# Water Licence Requirements

**Stave**
Water Licence Requirement Reporting

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*Stave Reservoir Fish Biomass Assessment*

Study Period: 2005 Assessment Year
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ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR DURING FALL 2005

**Final Report**

**March 20, 2006**

# ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR DURING FALL 2005

Submitted to

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*Cover photo*: Dolly Varden being released unharmed to Stave Reservoir by Josh Taylor. September 2005. Photo by Kiyo Masuda.

# EXECUTIVE SUMMARY


A survey of fish in Stave Reservoir was conducted from September 26 to October 8, 2005 using acoustic sampling (scientific echo sounding), gill nets, and Gee traps. Study objectives were to determine abundance, biomass, spatial distribution, and biological characteristics of the fish community, including species, size, age composition, and composition of ingested food. Food and age composition were only determined for salmonids. Temperature profiles of the water column were made at the time of fish sampling . The survey was 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.

Thermal stratification was well defined throughout the reservoir on September 30 and October 8. The epilimnion (the shallowest, warmest layer of water) extended to about 10 meters and its temperature was slightly warmer (14.1-15.4 °C) on September 30 than on October 8 (12.8-13.1 °C). The temperature decreased rapidly below 10 meters in the thermocline (zone of rapid temperature change), reaching 7.3-8.7 °C by 20 meters and 5.4-5.5 °C at 55-60 m, the depth limit of sampling. On both dates, the dissolved oxygen concentration was high (9.5-12.1 mg/L) throughout the range sampled (0-60 m), well above the minimum level considered adequate for protection of fish (>6.5 mg/L, CCME 2003).

A total of 65 fish were captured in Gee-traps during the study. Prickly sculpin made up 74% of the catch, which also included peamouth chub, northern pike minnow, and redside shiner. No salmonids were captured in Gee traps. Species composition did not differ significantly between the two stations (Peterson Chi$^2$ statistic, $P$ = 0.385).

A total of 401 fish were captured in gill nets, with non-salmonids accounting for 85.5% of all fish captured. Northern pike minnow (32.5% of total) and redside shiner (28% of total) were the predominant species. Other non-salmonids included large scale sucker and peamouth chub. Salmonids made up 14.5% of the gill net catch, of which 15 were cutthroat trout (4%), 2 were rainbow trout (0.5%), 15 were Dolly Varden (4%), and 26 were kokanee (6%).

Day and overnight mean gill net catch rates (CPUE) were similar for salmonids, whereas overnight catch rates were several-fold higher for non-salmonids. Overall species composition of the gill net catch differed significantly between stations (Peterson Chi$^2$ statistic, $P$ < 0.001).

During daytime gill netting, cutthroat trout and kokanee were captured only in the epilimnion of the pelagic zone (open water away from shore) over a depth range of 0-5 meters. However, we did not attempt to sample a fish layer that was observed on echograms between 45 and 65 meters that was probably kokanee. In contrast, Dolly Varden were caught below the epilimnion in the profundal zone (benthic habitat below the 6 meter depth contour) between 10 and 35 meters. Most non-salmonids (largescale sucker, peamouth chub, and redside shiner) occurred only in the littoral zone (shoreward of the 6 meter depth contour) during the day, with the exception of the northern pike minnow, which were found near bottom from 10 to 35 meters deep, and in the pelagic zone below the epilimnion (deeper than 10 meters).

During night time gill netting, trout and other species were more intermingled than during the day. Cutthroat trout remained almost exclusively in the epilimnion, with similar densities in the littoral and pelagic zones, while rainbow trout occurred only in the epilimnion of the pelagic zone. Dolly Varden were found mainly in the profundal and pelagic zones over a depth range of 15-30 m.. Kokanee were found above, within, and below the thermocline in the profundal and pelagic zones at depths ranging from 0-40 meters, with highest densities occurring at depths of 15-25 meters. Non-salmonids were most abundant in the littoral and profundal zones at night, however, large scale sucker, peamouth chub, and pike minnow were also captured in the pelagic zone during this period. Most notably, overnight CPUE for northern pike minnow was similar to that of salmonids in the epilimnion of the pelagic zone.

Mean lengths and weights of cutthroat trout, rainbow trout, kokanee, and Dolly Varden that were caught in gill nets (none were captured in traps) were 312 mm (369 g), 220 mm (119 g), 181 mm (76 g), and 457 mm (845 g), respectively. Mean condition factors of all salmonid species were greater than 1.0, ranging from 1.03 for cutthroat trout to 1.20 for kokanee, indicating that these fish were in good condition. Weight versus length regressions were highly significant ($P$<0.001) for all salmonids, with $r^2$ values exceeding 0.94. Growth rates of all salmonid species were appreciable for all ages that were sampled. Age ranges were 1-7 years for cutthroat trout, 0-3 years for kokanee, and 1-2 years for rainbow trout. Dolly Varden that were aged ranged from 4-7 years old. Larger Dolly Varden that were released without taking scales (to avoid mortality) were estimated to be 11 years old from age-length plots.

Mean lengths and weights of non-salmonids from catches of both gear types combined were: large scale sucker 301 mm (342 g), peamouth chub 124 mm (27 g), northern pike minnow 183 mm (252 g), prickly sculpin 95 mm (no weights taken), and redside shiner 102 mm (14.4 g). The mean condition factors of all non-salmonids from both gears were greater than or equal to 1.0. They ranged from 1.00 for northern pike minnow in traps to 1.35 for redside shiner in gill nets. Weight versus length regressions were highly significant ($P$<0.003) for all non-salmonids, with $r^2$ values exceeding 0.990, except for redside shiner ($r^2$=0.49). The low $r^2$ for redside shiner was attributed to measurement error caused by the difficulty of accurately weighing small fish in the field.

At the time of the study, the composition of food ingested by cutthroat trout was mainly flying terrestrial insects. Ants, aphids, and unidentified Dipterans were the predominant prey groups. Kokanee mainly ingested zooplankton, and cladocerans (Eubosmina, Daphnia, Holopedium) were the most abundant taxa. The composition of food ingested by Dolly Varden was almost exclusively fish that were digested beyond further recognition, except for two sticklebacks in one stomach.

During the day, fish were observed on echograms at low density over the whole 0-80 m range that was sampled, with main concentrations 30 to 60 meters deep and in the uppermost 5 meters of the water column. At night, fish were more abundant on both side and down looking echograms, with main concentrations from 10 to 30 meters and from 0 to 5 meters, and no fish below 40 meters. During the day, the distribution of fish was patchy. At night, fish densities were generally higher and less patchy, with high values near shore on many transects.

Target strength (TS) from down looking acoustics ranged from -63.1 to -34.6 dB during the day, and from –64.4 to -32.3 dB at night. Fork lengths that were estimated from TS ranged from 13 to 467 mm during the day, with fish less than 100 mm long most numerous by far. At night, fish length estimates ranged from 11 to 624 mm, with small fish again predominating, but larger size groups were better represented than during the day. A peak in the estimated length-frequency distribution of 30 mm was close to what would be expected for underyearling kokanee during the fall (about 40 mm). Length ranges and length frequency distributions that were estimated from TS for fish more than 100 mm long were similar to those from gill netting.

Daytime results were used to estimate the abundance of cutthroat trout, the only species that was well sampled at that time (other species were poorly sampled then because of unfavorable spatial distributions). The daytime population estimate for cutthroat trout in the acoustic sampling zone (main lake basin, offshore of the 13.5 m depth contour on average) was 1,684 fish, or 0.6 fish/ha, all in the upper 10 meters of the water column. Species composition for this estimate was based on a very small sample size, which reduced its certainty.

Night time results were used to estimate the abundance and biomass of all species that occurred in the acoustic sampling zone. At night, the abundance and biomass of fish less than 100 mm long was 307,550 fish (215 kg), all of which were assumed to be underyearling kokanee. Of fish 100 mm long or longer, numbers and biomass were 3,042 cutthroat trout (1,065 kg), 17,322 Dolly Varden (19,633 kg), 46,064 kokanee (3,413 kg), 713 rainbow trout (78 kg), 3,499 peamouth chub (101 kg), and 15,527 pike minnow (4,032 kg). The numbers and biomass of salmonids at least 100 mm long were also summarized by cohorts. Considering cutthroat trout, ages 2 and 3 were most abundant whereas ages 3 and 7 had the largest biomass. For Dolly Varden, all of which were at least age 4, ages 6 and 7 were most numerous, while ages 7 and 11 contributed most biomass. Kokanee of ages one to three were present in the catch, with age two dominant both numerically and in terms of biomass. Based on a catch of only two fish, age one and two rainbow trout were equal in abundance while age two had the larger biomass. Numbers and biomass of large and small fish combined were 1.1 cutthroat trout/ha (0.4 kg/ha), 6.1 Dolly Varden/ha (6.9 kg/ha), 125 kokanee/ha (1.3 kg/ha), 0.3 rainbow trout/ha (0.03 kg/ha), 1.2 peamouth chub/ha (0.04 kg/ha), and 5.5 northern pike minnow/ha (1.4 kg/ha), for a combined total of 139 fish/ha (10.1 kg/ha).

Night time surveys appeared to be superior for assessing abundance and biomass of trout and other fish species in Stave Reservoir. At night, all species were restricted to the upper 40 meters of the water column and most were semi-pelagic, putting them within reach of both acoustics and gill nets. Trout were not as shore oriented at night in Stave Reservoir as in many other lakes and reservoirs, perhaps due to its high density of non-salmonids in the littoral zone. Larger sample sizes (fish captured and acoustic targets) at night also made abundance and biomass estimates from that period more reliable.

Our night time fish biomass estimate for Stave Reservoir (10.1 kg/ha) was intermediate in a comparison of several other lakes and reservoirs. Kokanee and trout densities in Stave Reservoir were relatively low, possibly due to its ultra-ultra-oligotrophic status. In contrast, the density of Dolly Varden char (6.9 kg/ha) was high compared to that of other water bodies. This estimate may be accurate or it may be biased by disproportionately high catch rates of Dolly Varden in gill nets. This question deserves further attention in future sampling and analysis.

Results of fish sampling in 2005 were similar to those of previous studies at Stave Reservoir. The assemblage of fish species that was captured in nets and traps in 2005 was much the same as in other years of sampling (1987, 1988, and 1993). In 2005, the relative abundance of fish species was similar to that of 1987 and 1993 (e.g., pike minnow and redside shiner were most numerous), but different from that of 1988, when more open water areas were targeted. In 2005, the lengths of kokanee (mean and range) were similar to those of previous studies, while rainbow trout were smaller, and cutthroat trout and Dolly Varden were larger. Fish were only aged in 2005 and 1993. We did not make inter-year comparisons of population age structure because the range of ages identified appeared largely dependent on the number of fish that were aged, which differed considerably among years.

## ACKNOWLEDGEMENTS

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## 1.0 INTRODUCTION

Stave Reservoir is the major impoundment within BC Hydro's Stave River Hydroelectric Project (Figure 1). Improving fish production in this 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 the 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*-ultra-oligotrophic with the lowest levels of carbon production 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 (WCC) recommended that primary and secondary production – and ultimately fish production and the sport fishery - 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 ultimately fish production.

Preliminary estimates predicted that Combo 6 would increase primary production (total carbon) in the reservoir by 21% and the "effective littoral zone" by 830 ha, with production increasing mainly in the littoral zone (Failing 1999a&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 are enhanced, will the main beneficiaries be trout, which typically rely heavily on the benthic and terrestrial food sources (e.g., Stables et al. 1990, Johnston et al. 1999, Perrin and Stables 2000 and 2001), or kokanee, which mainly exploit the pelagic food chain (Burgner 1991, Quinn 2005)?

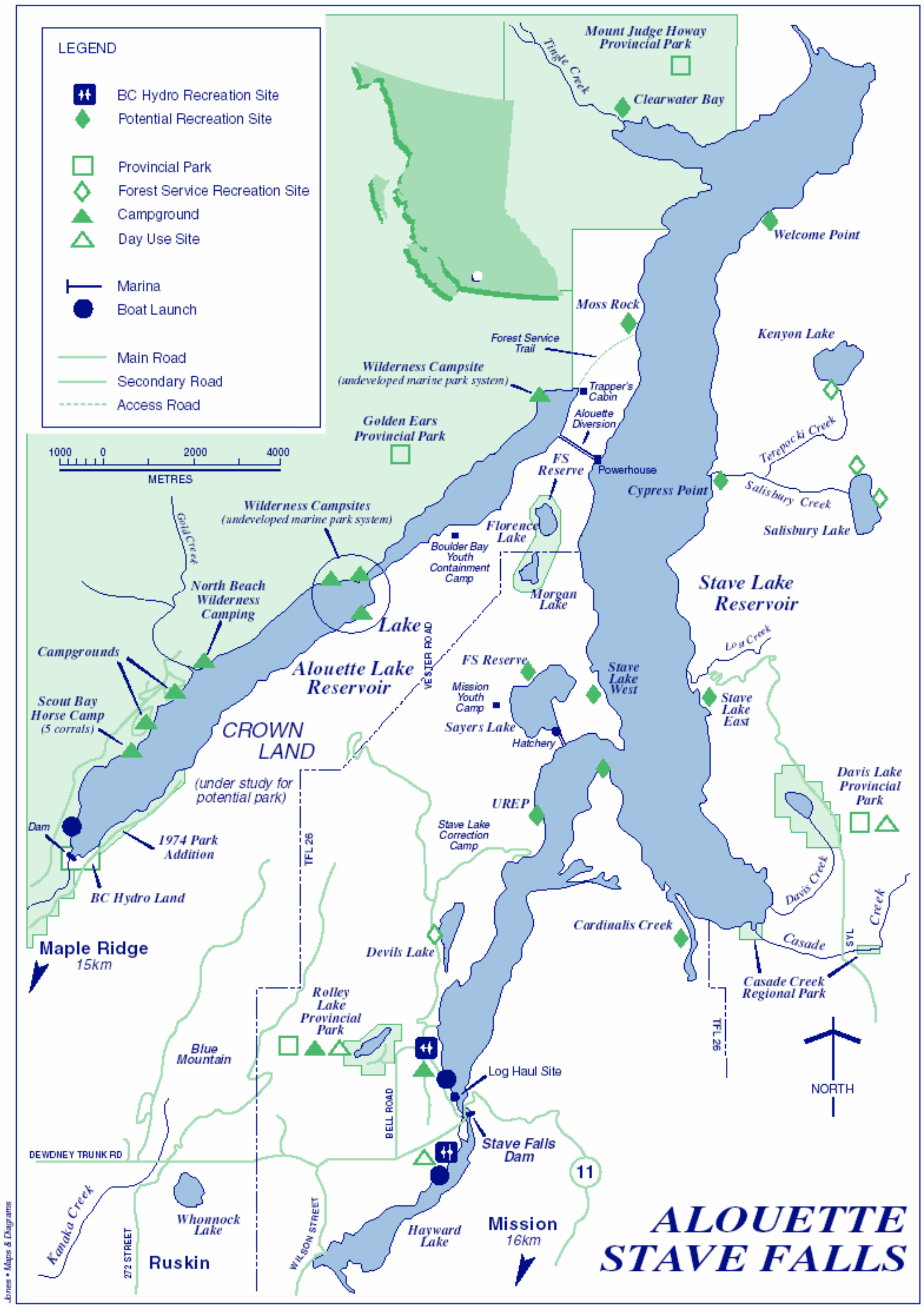



Figure 1. Stave Reservoir and the Stave River Hydroelectric Project.

Previous fish sampling found that Stave Reservoir supports several salmonid species (rainbow trout, *Oncorhynchus mykiss*; coastal cutthroat trout, *O. clarki clarki*; kokanee *O. nerka*; and Dolly Varden, *Salvelinus malma*,) and non-salmonid species (northern pike minnow *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 can be expected to 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 from it. 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, two major studies were approved by the WCC. Annual monitoring of fish population size will continue over ten years as Combo 6 is implemented. This monitoring, and companion monitoring of trophic production are intended to determine if the ecological benefits hoped for are realized. It will also expand general knowledge about the system's ecology to assist with future water management decisions. The specific goals of the ten-year fish population monitoring program are to:

1. Determine if overall numbers and biomass of fish in Stave Reservoir change over time following implementation of Combo 6; and
2. Determine if between-year differences in species and cohort-specific fish abundance and biomass are correlated with indicators of littoral and pelagic primary productivity.

Acoustic sampling (scientific echo sounding) coordinated with complementary fish collection methods were selected for determining fish population size, and the fish population to be assessed was restricted to those pelagic and semi-pelagic species that can be sampled effectively in this way. This approach has proved effective for rapidly assessing the abundance and distribution of fish in many other lakes and reservoirs (Kubecka et al. 1994, Kubecka and Wittingerova 1998, Yule 2000, Stables and Perrin 2004, Perrin et al. 2006). This report describes findings from year one (2005), for which specific objectives were to:

1. estimate the abundance and biomass of fish during fall 2005 for:
    a. total fish (all species combined)
    b. individual fish species
    c. individual age groups of salmonids
2. describe the spatial distribution of fish species;

3. describe biological characteristics of the fish community including species composition, size composition, age composition, and diet; and
4. 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 approximately 65 km east of Vancouver in the Fraser River watershed (Figure 1). The reservoir is approximately 25 km long with a total area of 5,860 ha and a mean depth of 36 m at full pool (Norris and Balkwill 1987, Stockner and Beer 2004). Its watershed is 1,150 $km^2$ in area, including Alouette Lake, which drains into it 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 formed by Stave Falls Dam. The central and largest portion of the main lake basin is steep sided and deep, reaching a maximum measured depth of 101 meters. The north and south ends of the main basin contain several kilometers of shallows outside the natural lake basin that are still 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 of 82.1 m above sea level) and 2,831 ha at 76 m, the elevation during the 2005 survey.

Stave Reservoir is an ultra-ultra-oligotrophic ecosystem characterized by extremely low dissolved phosphorus concentration, algal biomass, littoral and pelagic primary production, zooplankton standing crop (Stockner and Beer 2004). The reservoir also has a high flushing rate. During summer stratification, the average depth of the epilimnion (the uppermost and warmest layer of water) is approximately 7 m. Epilimnetic temperature typically reaches 20 ºC 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 very rare in Stave Reservoir and are absent from the 2005 study area (J. Bruce, BC Hydro, personal communication). Under Combo 6, the typical annual drawdown will be approximately 4.5 meters, with seasonally different target elevations. The surface elevation target will be a 77-79 meters above sea level year around, except from May 15 to September 7 when it will increase to 80-81.5 meters. A drawdown to as low as 72 meters above sea level will occur for six weeks one out of every three years on average, and it will not extend beyond March 31, or begin prior to January 1.

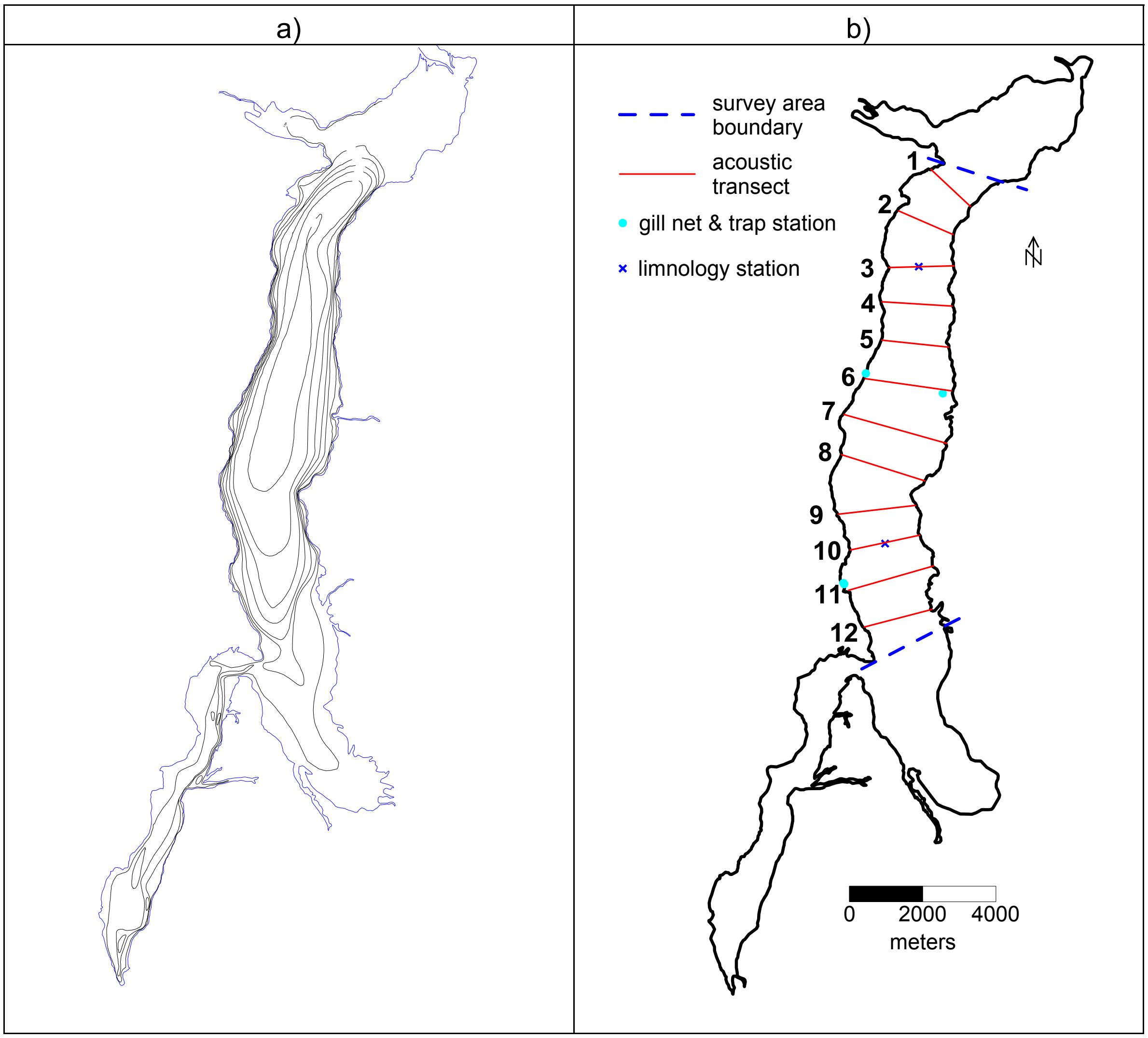



Figure 2. Maps of Stave Reservoir: a) bathymetric map showing the reservoir outline at full pool (82.1 m above sea level) and depth contours (10 m interval); b) limnology sampling stations, gill net and trap sites, and acoustic transects for the 2005 fish survey.

# 3.0 METHODS

A two part survey of Stave Reservoir was conducted during September 26 to October 8, 2005. First, day and night acoustic surveys were performed with a scientific echo sounder to estimate the abundance, size, and spatial distribution of fish during the two periods. Day and night surveys were intended to optimize sampling conditions for trout and kokanee, respectively, and to evaluate whether sampling either period alone would be satisfactory for future surveys. Fish sampling was conducted with gill nets and minnow traps to determine species, size, and age composition within a few days of the acoustic surveys. Composition of food that was ingested by fish was also determined at this time . Limited limnological data were collected at the time of gill net sampling. All sampling took place within the 2,831 ha 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 55 meters of the water column at two stations in the main lake basin using a calibrated YSI model 8750 Sonde (Figure 2). The meter also recorded other electrochemical parameters (pH, specific conductivity, total dissolved solids, and turbidity) that provided additional descriptive information about chemical attributes of the lake. Temperature and DO profiles of the water column were plotted to assist with the interpretation of vertical distributions of fish that were observed during acoustic and fish sampling.

## *3.2 Fish Sampling*

### 3.2.1 Field Activities

Fish were sampled near the ends of acoustic transects 6 and 11 (Figure 2). Overnight (September 30 - October 1) and daytime (October 8) gill net sets were made with standard 100 x 2.4 meter floating and sinking variable mesh gill nets (RIC 1997). Each net consisted of 6 panels, each of a different mesh size (25, 89, 51, 76, 38, and 64 mm stretch mesh). A surface set, a midwater set, and a bottom set were planned at each of two stations (northern and southern) per diel period for a total of 12 sets (6 day and 6 overnight). A preliminary plan to locate the northern station at the east end of transect 6 was changed when that location was found to be heavily timbered. Most sampling was therefore shifted to the clearer western shore, and a single midwater gill net set was made at the original east shore location.

All gill nets were set perpendicular to shore. Bottom sets were laid out from the littoral zone (shoreward of the 6 m depth contour) to deep water below the thermocline. Floating nets sampled the upper 2.4 meters of the water column in the littoral and pelagic (offshore open water) zones. Floating and bottom set gill nets were attached to shore and anchored at the offshore end. They were buoyed and clearly marked to minimize the hazard to boat traffic. Mid-water sets sampled horizontally from the bottom out into the pelagic zone at a selected depth (12 or 15 meters) within the thermocline where fish were observed on echograms. Midwater gill nets were suspended from floats on dropper lines to the desired depth and marked with buoys. In this way, gill nets sampled depths ranging from 0-50 m and extended over 100 meters from shore.

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. Daytime sets were deployed in the morning and retrieved before dark, while overnight sets were deployed in the evening and picked up as early as possible the following morning. Set and retrieval times were recorded to the nearest minute. The mesh size and position of each panel relative to shore was noted. Catches were recorded by individual net panel.

Gee-traps (42 cm length x 21 cm diameter with 0.5 cm rigid square mesh and 2.5 cm diameter opening in the intake cone, RIC 1997) were set on the bottom at the gill net sites in 3-16 meters of water (Figure 2). Traps were baited with salmon roe and set both overnight and during the day. Set and retrieval times were recorded to the nearest minute.

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 measurements when necessary. Scales were removed from preferred areas of all salmonids and stored in labeled envelopes. Otoliths were also taken from Dolly Varden. Stomachs were excised from at least seven fish of each salmonid species and preserved in 10% formalin for later examination. Neither scales nor stomachs were taken from non-salmonids. Special effort was made to return all live fish to the reservoir quickly without harm.

### 3.2.2 Processing and Analysis

In the lab, organisms that were found in the fish stomachs were identified to the lowest reliable taxon (usually family) and counted. For animals that were partly digested, heads or other unambiguous body part were used for enumeration. Scales and otoliths were read by a qualified expert.

Gillnet and trap data were analyzed with respect to several factors. Catch and catch per unit effort (CPUE) were calculated for each species and sampling period (daytime and overnight) for both gear types. Gill net data were also analyzed in relation to depth and lateral distance from shore or the lake bottom. CPUE was computed as catch per hour that a gear type was fished (fish/gear-hour) and CPUE of individual gill net panels (fish/panel-hour) was used to assess spatial patterns of abundance.

Stomach contents of salmonids were analyzed by comparing percent composition by numbers among fish species and by summarizing food composition by source (benthic, pelagic, or terrestrial). These data assisted in determining the relative importance of food produced within and outside of the reservoir for supporting the fish populations.

Other biological information 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/length$^3$, Ricker 1975).

## *3.3 Acoustic Surveys*

### 3.3.1 Sampling

Daytime and night time mobile acoustic surveys were conducted on September 26, 2005. Survey methods generally followed protocols described in standard fisheries acoustics texts (Thorne 1983, MacLennan and Simmonds 1992, Brandt 1996). Daytime sampling took place from 1100 to 1830 hours and night sampling extended from 2000 hours to midnight.

Sampling was performed from a 7 meter long, covered aluminum jet boat. The sampling speed on acoustic transects was approximately 2 meters/second. 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 meters 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 meters of the water column, the transducer was aimed 3.5 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). Both down-looking and side-looking scans were made on all acoustic transects.

The echo sounding system consisted of a 208 kHz BioSonics split-beam scientific echo sounder with a 6.5 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 26, 2005.

| Project Phase | Category | Parameter | Value |
|---|---|---|---|
| Data collection | transducer | type | split-beam[1] |
| " | " | sound frequency | 208 kHz |
| " | " | nominal beam angle | 6.5 deg |
| " | " | depth of face | 0.5 m |
| " | settings | pulse width | 0.4 msec |
| " | " | data collection threshold | -65 dB |
| " | " | minimum data range[2] | 1.0 m |
| " | " | Time Varied Threshold | 40 log R |
| " | " | ping rate | 4-6 pps |
| " | GPS | type | differential[3] |
| " | " | Datum | NAD83 |
| " | Other | Transecting speed | 2 m/sec |
| Data Analysis | general | calibration offset | 0.0 dB |
| " | " | Time Varied Gain | 40 log R |
| " | " | minimum threshold[4] | -65 dB |
| " | " | maximum threshold[4] | -25 dB |
| " | " | beam pattern threshold | -6 dB |
| " | " | beam full angle | 6.5 deg |
| " | " | Single target filters | 0.8-1.5 @ -6 dB |
| " | range processed[2] | down-looking | 2-80 m |
| " | " | side-looking | 15-60 m |
| " | fish tracking, per fish | minimum # echoes | 2 |
| " | " | max range change[5] | 0.2 m |
| " | " | max ping gap | 1 |

[1] BioSonics DT-X split-beam digital scientific echo sounder.
[2] range from transducer.
[3] WAAS differential GPS.
[4] Processing threshold after application of calibration offset.
[5] maximum allowable range change in x, y, or z dimension.

The survey was laid out over 12 pre-selected transect lines within the main reservoir basin (Figure 2). Transects were approximately perpendicular to the longitudinal axis of the lake, spaced at 1.1 km intervals, and they extended shoreward to the 2 meter depth contour when safety allowed. Because of steep drop-offs and standing timber in many parts of the littoral zone, transects ended at the 13.5 m depth contour on average. In accordance with the study plan, more transects were sampled during daytime than at night. Thus, 10 transects (1-9 and 11) were sampled during daylight and 6 transects (1, 3, 5, 7, 9, 11) were sampled at night. Time limitations prevented sampling of all 12 planned transects during daylight. 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© v2.25 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 for depths greater than five meters, while side-looking data were used to represent the uppermost five meters 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.

TS was determined by the split-beam method (MacLennan and Simmonds 1992). Accuracy of acoustic measurements was assured by shop and field calibration tests. The echo sounder was calibrated by BioSonics, its manufacturer, prior to the survey, and in-situ TS measurements of a standard sphere made during the survey. Results of the field test were within 0.7 dB of the expected value (-39.5 dB) on average, and data processing was adjusted by this factor. 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 55 m. 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 from the acoustic beam angle and distance transected corrected for bottom intrusion, using the wedge model (Keiser and Mulligan 1984) for all depth intervals. Processing settings were a -65 dB counting threshold and a 6.5º 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 that it included (shallow transects did not contain all intervals). For each depth 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 simple random sample stratified by depth intervals (Cochran 1977). Volumes of depth intervals used for analysis were calculated by BC Hydro Photogrametry Department staff from a bathymetric map of the reservoir from the BC Ministry of Water, Land, and Air Protection. Cutthroat trout abundance was estimated from the daytime survey. Abundance and biomass of trout and all other fish species were estimated from the night time survey (see further explanation in Results and Discussion sections).

Relative abundance of fish captured in gill nets was used to apportion the acoustic estimate among species. Fish and acoustic data from corresponding periods and locations were matched during this analysis (e.g., daytime floating gill net data were matched with daytime side-looking acoustic data). Only offshore gill net panels corresponding to the area sampled with acoustics (offshore of the 13.5 m depth contour on average) were used for species apportionment.

Relative catch rates (CPUE) in nearshore and offshore gill net panels were used to compare fish densities in near-surface offshore habitats sampled by acoustics and shallow nearshore habitats that were not sampled by acoustics. All floating gill net panels and the shallowest panel (north station) or shallowest two panels (south station) of sinking gill nets were included in this analysis.

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 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 kokanee.(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 well defined throughout the reservoir on both sampling dates (Figure 3). The epilimnion extended to about 10 meters in all cases, and its temperature was slightly warmer (14.1-15.4 °C) on September 30 than on October 8 (12.8-13.1 °C), indicating that some wind driven mixing had taken place between sampling dates. Temperature decreased rapidly below 10 meters, reaching 7.3-8.7 °C by 20 meters and 5.4-5.5 °C at 55-60 m, the depth limit of sampling. The dissolved oxygen concentration was high (9.5-12.1 mg/l) throughout the depth range of 0-60 m on both sampling dates, well above the minimum level considered adequate for protection of fish (>6.5 mg/L, CCME 2003).

## *4.2 Fish Sampling*

### 4.2.1 Gee Traps

A total of 65 fish were captured in the 12 Gee-trap sets that were made during the study (Table 2). Prickly sculpin dominated the catch at both stations and made up 74% of the total catch in traps. Peamouth chub, northern pike minnow, and redside shiner, were also captured at both stations. No salmonids were captured in Gee traps. Species composition did not differ significantly between the two stations (Peterson $Chi^2$ statistic = 5.43, $P$ = 0.385, df = 1; periods and species other than prickly sculpin were pooled to meet test assumptions for number of cells with low counts). Although the data were insufficient to statistically test for depth effects on species composition, it is noteworthy that the sculpins were found over the entire 3-15 m depth range of sampling while redside shiners were only captured at depths of 5 m or less. The CPUE for all species combined was higher at the south station (0.64 fish/trap-hour) than at the north station (0.44 fish/trap-hour), and it was higher during the daytime than at night at both stations. “Gear saturation” due to a much longer soak time for overnight sets may have contributed to the lower catch rate at night.

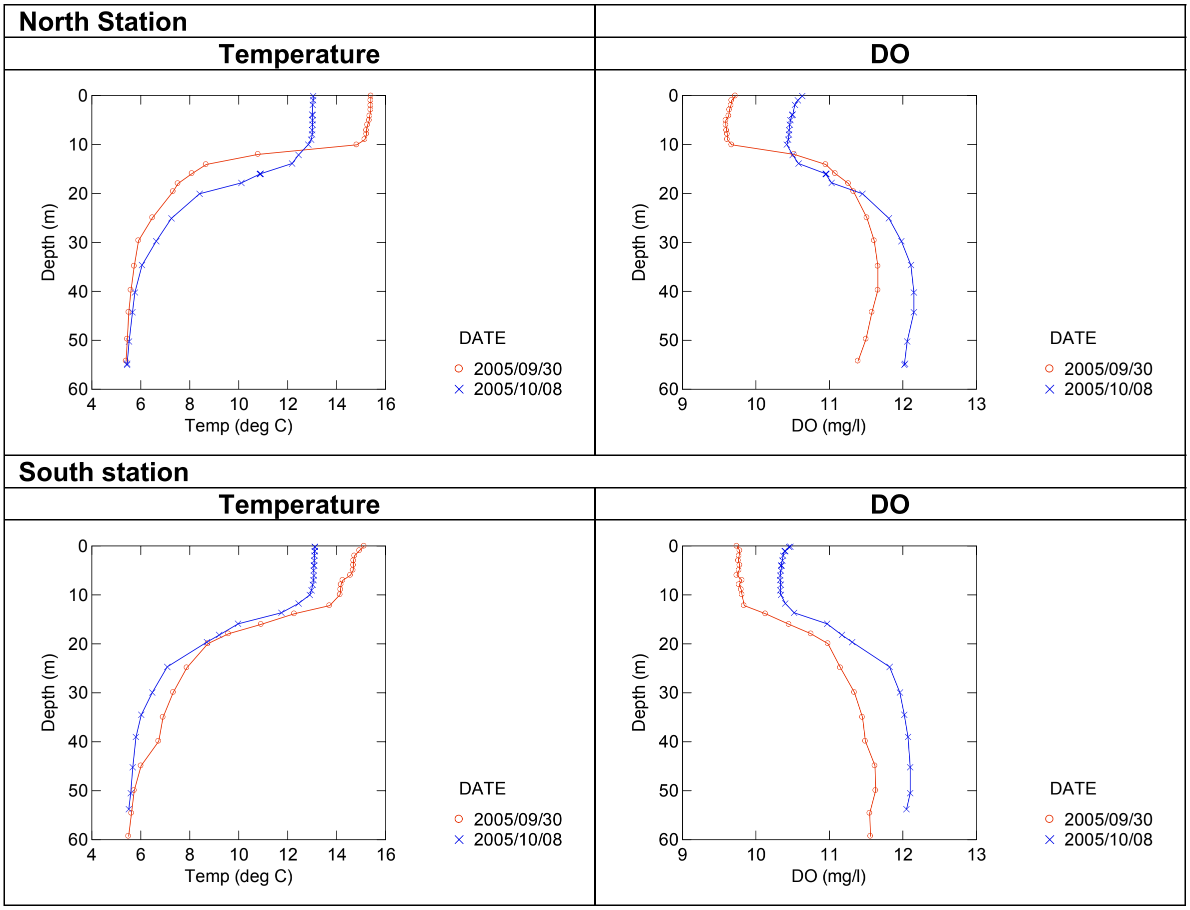



Figure 3. Temperature and dissolved oxygen profiles at north and south mid-reservoir stations on gill net sampling dates in 2005.

### 4.2.2 Gill Nets

#### 4.2.2.1 Catch and CPUE

A total of 13 sinking, floating, and midwater gill net sets captured 401 fish, with non-salmonids accounting for 85.5% of all fish captured (Table 3). Northern pike minnow (32.5% of total) and redside shiner (28% of total) were the predominant species. Other non-salmonids included large scale sucker and peamouth chub. Salmonids made up 14.5% of the total gill net catch (58 of 401 fish), of which 15 were cutthroat trout (4%), 2 were rainbow trout (0.5%), 15 were Dolly Varden (4%), and 26 were kokanee (6%).

Daytime and night time mean catch rates (CPUE as fish/panel-hour) were similar for salmonids, whereas overnight catch rates were several-fold higher for non-salmonids (Table 3). As with Gee traps, gear saturation due to a much longer soak time for overnight sets may have contributed to the lower catch rate during that period. The mean CPUE for kokanee and Dolly Varden was similar at the north and south stations. Cutthroat trout CPUE was approximately 7 fold higher at the south station. Rainbow trout were only captured at the north station. Mean CPUE was higher at the north station for peamouth chub, northern pike minnow, and redside shiner, whereas it was higher at the south station for large scale sucker. Overall species composition of the gill net catch differed significantly among stations (Peterson $Chi^2$ statistic = 74.99, $P < 0.001$, df = 7; periods were pooled to meet test assumptions for number of cells with low counts).

Table 2. Catch and CPUE (fish/trap-hour) in Gee-traps, summarized by station, period, and species.

| Station | Period | Depth Range (m) | Trap-hours | Number of traps | peamouth chub | | pike minnow | | prickly sculpin | | redside shiner | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Catch | CPUE | Catch | CPUE | Catch | CPUE | Catch | CPUE | Catch | CPUE |
| north | daytime | 4-13 | 28.0 | 5 | 0 | 0.00 | 0 | 0.00 | 18 | 0.64 | 3 | 0.11 | 21 | 0.75 |
| | overnight | 3-6 | 24.1 | 1 | 1 | 0.04 | 1 | 0.04 | 0 | 0.00 | 0 | 0.00 | 2 | 0.08 |
| | Total | 3-13 | 52.1 | 6 | 1 | 0.02 | 1 | 0.02 | 18 | 0.35 | 3 | 0.06 | 23 | 0.44 |
| south | daytime | 6-15 | 20.1 | 4 | 2 | 0.10 | 5 | 0.25 | 23 | 1.15 | 0 | 0.00 | 30 | 1.49 |
| | overnight | 4-5 | 45.5 | 2 | 0 | 0.00 | 6 | 0.13 | 7 | 0.15 | 1 | 0.02 | 14 | 0.31 |
| | Total | 6-15 | 65.6 | 6 | 2 | 0.03 | 11 | 0.17 | 30 | 0.46 | 1 | 0.02 | 44 | 0.67 |
| north & south | day & night | 3-15 | 117.7 | 12 | 3 | 0.03 | 12 | 0.10 | 48 | 0.41 | 4 | 0.03 | 67 | 0.57 |

Table 3. Catch and CPUE (catch per panel-hour) in gill nets, summarized by station, period, and species. Floating, sinking, and midwater catches were combined.

| Station | Period | Panel hours | cutthroat trout | | Dolly Varden | | kokanee | | largescale sucker | | peamouth chub | | pike minnow | | rainbow trout | | redside shiner | | Total Catch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | catch | CPUE | catch | CPUE | catch | CPUE | catch | CPUE | catch | CPUE | catch | CPUE | catch | CPUE | catch | CPUE | catch | CPUE |
| north | daytime | 157.2 | 1 | 0.006 | 3 | 0.019 | 4 | 0.025 | 0 | 0.000 | 1 | 0.006 | 2 | 0.013 | 0 | 0.000 | 3 | 0.019 | 14 | 0.089 |
| | overnight | 313.3 | 1 | 0.003 | 4 | 0.013 | 7 | 0.022 | 26 | 0.083 | 24 | 0.077 | 87 | 0.278 | 2 | 0.006 | 91 | 0.290 | 242 | 0.772 |
| | total | 470.5 | 2 | 0.004 | 7 | 0.015 | 11 | 0.023 | 26 | 0.055 | 25 | 0.053 | 89 | 0.189 | 2 | 0.004 | 94 | 0.200 | 256 | 0.544 |
| south | daytime | 106.5 | 3 | 0.028 | 1 | 0.009 | 0 | 0.000 | 1 | 0.009 | 0 | 0.000 | 8 | 0.075 | 0 | 0.000 | 0 | 0.000 | 13 | 0.122 |
| | overnight | 367.8 | 10 | 0.027 | 7 | 0.019 | 15 | 0.041 | 45 | 0.122 | 3 | 0.008 | 33 | 0.090 | 0 | 0.000 | 19 | 0.052 | 132 | 0.359 |
| | total | 474.3 | 13 | 0.027 | 8 | 0.017 | 15 | 0.032 | 46 | 0.097 | 3 | 0.006 | 41 | 0.086 | 0 | 0.000 | 19 | 0.040 | 145 | 0.306 |
| north & south | day & night | 944.8 | 15 | 0.016 | 15 | 0.016 | 26 | 0.028 | 72 | 0.076 | 28 | 0.030 | 130 | 0.138 | 2 | 0.002 | 113 | 0.120 | 401 | 0.424 |

#### 4.2.2.2 Effect of Depth and Lateral Distance from Shore or Bottom on Fish Abundance

During daytime gillnetting, cutthroat trout and kokanee were captured only in the epilimnion in the pelagic zone at a distance of 33 meters or more from shore (Figure 4). In contrast, Dolly Varden were caught only within 17 meters of bottom (laterally, from the shoreward end of the net) at depths of 10-35 meters (Figure 4). We did not attempt to sample a fish layer that was observed on echograms between depths of 45 and 65 meters, which was probably kokanee. No rainbow trout were captured during the day. Most non-salmonids (largescale sucker, peamouth chub, and redside shiner) occurred only in the littoral zone (0-5 m deep within 17 m of shore) during the day, with the exception of northern pike minnow, which were found near bottom from 10 to 35 meters deep, and in the pelagic zone below the epilimnion (deeper than 10 meters). Thus, cutthroat trout and kokanee were the only fish that occurred in the epilimnion of the pelagic zone during the day.

During night time gill netting, trout and other species were more intermingled (Figure 5). Cutthroat trout occurred in the littoral, pelagic, and upper profundal zones (profundal refers to benthic habitat below the 6 meter depth contour), mainly above the thermocline, with highest CPUE (0.07-0.08 fish per panel-hour) occurring at water depths of 0-5 meters and 17-50 meters from shore (Figure 5). Dolly Varden were found in the pelagic zone, both at the surface and below the epilimnion near the offshore limit of gill netting, and in the profundal zone from 15-30 m deep. The highest Dolly Varden CPUE (0.06-0.09 fish per panel-hour) occurred at a depth of 15-30 meters in the profundal zone. Kokanee were found above, within, and below the thermocline in the profundal and pelagic zones at depths ranging from 0-40 meters. The highest kokanee CPUE (0.17 fish per panel-hour) was found at a depth range of 20-25 meters from 67 to 83 meters (laterally) from bottom in a midwater set. Rainbow trout occurred only in the epilimnion of the pelagic zone (0-5 m deep, over 33 meters from shore). All non-salmonids were most abundant in the littoral and profundal zones at night, however, catch rates for large scale sucker, peamouth chub, and northern pike minnow were also appreciable in the pelagic zone during this period. This was especially true of northern pike minnow, for which CPUE was similar to that of salmonids (0.06-0.12 fish per panel-hour) throughout the pelagic portion of the epilimnion.

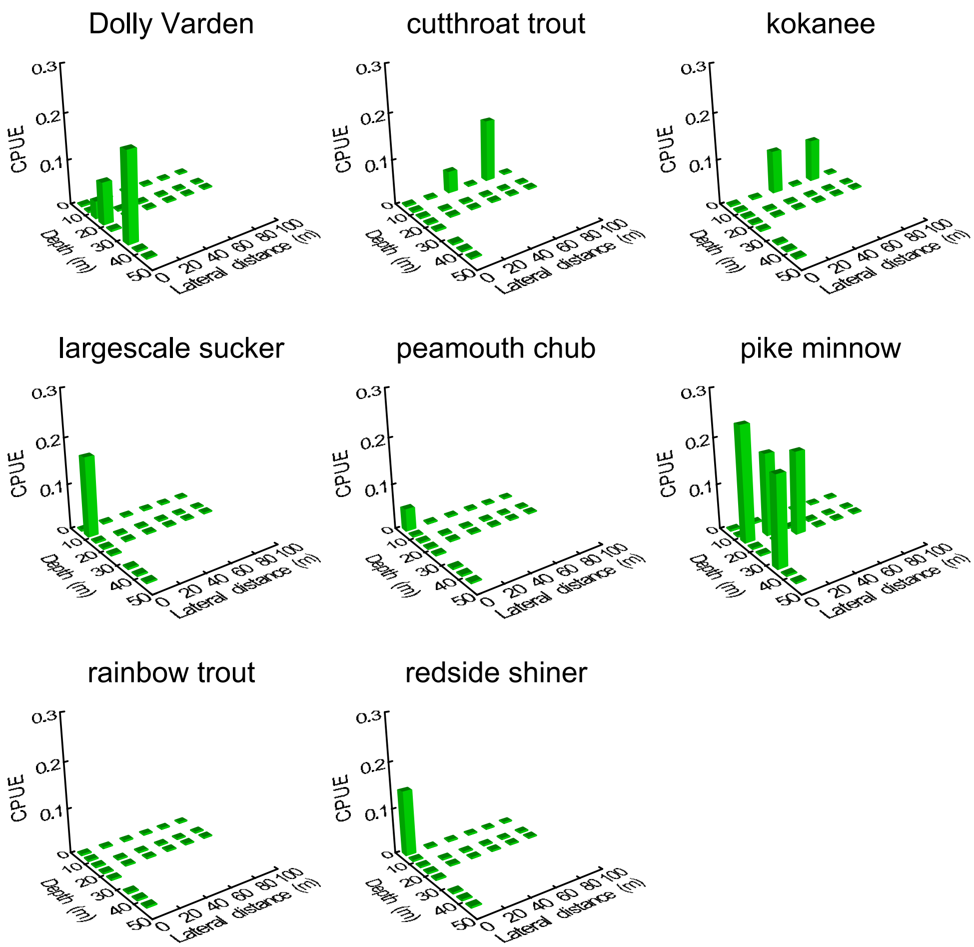



Figure 4. Daytime CPUE (catch per panel-hour) for each species captured in gill nets, categorized by depth and lateral distance from bottom. All surface, midwater, and bottom sets from both stations were pooled for this analysis. Bottom set panels were all within 5 m lateral distance of bottom; surface and midwater sets covered a lateral range of 0-100 m from where they were anchored to the bottom.

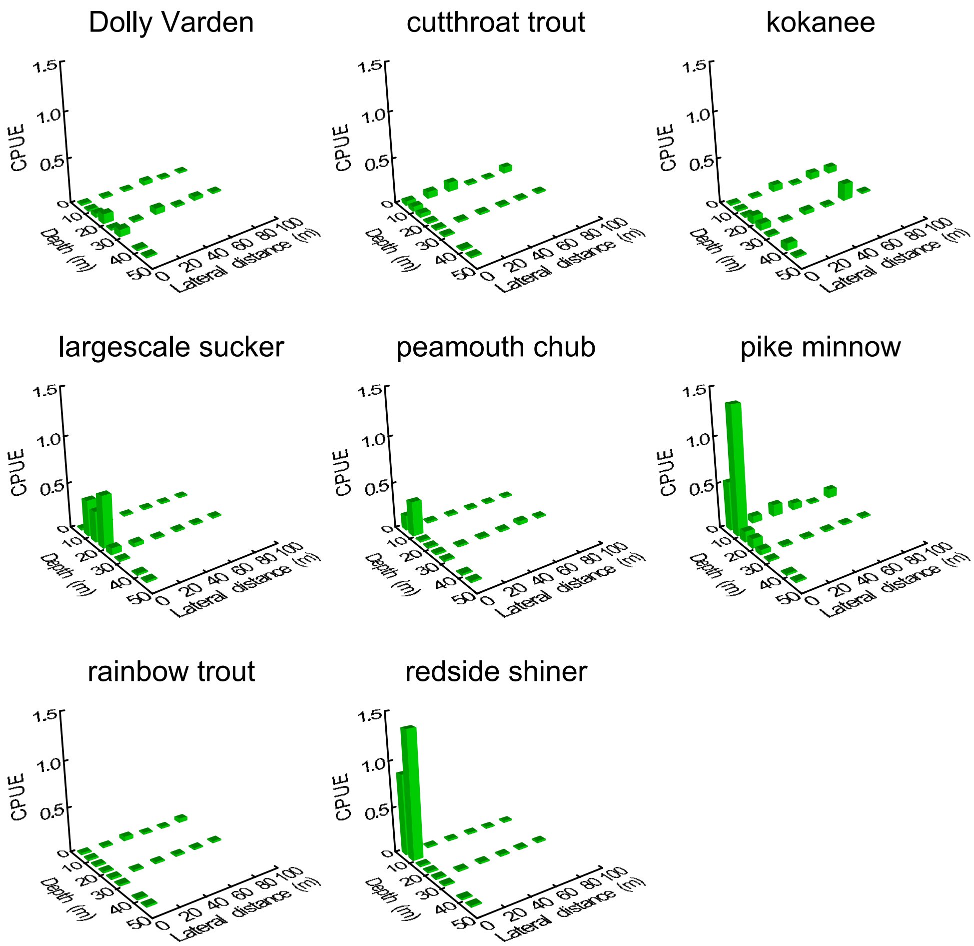



Figure 5. Night time CPUE (catch per panel-hour) for each species captured in gill nets, categorized by depth and lateral distance from bottom. All surface, midwater, and bottom sets from both stations were pooled for this analysis. Bottom set panels were all within 5 m lateral distance of bottom; surface and midwater sets covered a lateral range of 0-100 m from where they were anchored to the bottom.

Table 4. Mean gill net catch rates in the upper 5 meters of the water column in offshore and nearshore zones. The offshore zone corresponds to the area sampled with acoustics (beyond the 13.5 m depth contour, on average) and the nearshore zone is the area shoreward of this contour. All floating gill net panels and the shallowest panel (north station) or shallowest two panels (south station) of sinking gill nets were included in this analysis.

| **Species** | **Catch per panel-hour** | | | |
|---|---|---|---|---|
| | **Daytime** | | **Night time** | |
| | **Nearshore** | **Offshore** | **Nearshore** | **Offshore** |
| Dolly Varden | 0.000 | 0.000 | 0.000 | 0.006 |
| kokanee | 0.000 | 0.037 | 0.000 | 0.035 |
| pike minnow | 0.000 | 0.000 | 1.053 | 0.064 |
| cutthroat | 0.000 | 0.037 | 0.032 | 0.040 |
| sucker | 0.037 | 0.000 | 0.236 | 0.000 |
| peamouth | 0.037 | 0.000 | 0.279 | 0.000 |
| rainbow | 0.000 | 0.000 | 0.000 | 0.012 |
| shiner | 0.110 | 0.000 | 1.182 | 0.000 |
| Combined | 0.183 | 0.075 | 2.783 | 0.156 |

A comparison of CPUE in offshore areas sampled with acoustics (offshore of the 13.5 m depth contour, on average, in the 0-5 m depth interval) with nearshore areas that were not sampled with acoustics (inshore of the 13.5 m depth contour, on average, in the 0-5 m depth interval) showed that the mean CPUE for all species combined was higher near shore both day and night (Table 4). During the day, mean CPUE for all species combined was 0.183 fish/panel-hour near shore and 0.075 fish/panel-hour off shore. At night, the mean CPUE was 2.783 fish/panel-hour near shore and 0.156 fish/panel-hour off shore. Neither of these differences was statistically significant, although night values were nearly so (daytime: Mann-Whitney U = 7.0, $P = 0.714$; night time: Mann-Whitney U = 8.0, $P = 0.064$). Some fish species occupied one zone exclusively (e.g., redside shiner near shore), some shifted between zones during different periods (e.g., shoreward movement of cutthroat at night), and others were very rare in these zones at any time (e.g., Dolly Varden).

Species composition estimates from gill net catches for fish ≥ 100 mm long in the zone sampled with acoustics (main lake basin, offshore of the 13.5 m depth contour on average) are shown in Table 5. This information applies to the 0-45 m depth range where gill nets were fished. Intermediate depth intervals that were not sampled (e.g., 5-10 m) or had low catches were pooled with other intervals for species composition estimates. Large scale suckers were excluded from these estimates because most of the time they were probably too close to the bottom for detection with acoustics (also see TS results). During the day, the species composition in the upper 10 meters of the water column was 50% of cutthroat trout and 50% was kokanee. From 10 to 45 meters deep, no trout or kokanee were captured and the fish assemblage was mainly northern pike minnow and Dolly Varden. At night, cutthroat trout, kokanee, and northern pike minnow accounted for most fish from 0 to 10 meters (26%, 22%, and 41%, respectively). From 10 to 20 meters, Dolly Varden and northern pike minnow were the most numerous species, and kokanee was the most abundant species in the 20-40 meter interval (63% of fish).

Table 5. Catch (upper table) and species composition (lower table) by depth intervals of the acoustic sampling zone (off shore of the 13.5 m depth contour, approximately), not including largescale sucker. Depth intervals that were not sampled (5-10 m) or had low catches were pooled with other intervals for species composition estimates.

| Variable | Period | Interval number | Depth range (m) | Cutthroat trout | Dolly Varden | Kokanee | Peamouth chub | Pike minnow | Rainbow trout | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| catch | day | 1 | 0-5 | 4 | 0 | 4 | 0 | 0 | 0 | 8 |
| " | " | 2 | 5-10 | | | | | | | |
| " | " | 3 | 10-15 | 0 | 1 | 0 | 0 | 8 | 0 | 9 |
| " | " | 4 | 15-20 | 0 | 2 | 0 | 0 | 1 | 0 | 3 |
| " | " | 5 | 20-25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " | " | 6 | 25-30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " | " | 7 | 30-35 | 0 | 1 | 0 | 0 | 1 | 0 | 2 |
| " | " | 8 | 35-40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " | " | 9 | 40-45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " | " | combined | 0-45 | 4 | 4 | 4 | 0 | 10 | 0 | 22 |
| " | night | 1 | 0-5 | 7 | 1 | 6 | 0 | 11 | 2 | 27 |
| " | " | 2 | 5-10 | | | | | | | |
| " | " | 3 | 10-15 | 1 | 1 | 0 | 0 | 4 | 0 | 6 |
| " | " | 4 | 15-20 | 0 | 5 | 4 | 0 | 5 | 0 | 14 |
| " | " | 5 | 20-25 | 0 | 3 | 11 | 1 | 2 | 0 | 17 |
| " | " | 6 | 25-30 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| " | " | 7 | 30-35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " | " | 8 | 35-40 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| " | " | 9 | 40-45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " | " | combined | 0-45 | 8 | 11 | 22 | 1 | 22 | 2 | 66 |
| Species comp | day | 1 | 0-5 | 50.0% | 0.0% | 50.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| " | " | 2 | 5-10 | 50.0% | 0.0% | 50.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| " | " | 3 | 10-15 | 0.0% | 11.1% | 0.0% | 0.0% | 88.9% | 0.0% | 100.0% |
| " | " | 4 | 15-20 | 0.0% | 66.7% | 0.0% | 0.0% | 33.3% | 0.0% | 100.0% |
| " | " | 5 | 20-25 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| " | " | 6 | 25-30 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| " | " | 7 | 30-35 | 0.0% | 50.0% | 0.0% | 0.0% | 50.0% | 0.0% | 100.0% |
| " | " | 8 | 35-40 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| " | " | 9 | 40-45 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| " | " | combined | 0-45 | 26.7% | 13.3% | 26.7% | 0.0% | 33.3% | 0.0% | 100.0% |
| " | night | 1 | 0-5 | 25.9% | 3.7% | 22.2% | 0.0% | 40.7% | 7.4% | 100.0% |
| " | " | 2 | 5-10 | 25.9% | 3.7% | 22.2% | 0.0% | 40.7% | 7.4% | 100.0% |
| " | " | 3 | 10-15 | 16.7% | 16.7% | 0.0% | 0.0% | 66.7% | 0.0% | 100.0% |
| " | " | 4 | 15-20 | 0.0% | 35.7% | 28.6% | 0.0% | 35.7% | 0.0% | 100.0% |
| " | " | 5 | 20-25 | 0.0% | 21.1% | 63.2% | 5.3% | 10.5% | 0.0% | 100.0% |
| " | " | 6 | 25-30 | 0.0% | 21.1% | 63.2% | 5.3% | 10.5% | 0.0% | 100.0% |
| " | " | 7 | 30-35 | 0.0% | 21.1% | 63.2% | 5.3% | 10.5% | 0.0% | 100.0% |
| " | " | 8 | 35-40 | 0.0% | 21.1% | 63.2% | 5.3% | 10.5% | 0.0% | 100.0% |
| " | " | 9 | 40-45 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| " | " | combined | 0-45 | 10.0% | 16.0% | 42.7% | 2.7% | 26.0% | 2.7% | 100.0% |

### 4.2.3 Size and Age of Fish

Mean lengths and weights of cutthroat trout, rainbow trout, kokanee, and Dolly Varden caught in gill nets (none were captured in traps) were 312 mm (369 g), 220 mm (119 g), 181 mm (76 g), and 457 mm (845 g), respectively (Table 6). Mean condition factors of all salmonid species were greater than 1.0, ranging from 1.03 for cutthroat trout to 1.20 for kokanee, indicating that these species were in good condition (Table 6). Weight versus length regressions were highly significant *($P$<0.001)* for all salmonids, with $r^2$ values exceeding 0.94 (Figure 6 and Table 7). Due at least in part to low the low number of fish sampled, length frequency distributions of salmonids exhibited few clear modes (Figure 7). For Dolly Varden, a single distinct mode at 430 mm corresponded to the mean length of age 6 fish. Kokanee had modes at 130 and 190 mm, corresponding to age 1 and 2 fish, respectively. Rainbow and cutthroat trout length frequency distributions had no discernable modes. Age-length plots indicated that growth rates of all salmonid species were appreciable for all ages that were sampled (Figure 8). Age ranges were 1-7 years for cutthroat trout, 1-3 years for kokanee, and 1-2 years for rainbow trout. Dolly Varden that were aged ranged from 4-7 years old. Ages from otoliths of Dolly Varden were used in this analysis because annuli on their scales were unclear. Larger Dolly Varden that were released without taking scales or otoliths (to avoid mortality) were estimated to be 11 years old from plots of age versus length.

Mean lengths and weights of non-salmonids from both gear types combined were: 301 mm and 342 g for large scale sucker, 124 mm and 27 g for peamouth chub, 183 mm and 252 g for northern pike minnow, 95 mm (no weights taken) for prickly sculpin, and 102 mm and 14.4 g for redside shiner (Table 6). For the species that were captured in both traps and gill nets, the mean size of fish captured in traps was smaller (Table 6). The mean condition factors of all non-salmonids from both gear types were greater than or equal to 1.0, ranging from 1.00 for pike minnow in traps to 1.35 for redside shiner in gill nets (Table 6). Weight versus length regressions were highly significant ($P$<0.003) for all non-salmonids, with $r^2$ values exceeding 0.99, except for redside shiner (Figure 6 and Table 7). The lower $r^2$ (0.49) for redside shiner probably reflects measurement error due to the difficulty of accurately weighing small fish in the field. Length-frequency distributions of prickly sculpin, peamouth chub, northern pike minnow, and redside shiner had a single strong mode representing small fish in the 100 mm range. Northern pike minnow was the only species of this group with appreciable numbers of larger fish, up to about 480 mm long. In contrast, no large scale suckers smaller than 160 mm were captured, and their frequency distribution was at least bi-modal with the strongest mode at 330 mm.

Table 6. Length, weight, and condition factor of fish captured from Stave Reservoir in gill nets and Gee traps.

| Species | Gear type | Length (mm) | | | | | Weight (g) | | | | | Mean Condition factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sample size | Min | Max | Mean | SD | Sample size | Min | Max | Mean | SD | |
| cutthroat trout | gill net | 14 | 200 | 430 | 312 | 70 | 14 | 87 | 1,090 | 368.8 | 286.8 | 1.03 |
| rainbow trout | gill net | 2 | 220 | 220 | 220 | 6 | 1 | 119 | 119 | 119.0 | | 1.06 |
| kokanee | gill net | 23 | 120 | 240 | 181 | 38 | 18 | 20 | 166 | 76.2 | 38.4 | 1.20 |
| Dolly Varden | gill net | 15 | 320 | 640 | 457 | 86 | 11 | 362 | 1,149 | 844.9 | 273.0 | 1.11 |
| largescale sucker | gill net | 73 | 160 | 390 | 301 | 71 | 30 | 51 | 660 | 341.6 | 172.6 | 1.11 |
| peamouth chub | gill net | 28 | 110 | 170 | 126 | 13 | 10 | 17 | 54 | 29.0 | 12.9 | 1.15 |
| " | trap | 3 | 60 | 140 | 99 | 40 | 1 | 3 | 3 | 3.0 | | 1.23 |
| " | combined | 31 | 61 | 166 | 124 | 184 | 11 | 3 | 54 | 26.6 | 14.6 | 1.16 |
| pike minnow | gill net | 130 | 100 | 460 | 188 | 98 | 57 | 16 | 1,180 | 259.7 | 301.5 | 1.09 |
| " | trap | 12 | 100 | 150 | 126 | 14 | 2 | 11 | 20 | 15.5 | 6.4 | 1.00 |
| " | combined | 142 | 98 | 462 | 183 | 95.7 | 59 | 11 | 1,180 | 251.5 | 299.5 | 1.08 |
| prickly sculpin | trap | 48 | 50 | 180 | 95 | 22 | 0 | | | | | |
| redside shiner | gill net | 113 | 80 | 200 | 103 | 12 | 27 | 10 | 23 | 14.3 | 2.9 | 1.35 |
| " | trap | 4 | 60 | 120 | 84 | 26 | 1 | 17 | 17 | 16.9 | | 1.06 |
| " | combined | 117 | 63 | 198 | 102 | 125 | 28 | 10 | 23 | 14.4 | 2.9 | 1.34 |

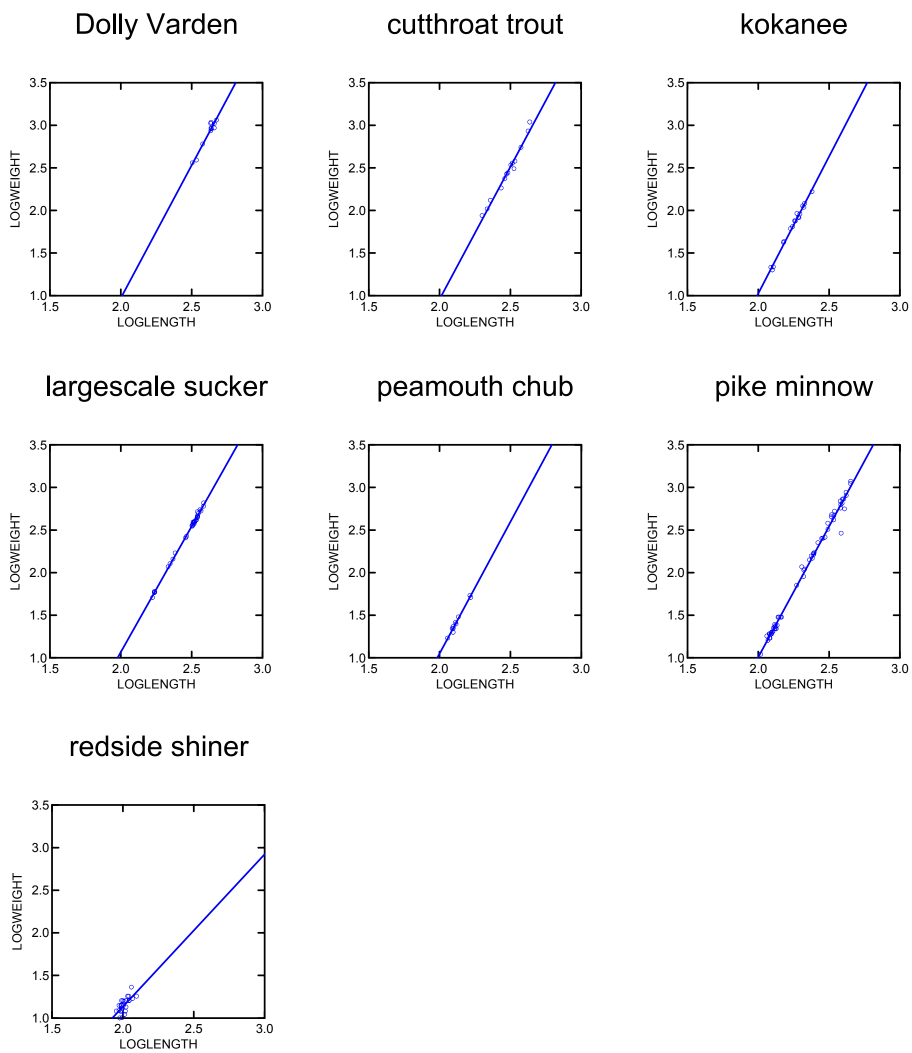



Figure 6. Weight versus length scatter plots for salmonids and non-salmonids from combined gill net and trap catches.

Table 7. Weight versus length regression equations for salmonids and non-salmonids from combined gill net and trap catches.

| **Species** | **Weight versus length equation** | | | | **Sample size** | **$r^2$** |
|---|---|---|---|---|---|---|
| cutthroat trout | Log(g) = | 3.10757 | x log(mm) | -5.25713 | 14 | 0.977 |
| kokanee | Log(g) = | 3.21712 | x log(mm) | -5.40917 | 18 | 0.989 |
| Dolly Varden | Log(g) = | 3.11783 | x log(mm) | -5.26470 | 11 | 0.942 |
| largescale sucker | Log(g) = | 2.95118 | x log(mm) | -4.83646 | 30 | 0.997 |
| peamouth chub | Log(g) = | 2.94373 | x log(mm) | -4.81933 | 11 | 0.995 |
| pike minnow | Log(g) = | 3.07118 | x log(mm) | -5.13436 | 59 | 0.991 |
| redside shiner | Log(g) = | 1.78875 | x log(mm) | -2.44471 | 28 | 0.491 |

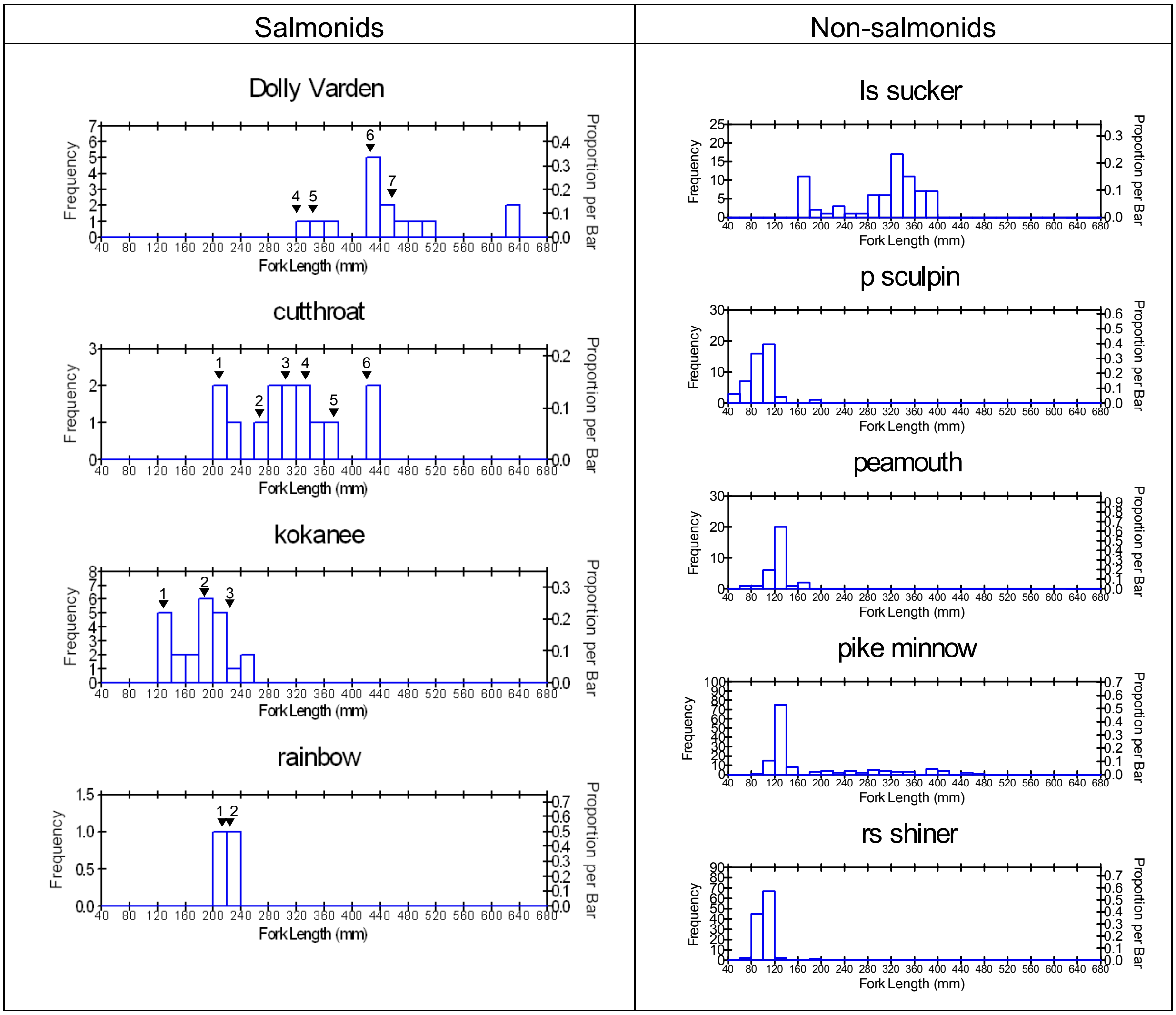



Figure 7. Length-frequency distributions of salmonids captured in gill nets and non-salmonids captured in both traps and gill nets. For salmonids, numbered arrows indicate mean lengths of designated age groups.

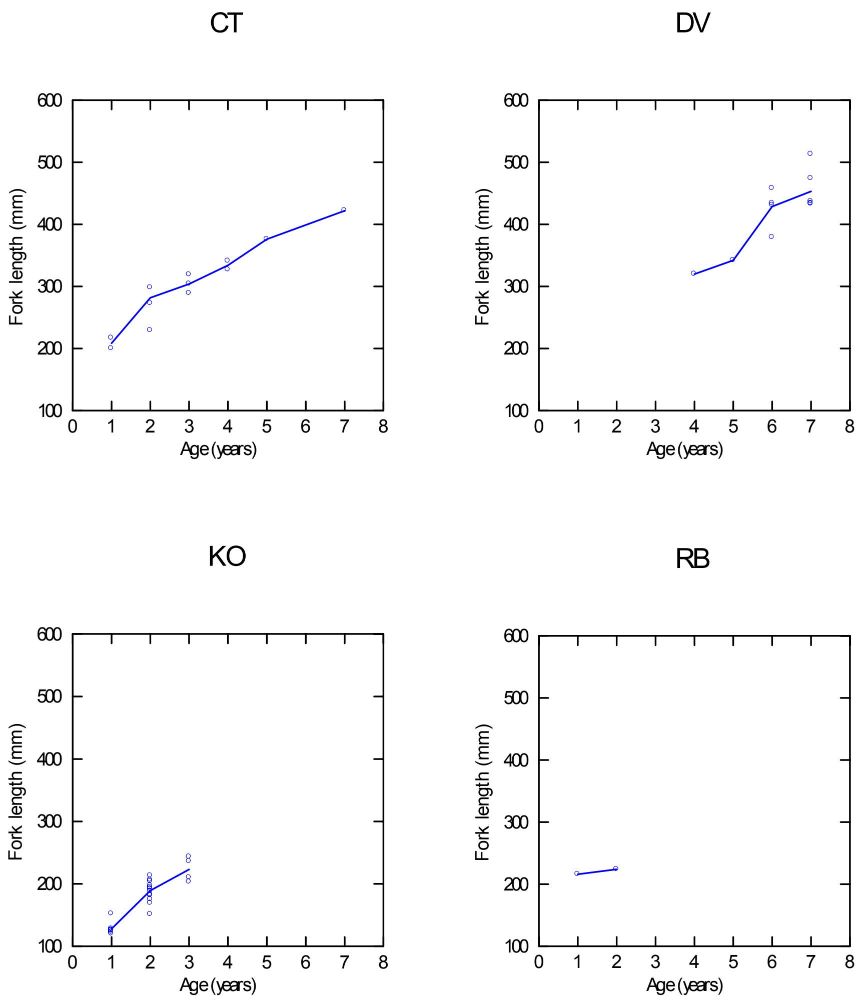



Figure 8. Length versus age of salmonids captured in gill nets in Stave Reservoir, September 2005. Lines connect mean lengths of age groups. CT = cutthroat trout, DV = Dolly Varden, KO = kokanee, RB = rainbow trout.

4.2.4 Contents of Salmonid Stomachs

Stomachs from 7 cutthroat trout, 7 kokanee, and 8 Dolly Varden were examined and all contained food except that of one Dolly Varden General prey categories were insects (both terrestrial and aquatic), other terrestrial invertebrates, zooplankton, and fish. The cutthroat trout stomachs mainly contained winged terrestrial insects with ants, aphids, and unidentified Dipterans being the predominant groups (Figure 9). Kokanee mainly ingested zooplankton, with cladocerans (Eubosmina, Daphnia, Holopedium) being the most abundant taxa. One kokanee captured in a floating net at the south station also contained small, early instar larvae of Chaoborus, an aquatic Dipteran that is of significance to acoustic sampling because it has a gas bladder. Dolly Varden stomachs almost exclusively contained fish, all of which were digested beyond further recognition, except for two sticklebacks in one stomach.

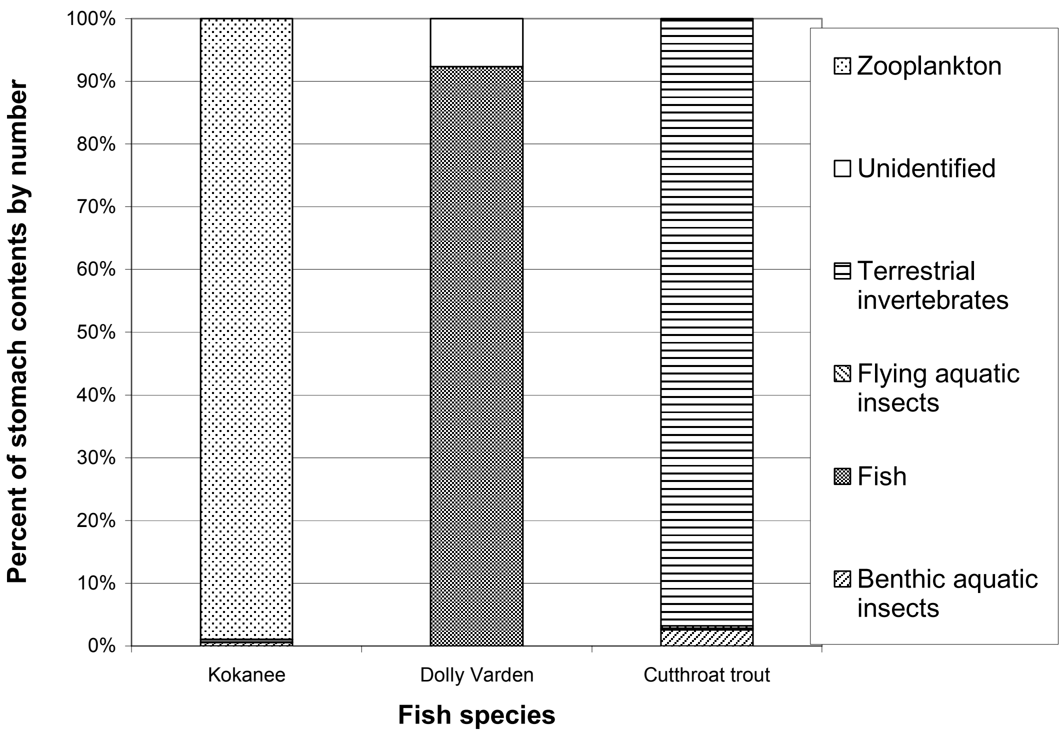



Figure 9. Contents of salmonid stomachs as percentage of composition by numbers. Stomachs were from fish captured in gill nets in Stave Reservoir, September 2005.

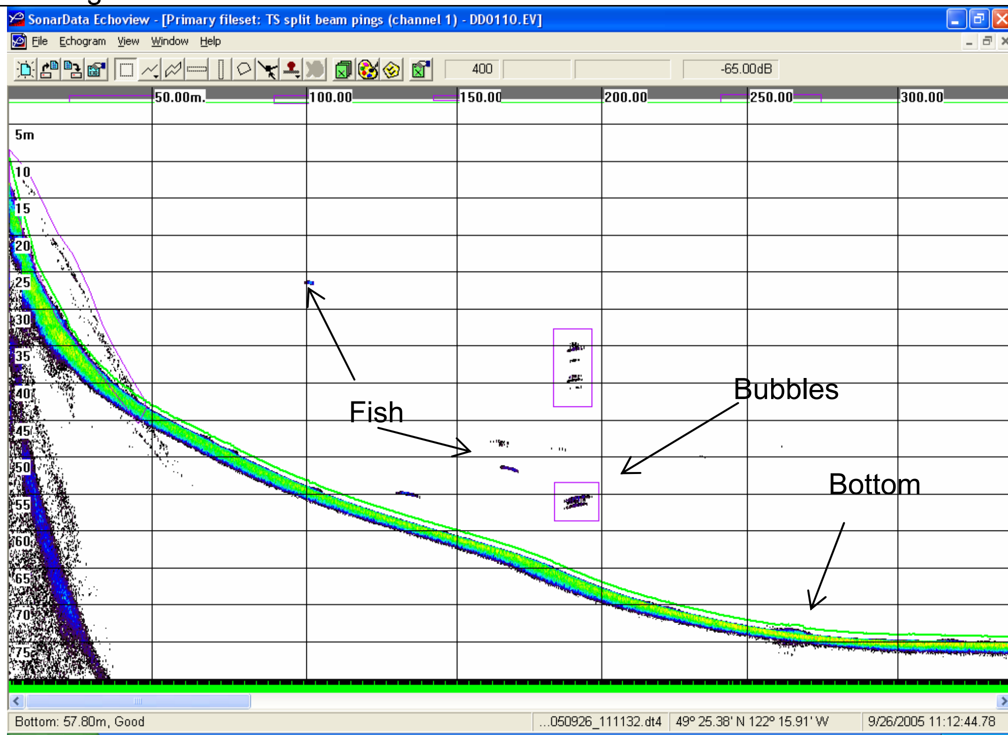
## *4.3 Acoustics*

### 4.3.1 Spatial Distribution of Fish

During the day, fish were observed on echograms at low density over the whole 0-80 m range, with main concentrations occurring at depths of 30-60 meters and in the uppermost 5 meters of the water column (Figures 10 and 11). At night, fish were more abundant on both side and down looking echograms, with main concentrations found at depths of 10-30 meters and 0-5 meters, and no fish below 40 meters (Figures 12 and 13). Columns of bubbles were common on the northern transect (transect 1) but they were rare at other locations (Figures 10 and 12). Bubbles were easily recognized and excluded from down looking data, but they were not identifiable in side-looking data on echograms or through three-dimensional split-beam processing. This factor resulted in somewhat inflated side-looking fish counts, mainly on transect 1. This error was most consequential during daytime. For transect 1, when the density of bubbles (estimated to be 0.00023 bubbles/$m^3$ from down looking data) was subtracted out, fish density in the upper 5 meters of the water column declined by 61% during the day (from 0.00038 to 0.00016 fish/$m^3$), and by 21% at night (from 0.00107 to 0.00084 fish/$m^3$, Figures 11 and 13). This correction made fish densities in the uppermost 5 meters of transect 1 similar to those of other transects.

Plots of areal fish density (fish/ha in 50 m long transect segments) showed a patchy distribution of fish during the day, with densities ranging from 0-1470 fish/ha (Figure 14). In the 0-5 m depth range, highest densities occurred at scattered locations near shore (high values shown at the west side of transect 1 were partly bubbles). In the 5-80 m range, densities were more uniform across transects, with highest values associated with a few fish schools away from shore. At night, fish densities in the 0-5 m depth range (0 to 3,804 fish/ha) were generally much higher and less patchy than during daytime, with the highest values near shore on most transects (Figure 14). Night time fish densities at depths of 5-80 meters were generally higher and more uniform than day time densities with large values both near and away from shore.

Downlooking




Sidelooking

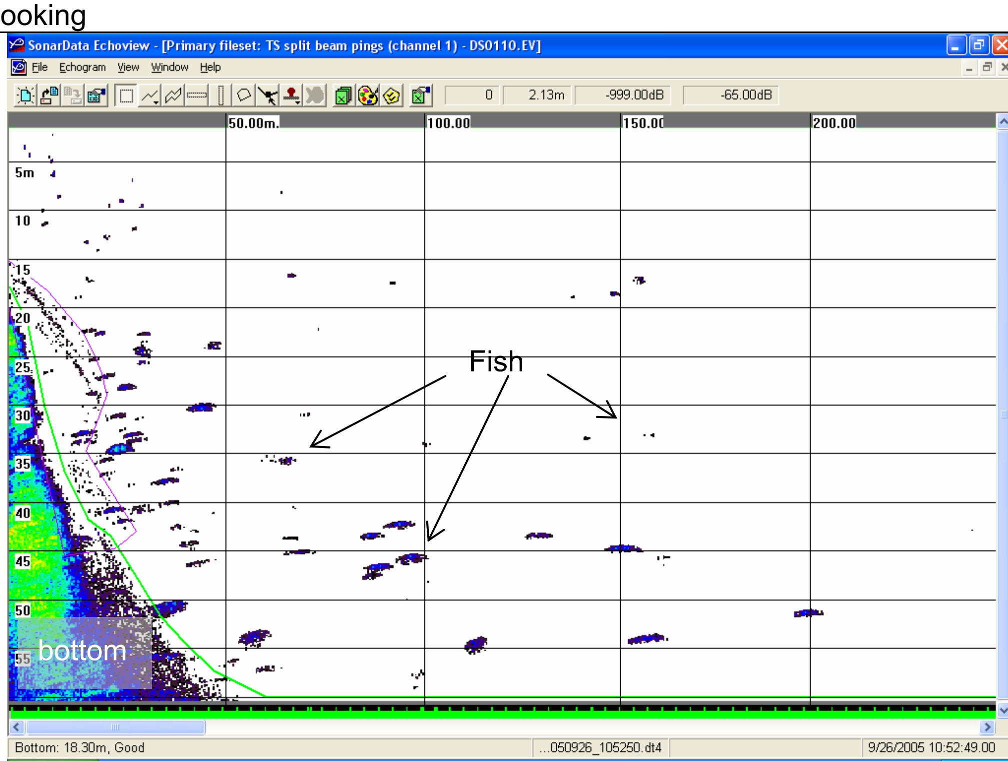



Figure 10. Day time echograms from the west side of Transect 1 in down-looking mode (upper) and side-looking mode (lower). Side looking represented only the upper 5 meters of the water column.

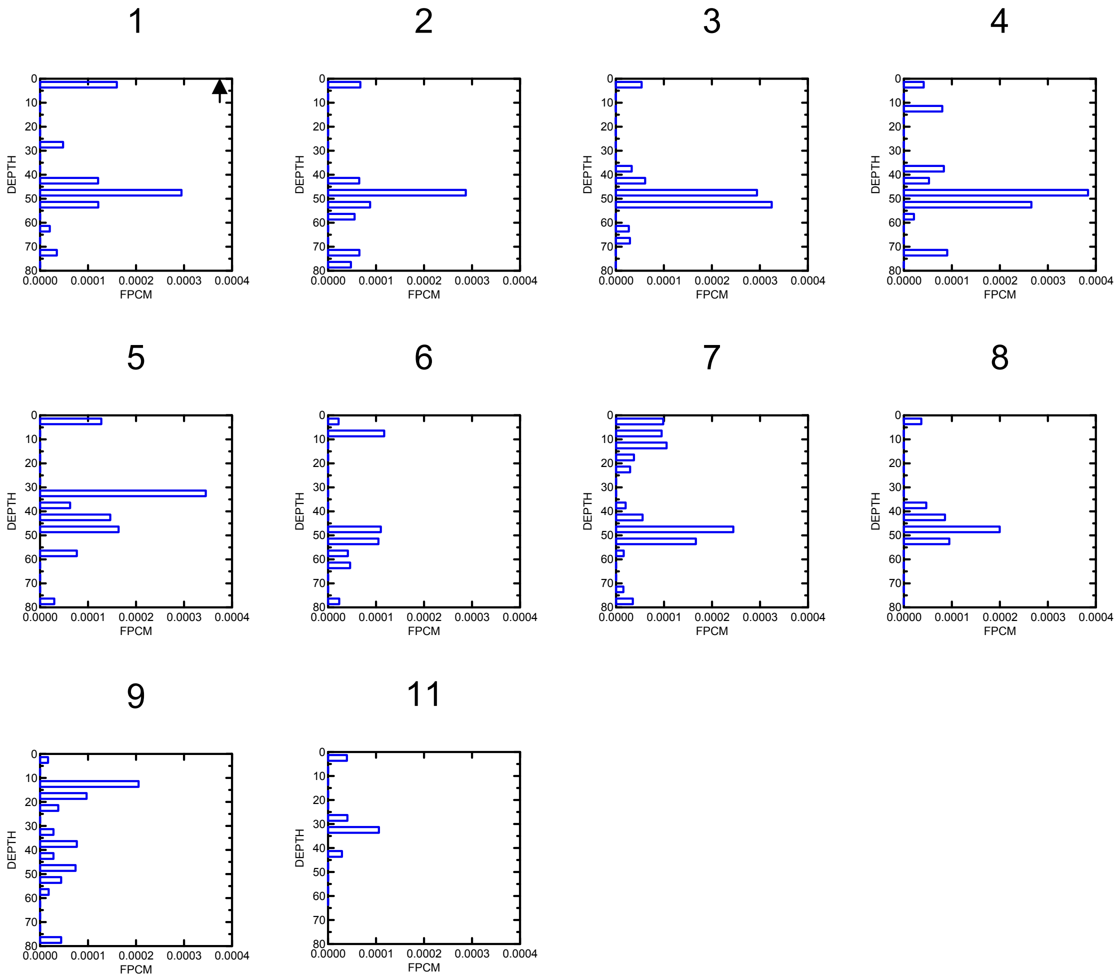
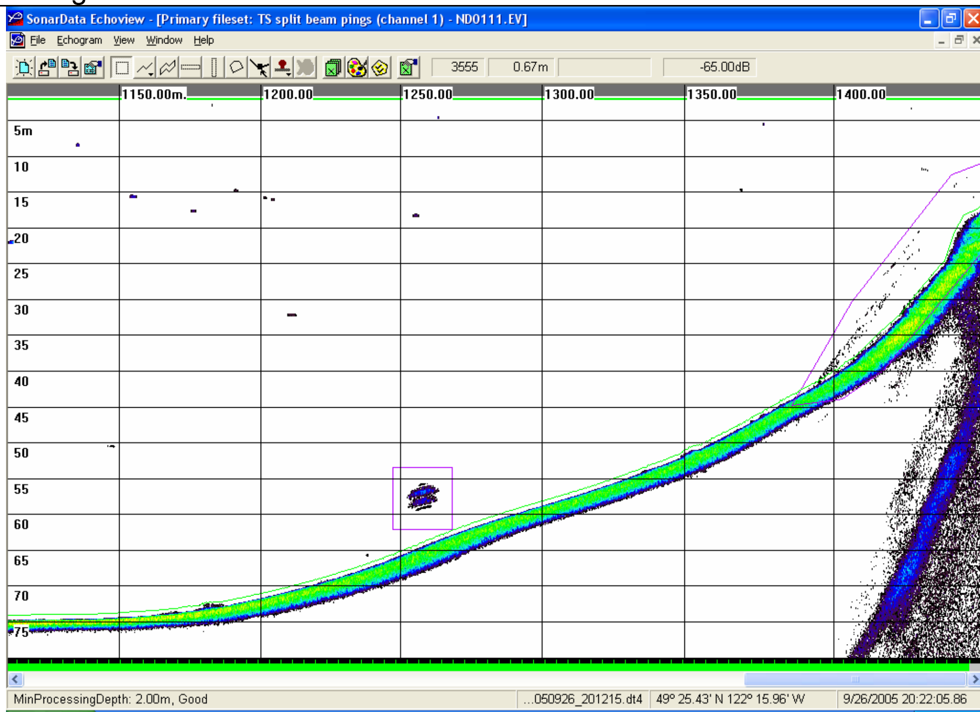



Figure 11. Daytime vertical distribution of fish in Stave Reservoir, from the September 2005 acoustic survey. Units are fish/$m^3$ for all species combined by 5 m depth intervals. Each graph represents a transect. For transect 1, an arrow indicates fish density in the 0-5 m range without correction for erroneous counts of bubbles.

Downlooking




Sidelooking

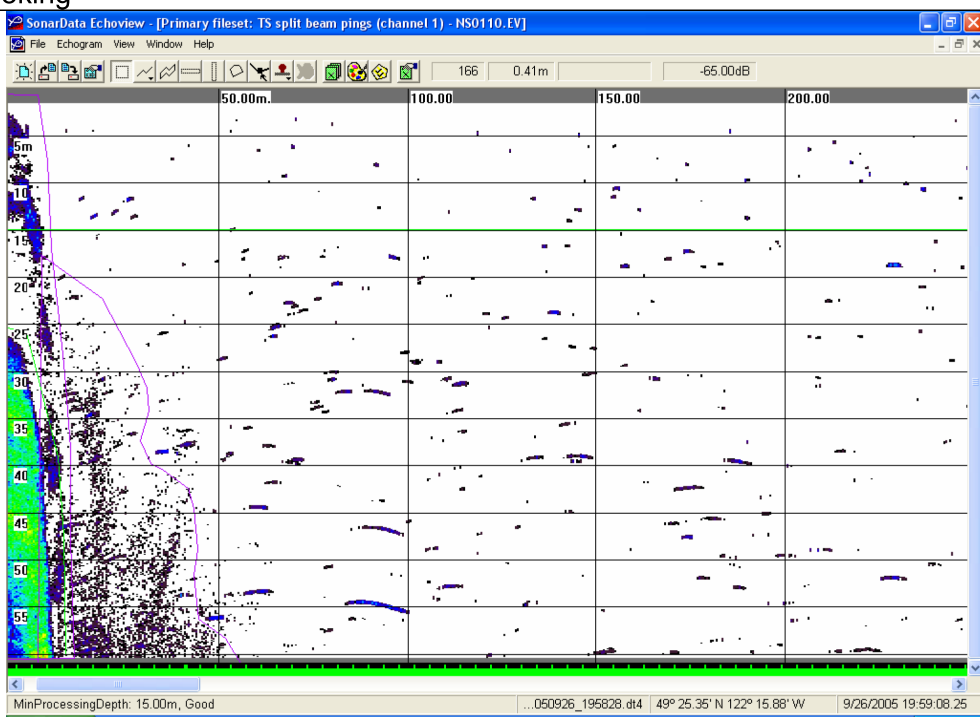



Figure 12. Night time echograms from the west side of Transect 1 in down-looking mode (upper) and side-looking mode (lower). Side looking represented only the upper 5 meters of the water column. Note that the down looking transect was run in opposite directions during day and night.

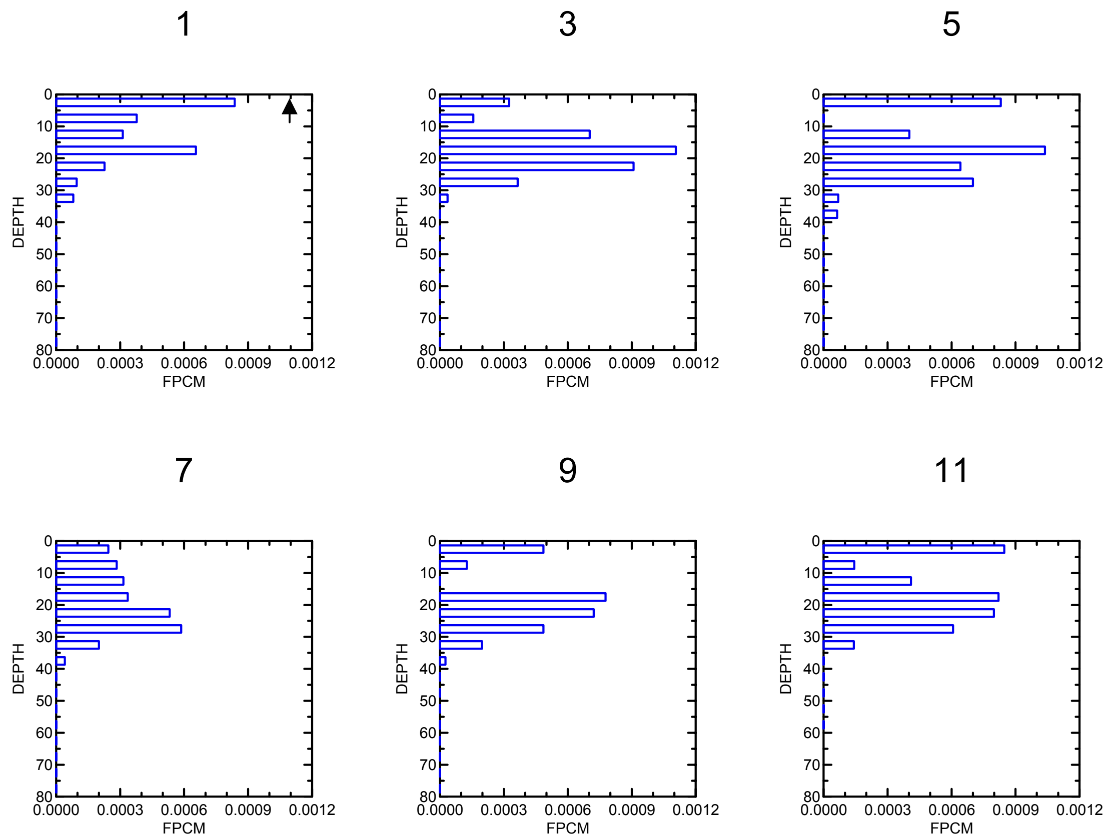



Figure 13. Night time vertical distribution of fish in Stave Reservoir, from the September 2005 acoustic survey. Units are fish/$m^3$ for all species combined by 5 m depth intervals. Each graph represents a transect. For transect 1, an arrow indicates fish density in the 0-5 m range without correction for erroneous counts of bubbles

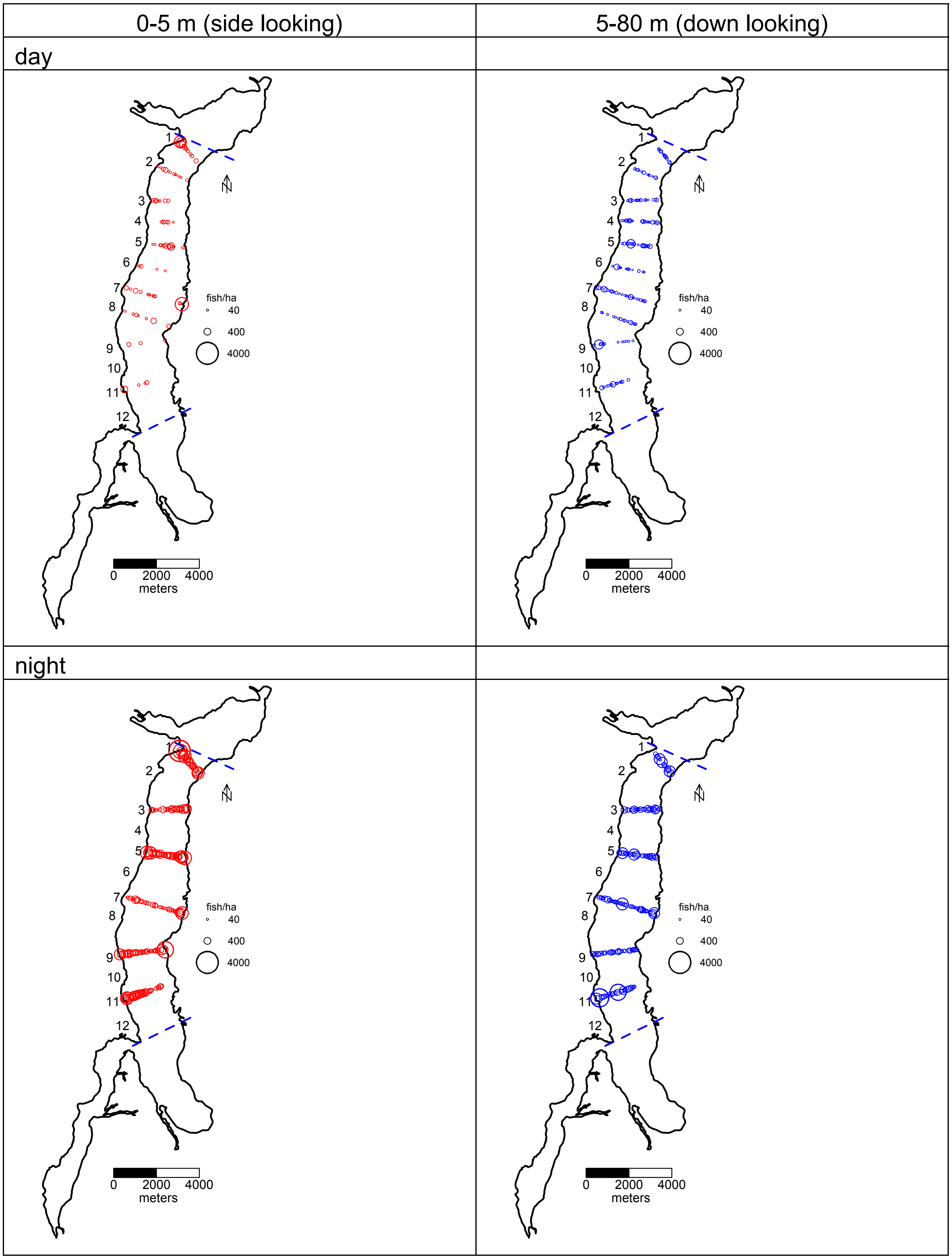



Figure 14. Horizontal distribution of fish density of all species combined (number of fish/ha in 50 m intervals along transects) during the September 2005 acoustic survey of Stave Reservoir.

### 4.3.2 Target Strength

Target strength from down looking acoustics indicated that large fish were relatively more abundant during the night survey than during the day. The TS from side looking data was not included in this analysis because it is inherently highly variable. During the day, TS ranged from -63.1 to -34.6 dB, with a frequency distribution dominated by a peak centered at about -57 dB (Figure 15). Night time TS ranged from –64.4 to -32.3 dB, with major peaks centered at -56 dB, -50 dB, and -40 dB.

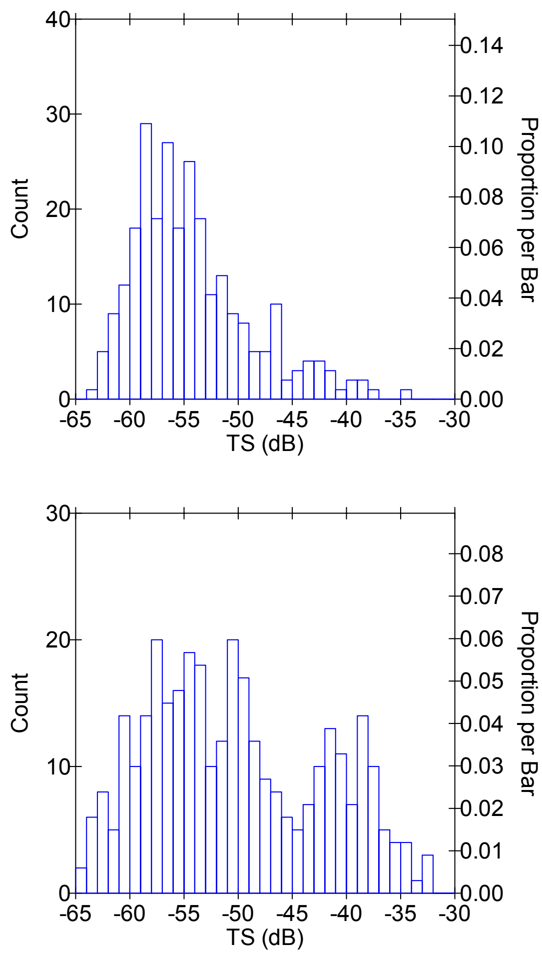



Figure 15. Frequency distribution of TS from day (upper) and night (lower) down looking acoustic data from Stave Reservoir, September 2005.

When TS values were converted to fork lengths using Love's (1977) relationship, estimated lengths of fish ranged from 13 to 467 mm during the day, with fish less than 100 mm in length by far the most numerous (Figure 16). At night, estimated lengths of fish ranged from 11 to 624 mm, with fish smaller than 100 mm long again predominating, but larger size groups better represented than during the day (Figure 16).

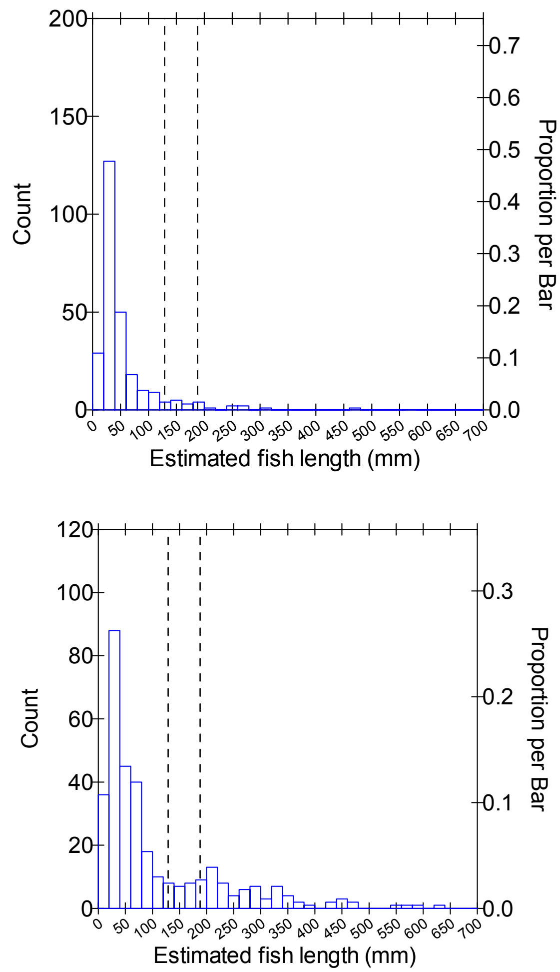



Figure 16. Length-frequency distributions for fish from daytime (upper) and night time (lower) acoustic surveys. Lengths were estimated from TS using Love's (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect using down looking acoustic data only. Dashed lines indicate mean length of age 1 and 2 kokanee.

A detailed examination of length-frequency distributions of fish at least 100 mm long showed similarities between frequency distributions estimated from acoustics and from gill net catches in the same offshore zone during the day (Figure 17). During this period, the length of fish (all species combined) caught in gill nets ranged from 121 to 513 mm, versus a range of 100-466 mm from acoustics (Figure 17). Modes were difficult to evaluate because the number of observations was small.

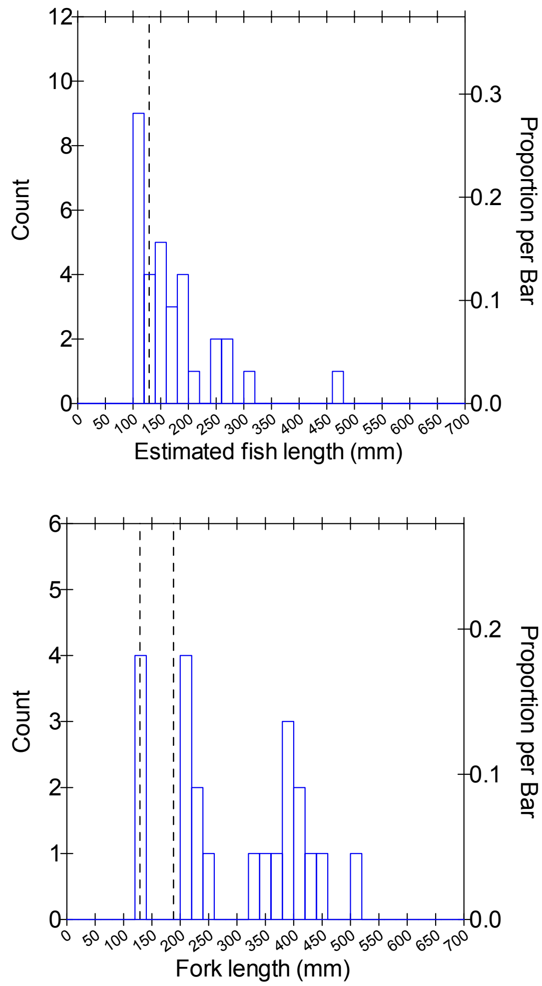



Figure 17. Daytime frequency distributions for fish >= 100 mm long estimated from TS (upper) and from gill nets (lower) for all species combined. Lengths were estimated from TS using Love's (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect using down looking acoustic data only. Gill net data were only from the offshore zone sampled with acoustics. Vertical dashed lines indicate mean length of age 1 and 2 kokanee.

At night, when gill net and acoustic sample sizes were both larger, the size range of fish caught in the gill nets was 120 to 636 mm compared to a size range of 100-624 mm estimated from acoustics (Figure 18). Modes occurred at similar locations in both data sets (at approximately 100 mm, 200 mm, 350 mm, and 640 mm), although the mode at 350 mm was most prominent in the gill net data. Exclusion of suckers from gill net results improved agreement of the relative size of modes between the data sets. Suckers may have occurred too close to the bottom for reliable detection with acoustics.

Close inspection of frequency distributions of small fish showed a peak at about 30 mm during the day and peaks at 30 mm and 70 mm at night (Figure 19). These fish were smaller than the age 1 fish we captured in Stave Reservoir (range=120-152 mm, mean=129 mm), and the peak at 30 mm is close to what would be expected for age 0 kokanee during the fall (about 40 mm). The peak at 70 mm is larger than would be expected for age 0 kokanee at the time of the survey, suggesting that it may represent another species or age group.

During the day, when fish were distributed over the whole 0-80 m depth range, a large proportion of fish less than 100 mm long occurred in the 35-55 m depth range and larger fish were distributed over the water column from 8 to 80 meters (Figure 20). Fish less than 100 mm long made up 85-99% of the fish detected between 35 m and 50 m (Table 8). Because low numbers of fish were detected above 35 meters and below 65 meters during the day, counts from several depth intervals were pooled to stabilize percentage estimates of small and large fish in these depth ranges (Table 8). At night, small fish were concentrated between 10 and 30 meters, with an appreciable number in the upper few meters of the water column, and larger fish were concentrated 20 to 30 meters deep (Figure 20). Above 25 meters, 69-93% of fish were less than 100 mm long, whereas below this depth 35 to 44% of the fish were of this size group (Table 8).

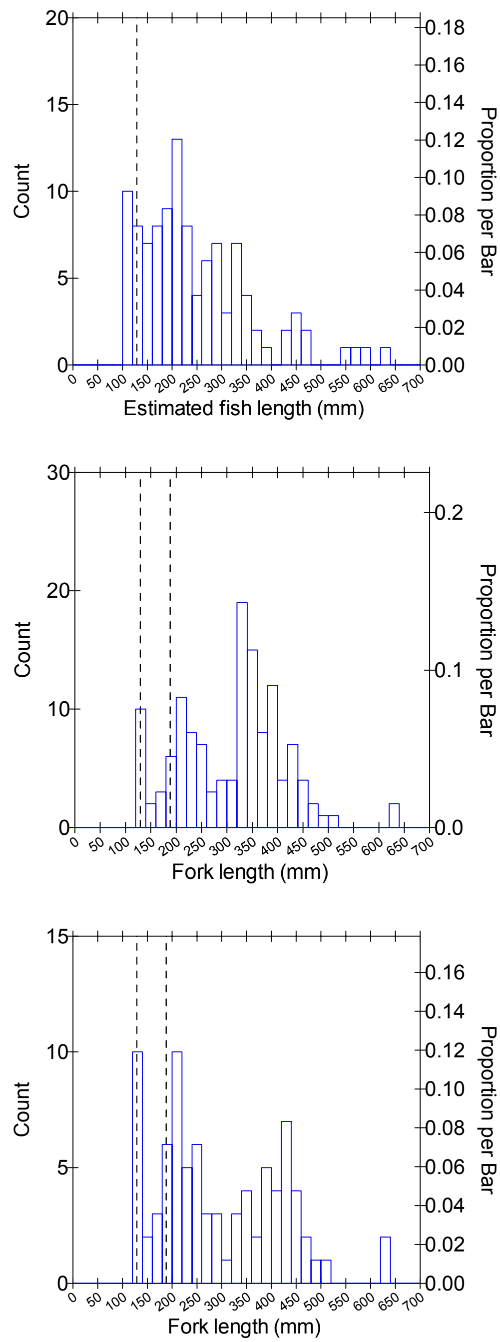



Figure 18. Night time length-frequency distributions for fish >100 mm long estimated from TS (upper), from gill nets for all species combined (middle), and from gill nets with all species except largescale sucker. Lengths were estimated from TS using Love's (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect using down looking acoustic data only. Gill net data were only from the offshore zone that was sampled with acoustics. The vertical dashed lines indicate mean length of age 1 and 2 kokanee.

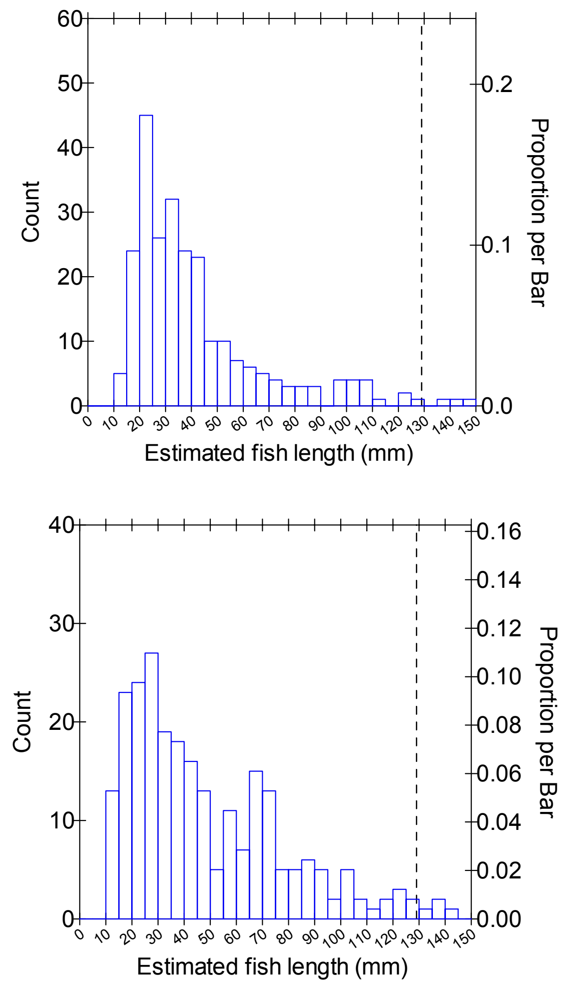
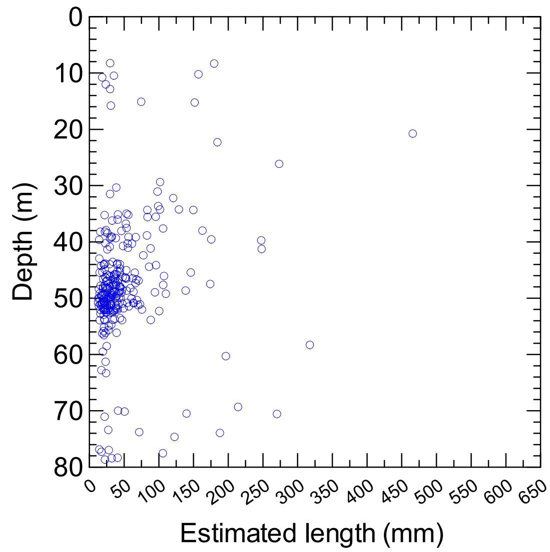



Figure 19. Length-frequency distributions for small fish from daytime (upper) and night time (lower) acoustic surveys. Lengths were estimated from TS using Love's (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect using down looking acoustic data only. The vertical dashed line indicates the mean length of age 1 kokanee.



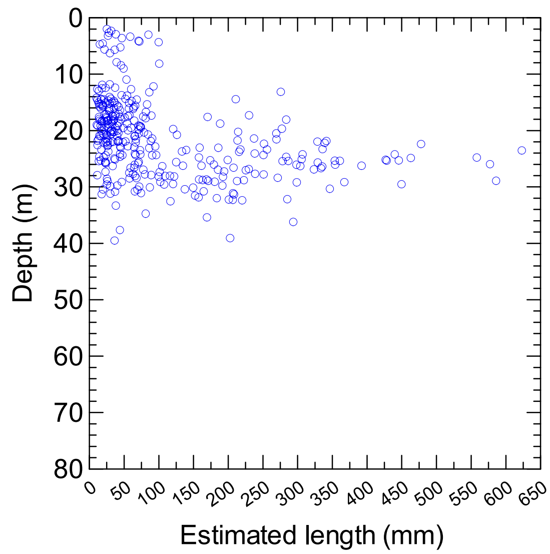




Figure 20. Fish length (mm) versus depth during daytime (upper) and night time (lower) acoustic surveys of Stave Reservoir, September 2005. Fish lengths were estimated from TS using Love's (1977) relationship for fish observed within +/- 45 degrees of dorsal aspect. Down looking data from all transects combined were used for this analysis.

Table 8. Percentages of fish in day and night acoustic estimates with estimated fork lengths <100 mm and ≥100 mm. The counts from several depth intervals above 35 meters and below 65 meters were pooled to stabilize percentage estimates because the numbers of fish detections were low during the day in these intervals,. The length estimates were from Love's (1977) +/- 45 degree dorsal relationship.

| Depth Interval (m) | Daytime estimate | | | | | | | Night time estimate | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | | | Raw Percentage | | Adjusted Percentage | | Count | | | Raw Percentage | | Adjusted Percentage | |
| | <100 mm | ≥100 mm | Total | <100 mm | ≥100 mm | <100 mm | ≥100 mm | <100 mm | ≥100 mm | Total | <100 mm | ≥100 mm | <100 mm | ≥100 mm |
| 0-5 | 0 | 0 | 0 | 0.0% | 0.0% | 71.4% | 28.6% | 12 | 1 | 13 | 92.3% | 7.7% | 92.3% | 7.7% |
| 5-10 | 1 | 1 | 2 | 50.0% | 50.0% | 71.4% | 28.6% | 7 | 1 | 8 | 87.5% | 12.5% | 87.5% | 12.5% |
| 10-15 | 4 | 1 | 5 | 80.0% | 20.0% | 71.4% | 28.6% | 25 | 2 | 27 | 92.6% | 7.4% | 92.6% | 7.4% |
| 15-20 | 2 | 1 | 3 | 66.7% | 33.3% | 28.6% | 71.4% | 78 | 6 | 84 | 92.9% | 7.1% | 92.9% | 7.1% |
| 20-25 | 0 | 2 | 2 | 0.0% | 100.0% | 28.6% | 71.4% | 63 | 28 | 91 | 69.2% | 30.8% | 69.2% | 30.8% |
| 25-30 | 0 | 2 | 2 | 0.0% | 100.0% | 28.6% | 71.4% | 29 | 53 | 82 | 35.4% | 64.6% | 35.4% | 64.6% |
| 30-35 | 4 | 5 | 9 | 44.4% | 55.6% | 44.4% | 55.6% | 11 | 14 | 25 | 44.0% | 56.0% | 44.0% | 56.0% |
| 35-40 | 23 | 4 | 27 | 85.2% | 14.8% | 85.2% | 14.8% | 2 | 3 | 5 | 40.0% | 60.0% | 40.0% | 60.0% |
| 40-45 | 22 | 1 | 23 | 95.7% | 4.3% | 95.7% | 4.3% | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |
| 45-50 | 76 | 6 | 82 | 92.7% | 7.3% | 92.7% | 7.3% | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |
| 50-55 | 78 | 1 | 79 | 98.7% | 1.3% | 98.7% | 1.3% | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |
| 55-60 | 10 | 1 | 11 | 90.9% | 9.1% | 90.9% | 9.1% | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |
| 60-65 | 3 | 1 | 4 | 75.0% | 25.0% | 66.7% | 33.3% | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |
| 65-70 | 0 | 1 | 1 | 0.0% | 100.0% | 66.7% | 33.3% | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |
| 70-75 | 5 | 4 | 9 | 55.6% | 44.4% | 66.7% | 33.3% | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |
| 75-80 | 6 | 1 | 7 | 85.7% | 14.3% | 66.7% | 33.3% | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |

### 4.3.3 Fish Abundance and Biomass

During the daytime survey, a total of 487 fish were counted on the 10 transects that were sampled. Fish occurred over the 0-80 m depth range, however a large number (215) were seen in the upper 5 meters of the water column in the side looking mode (Table 9). At night, a total of 1,318 fish were counted on only 6 transects (only odd numbered transects were sampled at night), and a high number (996) were again seen in the 0-5 m range (Table 9). No fish were counted below 40 meters at night.

Volumetric fish densities for individual layers of transects ranged from 0-0.00062 fish/$m^3$, with highest densities in the 45 to 55 m depth range (transect average = 0.00018 to 0.00021 fish/$m^3$, Table 10). At night, fish densities for individual depth layers of transects ranged from 0 to 0.00111 fish/$m^3$, with the highest densities from 0 to 5 m (transect average = 0.00063 fish/$m^3$) and from 15 to 25 m (transect average = 0.00064 to 0.00078 fish/$m^3$, Table 11). During the night survey, when fish were detected in the 0-5 m depth range in down as well as side looking mode, down looking densities were higher but not significantly so (Mann-Whitney U = 24, $P$ = 0.336, n=12). Both daytime and night time fish densities were fairly uniform among transects.

The daytime population estimate for the area sampled by acoustics (the main lake basin, offshore of the 13.5 m depth contour on average) was 81,739 ± 19,616 fish of all species combined (Table 12). The depth layers contributing the largest numbers of fish were 0 to 5 m and 45 to 55 m. The night time population estimate for the same area was 393,717 ± 61,380 fish of all species combined, with the 0 to 5 m and 15 to 25 m depth layers contributing the largest numbers of fish (Table 13).

The daytime sampling results were used to estimate the abundance of cutthroat trout, which only occurred offshore and from 0 to 10 deep at that time. Abundance and biomass of the other species (and trout as well) was estimated from night sampling because many species (e.g., kokanee, Dolly Varden, and pike minnow) were most accessible to acoustics and gill nets at that time (e.g., offshore and dispersed at a suitable depth range).

The daytime population estimate for cutthroat trout was 1,684 fish, or 0.6 fish/ha, all in the upper 10 meters of the water column (Table 14). Species composition for this estimate was based on a very small sample size (4 fish, Table 5), which reduced its certainty. All trout were assumed to be greater than 100 mm in length because no smaller ones were captured during gill net or trap sampling. No daytime abundance estimate of rainbow trout was made because this species was not captured during daytime fish sampling.

Table 9. Counts of fish from echograms, by transect and depth interval, from daytime and night time acoustic surveys in Stave Reservoir, September 2005. Counts for 0– 5 m and 5-80 m depth ranges were from side and down-looking data, respectively.

| Period | Interval number | Depth range (m) | Fish count by transect number | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
| day | 1 | 0-5 | 66 | 15 | 13 | 11 | 37 | 7 | 42 | 13 | 5 | | 6 | | 215 |
| " | 2 | 5-10 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | | 0 | | 2 |
| " | 3 | 10-15 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 3 | | 0 | | 6 |
| " | 4 | 15-20 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | | 0 | | 3 |
| " | 5 | 20-25 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | | 0 | | 2 |
| " | 6 | 25-30 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1 | | 2 |
| " | 7 | 30-35 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 1 | | 3 | | 14 |
| " | 8 | 35-40 | 0 | 0 | 1 | 3 | 2 | 0 | 1 | 2 | 3 | | 15 | | 27 |
| " | 9 | 40-45 | 4 | 2 | 2 | 2 | 5 | 0 | 3 | 4 | 1 | | 1 | | 24 |
| " | 10 | 45-50 | 11 | 9 | 10 | 16 | 6 | 5 | 14 | 10 | 3 | | 0 | | 84 |
| " | 11 | 50-55 | 5 | 3 | 13 | 10 | 24 | 5 | 10 | 5 | 2 | | 0 | | 77 |
| " | 12 | 55-60 | 0 | 2 | 0 | 1 | 3 | 2 | 1 | 0 | 1 | | 0 | | 10 |
| " | 13 | 60-65 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | | 0 | | 4 |
| " | 14 | 65-70 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 1 |
| " | 15 | 70-75 | 2 | 2 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | | | | 9 |
| " | 16 | 75-80 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 0 | 2 | | | | 7 |
| " | | 0-80 | 90 | 34 | 41 | 48 | 88 | 23 | 79 | 34 | 24 | 0 | 26 | 0 | 487 |
| night | 1 | 0-5 | 241 | | 88 | | 235 | | 105 | | 151 | | 176 | | 996 |
| " | 2 | 5-10 | 2 | | 1 | | 0 | | 3 | | 1 | | 1 | | 8 |
| " | 3 | 10-15 | 3 | | 8 | | 5 | | 6 | | 0 | | 5 | | 27 |
| " | 4 | 15-20 | 9 | | 18 | | 18 | | 9 | | 16 | | 14 | | 84 |
| " | 5 | 20-25 | 4 | | 19 | | 14 | | 18 | | 19 | | 17 | | 91 |
| " | 6 | 25-30 | 2 | | 9 | | 18 | | 23 | | 15 | | 15 | | 82 |
| " | 7 | 30-35 | 2 | | 1 | | 2 | | 9 | | 7 | | 4 | | 25 |
| " | 8 | 35-40 | 0 | | 0 | | 2 | | 2 | | 1 | | 0 | | 5 |
| " | 9 | 40-45 | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 |
| " | 10 | 45-50 | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 |
| " | 11 | 50-55 | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 |
| " | 12 | 55-60 | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 |
| " | 13 | 60-65 | 0 | | 0 | | 0 | | 0 | | 0 | | | | 0 |
| " | 14 | 65-70 | 0 | | 0 | | 0 | | 0 | | 0 | | | | 0 |
| " | 15 | 70-75 | 0 | | 0 | | 0 | | 0 | | 0 | | | | 0 |
| " | 16 | 75-80 | 0 | | 0 | | 0 | | 0 | | 0 | | | | 0 |
| " | | 0-80 | 263 | | 144 | | 294 | | 175 | | 210 | | 232 | | 1,318 |

Table 10. Fish density (fish/$m^3$) for all species combined, by transect and depth interval, from daytime acoustic sampling in Stave Reservoir, September 2005. Transects 10 and 12 were not sampled due to inadequate time. Densities for the 0– 5 m and 5-80 m depth ranges were from side and down-looking data, respectively.

| Period | Interval number | Depth range (m) | Fish density by transect number (number fish/$m^3$) | | | | | | | | | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | n | Mean | Var |
| day | 1 | 0-5 | 0.00016 | 0.00007 | 0.00005 | 0.00004 | 0.00013 | 0.00002 | 0.00010 | 0.00004 | 0.00002 | | 0.00004 | | 10 | 0.0000658 | 2.187E-09 |
| " | 2 | 5-10 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00012 | 0.00009 | 0.00000 | 0.00000 | | 0.00000 | | 10 | 0.0000212 | 2.024E-09 |
| " | 3 | 10-15 | 0.00000 | 0.00000 | 0.00000 | 0.00008 | 0.00000 | 0.00000 | 0.00011 | 0.00000 | 0.00021 | | 0.00000 | | 10 | 0.0000391 | 4.936E-09 |
| " | 4 | 15-20 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00004 | 0.00000 | 0.00010 | | 0.00000 | | 10 | 0.0000134 | 1.001E-09 |
| " | 5 | 20-25 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00003 | 0.00000 | 0.00004 | | 0.00000 | | 10 | 0.0000068 | 2.075E-10 |
| " | 6 | 25-30 | 0.00005 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | | 0.00004 | | 10 | 0.0000088 | 3.498E-10 |
| " | 7 | 30-35 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00035 | 0.00000 | 0.00000 | 0.00000 | 0.00003 | | 0.00011 | | 10 | 0.0000480 | 1.204E-08 |
| " | 8 | 35-40 | 0.00000 | 0.00000 | 0.00003 | 0.00008 | 0.00006 | 0.00000 | 0.00002 | 0.00005 | 0.00008 | | 0.00047 | | 10 | 0.0000795 | 2.011E-08 |
| " | 9 | 40-45 | 0.00012 | 0.00007 | 0.00006 | 0.00005 | 0.00015 | 0.00000 | 0.00006 | 0.00009 | 0.00003 | | 0.00003 | | 10 | 0.0000643 | 1.925E-09 |
| " | 10 | 45-50 | 0.00029 | 0.00029 | 0.00029 | 0.00038 | 0.00016 | 0.00011 | 0.00024 | 0.00020 | 0.00007 | | 0.00000 | | 10 | 0.0002051 | 1.400E-08 |
| " | 11 | 50-55 | 0.00012 | 0.00009 | 0.00032 | 0.00027 | 0.00062 | 0.00011 | 0.00017 | 0.00009 | 0.00004 | | 0.00000 | | 10 | 0.0001825 | 3.268E-08 |
| " | 12 | 55-60 | 0.00000 | 0.00006 | 0.00000 | 0.00002 | 0.00008 | 0.00004 | 0.00002 | 0.00000 | 0.00002 | | 0.00000 | | 10 | 0.0000228 | 7.197E-10 |
| " | 13 | 60-65 | 0.00002 | 0.00000 | 0.00003 | 0.00000 | 0.00000 | 0.00005 | 0.00000 | 0.00000 | 0.00000 | | 0.00000 | | 10 | 0.0000093 | 2.643E-10 |
| " | 14 | 65-70 | 0.00000 | 0.00000 | 0.00003 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | | | | 9 | 0.0000032 | 9.341E-11 |
| " | 15 | 70-75 | 0.00004 | 0.00007 | 0.00000 | 0.00009 | 0.00000 | 0.00000 | 0.00002 | 0.00000 | 0.00000 | | | | 9 | 0.0000229 | 1.142E-09 |
| " | 16 | 75-80 | 0.00000 | 0.00005 | 0.00000 | 0.00000 | 0.00003 | 0.00002 | 0.00004 | 0.00000 | 0.00004 | | | | 9 | 0.0000200 | 4.102E-10 |
| " | | 0-80 | 0.00005 | 0.00004 | 0.00005 | 0.00006 | 0.00010 | 0.00003 | 0.00006 | 0.00003 | 0.00004 | | 0.00005 | | | | |

Table 11. Fish density (fish/m$^3$) for all species combined by transect and depth interval from night time acoustic sampling, Stave Reservoir, September 2005. Only odd numbered transects were sampled at night. Densities for 0– 5 m and 5-80 m depth ranges were from side and down-looking data, respectively.

| Period | Interval number | Depth range (m) | Fish density by transect number (number fish/m$^3$) | | | | | | | | | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | n | Mean | Var |
| night | 1 | 0-5 | 0.00107 | | 0.00032 | | 0.00083 | | 0.00025 | | 0.00049 | | 0.00085 | | 6 | 0.0006334 | 1.082E-07 |
| " | 2 | 5-10 | 0.00038 | | 0.00016 | | 0.00000 | | 0.00028 | | 0.00013 | | 0.00014 | | 6 | 0.0001813 | 1.744E-08 |
| " | 3 | 10-15 | 0.00031 | | 0.00070 | | 0.00040 | | 0.00032 | | 0.00000 | | 0.00041 | | 6 | 0.0003567 | 5.098E-08 |
| " | 4 | 15-20 | 0.00065 | | 0.00111 | | 0.00104 | | 0.00034 | | 0.00078 | | 0.00082 | | 6 | 0.0007889 | 7.742E-08 |
| " | 5 | 20-25 | 0.00023 | | 0.00091 | | 0.00064 | | 0.00053 | | 0.00072 | | 0.00080 | | 6 | 0.0006382 | 5.717E-08 |
| " | 6 | 25-30 | 0.00010 | | 0.00036 | | 0.00070 | | 0.00059 | | 0.00049 | | 0.00061 | | 6 | 0.0004731 | 4.717E-08 |
| " | 7 | 30-35 | 0.00008 | | 0.00004 | | 0.00007 | | 0.00020 | | 0.00020 | | 0.00014 | | 6 | 0.0001206 | 4.849E-09 |
| " | 8 | 35-40 | 0.00000 | | 0.00000 | | 0.00006 | | 0.00004 | | 0.00003 | | 0.00000 | | 6 | 0.0000217 | 7.087E-10 |
| " | 9 | 40-45 | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 6 | 0.0000000 | 0.000E+00 |
| " | 10 | 45-50 | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 6 | 0.0000000 | 0.000E+00 |
| " | 11 | 50-55 | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 6 | 0.0000000 | 0.000E+00 |
| " | 12 | 55-60 | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 6 | 0.0000000 | 0.000E+00 |
| " | 13 | 60-65 | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | | | 5 | 0.0000000 | 0.000E+00 |
| " | 14 | 65-70 | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | | | 5 | 0.0000000 | 0.000E+00 |
| " | 15 | 70-75 | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | | | 5 | 0.0000000 | 0.000E+00 |
| " | 16 | 75-80 | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | 0.00000 | | | | 5 | 0.0000000 | 0.000E+00 |
| " | | 0-80 | 0.00018 | | 0.00022 | | 0.00023 | | 0.00016 | | 0.00018 | | 0.00031 | | | | |

Table 12. Daytime population estimate for fish of all species combined in areas sampled by acoustics (main lake basin, offshore of the 13.5 m depth contour, on average).

| Period | Interval number | Depth range (m) | Mean no. per $m^3$ | Var | Sample size * | Stratum Volume ($m^3$) | Pop. Est. | SE of Pop. est. | 95% CL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower | Upper |
| day | 1 | 0-5 | 0.00007 | 2.2E-09 | 10 | 1.4E+08 | 9,050 | 2,034 | 4,449 | 13,651 |
| " | 2 | 5-10 | 0.00002 | 2.0E-09 | 10 | 1.3E+08 | 2,738 | 1,838 | -1,419 | 6,895 |
| " | 3 | 10-15 | 0.00004 | 4.9E-09 | 10 | 1.2E+08 | 4,840 | 2,752 | -1,385 | 11,064 |
| " | 4 | 15-20 | 0.00001 | 1.0E-09 | 10 | 1.2E+08 | 1,621 | 1,206 | -1,107 | 4,348 |
| " | 5 | 20-25 | 0.00001 | 2.1E-10 | 10 | 1.2E+08 | 792 | 533 | -414 | 1,999 |
| " | 6 | 25-30 | 0.00001 | 3.5E-10 | 10 | 1.1E+08 | 1,002 | 671 | -516 | 2,519 |
| " | 7 | 30-35 | 0.00005 | 1.2E-08 | 10 | 1.1E+08 | 5,263 | 3,808 | -3,351 | 13,877 |
| " | 8 | 35-40 | 0.00008 | 2.0E-08 | 10 | 1.1E+08 | 8,448 | 4,766 | -2,332 | 19,229 |
| " | 9 | 40-45 | 0.00006 | 1.9E-09 | 10 | 1.0E+08 | 6,554 | 1,415 | 3,353 | 9,755 |
| " | 10 | 45-50 | 0.00021 | 1.4E-08 | 10 | 9.7E+07 | 19,881 | 3,628 | 11,674 | 28,088 |
| " | 11 | 50-55 | 0.00018 | 3.3E-08 | 10 | 9.2E+07 | 16,811 | 5,266 | 4,899 | 28,723 |
| " | 12 | 55-60 | 0.00002 | 7.2E-10 | 10 | 8.3E+07 | 1,901 | 706 | 304 | 3,499 |
| " | 13 | 60-65 | 0.00001 | 2.6E-10 | 10 | 7.5E+07 | 702 | 388 | -175 | 1,579 |
| " | 14 | 65-70 | 0.00000 | 9.3E-11 | 9 | 6.8E+07 | 220 | 220 | -287 | 726 |
| " | 15 | 70-75 | 0.00002 | 1.1E-09 | 9 | 5.1E+07 | 1,157 | 570 | -158 | 2,472 |
| " | 16 | 75-80 | 0.00002 | 4.1E-10 | 9 | 3.8E+07 | 759 | 257 | 168 | 1,351 |
| " | | 0-80 | | | 157 | 1.6E+09 | 81,739 | 9,923 | 62,123 | 101,354 |
| 95% CI is the population estimate +/- 24% | | | | | | | | | | |

* Number of transects with corresponding depth interval.

Table 13. Night time population estimate for fish of all species combined in areas sampled by acoustics (main lake basin, offshore of the 13.5 m depth contour, on average).

| Period | Interval number | Depth range (m) | Mean no. per $m^3$ | Var | Sample size * | Stratum Volume ($m^3$) | Pop. est. | SE of pop. est. | 95% CL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower | Upper |
| night | 1 | 0-5 | 0.00063 | 1.1E-07 | 6 | 1.4E+08 | 87,122 | 18,469 | 39,647 | 134,598 |
| " | 2 | 5-10 | 0.00018 | 1.7E-08 | 6 | 1.3E+08 | 23,416 | 6,964 | 5,514 | 41,319 |
| " | 3 | 10-15 | 0.00036 | 5.1E-08 | 6 | 1.2E+08 | 44,174 | 11,417 | 14,827 | 73,521 |
| " | 4 | 15-20 | 0.00079 | 7.7E-08 | 6 | 1.2E+08 | 95,071 | 13,690 | 59,880 | 130,262 |
| " | 5 | 20-25 | 0.00064 | 5.7E-08 | 6 | 1.2E+08 | 74,724 | 11,429 | 45,345 | 104,102 |
| " | 6 | 25-30 | 0.00047 | 4.7E-08 | 6 | 1.1E+08 | 53,666 | 10,057 | 27,813 | 79,518 |
| " | 7 | 30-35 | 0.00012 | 4.8E-09 | 6 | 1.1E+08 | 13,236 | 3,120 | 5,216 | 21,256 |
| " | 8 | 35-40 | 0.00002 | 7.1E-10 | 6 | 1.1E+08 | 2,308 | 1,155 | -661 | 5,277 |
| " | 9 | 40-45 | 0.00000 | 0.0E+00 | 6 | 1.0E+08 | 0 | 0 | 0 | 0 |
| " | 10 | 45-50 | 0.00000 | 0.0E+00 | 6 | 9.7E+07 | 0 | 0 | 0 | 0 |
| " | 11 | 50-55 | 0.00000 | 0.0E+00 | 6 | 9.2E+07 | 0 | 0 | 0 | 0 |
| " | 12 | 55-60 | 0.00000 | 0.0E+00 | 6 | 8.3E+07 | 0 | 0 | 0 | 0 |
| " | 13 | 60-65 | 0.00000 | 0.0E+00 | 5 | 7.5E+07 | 0 | 0 | 0 | 0 |
| " | 14 | 65-70 | 0.00000 | 0.0E+00 | 5 | 6.8E+07 | 0 | 0 | 0 | 0 |
| " | 15 | 70-75 | 0.00000 | 0.0E+00 | 5 | 5.1E+07 | 0 | 0 | 0 | 0 |
| " | 16 | 75-80 | 0.00000 | 0.0E+00 | 5 | 3.8E+07 | 0 | 0 | 0 | 0 |
| " | | 0-80 | | | 92 | 1.6E+09 | 393,717 | 30,825 | 332,337 | 455,097 |
| 95% CI is the population estimate +/- 16% | | | | | | | | | | |

* Number of transects with corresponding depth interval.

Table 14. Daytime population estimate for trout in the upper 10 m of the offshore zone, which the trout and large kokanee (>100 mm long) occupied exclusively at that time. The trout were captured in no other habitat during the day. This table incorporates results from species, size, and population estimate tables.

| Interval number | Depth range (m) | Cutthroat trout | | Kokanee | | Species combined | |
|---|---|---|---|---|---|---|---|
| | | Percent | Number | Percent | Number | Percent | Number |
| 1 | 0-5 | 50.0% | 1,293 | 50.0% | 1,293 | 100.0% | 2,586 |
| 2 | 5-10 | 50.0% | 391 | 50.0% | 391 | 100.0% | 782 |
| Combined | 0-10 | | 1,684 | | 1,684 | | 3,368 |

At night, the population estimate for fish less than 100 mm long was 307,550 fish (215 kg), all of which were assumed to be age 0 kokanee (Table 15), although TS frequency distributions suggested that other species may also have been present (Figure 19). Numbers and biomass of larger fish (≥100 mm in length) were estimated to be 3,042 cutthroat trout (1,065 kg), 17,322 Dolly Varden (19,633 kg), 46,064 kokanee (3,413 kg), 713 rainbow trout (78 kg), 3,499 peamouth chub (101 kg), and 15,527 pike minnow (4,032 kg). For these larger fish, numbers and biomass of salmonids were summarized by cohorts. Considering cutthroat trout, ages two and three were most abundant, whereas ages three and seven had the largest biomass (Table 15). For Dolly Varden, all of which were at least age 4, age 6 and 7 fish were most numerous, while age 7 and 11 fish contributed most to biomass. Considering kokanee, ages 1-3 were present, with age 2 strongly dominant both numerically and in terms of biomass. Age 1 and 2 rainbow trout were equal in numbers while age two had the larger biomass, however, these figures are based on a catch of only two fish. Numbers and biomass per hectare of large and small fish combined were 1.1 cutthroat trout/ha (0.4 kg/ha), 6.1 Dolly Varden/ha (6.9 kg/ha), 125 kokanee/ha (1.3 kg/ha), 0.3 rainbow trout/ha (0.03 kg/ha), 1.2 peamouth chub/ha (0.04 kg/ha), and 5.5 pike minnow/ha (1.4 kg/ha), for a combined total of 139 fish/ha (10.1 kg/ha, Table 15).

Table 15. Night time population estimate for all species and size groups of fish in the zone sampled with acoustics (main lake basin, offshore of the 13.5 m depth contour). This table incorporates results from species composition, size fraction, and population estimate tables.

| Size group | Estimate | Age | Species: Cutthroat | Dolly Varden | Kokanee | Rainbow | Peamouth | Pike minnow | Total |
|---|---|---|---|---|---|---|---|---|---|
| **<100 mm** | **abundance** | **0** | **0** | **0** | **307,550** | **0** | **0** | **0** | **307,550** |
| **"** | **biomass (kg)** | **0** | **0** | **0** | **215** | **0** | **0** | **0** | **215** |
| ≥100 mm | percentage | 1 | 14.3% | 0.0% | 25.0% | 50.0% | - | - | |
| " | " | 2 | 21.4% | 0.0% | 54.2% | 50.0% | - | - | |
| " | " | 3 | 28.6% | 0.0% | 20.8% | 0.0% | - | - | |
| " | " | 4 | 14.3% | 6.7% | 0.0% | 0.0% | - | - | |
| " | " | 5 | 7.1% | 6.7% | 0.0% | 0.0% | - | - | |
| " | " | 6 | 0.0% | 26.7% | 0.0% | 0.0% | - | - | |
| " | " | 7 | 14.3% | 46.7% | 0.0% | 0.0% | - | - | |
| " | " | 11 | 0.0% | 13.3% | 0.0% | 0.0% | - | - | |
| " | " | total | 100.0% | 100.0 % | 100.0% | 100.0% | - | - | |
| " | abundance | 1 | 435 | 0 | 11,516 | 357 | - | - | |
| " | " | 2 | 652 | 0 | 24,952 | 357 | - | - | |
| " | " | 3 | 869 | 0 | 9,597 | 0 | - | - | |
| " | " | 4 | 435 | 1,155 | 0 | 0 | - | - | |
| " | " | 5 | 217 | 1,155 | 0 | 0 | - | - | |
| " | " | 6 | 0 | 4,619 | 0 | 0 | - | - | |
| " | " | 7 | 435 | 8,084 | 0 | 0 | - | - | |
| " | " | 11 | 0 | 2,310 | 0 | 0 | - | - | |
| " | " | total | 3,042 | 17,322 | 46,064 | 713 | 3,499 | 15,527 | 86,167 |
| " | biomass (kg) | 1 | 41 | 0 | 306 | 35 | - | - | |
| " | " | 2 | 126 | 0 | 2,061 | 42 | - | - | |
| " | " | 3 | 247 | 0 | 1,046 | 0 | - | - | |
| " | " | 4 | 160 | 418 | 0 | 0 | - | - | |
| " | " | 5 | 119 | 450 | 0 | 0 | - | - | |
| " | " | 6 | 0 | 4,044 | 0 | 0 | - | - | |
| " | " | 7 | 371 | 8,076 | 0 | 0 | - | - | |
| " | " | 11 | 0 | 6,645 | 0 | 0 | - | - | |
| " | " | total | 1,065 | 19,633 | 3,413 | 78 | 101 | 4,032 | 28,322 |
| Combined | abundance | total | 3,042 | 17,322 | 353,614 | 713 | 3,499 | 15,527 | 393,717 |
| " | biomass (kg) | " | 1,065 | 19,633 | 3,628 | 78 | 101 | 4,032 | 28,538 |
| " | number/ha | " | 1.1 | 6.1 | 124.9 | 0.3 | 1.2 | 5.5 | 139.1 |
| " | kg/ha | " | 0.4 | 6.9 | 1.3 | 0.03 | 0.04 | 1.4 | 10.1 |

# 5.0 DISCUSSION

## *5.1 Comparison of 2005 Biological Data with Previous Studies of Stave Reservoir*

Results of fish sampling in 2005 were similar to those of previous studies at Stave Reservoir. The assemblage of fish species that was captured in nets and traps in 2005 was much the same as in other years of sampling (1987, 1988, and 1993). In 2005, 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 did capture peamouth chub in significant numbers, whereas this species was previously unreported. In 2005, the relative abundance of fish species was similar to that of 1987 and 1993 (e.g., pike minnow and redside shiner were most numerous), but different from that of 1988, when more open water areas were targeted (Table 16). The total CPUE in 2005 was intermediate among all years of sampling. In 2005, the lengths of kokanee (mean and range) were similar to those reported in previous studies, rainbow trout were smaller, and cutthroat trout and Dolly Varden were larger (Table 17).

Table 16. Gill net catch rates (number of fish x 100 $m^{-2}$ x 24 $hr^{-1}$) in 2005 compared to catch rates in previous studies.

| Survey date | Fish x 100$m^{-2}$ x 24 $hr^{-1}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rainbow trout | Cutthroat trout | Kokanee | Dolly Varden | Pike Minnow | Redside shiner | Large-scale sucker | Brown bullhead | Pea-mouth chub | Total |
| July-1987[a] | 0.15 | 1.74 | 3.63 | 1.16 | 12.50 | 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[d] | 0.01 | 0.96 | 1.68 | 0.96 | 8.28 | 7.20 | 4.56 | 0.00 | 1.80 | 25.45 |

[a] Norris and Balkwill 1987 in Bruce et al. 1994.
[b] B. Gadbois, B.C. Hydro, personnel communication in Bruce et al. 1994. Targeted open water areas.
[c] Bruce et al. 1994. Targeted timber and debris choked areas.
[d] This report. Targeted main lake basin, littoral and pelagic.

Table 17. Size of salmonids in 2005 compared to that in previous studies.

| Survey date | Fork Length (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rainbow trout | | | Cutthroat trout | | | Kokanee | | | Dolly Varden | | |
| | 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 |

[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.

Comparing salmonids ages among studies was not useful. Fish were only aged in 2005 and 1993. A comparison of population age structure between those years would probably be misleading because the range of ages identified appeared to be largely dependent on the number of fish that were aged and sample sizes differed greatly among the two years (Table 18). .

Table 18. Age of salmonids in 2005 compared to previous studies.

| Survey date | Range of ages captured | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Rainbow trout | | Cutthroat trout | | Kokanee | | Dolly Varden | |
| | 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 |

[a] Bruce et al. 1994. Targeted timber and debris choked areas.
[b] This report. Targeted main lake basin, littoral and pelagic.
* The oldest fish actually aged were age 7. The largest Dolly Varden captured in 2005 were not aged, but based on the length-age plot, they were estimated to be age 11.

## *5.2 Fish Abundance and Biomass*

Our night time total fish population estimate (393,717 fish of all species) was approximately five times the daytime population estimate (81,739 fish). Precision of both estimates was good. The daytime 95% confidence interval (95% CI) was +/- 24% of the daytime population estimate and the night time 95% CI was +/- 16% of the night time population estimate. The night survey attained a higher precision with four fewer transects than were run in the daytime survey. During daytime, all species except trout were poorly distributed for acoustics (mainly benthic or littoral, schooled, or in very deep water) and gill netting (those in very deep water), so most species were poorly sampled during that period. At night, all species were restricted to the upper 40 meters of the water column and most were semi-pelagic, making them easy targets for both acoustics and gill nets. Hence, night surveys were clearly superior for population assessment of most fish in Stave Reservoir. This finding was not surprising because night acoustic surveys are preferred for many fish species (Thorne 1983, MacLennan and Simmonds 1992, Brandt 1996).

Daytime is often the best period for acoustic surveys of trout because their behavior is frequently well suited to sampling then (e.g., Stables and Thomas 1992, Yule 2000, Stables and Perrin 2004). In Stave Reservoir, daytime surveys succeeded in finding trout in isolation from most other species in the offshore portion of the epilimnion. Only trout and kokanee were found there at that time, and trout were captured nowhere else. This spatial separation simplified species apportionment and it simplified assumptions about offshore versus nearshore relative abundance for the daytime trout estimate. However, low daytime gill net catches (due a combination of short day length, sampling logistics, and fish behavior) made daytime species composition estimates relatively volatile. This problem may partially explain differences between the day and night estimates of cutthroat trout abundance (1,684 during daytime and 3,042 fish at night). For example, a catch of one additional cutthroat trout in gill nets during daytime sampling would have increased the percentage of this species from 50% to 55% of the daytime total (see Table 5). This would have increased the daytime cutthroat population estimate from 1,684 fish to 2,105 fish, or 69% rather than 55% of the night time population estimate. Compared to daytime gill net catches, night time catches were twice as high for cutthroat trout and three times as high for all species combined, making them much more reliable for species composition estimates. Also, rainbow trout were only captured at night. Unlike trout in many lakes and reservoirs (e.g., Nillson and Northcote 1981, Stables and Perrin 2004), most trout in Stave Reservoir did not migrate to the littoral zone at night, perhaps to avoid competition with non-salmonids that were abundant in that habitat. Thus, most trout remained offshore and accessible to acoustics at that time. On this basis, night time appears to be the best period for trout population size assessment in Stave Reservoir.

Total fish biomass in Stave Reservoir (10.1 kg/ha) was intermediate among estimates from several other lakes and reservoirs to which it was compared (Table 19). Biomass in Ross Lake, a northern Washington reservoir that mainly supports rainbow trout, was considerably lower (2.8-5.7 kg/ha, Loof 1992), while biomass in Coquitlam Reservoir that is dominated by non-salmonids was much higher (31.2 kg/ha, Bussanich et al. 2005). The fish assemblages of Stave and Coquitlam Reservoirs are similar, except that Coquitlam has no Dolly Varden. Biomass of kokanee in Stave Reservoir was low compared to other lakes with the exception of Williston Reservoir, which is dominated by lake whitefish (Sebastian et al. 2003). Trout densities and biomass in Stave Reservoir (1.4 fish/ha and 0.43 kg/ha for rainbow and cutthroat combined) were also somewhat lower than those reported for Ross Lake (8 to 15 trout/ha, 3 to 6 kg/ha, Loof 1992). These low values seem appropriate for the low limnetic primary production levels that have been documented in Stave Reservoir (Stockner and Beer 2004).

The high biomass of Dolly Varden char in Stave Reservoir (6.9kg/ha, or nearly 70% of total fish biomass) stands out among the lakes we compared (Table 19). Although both TS data and the relatively high gill net catch rates indicated a high proportion of large fish in Stave Reservoir, it is possible that catch rates were disproportionately high for Dolly Varden, over-inflating the abundance estimate for this species. Two causes for this of error are plausible. First, piscivorous Dolly Varden may have been attracted to fish tangled in the gill nets. Shorter soak times in the future might reduce this problem. Second, large Dolly Varden likely had higher cruising speeds and thus higher encounter rates with gill nets than smaller fish (Rudstam et al. 1984). Catch rates might be adjusted for fish size and swimming speed in future analysis. These questions about Dolly Varden deserve further attention in future sampling and analysis.

Table 19. Estimates of areal fish density (fish/ha and kg/ha) in Stave Reservoir compared to selected BC and Washington lakes and reservoirs. Values for Ross Lake and Williston Reservoir are rough approximations.

| 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 | 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 | DV, 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 Sebstian et al. 2003, 6 Looff 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 pike minnow; CT=cutthroat trout; PMC=peamouth chub;
LT=lake trout; BT=bull trout; MS=mixed species including PMC, NPM, CT; LWF=lake whitefish; SS=sockeye salmon.

Other errors in species composition estimates could have affected our population estimates. Although gill nets extended only about 100 meters from shore, we assumed that the relative abundance of fish in offshore panels was representative of the entire pelagic zone. Evidence from other studies mostly supports this assumption for the fish that we found in the pelagic zone at night (mainly trout, kokanee, Dolly Varden, and pike minnow). Rainbow and cutthroat trout are commonly found throughout the pelagic portion of the epilimnion in other lakes during both day and night (Stables and Thomas 1992, Quinn 2005). Northern pike minnow inhabit offshore pelagic waters in many lakes at night, both above and below the thermocline. During the summer, they are often found near the surface in the pelagic zone (Wydoski and Whitney 2003). MacLellan (S. MacLellan, DFO, personal communication) reports that adult pike minnow are frequently captured in midwater trawls below the thermocline in the pelagic zone during fall sampling in Cultus Lake. Bussanich et al. (2005) reported that pike minnow co-exist with kokanee in the pelagic zone of Coquitlam Reservoir. Bull trout (*S. confluentus*), a species closely related to Dolly Varden, prey extensively on kokanee in Lake Pend Oreille, occupying “nearshore habitats” (<70 m deep) more often than waters further offshore (Bassista et al. 2005). Although our gill net data showed no trend in abundance related to distance from shore for Dolly Varden, this is another possible source of error that may contribute to our high abundance estimate for this species. Comparative gill netting further offshore in the future would help to answer this question both for Dolly Varden and for other fish species.

Random error could have also affected the accuracy of species and size composition estimates, especially when catches or fish detections with acoustics were few. We attempted to address this deficiency by pooling estimates from depth intervals with low sample sizes, but this procedure in itself may mask real differences between depths. Obtaining larger sample sizes in the future would be the best solution to this problem.

The amount of time between acoustic sampling and gill netting (4 days until overnight sets; 12 days until daytime sets) may have allowed fish distribution patterns to change, leading to mismatch between acoustic targets and fish samples. Over this interval, the depth of the epilimnion changed little, but the epilimnion temperature dropped two degrees and the thermocline became less abrupt. Close agreement between length frequency distributions from the catch and estimated from TS suggests that the data sets were still well matched, but the time between acoustic and fish sampling should always be minimized.

Without trawling, there is some question whether all fish less than 100 mm long were kokanee fry. We observed two modes in the length-frequency distribution of small fish estimated from TS. One mode (30 mm) was close to the size of kokanee fry in other lakes (e.g., mean fall fry length was 43 mm in Williston Reservoir [Sebastian et al. 2003] and 40 mm in Pend Oreille Lake [Bassista and Maiolie 2002]) suggesting that it represented kokanee fry. A second mode at 70 mm suggested that another type or age group of small fish was also present. Sticklebacks did not appear to be common in Stave reservoir; none were captured in Gee traps and the only evidence of them was in one Dolly Varden stomach. It would be beneficial to conduct some trawling in future years to identify small fish, however, a relatively small portion of the fish biomass in the lake (<1%) will be unidentified if this is not possible. Also, the presence of *Chaoborus sp.* in a kokanee stomach suggests that they may account for some of the acoustic targets. This insect species, which has a gas bladder, has a target strength similar to salmonid fry and can sometimes be a problem for acoustic surveys (Eckman 1998). No Chaoborus layer was seen on echograms, but small targets that were abundant near the surface at night are of special interest. This layer could be sampled easily with a plankton net.

Analysis of fish stomach contents was useful for determining food sources of salmonids at the time of the 2005 survey. The composition of food ingested was distinctly different for each fish species. Cutthroat mainly ingested terrestrial insects that had fallen or landed on the reservoir surface. Kokanee ingested plankton, and Dolly Varden mainly targeted fish. Fish were also found in 5 of 7 cutthroat stomachs, so they were also important to this species even if they were not the numerically dominant prey. Unfortunately, with the exception of two sticklebacks in one Dolly Varden stomach, all fish were digested beyond further recognition, so we cannot say whether they were kokanee or other species. Shorter soak times might reduce this problem in the future. Although both Dolly Varden and cutthroat trout roamed the pelagic zone and are know to prey on kokanee (Quinn 2005), the low biomass of kokanee in Stave Reservoir suggests that other fish may have been important prey items. Non-salmonids that were relatively abundant in nearshore habitats may have fallen into this category.

Some modifications to the diet studies would be beneficial in future years. Although stomach content analysis described the composition of ingested food at the time of sampling, it said nothing about food preferences during the remainder of the year. Addition of stable isotope analysis to future studies to determine the long-term contributions of terrestrial, benthic, and zooplankton to fish diets would be useful for linking changes in the fish community to the effects of Combo 6 on lower trophic levels. Also, analysis of northern pike minnow stomach contents would help to clarify the role of this abundant species as predator, prey, or both in the Stave Reservoir fish community.

## 6.0 RECOMMENDATIONS

We make the following recommendations to address the questions and deficiencies described above, and to generally improve the precision and accuracy of fish abundance and biomass estimates in future years. Time and budget limitations will determine which of these recommendations can be implemented and not all may be possible within these constraints..

- Eliminate daytime sampling and focus all effort on night sampling, which was found to be most suitable for population estimates of all species in Stave Reservoir . This strategy should automatically increase sample sizes for the same amount of effort as in 2005 (e.g., if total planned gill netting effort is again 12 sets, then 12 of 12 rather than 6 of 12 would be overnight sets);
- Increase the number of night time transects to 10;
- Perform limited up-looking acoustics to obtain additional TS samples in the upper water column;
- Conduct comparative offshore versus nearshore gill netting to clarify the use of these habitats by fish;
- Make night time plankton tows to determine if *Chaoborus sp*. that may confused with small fish in acoustic surveys are present in appreciable numbers;
- Conduct trawling to determine if fish less than100 mm long are all kokanee fry.
- Conduct gill netting within 2-3 days of acoustic sampling, if at all possible, to minimize changes in fish distributions;
- Analyze stomach contents of northern pike minnow as well as salmonids;
- Perform stable isotope analysis to examine the relative importance of terrestrial and aquatic sources of fish food;
- Conduct genetic sampling to determine if char in Stave Reservoir are Dolly Varden or bull trout; and
- Obtain information about age and diet of large Dolly Varden. Some fish would have to be sacrificed to obtaining otoliths. Stomach contents might be sampled without fish mortality by using a stomach pump.

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