Kokanee		Native char	
	range	n	range	n	range	n	range	n
Sept-1993[a]	2-4	8	2-3	2	all age 2	10	-	-
Sept-2005[b]	1-2	2	1-7	14	1-3	23	4-11*	15
Oct-2007[b]	2	1	2-4	10	1-3	2	3-10**	4

[a] Bruce et al. 1994. Targeted timber and debris choked areas.
[b] This report. Targeted main lake basin, littoral and pelagic.
* The oldest fish aged from otoliths were 7. Ages of larger fish were estimated from the 2005 length-age regression equation.
** The oldest fish aged from otoliths was 5. Ages of larger fish were estimated from the 2005 & 2007 length-age regression equation.

5.2 Fish Abundance and Biomass

The 2008 population estimate was stratified by slope and pelagic habitat zones to improve accuracy over the analysis design, without such stratification, that was used in 2005 and 2006 (Stables and Perrin 2008). The 2008 results are fully comparable to 2007 results (which had the same stratification), but are only partially comparable to 2005 and 2006 results. The 2005 and 2006 abundance and biomass estimates will be recalculated using stratification once 2009 gill net sampling has provided another year of data for assessing the consistency of nearshore versus offshore fish distribution patterns.

The 2008 native char biomass estimates agreed closely with the 2007 estimate and with char biomass estimates from other western lakes and reservoirs, whereas 2005 and 2006 estimates (without stratification) were high outliers (Table 19). The 2008 biomass of char in Stave Reservoir (0.3 kg/ha) was higher than in Ross Lake (0.04-0.08 kg/ha), however, the combined biomass of char and trout in Stave Reservoir (1.28 kg/ha) was intermediate among values from Ross Lake (2.8-5.7 kg/ha) and Lake Pend Oreille (0.8-1.9 kg/ha).

The total 2008 fish biomass estimate for Stave Reservoir (6.7 kg/ha of all species combined) and estimates for individual species other than char were also similar to the 2007 estimate (4.9 kg/ha for all species) and in line with other lakes and reservoirs in the comparison (Table 19). Total biomass in Ross Lake, a northern Washington reservoir that mainly supports rainbow trout, was slightly less (2.8-5.7 kg/ha, Loof 1992), while biomass in Coquitlam Reservoir, which is dominated by non-salmonids, was much higher (31.2 kg/ha, Bussanich et al. 2005). Biomass of kokanee was lower in Stave Reservoir than in other lakes except Williston Reservoir, which is dominated by lake whitefish (Sebastian et al. 2003). Trout densities and biomass in Stave Reservoir (2.87 fish/ha and 0.91 kg/ha for rainbow and cutthroat combined) were also lower than those reported in Ross Lake (8-15 trout/ha, 3-6 kg/ha, Loof 1992). These low values are consistent with the ultra-oligotrophic conditions in Stave Reservoir (Stockner and Beer 2004).

Some other comparisons between habitat stratified population estimates (2007 and 2008) and unstratified estimates (2005 and 2006) are possible at this time. Total fish abundance estimates were probably changed little by stratification. The 2008 value of 630,907 fish was the highest to date by a margin of 16% (Figure 17). Its 95% confidence interval of +/- 15% was similar to the precision of earlier estimates (+/- 16-20%). Higher abundance in 2008 was also supported by the highest fish density to date on all transects sampled this year, a comparison that was unaffected by stratification (Figure 18).

The total fish biomass estimate and biomass estimates for individual species were greatly affected by stratifying into habitat zones, so comparisons of 2007 and 2008 data to earlier years using these metrics are not currently valid.

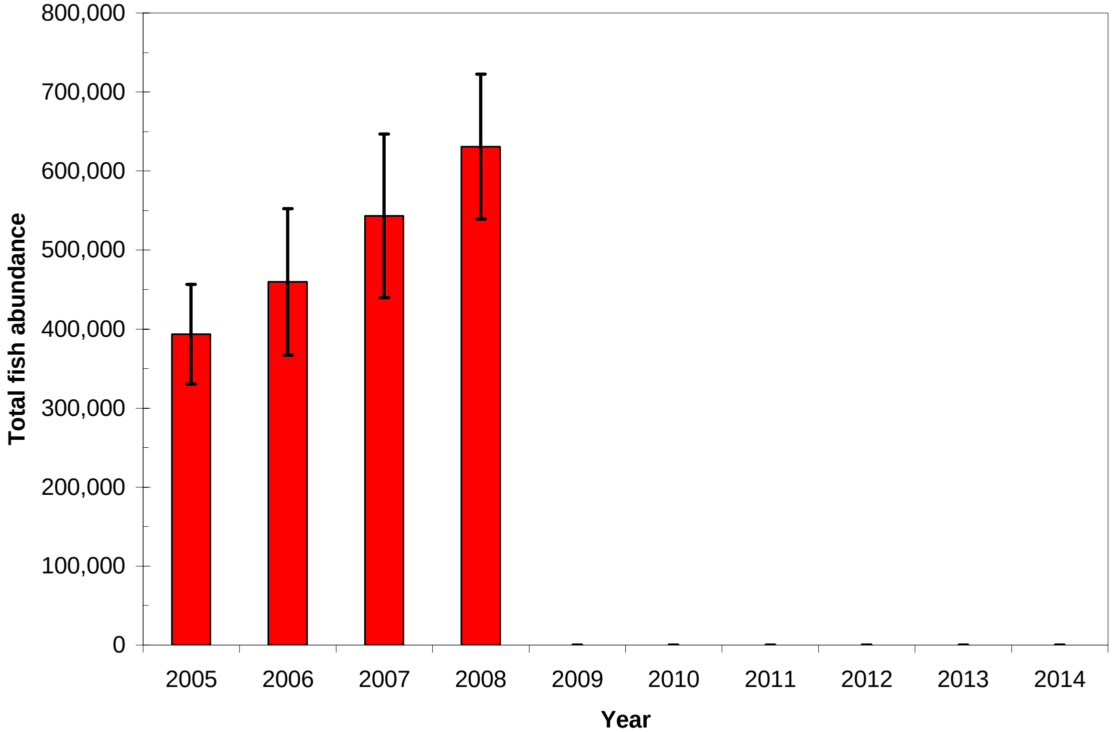

Figure 17. Time series of annual total population estimates (species combined) for Stave Reservoir with 95% confidence intervals.

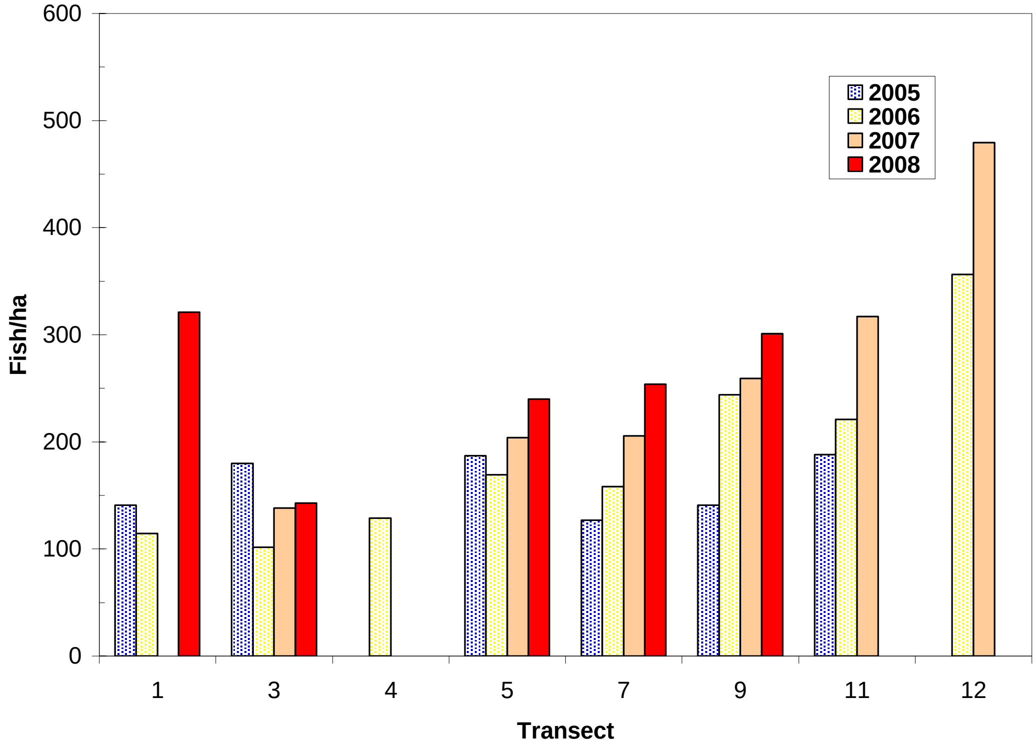

Figure 18. Mean areal fish density (fish/ha) on transects during 2005-2008 night time acoustic surveys. Transects are numbered 1-12 from north to south.

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Table 19. Fish density (fish/ha) and biomass (kg/ha) in Stave Reservoir 2005-2008 compared to selected BC and Washington lakes and reservoirs. Values for Ross Lake and Williston Reservoir are rough approximations. Stave 2007 and 2008 estimates were stratified by slope and pelagic habitat zones, whereas the 2005 and 2006 estimates were not.

Water Body	Data source*	Kokanee or sockeye						Trout		Char		Trout & char combined		Non salmonids		Total		Species**
		Fry		Age 1 & older		All ages												
		#/ha	kg/ha	#/ha	kg/ha	#/ha	kg/ha	#/ha	kg/ha	#/ha	kg/ha	#/ha	kg/ha	#/ha	kg/ha	#/ha	kg/ha	
Stave Reservoir 2005	1	109	0.08	16.3	0.83	125	0.9	1.4	0.43	6.1	6.9	7.5	7.3	6.7	1.4	139	10.1	NC, KO, NPM, CT, PMC, RB
Stave Reservoir 2006	1	114	0.08	23.8	1.76	138	1.8	2.14	0.64	10.6	12.1	12.7	12.7	11.7	2.6	162	17.2	NC, KO, NPM, CT, PMC, RB
Stave Reservoir 2007	1	147	0.07	37.9	2.94	185	3.0	3.36	1.08	0.6	0.5	4.0	1.6	3.19	0.23	192	4.9	NC, KO, NPM, CT, PMC, RB
Stave Reservoir 2008	1	149	0.11	66.6	5.1	216	5.2	2.87	0.94	0.4	0.3	3.35	1.28	3.27	0.22	223	6.7	NC, KO, NPM, CT, PMC, RB
Lake Pend Oreille (2002)	2						5.1					1.02	1.9				7.0	KO, RB, LT, BT
Lake Pend Oreille (2003)	3						6.9					0.31	0.8				7.7	KO, RB, LT, BT
Coquitlam Reservoir	4	88	0.2	126.0	6.2	214	6.4									538	31.2	MS, KO
Williston Reservoir	5	8.5	0.005	4.4	0.43	13	0.4									70	11.5	LWF, KO
Ross Lake (1971)	6							15.2	5.6	0.2	0.08	15.4	5.7			15	5.7	RB, DV
Ross Lake (1991)	6							7.6	2.8	0.1	0.04	7.7	2.8			8	2.8	RB, DV
Shuswap Lake	7	4,750	11.4			4,750	11.4									4,750	11.4	SS
Quesnel Lake	7	2,500	10.0			2,500	10.0									2,500	10.0	SS

* 1 this study, 2 Bassista & Maiolie 2004, 3 Bassista et al. 2005, 4 Bussanich et al 2005, 5 Sebastian et al. 2003, 6 Loof 1992, 7 Hume et al. 1996
** species listed in order of their contribution to total biomass for each lake. Codes: DV=Dolly Varden; KO=kokanee; NPM=northern pikeminnow; CT=cutthroat trout; PMC=peamouth chub; LT=lake trout; BT=bull trout; NC=native char (bull trout or Dolly Varden); MS=mixed species including PMC, NPM, CT; LWF=lake whitefish; SS=sockeye salmon.

5.2 Potential Sources of Error

Bad weather during the 2008 acoustic survey limited sampling to only five transects (six was the target) and rendered some of the sidelooking data unusable. However, the transects sampled covered most of the lake and statistical precision of the population estimate (+/- 15%) was still good, so the survey was satisfactory.

Discrepancies between fish length frequency distributions from 2007 gill net data and estimated from 2008 acoustic data (TS) suggest that use of 2007 gill net data to apportion the 2008 acoustic estimate may have caused error in kokanee age composition estimates. The net effect of this error on the 2008 biomass estimates of kokanee and of all species combined appeared to be less than 10%.

The 2008 TS data also indicated a much higher fraction of fish more than 300 mm long than in the 2007 gill net sample. Habitat use patterns in 2007 suggest that these large fish were trout and northern pike minnow. However, without supporting 2008 gill net data their identity is uncertain.

6.0 RECOMMENDATIONS

Several of the recommendations made in the 2005-2007 annual reports (Stables and Perrin 2006-2008) have already been implemented. Day time gill netting and acoustic sampling were eliminated after 2005. Genetic analysis of char and comparative nearshore and mid-lake gill netting were begun in 2007. Stratification of acoustic and gill net analysis by habitat zones were also begun in 2007. The recommendations below would further enhance the study if they could be implemented, although they are not essential to its success. They are included in case additional funding allows for expanded sampling activities in the future.

- Continue genetic sampling of char. Due to low catch rates in 2007, only three char have been sampled to date, so expenditures on this item have been low;
- Examine contents of more fish stomachs to better understand habitat use and trophic linkages between species;
- Make limited night time plankton tows to determine if *Chaoborus sp*. are present in appreciable numbers; these invertebrates can sometimes be confused with small fish in acoustic surveys;
- Conduct trawling to identify fish less than 100 mm long that are presently all assumed to be kokanee fry.

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8.0 RAW DATA APPENDICES

Raw data appendices are available on CD or via file transfer from BC Hydro.