

**Stave River Water Use Plan**  
**Fish Biomass Assessment**

**Implementation Year 10**

**Reference: SFLMON-3**

**Abundance and Biomass of Fish in Stave Reservoir in October 2012**

**Study Period: 2005 to 2014**

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**January 31, 2016**



**ABUNDANCE AND BIOMASS OF FISH IN STAVE RESERVOIR,  
2005 - 2014**

**BC Hydro project number SFLMON#3**

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**SHUKSAN**

**LIMNOTEK**

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2005 - 2014**

**BC Hydro project number SFLMON#3**

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

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## **EXECUTIVE SUMMARY**

From 2005 through 2014, coordinated acoustics (scientific echo sounding) and gill netting were conducted in Stave Reservoir each fall to measure fish biomass and abundance for the purpose of testing the effect of Combo6, an operational plan designed to reduce reservoir drawdown during the summer growing season.

An abundance of 388,820 fish (species combined) in 2005 increased to 1,687,129 fish in 2010 but then declined to 466,848 fish in 2014, resulting in little net change over the 10 year monitoring period. Biomass showed a similar pattern of increase and decrease, from 3.3 kg/ha in 2005, to 12.5 kg/ha in 2010, to 6.5 kg/ha in 2014. Most changes in abundance were due to fish < ~ 100 mm in length, based on acoustic estimates of size, that were assumed to be kokanee fry (small fish were not captured for identification). Most changes in biomass were due to age-2-3 kokanee and age-2-3 and older cutthroat and Bull Trout. Neither absolute abundance nor biomass were estimated for the littoral zone, but relative abundance of most highly littoral species in the gill net catch (mean catch per unit effort for Largescale Sucker, Northern Pikeminnow, Redside Shiner) decreased rather than increased over time.

These data did not indicate that Combo6 increased fish abundance or biomass in Stave Reservoir, as would have been shown by a consistent rising trend or an increase followed by variation around a mean greater than the initial level. Similarly, no other available data or lines of evidence could explain the observed changes in fish abundance or biomass. No relationship was apparent between fish abundance and the four years of primary production rate data that were available from a related study. No pattern was found between condition factor (CF) of kokanee and the minimum water surface elevation during the critical growth period of May 15 – September 7 as defined in Combo6. Nor was a pattern evident between kokanee CF and the number of days between May 15 and September 7 when the water surface elevation exceeded 80 m. No pattern was found between phosphorus loading to Stave from Alouette Lake and fish abundance or biomass. Neither the appearance of parasitic gill lice on kokanee in 2011 nor discharge patterns in salmonid spawning streams could be linked with declines from peak abundance and biomass in 2010.

These findings do not mean that Combo6 had no effect on fish in Stave Reservoir; rather, they mean that an effect could not be detected with the experimental design employed. This design was weak in several ways. One problem was the lack of data from years before implementation of the water use plan with which to make before – after comparisons. Also, the collection of gill net data that was fundamental to biomass estimates only in alternate years greatly undermined its value for statistical testing, and the influence of mortality in spawning streams on fish abundance and biomass in the reservoir was not accounted for. As a result, for the time period studied

inter-year variation exceeded any time course trend due to Combo6 that may have been present.

With that said, the Fish Biomass Study produced much valuable information suggesting ecological reasons to expect no effect of Combo6 on the measured fish populations. The water use plan did not alter the extent of annual drawdown, just variability in water elevations during the high water period, and that variation would be expected to only influence benthic production in substrata near the highest littoral elevations. Kokanee, by far the most abundant of fish in the study area, are a mainly pelagic species that occupied habitat that would not be affected by this change. Their habitat might be reduced during the winter drawdown each year, but the extent of that drawdown did not change with Combo6. Lack of a relationship between kokanee condition factor and hydrologic metrics of Combo6 further supports this idea. This disconnect between habitat use by kokanee and the effects of Combo6 means there was no reason to expect an appreciable increase in kokanee abundance from it. In addition, less pelagic fish that made up a large fraction of the biomass estimates (e.g., Cutthroat Trout, Bull Trout) were opportunistic feeders, ingesting terrestrial insects (Cutthroat Trout) and other fish (Cutthroat Trout, Bull Trout) as well as benthic invertebrates (both). Any change in availability of benthos in the upper littoral may have had little to no effect on availability of food for these fish. Given these lines of evidence, there was not a strong rationale to expect Combo6 to provide a benefit to fish populations in Stave Reservoir.

## **ACKNOWLEDGEMENTS**

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## 1 INTRODUCTION

Stave Reservoir is the major impoundment within BC Hydro's Stave River Hydroelectric Project (Figure 1). Improving fish production in Stave Reservoir is a key goal of the Stave River Water Use Plan (WUP, Failing 1999a). Based on limited information that was available for early planning (e.g., Bruce et al. 1994, Slaney 1989), the WUP Consultative Committee (WCC) hypothesized that a low rate of fish production in the reservoir is due to low nutrient loading that is characteristic of ultra-oligotrophic conditions, a high flushing rate, and extensive drawdown during the growing season. Together these factors were thought to severely limit primary and secondary production and limit the forage base for fish in both littoral (shoreward of the 6 m depth contour) and pelagic (open water offshore) habitats (Failing 1999a). Indeed, monitoring of primary production since the WCC report determined that the reservoir is ultra-oligotrophic with one of the lowest rates of carbon fixation so far observed in any lake or reservoir ecosystem in British Columbia (Stockner and Beer 2004).

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

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

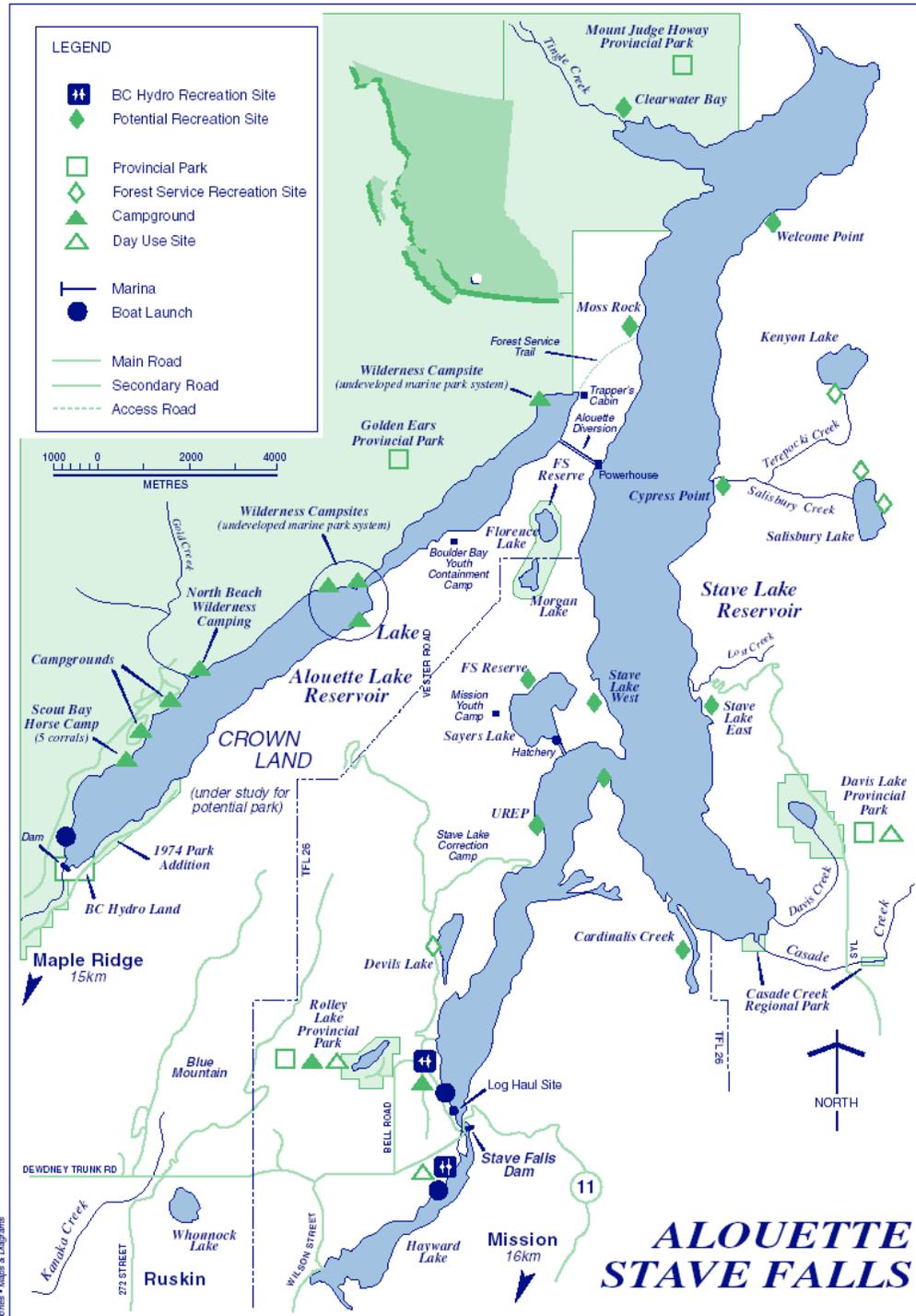


Figure 1. Stave Reservoir and the Stave River Hydroelectric Project.

Earlier studies of Stave Reservoir (Norris and Balkwill 1987, Bruce et al. 1994) found that it supported several salmonid species (Rainbow Trout, *Oncorhynchus mykiss*; Coastal Cutthroat Trout, *O. clarki clarki*; kokanee, *O. nerka*; and native char, Dolly Varden *Salvelinus malma* or Bull Trout *S. confluentus*) and non-salmonid species (Northern Pikeminnow, *Ptychocheilus oregonensis*; Peamouth, *Mylocheilus caurinus*; Three-Spine Stickleback, *Gasterosteus aculeatus*; Largescale Sucker, *Catostomus macrocheilus*; and Redside Shiner *Richardsonius balteatus*.) that may compete for food and space and interact as predators and prey to some degree. Since non-salmonids were thought to be the more abundant group in the littoral zone (Bruce et al. 1994) where the benefits of Combo 6 were expected to accrue, it was speculated by the WCC that they might benefit most from this program. However, it was thought that the species of trout and char present in the reservoir may also benefit, since they 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 (e.g., Andrusak and Northcote 1971, Stables and Perrin 2004). Further study was required to resolve these uncertainties and to measure the effect of Combo 6 on the fish community.

Ultimately, the WCC approved studies to monitor primary production and fish biomass in Stave Reservoir for ten years after Combo 6 was put into effect. In the study Terms of Reference (TOR) that followed in 2005, fish biomass was chosen as a metric because it is a useful surrogate for fish production that is relatively easy and inexpensive to obtain. Early fall (mid-September to mid-October) was chosen as the time of fish sampling to encompass most of each year's growth in a single sampling event. The methods chosen for monitoring the fish community were coordinated acoustic (echo sounding) and gill net surveys to be conducted from 2005-2014, following the implementation of Combo 6 in 2004. The TOR also required that the study design economize in two major ways: 1) gill netting was to be done in alternate years only (every other year), and species, size, and age information from a given year of gill netting were to be used in combination with acoustic data from that year and the next (each year of gill net data would be used in two annual biomass estimates); and 2) small fish (fish < ~ 100 mm in length) were all assumed to be kokanee fry, thereby eliminating the need for trawling to sample them. It was also specified that sampling should take place between September 12 and October 15 to reduce year to year variability of kokanee estimates by consistently excluding kokanee spawners, which were expected to be in spawning streams by that time (D. Hunter, BC Hydro, personal communication to B. Stables, July 25, 2005).

The experimental design chosen by the WUP Consultative Committee was not a before-after control-impact (BACI) design that would allow definitively testing the null hypothesis that reduced variation in water levels did not increase fish biomass (there is no comparable data from before initiation of Combo 6 or from an analogous reservoir; James Bruce, BC Hydro, personal communication). Therefore, whether biomass

increased, stayed the same, or decreased, factors other than Combo 6 might be responsible. Also, the use of each year of gill net data in two biomass estimates is invalid for statistical analysis (violates the requirement that each measurement of biomass be independent of the others, Sokal and Rohlf 1969). Even so, it was surmised that the presence of significant trends in fish biomass over time (or the lack thereof) would provide insights into how Combo 6 had affected fish production that would support decision making by the WUP Consultative Committee. The study's outcome could also point to new research directions and aid in planning of more powerful future experiments if so desired.

As such, the key management questions to answer and the associated null hypotheses to test statistically at the end of the ten year long monitoring period were:

Q<sub>1</sub>: Would overall fish biomass change following initiation of Combo 6?

(H<sub>1</sub>: Overall fish biomass did not change following implementation of Combo 6), and

Q<sub>2</sub>: Would changes, if any, in species and cohort-specific biomass after initiation of Combo 6 be related to changes in littoral or pelagic primary production?

(H<sub>2</sub>: Between-year differences in species and cohort-specific biomass were not correlated with indices of littoral or pelagic primary production following implementation of Combo 6).

Answering these key questions to evaluate the importance of water level management in sustaining the health of Stave Reservoir and its fish populations was the main objective of this study. Expanding general knowledge about Stave Reservoir's ecology to assist with future water management decisions was an additional important objective.

## **2 STUDY SITE DESCRIPTION**

Stave Reservoir is located 65 km east of Vancouver in the Fraser River watershed (Figure 1). The reservoir is 25 km long, it has a surface area of 5,860 ha, a mean depth of 36 m at full pool (Norris and Balkwill 1987, Stockner and Beer 2004), and it flushes approximately 5 times between April and October each year (Stockner and Beer, 2004). The Stave watershed (1,150 km<sup>2</sup>), includes Alouette Lake, which drains into Stave Reservoir through a BC Hydro diversion tunnel and power plant. Stave Reservoir is composed of a main basin that contains the original natural lake, plus a 9.5 km long outlet arm that was formerly part of the Stave River. The present outlet of the reservoir is at the Stave Falls Dam. The central and largest portion of the reservoir that includes the original lake is steep sided and deep, reaching a maximum measured depth

of 101 m (Figure 2a). The north and south ends of the main basin contain several km of shallows outside the natural lake that are densely covered with dead standing timber from the forest that existed before the water surface elevation was raised to create the reservoir (Figures 3 and 4). 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 2b). The area of this selected portion of the reservoir is 2,962 ha at full pool (elevation 82.1 m above sea level)

Stave Reservoir is an ultra-oligotrophic ecosystem characterized by extremely low dissolved phosphorus concentration, very low algal biomass, very low littoral and pelagic primary production, and low zooplankton standing crop (Stockner and Beer 2004). During summer stratification, the average depth of the epilimnion (the uppermost and warmest layer of water) is historically approximately 7 m. Epilimnetic temperatures often reach 20°C in summer. Dissolved oxygen concentration typically 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 study 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 (Figures 2c, 3, and 4). Rooted aquatic plants are rare in Stave Reservoir (J. Bruce, BC Hydro, personal communication) and were not observed in the study area during this project.

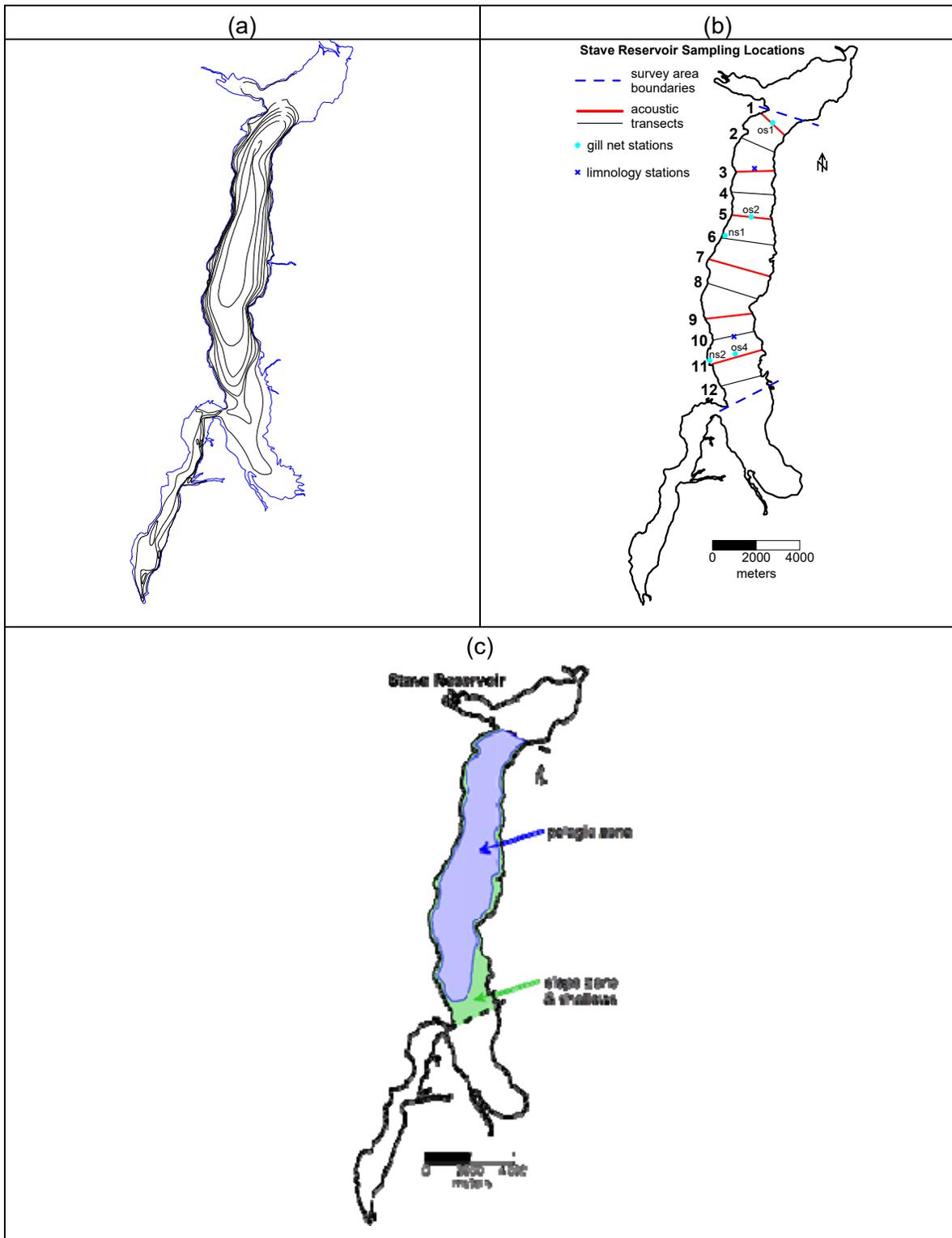


Figure 2. Maps of Stave Reservoir: a) bathymetric map showing the reservoir outline at full pool (82.1 m above sea level) with 10 m depth contours; b) the study area showing sampling stations and acoustic survey transects (main transects in bold red lines), and c) horizontal extent of the pelagic and slope/shallows zones within the study area.

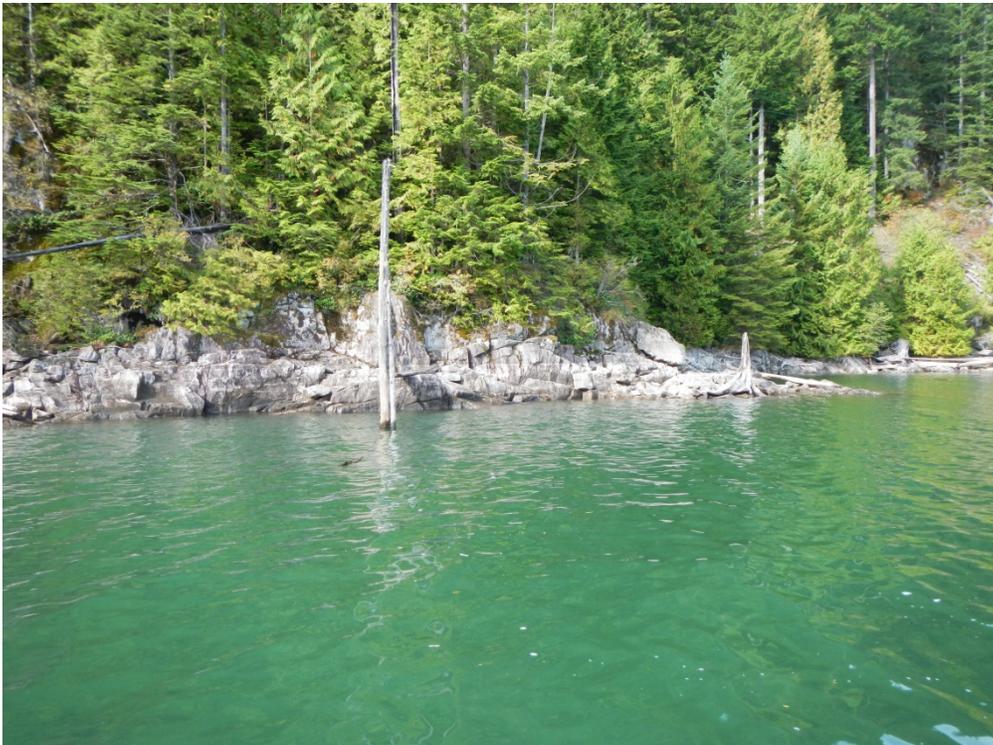


Figure 3. The Stave Reservoir Fish Biomass Study site: (Upper) Looking north to south across the study area; (Lower) a steep, rocky shoreline with stumps and submerged timber at the southern nearshore gill netting station in the southwest corner of the study area.



Figure 4. Extensive, dense standing timber in the southeast corner of the study area at the east end of Transect 12. Areas within the stand of deadheads were not sampled.

Under Combo 6, the following operating rule was applied beginning in May 2004 (BC Hydro 2013):

“The normal operating range of Stave Lake Reservoir is between the normal minimum elevation,  $N_{min}$ , of El. 73.0 m, and the normal maximum elevation,  $N_{max}$ , of El. 82.08 m. From 15 May to 07 September (116 days), Stave Lake Reservoir must be El. 76.0 m or higher and within an elevation band of 80.0 to 81.5 m for 53 days or more. If conflicts arise between these reservoir level obligations and flow requirements downstream of Ruskin Dam, the flow obligations for Ruskin have priority.”

Using data from BC Hydro Power Records (data received March 5, 2015), Tables 1 and 2 show that water surface elevations met conditions of Combo 6 in all but two years. The exceptions were 2006 and 2008 when the minimum water surface elevation was approximately 1m below the minimum set in Combo6 and the minimum elevation during the critical period of May 15 through September 7 was  $\leq 1.5$ m below the target minimum elevation of 76m.

During 2005 – 2014, mean annual water surface elevations were within a narrow range of 78-79m (Figure 5) and the mean monthly water surface elevation averaged among years ranged from 76.6m in March to 81m in July with a standard deviation of 0.4m to 2m (Figure 5).

Table 1. Minimum and maximum water surface elevation in Stave Reservoir by year.

Year	Minimum elevation (m)*	Maximum elevation (m)*	Drawdown (m)
2005	75.30	81.39	6.09
2006	71.94	81.36	9.43
2007	74.97	81.73	6.77
2008	72.00	81.88	9.87
2009	75.28	81.60	6.32
2010	75.52	80.96	5.44
2011	75.15	81.71	6.56
2012	75.11	81.52	6.42
2013	74.42	81.84	7.42
2014	75.87	81.11	5.24

\*Green shading indicates water surface elevation met the normal operating range (73 – 82.08m); red indicates it did not.

Table 2. Criteria to determine if water surface elevation met conditions of Combo6 during the critical period of May 15 – September 7, by year.

Year	Minimum elevation during May 15 – Sep 7 (m)*	Number of days water surface elevation was 80-81.5m during May 15 – Sep 7*
2005	77.8	80
2006	75.19	98
2007	76.60	69
2008	74.46	93
2009	78.50	86
2010	78.19	68
2011	77.25	82
2012	78.45	95
2013	77.66	55
2014	77.87	81

\*Operating rule under Combo6 is that water surface elevation must be  $\geq 76$ m during May 15 – September 7 and within an elevation band of 80.0 to 81.5 m for  $\geq 53$  days. Green colour indicates condition was met; red shows it was not met.

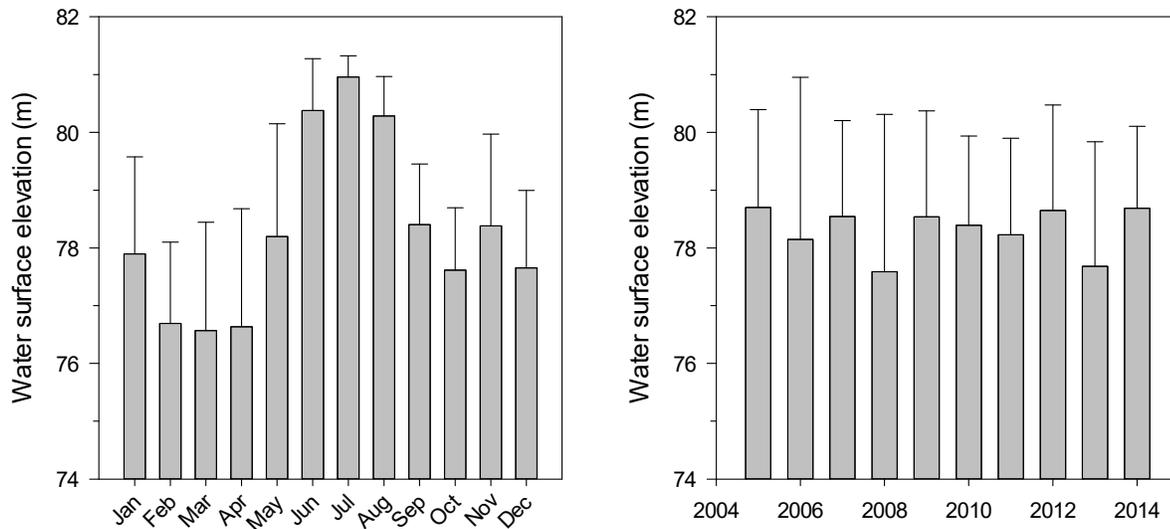


Figure 5. Mean monthly (left) and mean annual (right) water surface elevation in Stave Lake Reservoir in 2005 through 2014 (error bars are + 1 sd).

Before implementation of the water use plan in May 2004, the annual minimum and maximum water surface elevations were the same as in years after the plan was implemented (Regional Consulting 2000). There was no requirement before the plan to limit drawdown and maintain high water surface elevations during the biological productive spring and summer months as required after the plan was implemented. However, water surface elevation was typically high in spring and summer even before the plan because that is a time when snowmelt water filled the reservoir. In addition, water demand at the downstream Ruskin generating station takes precedence over control of high water surface elevation in Stave in spring and summer in the present water use plan. Hence, in some years there might be no difference in management of water surface elevation in spring and summer between the before and after periods while in other years there can be higher and less variable water elevations in the after period than in the before period with differences dependent on snowpack and demand downstream at Ruskin.

### **3 METHODS**

#### **3.1 Overview**

Coordinated surveys using mobile acoustics (scientific echo sounding) and gill netting were used to estimate fish abundance, biomass, and spatial distribution patterns in Stave Reservoir for the 2005-2014 Fish Biomass Study. Protocols for this type of sampling scheme are described in Beauchamp et al. (2009) and RIC (1997). All field activities for the study (mobile acoustic surveys, gill netting, minnow trapping, and water quality sampling) were performed within the prescribed September 15 to October 15 sampling window each year (Table 3). Both day and night sampling were conducted in 2005, and based on findings of that year, night surveys were determined to be more effective (Stables and Perrin 2006). Only night sampling was done thereafter. Acoustics and water quality sampling were performed in all years. Other activities (gill netting and minnow trapping) were only done every other year, except at the end of the study when gill netting was performed in two consecutive years (2013 and 2014). In years with acoustics and gill netting, the acoustic survey was conducted about one week before gill netting, except in 2013 when it took place two weeks before (due to a weather delay of gill netting). Echograms from acoustics were inspected to determine the depth of fish layers to target with gill nets. Although the core tasks (acoustics, gill netting, and water quality) were consistent throughout the study some methods evolved as knowledge and experience were gained. Significant changes in sampling procedures are summarized in Table 3 and described in the following Methods section, and additional details of the project's evolution appear in the Stave Reservoir Fish Biomass Study annual reports (Stables and Perrin 2006-2014).

Table 3. Field tasks, sampling stratification, weather conditions during acoustics, and types of data collected during each year of the Stave Reservoir 2005-2014 Fish Biomass Study.

Year	Field task	Date	Stratification		Weather Conditions*	Metric or type of sample collected from fish that were captured							
			Horizontal strata	Sampling periods		Species ID	Length	Weight	Age	Sex & Maturity	Stomachs	DNA**	Gill lice
2005	acoustics	9/26-27	nearshore & offshore	day & night	good								
"	temp/DO profiles	9/30, 10/8	offshore										
"	RISC gill netting	9/30-10/1	nearshore	day & overnight		x	x	x	x	x	x		
"	minnow trapping	9/30-10/1	nearshore	day & overnight		x	x	x					
2006	acoustics	9/21	nearshore & offshore	night	good								
"	temp/DO profiles	9/21	offshore										
2007	acoustics	10/4	nearshore & offshore	night	moderate								
"	temp/DO profiles	10/5,11,14	offshore										
"	RISC gill netting	10/8-13	nearshore & offshore	night		x	x	x	x	x	x	BT	
"	minnow trapping	10/8-13	offshore	night		x	x	x					
2008	acoustics	9/23	nearshore & offshore	night	poor								
"	temp/DO profiles	9/23	offshore										
2009	acoustics	9/24	nearshore & offshore	night	good								
"	temp/DO profiles	10/1	offshore										
"	RISC gill netting	9/28-10/1	nearshore & offshore	overnight		x	x	x	x	x	x	BT, KO	
2010	acoustics	9/27	nearshore & offshore	night	moderate								
"	temp/DO profiles	9/27	offshore										
2011	acoustics	9/28	nearshore & offshore	night	poor								
"	temp/DO profiles	9/17, 10/18	offshore										
"	RISC gill netting	10/3-6	nearshore & offshore	overnight		x	x	x	x	x	x	BT, KO	x
2012	acoustics	10/9	nearshore & offshore	night	good								
"	temp/DO profiles	10/9	offshore										
2013	acoustics	9/17	nearshore & offshore	night	poor								
"	temp/DO profiles	9/17, 10/3	offshore										
"	RISC gill netting	10/1-4	nearshore & offshore	overnight		x	x	x	x	x	x	KO, RB, CT	x
"	small-mesh gill netting	10/1-4	offshore	overnight		x	x	x					x
2014	acoustics	9/15	nearshore & offshore	night	good								
"	temp/DO profiles	9/23	offshore										
"	RISC gill netting	9/22-25	nearshore & offshore	overnight		x	x	x	x	x	x	KO	x
"	small-mesh gill netting	9/22-25	offshore	overnight		x	x	x					x

\* Weather conditions: good = mostly calm and smooth, > 75 % of side-looking (SL) data usable; moderate = occasional wind and whitecaps, 50-75% of SL data usable; poor = frequent wind and whitecaps, < 50% of SL data usable.

\*\* Species codes for DNA samples: KO = kokanee, RB = Rainbow Trout, CT = Coastal Cutthroat Trout.

## 3.2 Water quality sampling and analysis

Temperature and dissolved oxygen (DO) concentrations were measured over the upper 60 m of the water column at two locations in the main lake basin (Figure 2b) using a calibrated YSI model 6920 Sonde. Measurements were typically made every metre for the first 10m, every 2 m in the depth range of 10-20 m, every 5 m over the range of 20-30 m, and every 10 m in the range of 30-60 m. These water-column profiles were taken to assess fish habitat conditions and to aid interpretation of vertical distributions of fish that were observed during acoustic and gill net surveys.

## 3.3 Fish sampling

### 3.3.1 Field Activities

#### 3.3.1.1 Minnow trapping

Minnow trapping was conducted concurrently with gill netting at nearshore stations (Figure 2b) in 2005 and 2007, then deemed peripheral to study objectives and discontinued (Table 3). Trapping was done using 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) set on the bottom at the gill net sites in 3-16 meters of water. Traps were baited with salmon roe and set both overnight and during the day in 2005, and only overnight in 2007. Set and retrieval times were recorded to the nearest minute. Fish processing methods in the field were the same for minnow traps as for gill nets (see below). Minnow trap data were not analyzed in this report, but catch summary tables appear in Appendix 7.1.

#### 3.3.1.2 Gill netting

Although gill net sampling methods were kept as similar as possible for all years of the study to ensure between-year comparability, some noteworthy changes were made over time to better meet study needs:

- Only nearshore stations were sampled with gill nets in 2005, the initial year of the study. It was quickly realized that offshore surface and midwater gill netting were also needed to properly represent the pelagic fish community, so the required methods were developed in 2007 and applied from then on.
- Both day and night gill netting were done in 2005, and based on findings of that year only night sampling was done thereafter (acoustics and gill netting were more effective at night in Stave Reservoir).
- Gill netting during the night period consisted of overnight sets (late afternoon-morning) in all years except 2007. In 2007, all nets were pulled before daylight to minimize the chance that Bull Trout would be attracted to nets containing prey species, but this practice proved to be logistically impractical and was discontinued after that year. The decision to return to overnight sets was made after

consultation with BC Hydro staff and an outside expert on predator-prey interactions (Dr. D. Beauchamp, University of Washington School of Fisheries, personal communication), from which it was concluded that there was probably no appreciable attraction of Bull Trout to prey in nets.

Gill net sampling was performed by a crew of three from an 8 m long open skiff that was equipped with a hydraulic capstan winch for retrieving anchors set in deep water (Figure 6). Each year gill netting took place on three to four consecutive nights in late September or early October. Nearshore sets were always made at two fixed stations near the west ends of acoustic transects 6 and 11 (Figures 2b and 6). Offshore sets were made at two adjacent mid-lake stations in 2007, and also at a third mid-lake station at the north end of the lake from 2009 on (Figures 2b and 6). In all years, most nets were standard 91.2 x 2.4 m floating or sinking variable mesh RISC gill nets (RIC 1997) consisting of 6 panels, each of a different mesh size (25, 89, 51, 76, 38, and 64 mm stretched mesh). RISC nets are ideal for salmonids 100-400 mm in length (RIC 1997). In 2013 and 2014, mid-lake stations were also sampled with small-mesh gill nets targeting fish as small as 70 mm in length. These nets were 15.8 m long by 1.5 or 3.7 m tall, with four panels of stretched mesh sizes of 12.5, 20, 16, and 25 mm in that order. In this report a "set" is defined as one net (RISC or small-mesh) fished for one nocturnal period (late afternoon-night, or overnight). The total number of sets per year (nearshore and offshore combined) was 13-22 RISC sets and 3-4 small-mesh sets.

Surface, mid-water, and bottom sets were made at each nearshore station. All sets were perpendicular to the shoreline, with large and small mesh ends of nets placed toward shore on alternate nights to minimize the effects of size selectivity on spatial trends. Surface and bottom sets were attached to shore and anchored and marked with a buoy at the offshore end. Bottom sets typically fished the 0-50 m range of the water column, which included all thermal layers. Floating sets sampled the upper 2.4 m of the water column from the littoral (shoreward of the 6 m depth contour) to the pelagic zone (offshore of the 40 m depth contour in Stave Reservoir). Mid-water sets sampled horizontally from their point of contact with bottom for two to three net lengths (184-276 m) offshore from that point (nets were joined end to end), and they were fished in the 15-30 m depth range during years of the study. Midwater sets were suspended to the desired depth from floats on dropper lines, and fishing depths were spot-checked using a depth sounder. This procedure showed that due to sag between suspension floats, the 2.4 m tall RISC nets fished an approximately 5 m thick depth layer. Each year four surface sets, four to eight midwater sets, and four bottom sets were made at nearshore stations.

Surface and midwater sets at mid-lake stations were similar to those at nearshore stations, except they were anchored and buoyed at both ends in 60-100 m of water. Typically, each station was fished with a gang of three RISC nets strung end to end between the terminal buoys (one surface set and two mid-water sets at different depths), plus an optional surface or midwater small-mesh net in some cases. These

nets were set parallel to shore to facilitate deployment and retrieval in the windy conditions that were often encountered. Surface sets fished the 0-2.4 m depth range (in the epilimnion) and mid-water sets were fish between 10 and 30 m during the study (the thermocline and upper hypolimnion). Midwater sets were at least 30 m above the bottom and 400 to 1,300 m from shore.

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

In the field, all fish were identified to species, counted, measured to the nearest mm (fork length), and weighed to the nearest gram on an Ohaus Scout Pro SP4001 top loading balance. Fish were anaesthetized with clove oil prior to handling when necessary. Structures for aging were taken from salmonids only. Scale smears were removed from preferred body areas of all trout and kokanee and stored in labeled envelopes. Otoliths were obtained from all Bull Trout sacrificed for biological sampling. Stomachs were excised from a target of seven fish of each salmonid species per year and preserved in 70% isopropyl alcohol or 10% formalin for later examination. All salmonids from which stomachs were obtained, and others as time allowed, were examined for sex and stage of sexual maturity according to the following maturity stages: undeveloped = gonads small threads, ovaries and testes indistinguishable; developing stage 1 = gonads small but ovaries and testes distinguishable; developing stage 2 = gonads medium to large, but didn't extrude under light pressure; mature = gonads large, extruded milt or eggs under light pressure; spent = gonads empty and flaccid. Tissue samples (fin clips or opercular punches) for DNA analysis were taken from Bull Trout, rainbow and Cutthroat Trout, and kokanee in various years of the study (Table 3). DNA samples were individually stored in glass vials filled with non-denatured ethanol to await analysis. In 2013 and 2014, all salmonids were examined to determine the presence or absence of gill lice and the gill lice were counted on a sample of approximately 20 kokanee per year.

### **3.3.2 Processing and analysis**

In the lab, scales and otoliths from a sub-sample of approximately 60 salmonids per year were read by a qualified expert to determine the age of fish. Typically, about 40 kokanee, 10 each of Bull Trout and Cutthroat Trout (if available), and any Rainbow Trout that were captured were aged, except in 2014 when nearly all salmonids were processed. In years when a sub-sample of fish was aged, the list of candidate fish was sorted by length and samples to process were chosen systematically (e.g., every third fish) from 25 mm size bins for kokanee or 50 mm size bins for trout (e.g., 100-125 mm or

100-150 mm). For each species, the number of samples from a given size bin was proportional to the fraction of the total catch of that species represented by that size bin, so the sample thus obtained provided a representative age structure estimate.

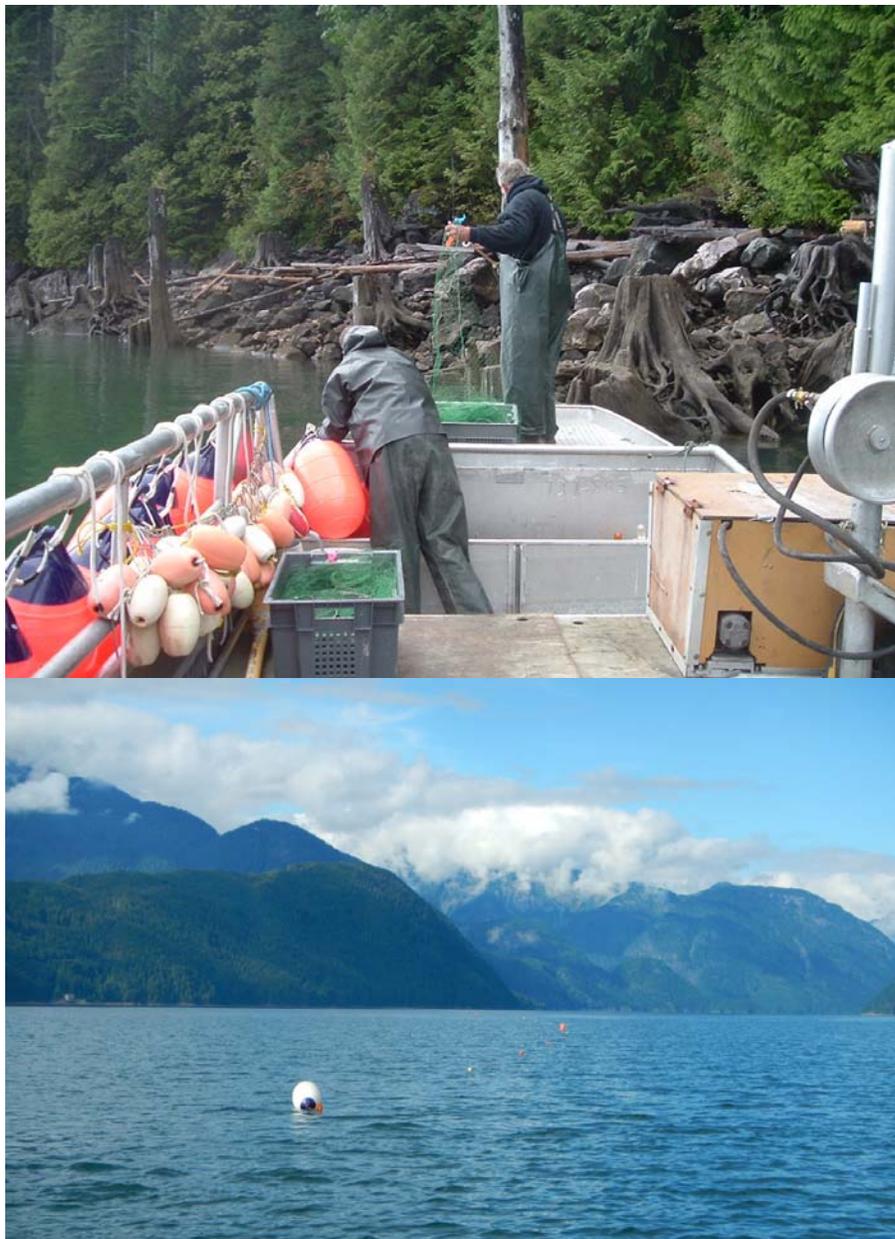


Figure 6. Preparing to set a net at the north nearshore station from the 8 m open skiff used for gill netting (upper) and buoys marking a gang of three RISC gill nets (1 surface and 2 midwater) at the central mid-lake station (OS2).

Trout and char tissue samples collected 2007-2013 were sent to Dr. Eric Taylor of UBC for DNA analysis using methods described in Redenbach and Taylor (2003) and Ostberg and Rodriguez (2002 and 2004). Tissue samples from kokanee were collected for and sent to Dr. Lyse Godbout of DFO for processing (their results are outside the scope of this report).

Organisms from Salmonid stomachs were identified to the lowest reliable taxon (usually family) and counted. Heads or other unambiguous body parts were used for enumeration of organisms that were partly digested. Stomach contents of salmonids were analyzed by comparing percent composition by numbers among fish species and by summarizing food composition by major categories (terrestrial invertebrates, benthic invertebrates, zooplankton, fish). Stomach content data was used to compare the diets of the Salmonid species and to loosely describe the relative importance of food produced within and outside of the reservoir for supporting the fish populations.

Gill net catch and catch per unit effort (CPUE) were computed per set (catch per set-hour) for descriptive purposes. CPUE, an indicator of relative abundance of fish, was also computed for individual RISC gill net panels (catch per panel-hour) to estimate species-specific spatial distribution patterns of fish  $\geq 100$  mm in length. For each species, mean CPUE was calculated in relation to depth within the water column (depth of capture) and the total water column depth where fish were captured (bottom depth), and this information was used to determine the boundary between nearshore (slope zone) and offshore (pelagic zone) fish assemblages for habitat-stratified biomass estimates. By application of this method to 2007 data the boundary between zones was set at the 40 m depth contour (Stables and Perrin 2008). Examination of subsequent years of data showed that this boundary was appropriate for all years of the study, so it was used in the computation of all abundance and biomass estimates in this report. In turn, depth and habitat stratified estimates of relative abundance of species (from CPUE) were used as estimates of species composition for apportioning the acoustic estimate. This type of vertical and horizontal stratification is recommended by Beauchamp et al. (2009) for lakes large enough to have distinct slope and pelagic zones.

Other descriptive biological statistics computed for each species for use in this report were mean and standard deviation of length and weight, length-frequency and age distributions, weight-length regressions, and the residuals from the weight-length regression of all years of data combined used as condition factors (CF). For computation of condition factors in this way we followed the methods of Bentley and Schindler (2013). The CF was determined by calculating the residuals from a linear regression of the logarithm transformed values of weight and length (Neff et al. 2004):

$$CF = \log_e(W) - \log_e(a) - b \cdot \log_e(L)$$

where  $W$  and  $L$  = measured weight (g) and fork length (mm);  $a$  and  $b$  are from the linearized version of the power function  $W = aL^b$  fitted to all of the data for the species and location.

Several other meta analyses were performed in this report using basic gill netting results:

- Annual species and age (for Salmonids) specific estimates of the following quantities were examined for trends over time (study years) that might be due to effects of Combo 6: mean CPUE (catch per set-hour), mean lengths and weights, mean length at age, age composition, relative CPUE (catch per set-hour) among nearshore and offshore stations, major food categories, and condition factor (CF).
- Species, age, and weight data were also used to generate annual abundance and biomass estimates

### 3.4 Acoustic surveys

#### 3.4.1 Sampling

A single mobile acoustic survey was conducted at night (from one hour after sunset to one hour before sunrise) each year between September 15 and October 9 to estimate fish abundance and biomass in the reservoir. Survey methods generally followed protocols described in standard fisheries acoustics texts (Thorne 1983, Brandt 1996, Simmonds and MacLennan 2005, Parker-Stetter et al. 2009). Acoustic sampling methods were consistent throughout the study to maintain comparability between years.

Acoustic sampling was performed by a crew of two on a 6-8 m long, covered aluminum skiff (Figure 7). The transducer was deployed in two configurations from a pole-mount attached to the side of the boat. For coverage of the water column from 2 m deep to the lake bottom, it was aimed vertically with the face 0.5 m beneath the surface (down-looking mode). For increased coverage of the upper 5 m of the water column, the transducer was aimed 7 degrees below the horizontal plane looking sideways from the boat (side-looking mode). The collection of side-looking data was deemed necessary because trout are often surface oriented (Johnston 1981, Yule 2000, Stables and Thomas 1992). Side-looking and down-looking scans were made consecutively on each acoustic transect during surveys (two passes of each transect). Down-looking data were collected to 80 m, except in 2009 when sampling to the maximum lake depth of the 100 m confirmed that almost no fish were found below 80 m.

The echo sounding system consisted of a 201 kHz (2005-2012 and 2014) or 206 kHz (2013) BioSonics DTX split-beam scientific echo sounder with a 6.7 degree beam,

paired with a differential GPS (Garmin model 182 or 546). The echo sounder was operated by a laptop computer, which also served as a data logger and allowed monitoring of data quality on echograms during collection. Latitude and longitude from the GPS were added to acoustic data files as they were logged. Transecting speeds were 1.5-2.0 m/s and data collection thresholds were -80 dB for side-looking and -100 dB for down-looking scans. Additional equipment specifications and data collection settings appear in Table 4.

Twelve transects were originally planned, but from five to eight transects were sampled per year due to time constraints, with six sampled in eight of ten years (Figure 2b). Transects that were sampled extended from shore to shore at 2.2 km intervals, approximately perpendicular to the longitudinal axis of the lake. In practice, transects were ended at approximately the 17 m depth contour, on average, due to the steep shoreline and submerged stumps and standing timber that made closer approach to shore hazardous, especially at night.

Table 4. Equipment specifications and settings for collection and processing of acoustic data collected during the 2005-2014 Stave Reservoir Fish Biomass Study. D = down-looking, S = side-looking, unspecified = both.

Project Phase	Category	Parameter	Value
Data collection	transducer	type <sup>1</sup>	split-beam
"	"	sound frequency (kHz)	201 or 206
"	"	nominal (full) beam angle	6.7°
"	"	depth of face (m)	0.80 D, 0.50 S
"	settings	pulse width (ms)	0.4
"	"	data collection threshold (dB)	-100 D, -80 S
"	"	minimum data range <sup>2</sup> (m)	1.0
"	"	maximum data range <sup>2</sup> (m)	80-100 D, 30 S
"	"	ping rate (pings/s)	6 D, 4-6 S
"	GPS	type <sup>3</sup>	differential
"	"	Datum	NAD83
"	Other	transecting speed (m/s)	1.5-2.0
Data Analysis	general	calibration offset	-1.0 to 0.0
"	"	Time Varied Gain	40 log R
"	"	minimum threshold <sup>4</sup> (dB)	-65
"	"	maximum threshold <sup>4</sup> (dB)	-25 to -20
"	"	beam pattern threshold <sup>4</sup> (dB)	-6
"	"	full beam angle (deg)	6.7
"	"	single target filters <sup>4</sup>	0.5-1.5 @ -6 dB
"	range processed <sup>2</sup>	down-looking <sup>5</sup> (m)	2-100
"	"	side-looking (m)	10-25
"	fish tracks (per fish)	minimum # echoes	2
"	"	max range change <sup>6</sup> (m)	0.2 m
"	"	max ping gap	1

<sup>1</sup> BioSonics DT-X split-beam digital scientific echo sounder.

<sup>2</sup> Range from transducer face.

<sup>3</sup> WAAS differential GPS.

<sup>4</sup> Processing threshold after application of calibration offset.

<sup>5</sup> Typically 80 m.



Figure 7. The acoustic sampling boat, with the pole mounted transducer out of the water for fast travel (upper) and in the water while sampling (lower).

### 3.4.2 Processing and analysis

Fish were counted on electronic echograms according to standard echo-trace counting methods (Thorne 1983, Brandt 1996, Simmonds and MacLennan 2005, Parker-Stetter et al. 2009). Computer files were processed in the office using Echoview© software to extract fish traces, measure target strength (TS, the acoustic size of fish), and determine sampling volumes. Side-looking data were excluded from processing where surface reverberation from windy, rough conditions obscured fish echoes. Down-looking data never required this procedure.

Down-looking data were used to compute fish density at depths greater than 5 m, while side-looking data were used to represent the uppermost 5 m of the water column. Fish traces were recognized on echograms by their shape, cohesiveness, TS, and number of echoes. The minimum acceptance threshold for trace counts was -65 dB. A maximum threshold of -25 or -20 dB was also applied in processing (larger targets were assumed to be submerged timber), but no target that large were ever encountered. Other fish tracking settings appear in Table 4.

TS was determined by the split-beam method (Simmonds and MacLennan 2005). Accuracy of acoustic measurements was assured by field calibration tests during each survey using a standard sphere (expected TS = -39.5 to -39.6 dB). Results of these tests varied from the expected value by  $\leq 1.0$  dB in any year, so calibration corrections applied during data processing were  $\leq 1.0$  dB.

Target strength data from down-looking observations were used to describe the size distribution of fish observed with acoustics, and to partition them into fish corresponding to the catch of RISC gill nets and those that were smaller. In each year of the study, the proportions of these two size groups were estimated from TS for each 5 m thick layer of the water column. Based on analysis of the 2005 data, a value of -46.9 dB was chosen for the division between these groups, and this value was used for all abundance and biomass estimates in this report. This value was the estimated TS of a 100 mm long fish using Love's (1977) equation for fish insonified within  $\pm 45$  degrees of dorsal aspect:

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

When considering results of this and subsequent analysis of TS data it is important to remember that size estimates from TS are much less precise than hands-on physical measurements because TS is affected by many factors other than fish size (Simmonds and MacLennan 2005) and Love's (1977) equations were generalization from fish of many species and sizes. Fish size estimates from side-looking TS data are even more variable (Love 1977, Simmonds and MacLennan 2005), so they were not used for any analysis in this report, and the TS distribution of fish in the upper 5 m of the water column was estimated from down-looking data from the 3-5 m depth range, or from the 3-10 m depth if targets in the 3-5 m range were insufficient.

A modification of Crockett et al.'s (2006) method was used to subdivide the group with  $TS \geq -49.6$  dB into medium sized fish, such as age-1 and older kokanee, and large piscivores such as Bull Trout and Cutthroat Trout. Crockett et al. (2006) used a highly statistical approach that is beyond the scope of this project to avoid classification of kokanee as large piscivores. Greatly simplified, their findings showed that using a TS threshold for large piscivores that was about 2 dB greater than the predicted TS of the largest kokanee in their population would prevent most misclassification of kokanee as large predators. For predicting TS they used Loves (1977) equation for fish insonified dorsally:

$$\text{Length (mm)} = 10 * 10^{((TS + 0.9 \log (\text{kHz}) + 62.0) / 19.1)}$$

The largest kokanee captured from Stave Reservoir in any year was 264 mm in fork length, which translates to -36.9 dB using Love's (1977) dorsal equation, so a preliminary threshold for large predators was -34.9 dB (i.e, 2.0 dB > -36.9 dB). Crockett et al.'s (2006) analysis included a variance component not available for the Stave data, so the threshold for large predators in Stave was increased to -34.0 dB to be sure that no kokanee would be classified as large predators in this analysis. The resulting categories were:

Small fish:  $TS < -49.6$  dB, representing fish < ~ 100 mm long, this group was too small for capture in RISC gill nets;

Medium fish:  $TS \geq -46.9$  dB and  $\leq -34$  dB, representing fish ~ 100-375 mm long, such as age-1 and older kokanee, this group was vulnerable to RISC gill nets;

Large fish:  $TS < -34$  dB, representing fish > ~ 375 mm such as piscivorous Cutthroat Trout and Bull Trout, this group was vulnerable to RISC gill nets.

Figure 8 outlines the series of computations and data sets used for construction of annual fish abundance and biomass estimates. Depth intervals for acoustic data analysis were 0-5 m, 5-10 m, 10-15 m, and so forth to 80 m (to 100 m in 2009). Data were categorized into slope and pelagic zones using the 40 m depth contour as the boundary between them. Fish densities were summarized as fish/m<sup>3</sup> within depth intervals of transects for the population estimate, and as fish/ha in 50 m long segments of transects for spatial analysis. For each spatial cell of interest, fish density was calculated as the total number of fish counted divided by the volume sampled. The volume sampled in each spatial cell was calculated using the acoustic beam angle, distance transected, and a correction for bottom intrusion. The wedge model (Keiser and Mulligan 1984) was used for all depth intervals. Processing settings were a -65 dB counting threshold and a 6.7° nominal beam angle. In each year, the effective beam angle for each depth interval was modeled considering the nominal beam angle, boat speed, ping rate, and echoes required per fish trace, and the sampling volume was

adjusted accordingly at ranges where the effective beam angle was less than the nominal beam angle. Under the conditions of the surveys, the effective beam angle was never less than 4.6°, and was only less than 6.0° within 10 meters of the transducer. A complete list of data analysis settings appears in Table 4.

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

Relative abundance of fish captured in RISC gill nets was used to apportion the acoustic abundance estimate of medium and large fish combined ( $TS \geq -46.9$  dB) among species (Figure 8). Fish and acoustic data from corresponding depths and locations were matched for this analysis (e.g., floating gill net data were matched with side-looking acoustic data from the 0-5 m depth range), however, age composition of Salmonids was pooled for all depth layers because the number of fish aged was insufficient for stratification by depth. Only gill net panels corresponding to the area sampled with acoustics (offshore of the 17 m depth contour on average) were used for species apportionment. Species composition was computed separately for slope and pelagic zones using the 40 m depth contour as the boundary between them. Benthic species such as suckers and sculpins were excluded from species composition estimates applied to acoustic data. This had no effect on pelagic zone estimates where benthic species were not encountered. All small fish in the acoustic sample ( $TS < -46.9$  dB, estimated  $< 100$  mm long) were assumed to be kokanee.

Species and (for Salmonids) age specific biomass estimates of medium and large fish combined ( $TS \geq -46.9$  dB) were computed by applying mean weights of fish captured in RISC gill nets to abundance estimates from acoustics. Age specific weights were from gill net samples pooled from all depth layers because the number of fish aged was insufficient for stratification by depth. The mean weight of small fish that were detectable with acoustics but too small to be captured in RISC gill nets ( $TS < -46.9$  dB) was computed by estimating a mean length per fish from TS and then calculating a corresponding mean weight from a weight-length regression developed for larger kokanee from the corresponding year's RISC gill net data (all small fish in the acoustic sample were assumed to be kokanee).

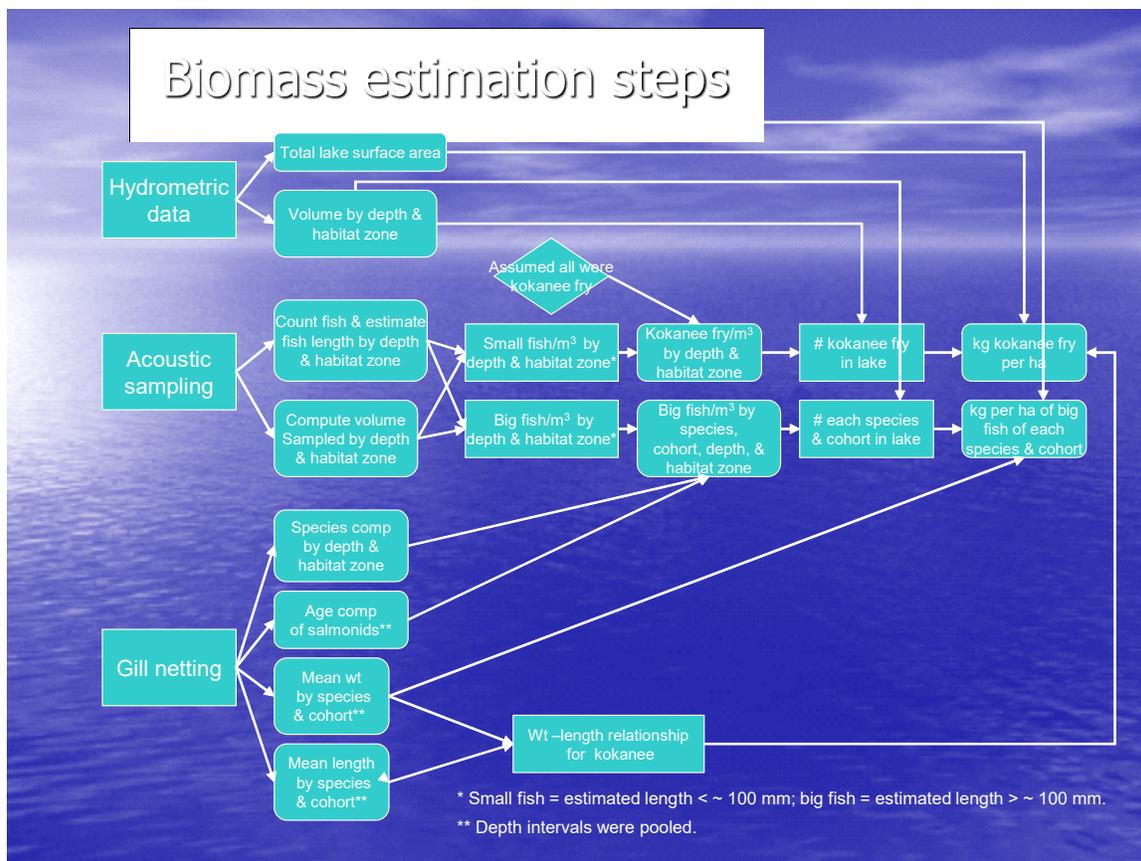


Figure 8. Schematic diagram of annual fish abundance and biomass estimation process.

### 3.5 Answers to management questions

#### 3.5.1 Question 1: Relationship between temporal change in fish biomass and Combo6

Annual fish abundance and biomass estimates were plotted over time to look for temporal trends. An increase or positive trend might be expected if Combo6 was providing a benefit for the fish populations. Alternatively, abundance or biomass might be expected to initially increase and then vary around a new but greater level than where it started in 2005 in association with improved habitat and growing conditions if Combo6 provided those improvements. Time course changes in spatial distribution patterns seen with acoustics were also examined to gain insight into possible influence from Combo6.

If a temporal trend was apparent in the total fish abundance data, regression analysis was used to fit a model to the data to statistically describe the response by total fish abundance to Combo6. Regression yields an equation (a model) that retains the original units of measure and allows quantitative prediction of the dependent variable (fish abundance) as a function of the independent variable (time) with estimated error.

Fit of the regression model to the data will be determined from the value of the multiple correlation coefficient ( $R^2$ ) and standard error of the estimate.

Regression analysis was not run for fish biomass or for species-specific abundance because in four of ten years these measurements violated an assumption in regression that observations are independent. Gill netting used to collect fish for measurement of size and apportionment of abundance by species was conducted once every two years. That gill netting data was used in the following non-gill netting year for calculation of the same metrics. This approach resulted in observations in the non-gill netting year to not be independent of observations in the corresponding gill netting year, thus violating the assumption of independence in regression (Sokal and Rohlf 1969). Gill netting every second year rather than every year was done as a cost saving measure as instructed by BC Hydro (SFLMON#3 request for proposals #RFP-491 dated August 17, 2010).

### 3.5.2 Question 2: relationship between fish and primary production

If Combo6 was effective in supporting increased biological production in Stave Lake Reservoir, we expect increased production to be realized as a time course increase in fish biomass. To realize that change, we also expected a commensurate change in primary production, particularly in pelagic habitat that supports the food web for kokanee that by far is the most abundant fish species in Stave Lake Reservoir (Stables and Perrin 2014). Regardless of whether Combo6 was effective in influencing biological production, we expected a relationship to exist between pelagic primary production and fish biomass or abundance, consistent with work by Shortreed et al. (2000). As mentioned in Section 3.5.1, fish biomass could not be used in parametric statistical procedures to examine relationships between that biomass and independent variables because the assumption of independence of observations was violated. We could and did, however, use abundance of all fish species combined in all ten years to explore the relationship.

Regression analysis was used for this analysis wherein the independent variable was photosynthetic rate (PR) and the dependent variable was total fish abundance. Pelagic PR data was obtained from BC Hydro as part of another study for water use planning and the fish abundance data was that explained above in Section 3.4.2.

If a relationship between PR and fish abundance was not found or data were not adequate with which to run the regression analysis (e.g. insufficient sample size, violation of statistical assumptions), other metrics were explored. A regression was run to determine if a relationship between fish condition and the minimum water surface elevation during the critical period of May 15 – September 7. Another was run to determine if a relationship existed between fish condition and the number of days when the water surface elevation was >80m also during the critical period of May 15 –

September 7. Data for these analyses came from all study years of 2005 – 2014. The hydrology metrics (minimum water surface elevation and number of days where the surface elevation was >80m) were considered indicators of Combo6 water management actions because they are written into the Operating Order for Stave (BC Hydro 2013). Fish condition factor (CF) was calculated according to methods reported by Bentley and Schindler (2013) in which CF is correlated with fish growth rate. We also examined the relationship between nutrient loading rate from Alouette Lake and fish abundance in Stave Lake Reservoir because nutrient loading can increase abundance and biomass of planktivorous fish like kokanee (Hyatt and Stockner 1985, Perrin et al. 2006). Alouette Lake was being fertilized during the study years (e.g., Hebert et al. 2013), potentially affecting primary production and the food web in Stave Lake as water flowed from Alouette to Stave. Given that Stave Reservoir flushes several times a year (Stockner and Beer, 2004), nutrient discharge from Alouette Lake in a given year may influence biological production in Stave only during the year of discharge and not in later years. Hence, no lag effect was applied to the paired fish abundance and nutrient loading data.

Multiple lines of evidence were used to examine links between time after the onset of Combo6 and fish abundance and underlying biological production supporting fish. If a clear positive trend in total fish abundance was found over years following implementation of Combo6 and there was a significant relationship between fish abundance and PR, then the conclusion was that Combo6 may have improved conditions for fish that rely on planktivory. Other factors may have also contributed to the time course change in fish abundance, but this outcome would show that Combo6 may have contributed. If no trend in non-specific fish abundance was found over years following implementation of Combo6 and there was a significant relationship between fish abundance and PR, then the conclusion was that Combo6 did not improve conditions for fish and that PR was disconnected from water management actions associated with Combo6. If no trend in total fish abundance was found over years following implementation of Combo6 and there was no significant relationship between fish abundance and PR, then the conclusion was that Combo6 did not improve conditions for fish and that fish abundance was disconnected from PR, or PR as measured in Stave Reservoir was not a reliable indicator of food supply for fish that were included in the fish abundance data.

## **4 RESULTS**

### **4.1 Water quality**

The reservoir surface elevation ranged from 76.2 to 79.6 m above sea level on acoustic surveys dates (between September 15 and October 9, 2005-2014, Figure 9). The surface elevation was similar during gill netting.

The reservoir was thermally stratified with an epilimnion 10-12 m deep during all acoustic and gill net surveys (Figure 10). Epilimnion temperatures ranged from 14.5-19°C (depending on the year) at north and south water quality stations, except in 2007 when they were 12°C at the southern station (Figure 10). In the thermocline, which typically extended from about 10 to 20 m, temperature dropped rapidly to 7-9°C. Below the thermocline, temperatures dropped slowly to a minimum of 4-6°C at the maximum sampling depth of 60 m.

Dissolved oxygen (DO) exceeded 9 mg/l at all depths of both water quality stations in all years except 2012 (Figure 10). In that year, DO was 7-9 mg/l at the south station, and from 10 mg/l at the surface to 6.1-6.5 mg/l below 20 m at the north station. Except below 15 m at the north station, DO exceeded the minimum level considered adequate for protection of fish (> 6.5 mg/L, CCME 2003), and it was not < 6.0 mg/l anywhere we sampled. The relatively low DO levels of 2012 can be attributed to strong thermal stratification that lasted later than usual into autumn in that year. Relatively high DO concentrations in the epilimnion in 2012 can be ascribed to the production of oxygen by photosynthesis while demand for oxygen by respiration at depths below the euphotic zone may explain lower concentrations in the hypolimnion.

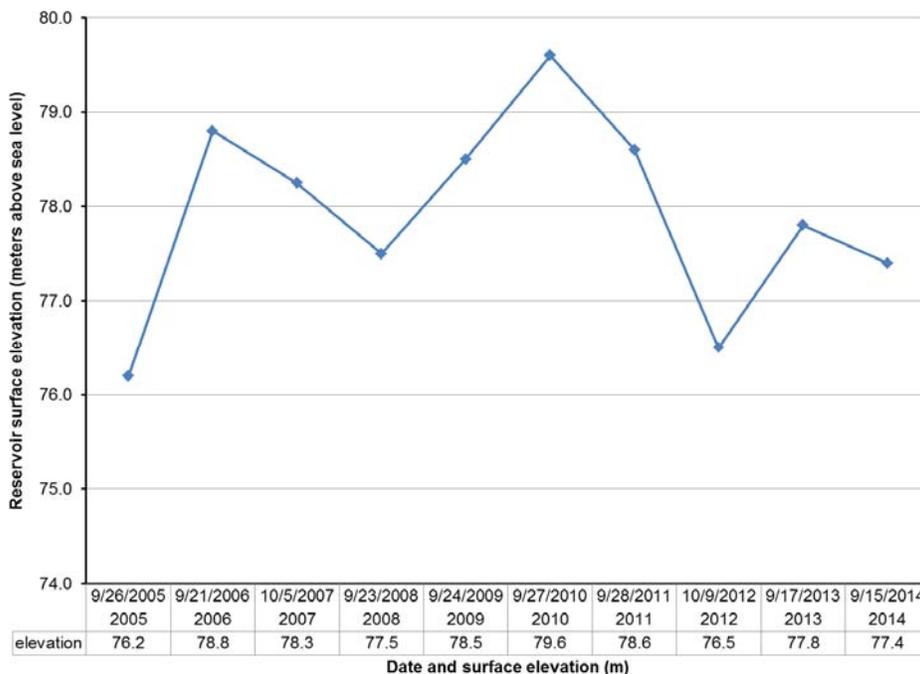


Figure 9. Stave reservoir surface elevation on the dates of the 2005-2014 acoustic surveys.

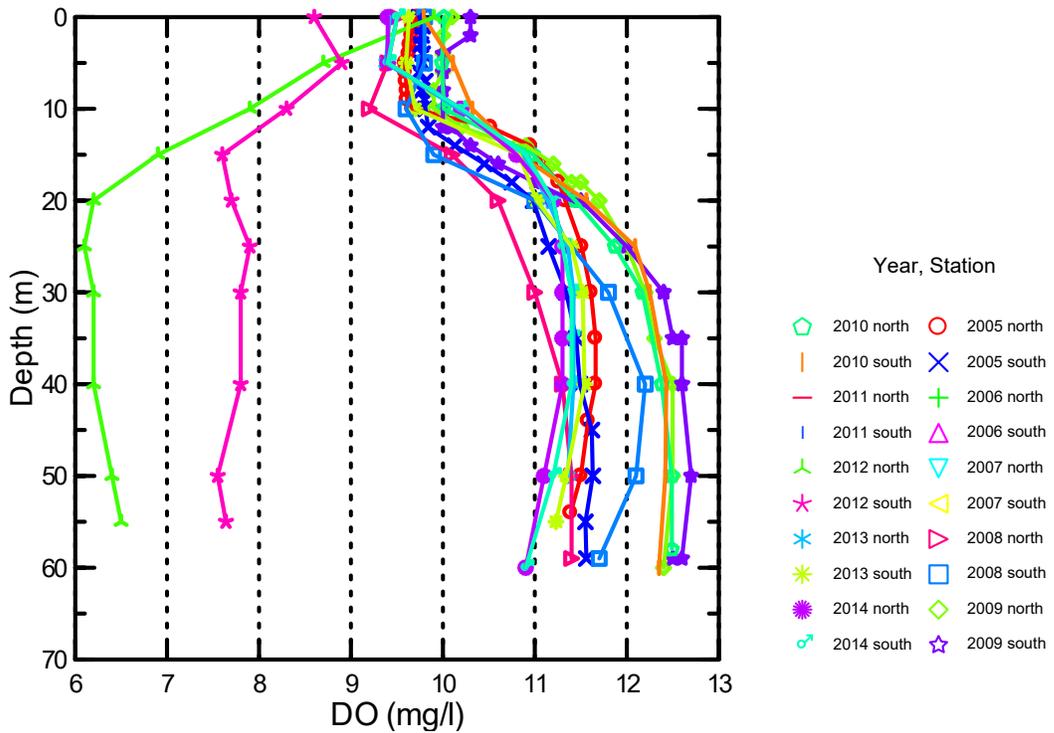
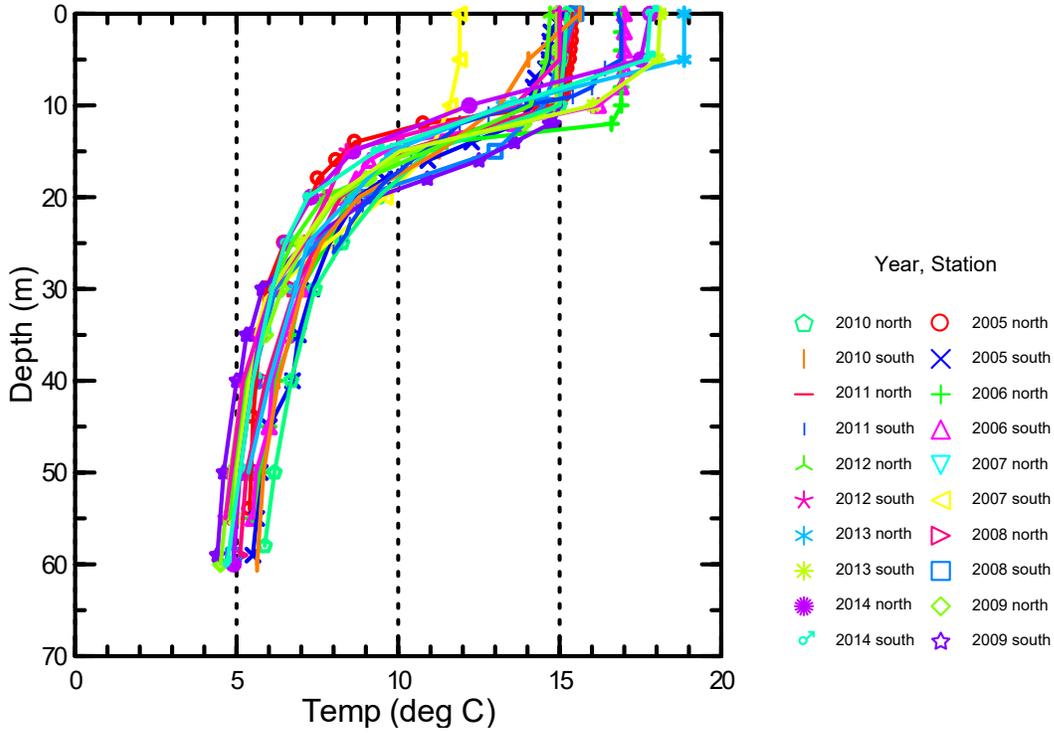


Figure 10. Temperature (upper) and DO (lower) profiles at north and south water quality stations in Stave Reservoir at the time of acoustic surveys during September and October 2005-2014.

## 4.2 Fish sampling with gill nets

### 4.2.1 Catch and CPUE

A total of nine fish species were captured in the 119 gill net sets (1,924 set-hours) made during the study: four Salmonids (Cutthroat Trout, Rainbow Trout, kokanee, Bull Trout), one Catostomid (Largescale Sucker), three Cyprinids (Northern Pikeminnow, Peamouth, Redside Shiner), and one Cottid (Prickly Sculpin, Table 5). Minnow trapping conducted in littoral areas in 2005 and 2007 captured no additional species (Appendix 7.1). Genetic testing (DNA analysis) of tissue samples collected from char in 2007, 2009, and 2011 showed that all were Bull Trout (*Salvelinus confluentis*). After 2011 it was assumed that all char in the reservoir were Bull Trout and genetic testing of this species was discontinued. A similar analysis of a sample of questionable Cutthroat Trout in 2013 confirmed that they were correctly identified in the field, despite a frequent lack of the typical (McPhail 2007) orange marks beneath the jaw and the absence of basibranchial teeth in some cases. This validated identification of this species in other years. Genetic analysis of kokanee collected in 2009, 2013, and 2014 showed that kokanee from Stave Reservoir and nearby Alouette Reservoir are distinctly different stocks (S. Harris, BC MOE, personal communication to B. Stables).

Catch rates (CPUE) in gill nets as an indicator of salmonid relative abundance showed wide fluctuations over the years, with no discernible trend of increase or decrease at either nearshore or offshore stations (Figure 11, Table 6, Appendix 7.2). Catch rates of non-salmonids at offshore stations also varied erratically with no consistent trend. However, at nearshore stations non-salmonid CPUE (except for Peamouth) showed a generally declining trend suggesting that abundance of this group decreased over the course of the study, at least at the two stations sampled. Catch rates for Northern Pikeminnow and Redside Shiner dropped most markedly, from > 10 fish per set-hour in 2005 to <4 fish per set-hour since 2009.

In 2005, when nets were fished both day and night at nearshore stations only, catch rates were much higher overnight for most species, but only slightly so for cutthroat and Bull Trout (Table 6). In subsequent years, when nearshore and offshore stations were fished only at night, the species composition of catches (indicated by relative CPUE of species) in the two set-zones differed greatly. All species were found to some extent in both zones, except suckers and sculpins, which were only captured in nearshore sets (Figure 12, Table 6). In offshore sets, kokanee were the most abundant species by far, followed by Cutthroat Trout and Redside Shiner, a pattern that persisted through the years. In 2007 and 2009, kokanee abundance was similar in both set-zones, whereas in later years it was much higher offshore. In all years Cyprinids were caught mainly in nearshore sets where they made up a large portion of the catch.

Analysis of night time RISC catch rates with respect to depth of capture and water column depth showed quite consistent species-specific spatial distribution patterns during the six years of gill net sampling. Plots of CPUE (mean catch per panel-hour) for

all surveys pooled show that all species except kokanee had their highest densities shoreward of the 40 m depth contour (Figure 13). Bull Trout, Cutthroat Trout, and Northern Pikeminnow also occurred to some extent in midwater layers (15-30 m) over deep water. Several species, including rainbow and Cutthroat Trout, Northern Pikeminnow, Peamouth, and Redside Shiner occurred offshore in the epilimnion at low to moderate density. Kokanee were most abundant offshore in midwater layers (15-30 m), however they were also quite abundant in all other areas sampled. Prickly Sculpin and Largescale Suckers were closely associated with the bottom, mainly shoreward of the 40 m depth contour. Although pooling data from all years in Figure 13 blurred some of the annual variation that was present (Appendix 7.3), it accurately portrayed the general patterns that were observed throughout the study.

Based on these observations, species composition and the acoustic abundance and biomass estimates were stratified by 5 m depth layers and pelagic and slope zones with their boundary at the 40 m depth contour. Sculpins and suckers were excluded from species composition for the acoustic estimate because they occurred too close to the bottom most of the time to be detected with acoustics. In each year with gill netting, species composition for apportionment of acoustic estimate came from the same year of gill net data. In each year without gill netting species composition for apportionment of acoustic estimate came from the previous year of gill net data. Species composition values used for apportioning the acoustic estimates appear in Appendix 7.4.

Table 5. Gill netting effort (sets and set-hours) and catch by species during the 2005-2014 Stave Reservoir fish biomass study. Data are grouped by year, set zone (nearshore or offshore), period (day, night, or overnight), and gear type (RISC or small mesh gill net; small mesh nets were 1.5 or 3.7 m tall).

Year	Set		Gear Type	No. of sets	Set-hours	Catch										Total
	zone	Period				C. Trout	R. Trout	Kokanee	Bull Trout	L. Sucker	N. Pikeminnow	Peamouth	R. Shiner	P. Sculpin		
2005	ns	day	RISC gn	7	43.9	4	0	4	4	1	10	1	3	0	27	
"	"	overnight	RISC gn	6	113.5	11	2	22	11	72	120	27	110	0	375	
"			2005 combined	13	157.5	15	2	26	15	73	130	28	113	0	402	
2007	ns	night	RISC gn	16	68.0	7	1	29	4	33	53	9	66	0	202	
"	os	"	RISC gn	6	43.0	3	0	13	0	0	1	0	0	0	17	
"			2007 combined	22	111.0	10	1	42	4	33	54	9	66	0	219	
2009	ns	overnight	RISC gn	12	209.1	15	0	84	4	39	95	59	74	7	377	
"	os	"	RISC gn	9	160.8	17	0	74	1	0	8	0	8	0	108	
"			2009 combined	21	369.9	32	0	158	5	39	103	59	82	7	485	
2011	ns	overnight	RISC gn	11	232.9	22	1	38	14	17	60	52	81	5	290	
"	os	"	RISC gn	9	169.7	4	7	79	2	0	1	3	10	0	106	
"			2011 combined	20	402.6	26	8	117	16	17	61	55	91	5	396	
2013	ns	overnight	RISC gn	8	155.7	13	1	16	5	53	27	50	60	0	225	
"	os	"	RISC gn	9	183.3	11	0	56	2	0	1	0	7	0	77	
"	"	"	SM1.5 gn	2	42.7	0	0	0	0	0	0	0	0	0	0	
"	"	"	SM3.7 gn	2	41.1	1	0	0	0	0	0	0	7	0	8	
"			2014 combined	21	422.8	25	1	72	7	53	28	50	74	0	310	
2014	ns	overnight	RISC gn	12	259.5	14	1	65	19	36	85	66	82	0	368	
"	os	"	RISC gn	7	141.8	11	0	62	1	0	4	0	3	0	81	
"	"	"	SM1.5 gn	1	20.0	0	0	0	0	0	1	0	8	0	9	
"	"	"	SM3.7 gn	2	39.3	0	0	0	0	0	0	0	0	0	0	
"			2014 combined	22	460.6	25	1	127	20	36	90	66	93	0	458	
			Overall combined	119.0	1,924.4	133	13	542	67	251	466	267	519	12	2,270	

Table 6. Gill netting effort (sets and set-hours) and catch per unit effort (catch per set-hour) by species during the 2005-2014 Stave Reservoir fish biomass study. Data are grouped by year, set zone (nearshore or offshore), period (day, night, or overnight), and gear type (RISC or small mesh gill net; small mesh nets were 1.5 or 3.7 m tall).

Year	zone	Period	Gear Type	sets	hours	Mean CPUE (catch per set-hour)								Total CPUE	
						C. Trout	R. Trout	Kokanee	Bull Trout	L. Sucker	N. Pikeminnow	Peamouth	R. Shiner		P. Sculpin
2005	ns	day	RISC gn	7	43.9	0.091	0.000	0.091	0.091	0.023	0.228	0.023	0.068	0.000	0.614
"	"	overnight	RISC gn	6	113.5	0.097	0.018	0.194	0.097	0.634	1.057	0.238	0.969	0.000	3.303
			2005 combined	13	157.5	0.095	0.013	0.165	0.095	0.464	0.826	0.178	0.718	0.000	3.918
2007	ns	night	RISC gn	16	68.0	0.103	0.015	0.426	0.059	0.485	0.779	0.132	0.971	0.000	2.971
"	os	"	RISC gn	6	43.0	0.070	0.000	0.302	0.000	0.000	0.023	0.000	0.000	0.000	0.395
			2007 combined	22	111.0	0.090	0.009	0.378	0.036	0.297	0.486	0.081	0.595	0.000	3.366
2009	ns	overnight	RISC gn	12	209.1	0.072	0.000	0.402	0.019	0.187	0.454	0.282	0.354	0.033	1.803
"	os	"	RISC gn	9	160.8	0.106	0.000	0.460	0.006	0.000	0.050	0.000	0.050	0.000	0.672
			2009 combined	21	369.9	0.087	0.000	0.427	0.014	0.105	0.278	0.160	0.222	0.019	2.475
2011	ns	overnight	RISC gn	11	232.9	0.094	0.004	0.163	0.060	0.073	0.258	0.223	0.348	0.021	1.245
"	os	"	RISC gn	9	169.7	0.024	0.041	0.466	0.012	0.000	0.006	0.018	0.059	0.000	0.625
			2011 combined	20	402.6	0.065	0.020	0.291	0.040	0.042	0.152	0.137	0.226	0.012	1.870
2013	ns	overnight	RISC gn	8	155.7	0.083	0.006	0.103	0.032	0.340	0.173	0.321	0.385	0.000	1.445
"	os	"	RISC gn	9	183.3	0.060	0.000	0.306	0.011	0.000	0.005	0.000	0.038	0.000	0.420
"	"	"	SM1.5 gn	2	42.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
"	"	"	SM3.7 gn	2	41.1	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.170	0.000	0.195
			2013 combined	21	422.8	0.059	0.002	0.170	0.017	0.125	0.066	0.118	0.175	0.000	2.060
2014	ns	overnight	RISC gn	12	259.5	0.054	0.004	0.250	0.073	0.139	0.328	0.254	0.316	0.000	1.418
"	os	"	RISC gn	7	141.8	0.078	0.000	0.437	0.007	0.000	0.028	0.000	0.021	0.000	0.571
"	"	"	SM1.5 gn	1	20.0	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.400	0.000	0.450
"	"	"	SM3.7 gn	2	39.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			2014 combined	22	460.6	0.054	0.002	0.276	0.043	0.078	0.195	0.143	0.202	0.000	2.439
			Overall combined	119	1,924.4	0.069	0.007	0.282	0.035	0.130	0.242	0.139	0.270	0.006	1.180

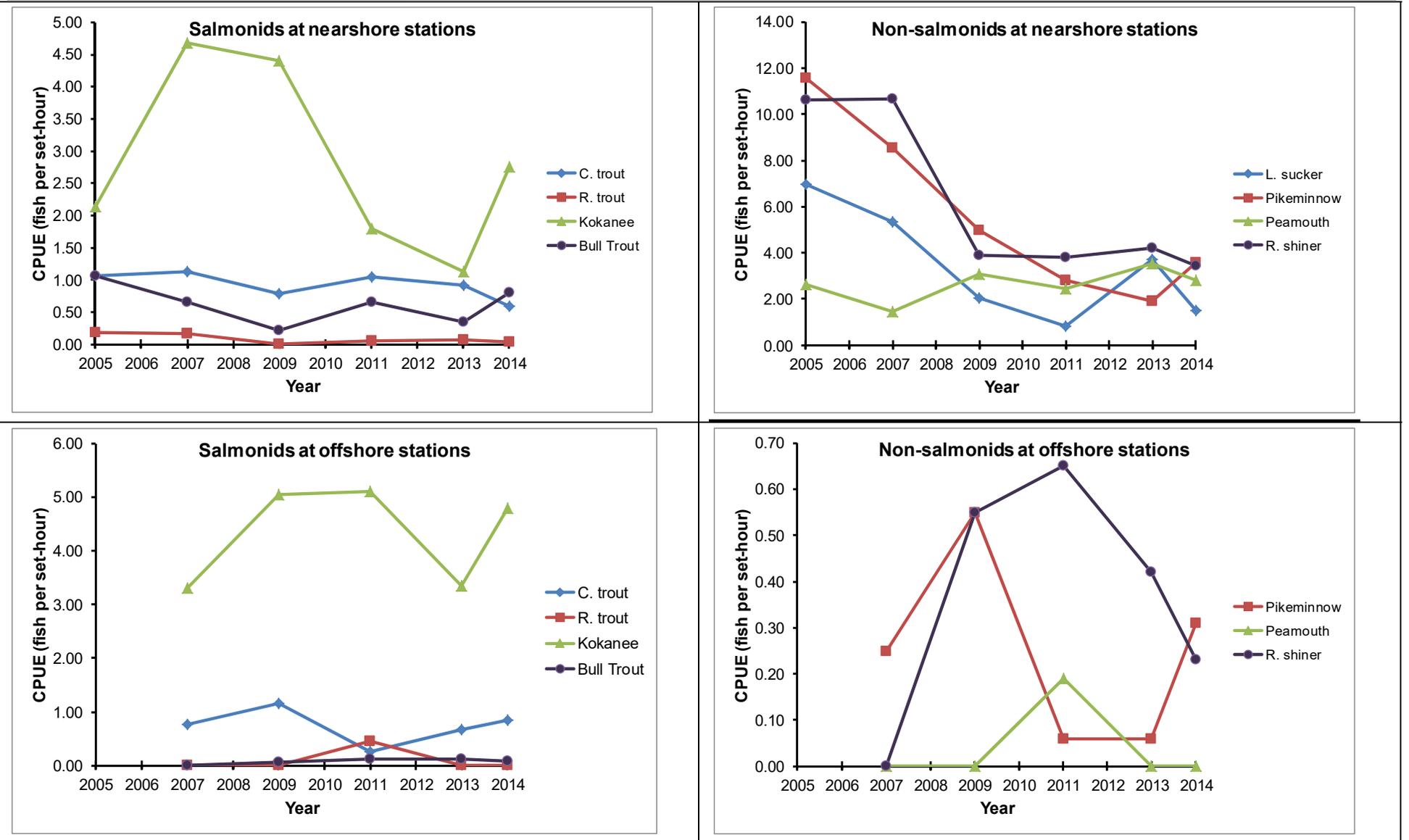


Figure 11. Catch rate (CPUE) in RISC gill nets as an index of fish abundance on a relative scale at nearshore and offshore sampling stations, Stave Reservoir 2005-2014 Fish Biomass Study. CPUE is fish · 100 m<sup>-2</sup> · 24 hours<sup>-1</sup>.

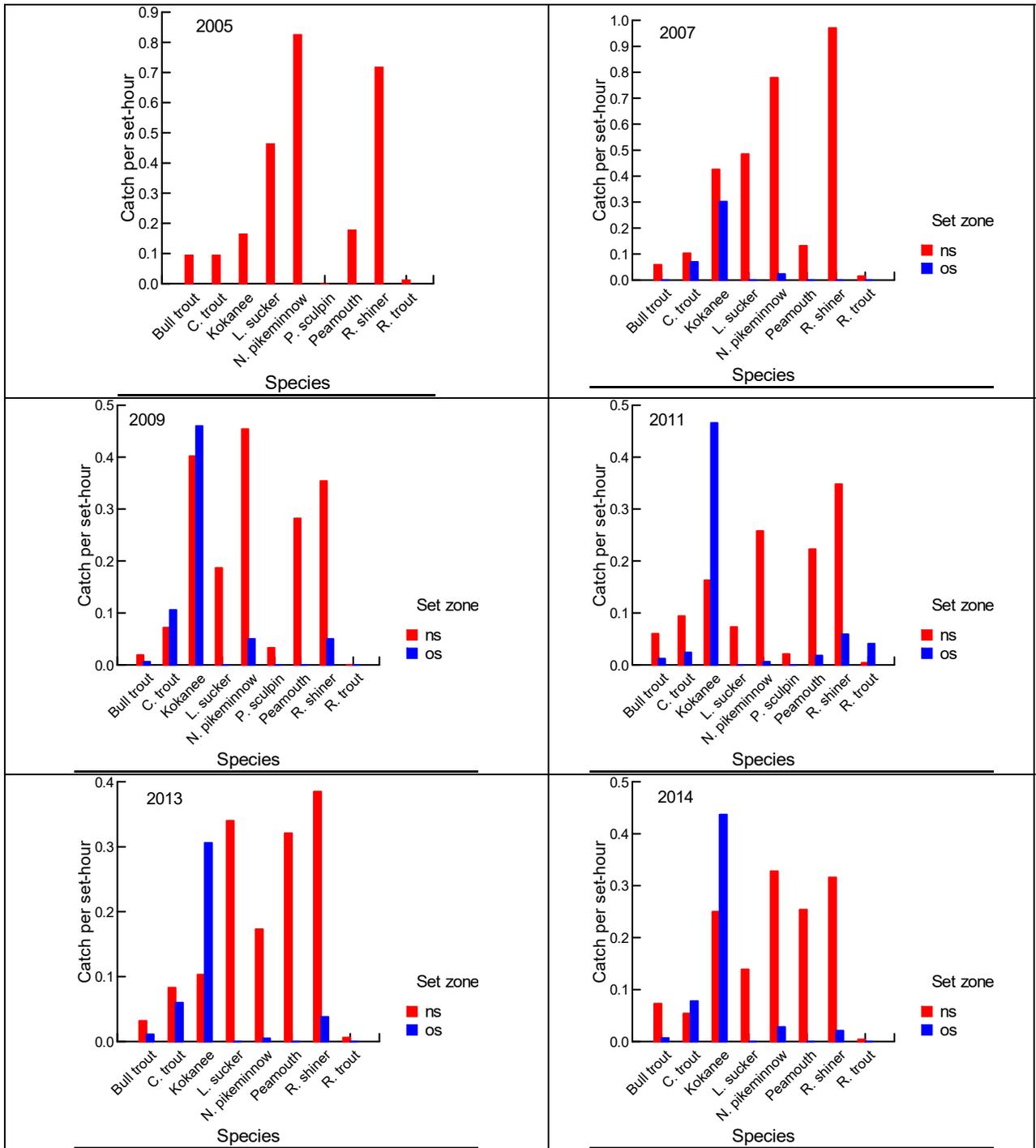


Figure 12. CPUE by species in nearshore (ns) and offshore (os) gill net sets during each year of gill netting during the Stave Reservoir 2005-2014 fish biomass study. Only nearshore sets were made in 2005.

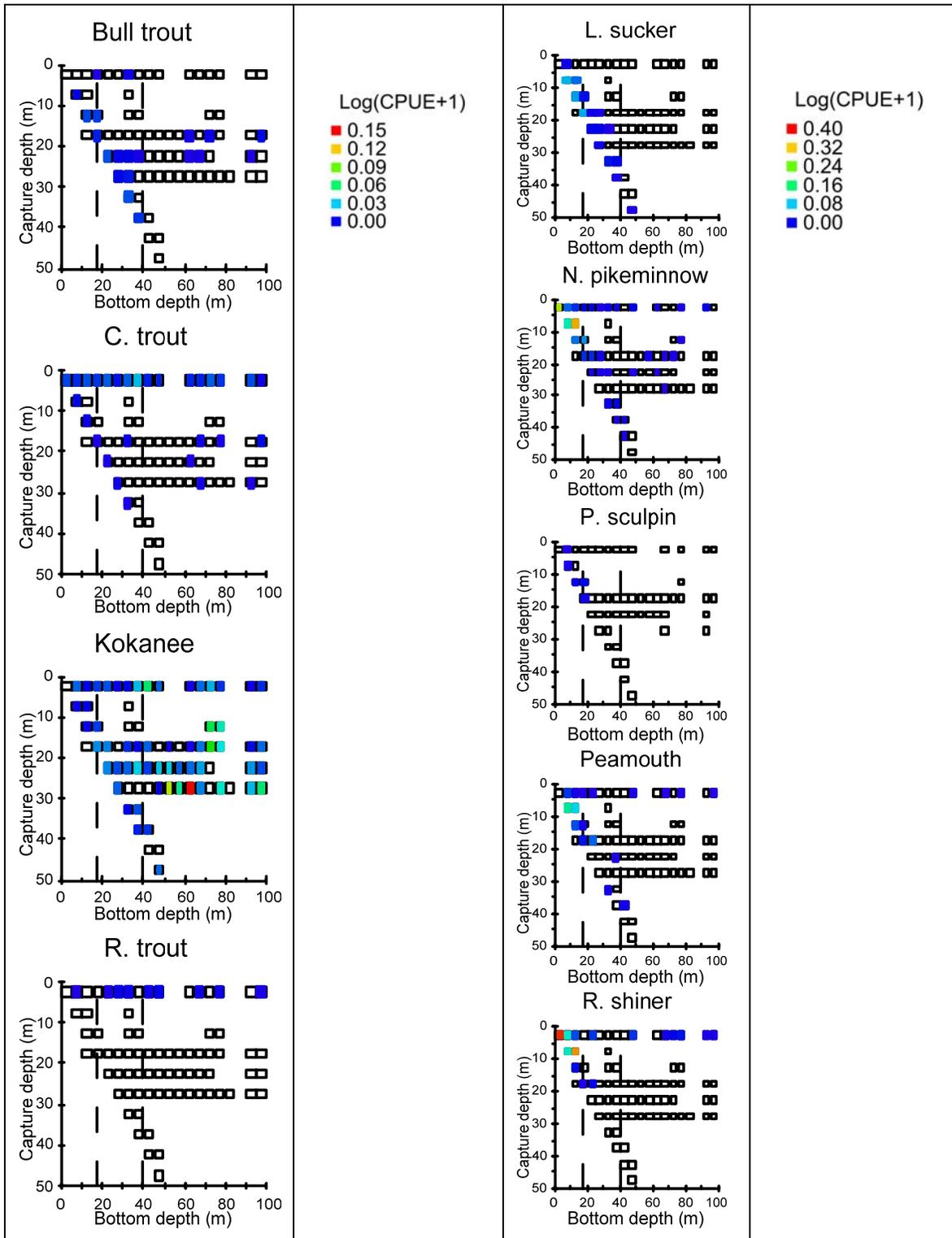


Figure 13. Mean CPUE by species (log [catch per panel-hour+1]) in RISC gill nets versus capture depth and water column depth during the 2005-2014 Stave Reservoir fish biomass study (all years pooled). Empty boxes indicate panels with no catch. Vertical dashed lines indicate the

typical shoreward limit of acoustic coverage (17 m bottom depth) and the boundary between slope and pelagic zones (40 m).

#### 4.2.2 Length, weight, and condition factor

The size of fish in the gill net catch varied considerably over the years, however, there was no clear time trend of increase or decrease in length or weight for any species (Figures 14 and 15, Appendices 7.5 and 7.6). Weight-length relationships of individual species were similar in all years, and linear regressions of log-log transformed weight and length data for each species for all years pooled showed a high degree of correlation ( $R^2=0.895-0.996$ , Figure 16). When condition factors (CF) derived from these plots (CF were the residuals from the weight-length regression line, REF) were compared over time using linear regression, there was little correlation ( $R^2=0.00006-0.15$ ), indicating that CF did not consistently increase or decrease during the study (Figure 17).

#### 4.2.3 Length at age and age composition

Over all years, Salmonids in the RISC gill net catch ranged in age from 1-7 for Cutthroat Trout, age 1-3 for Rainbow Trout, age 1-4 for kokanee, and age 3-12 for Bull Trout (Figure 18). None of these species showed a consistent increase or decrease in median length at age for any age group during the study period (Figure 18). For Cutthroat Trout of all ages, length-at-age was quite consistent over time, as it was for age-2 Rainbow Trout, the only age of this species that was captured in more than one year. The median lengths of age-2 and 3 kokanee were also quite consistent, except in 2011 when they were both relatively low. The length of age-1 kokanee was more variable than older age-groups, and it was also low in 2011.

Age composition of trout and kokanee > 100 mm in length, as indicated by catch rate in RISC gill nets (CPUE), varied considerably from year to year (Figure 19, Appendix 7.7). Among Cutthroat Trout, ages 2 and 3 predominate in most years, however, age-4 fish were relatively abundant and age-2 were rare in 2014, the final year of sampling. The catch of Rainbow Trout was too small for accurate estimation of age composition, but age-2 fish were relatively common in three of four years when this species was captured. Among kokanee, in the first three years of sampling (2005-2009) ages 1 and 2 predominated (79-98% of total) and relative abundance of age-1 fish increased steadily, while age-3 abundance remained low (2-21%). In 2011, age-3 became the predominant group (71% of total) as combined age-1 and 2 relative abundance dropped by 79%, and age-3 abundance increased nearly 10-fold relative to 2009 values. In 2013 and 2014, relative abundance of age-1 kokanee recovered somewhat (in 2014), age-2 abundance remained relatively low, and age-3 abundance remained relatively high. Age composition of Bull Trout varied erratically, with ages 3-7 predominating at various times in no particular pattern.

The lack of gill net data in alternate years made it difficult to track cohort (brood-year) abundance over time. In particular, each cohort of kokanee was probably sampled well with nets only at age-2. At age-1 a variable percentage of kokanee (depending on growth rate) may have been large enough for capture in the smallest mesh size of RISC nets (25 mm stretched mesh, minimum nominal length of capture 100 mm), and at age-3 a variable percentage of kokanee (depending on dates of gill netting and spawning) may have exited the lake to spawn before the sampling date. The lower relative abundance of age-1 kokanee compared to older age groups supports the idea that some of them were too small for capture in RISC gill nets.

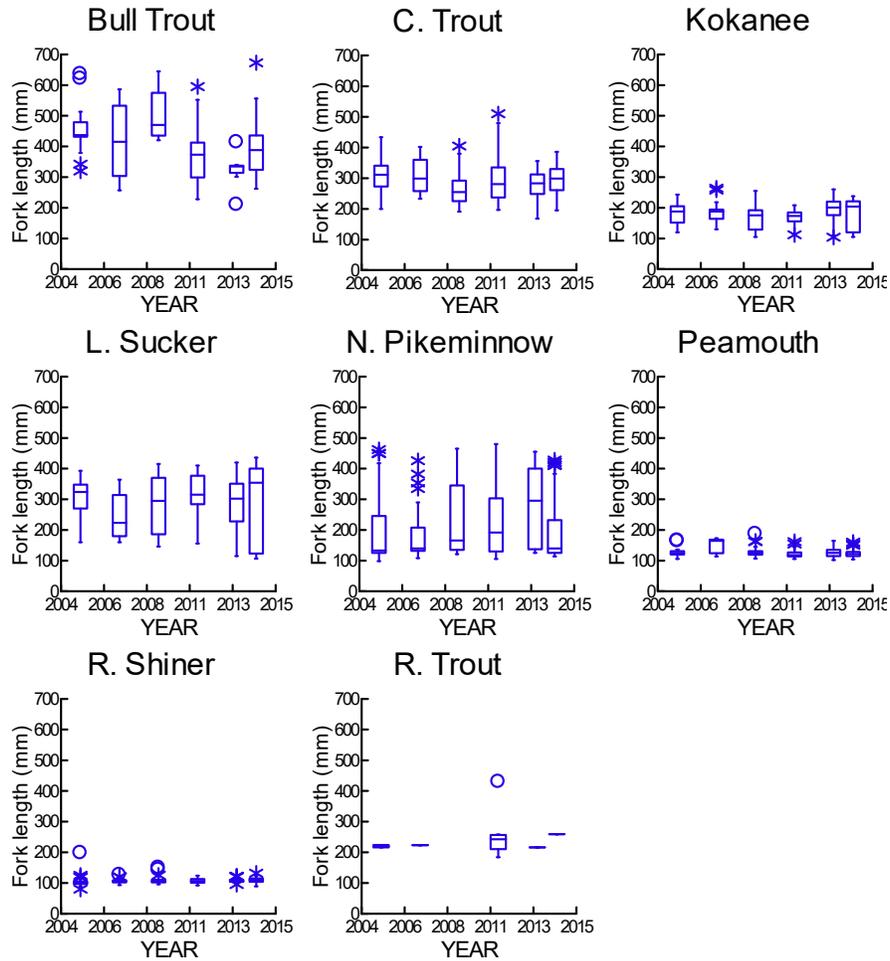


Figure 14. Median and range of fish lengths by year from RISC gill net catches from Stave Reservoir, 2005-2014. In box and whisker plots: centerline = median; box edges = first and third quartiles (the central 50% of values lie inside the box); distance between box edges = the interquartile range (IQR); whiskers show the range of values that fall within 1.5 IQR of the box edges; values 1.5-3.0 IQR outside box edges are plotted with asterisks; values > 3 IQR outside the boxes are plotted with empty circles.

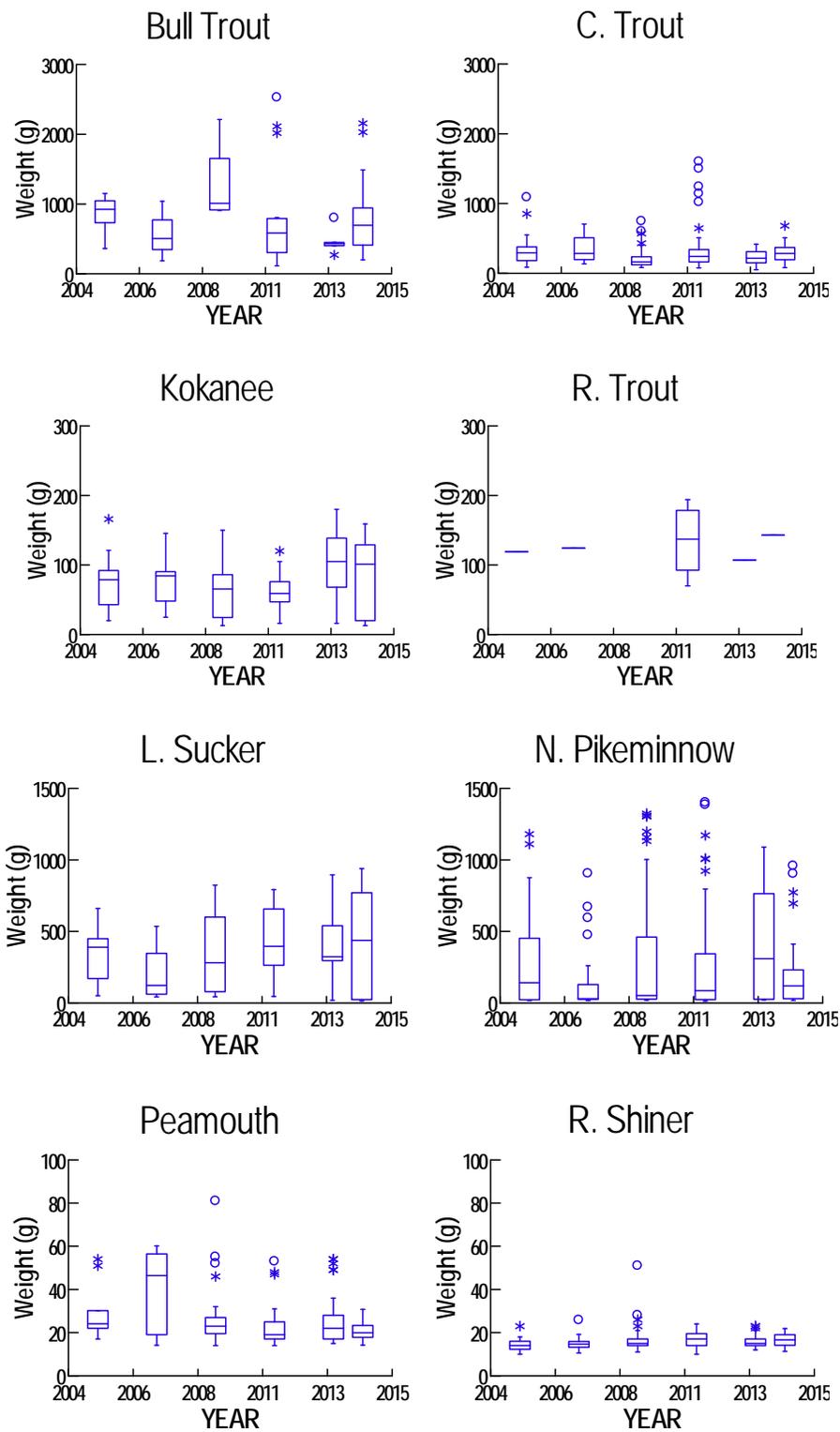


Figure 15. Median and range of fish weights by year from RISC gill net catches from Stave Reservoir. In box and whisker plots: centerline = median; box edges = first and third quartiles (the central 50% of values lie inside the box); distance between box edges = the interquartile range (IQR); whiskers show the range of values that fall within 1.5 IQR of the box edges; values 1.5-3.0 IQR outside box edges are plotted with asterisks; values > 3 IQR outside the boxes are plotted with empty circles.

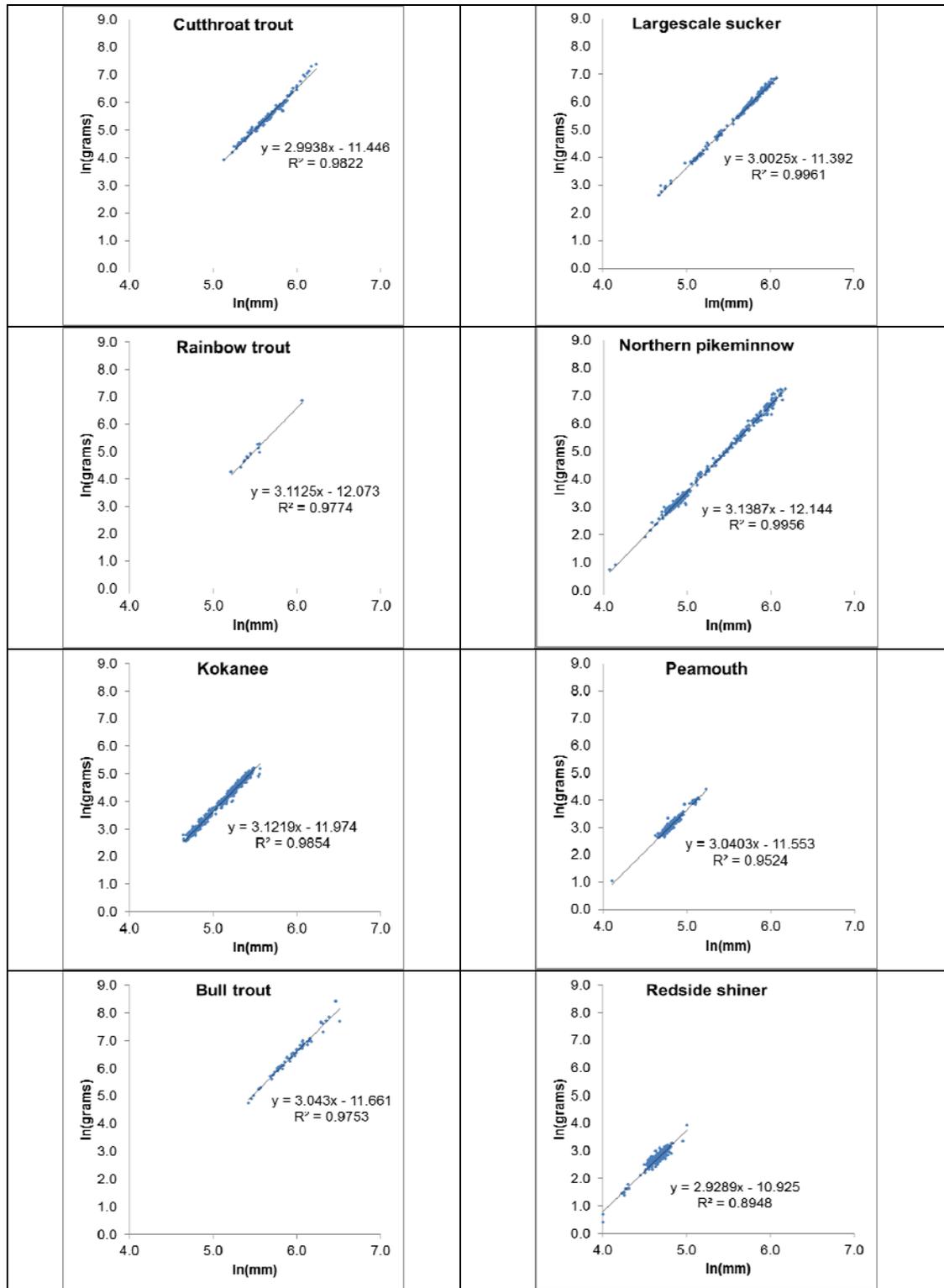


Figure 16. Weight-length relationships for individual fish species from all years of trap and gill net data pooled from the Stave Reservoir 2005-2014 fish biomass study. Lengths and weights were transformed to natural logarithms. Equations are from least squares linear regressions.

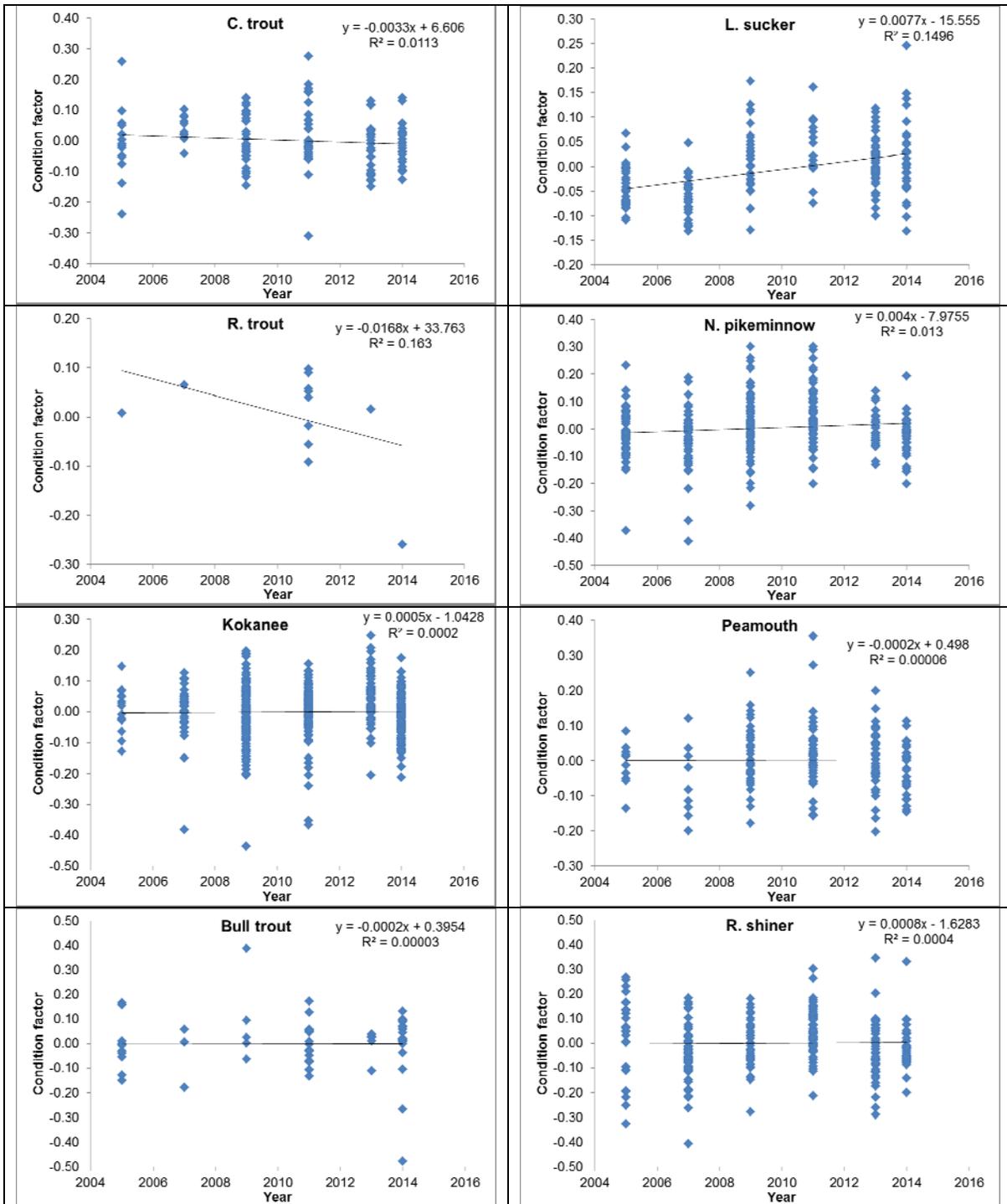


Figure 17. Linear regressions of fish condition factor (CF) on year of sampling for individual fish species captured by all sampling methods during the Stave Reservoir 2005-2014 fish biomass study. Equations are from least squares linear regressions.

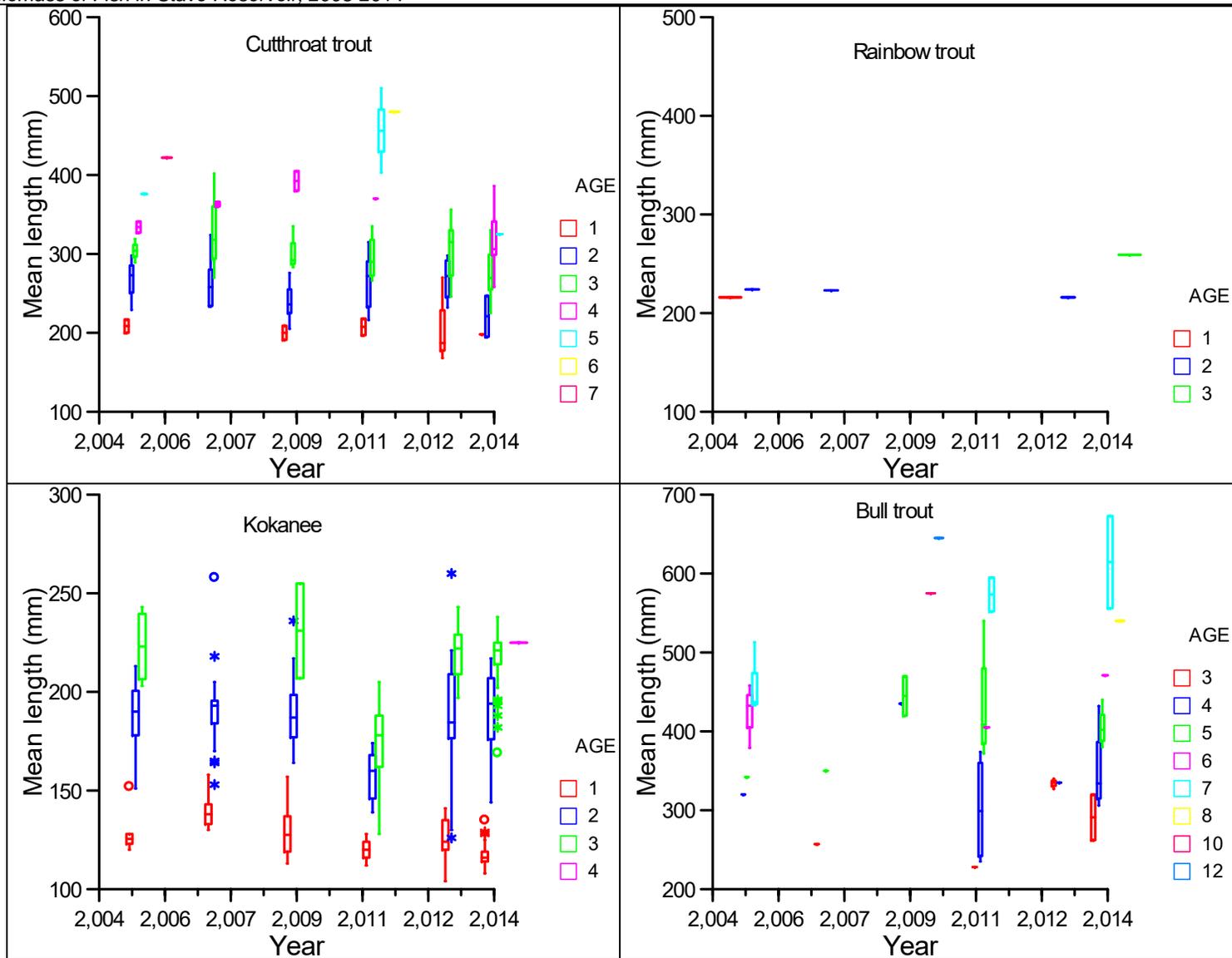


Figure 18. Length-at-age (median and range) of Salmonids caught in RISC gill nets during the 2005-2014 Stave Reservoir fish biomass study. In box and whisker plots: centerline = median; box edges = first and third quartiles (the central 50% of values lie inside the box); distance between box edges = the interquartile range (IQR); whiskers show the range of values that fall within 1.5 IQR of the box edges; values 1.5-3.0 IQR outside box edges are plotted with asterisks; values > 3 IQR outside the boxes are plotted with empty circles. In this and several subsequent figures, dates include a comma due to a graphics software default.

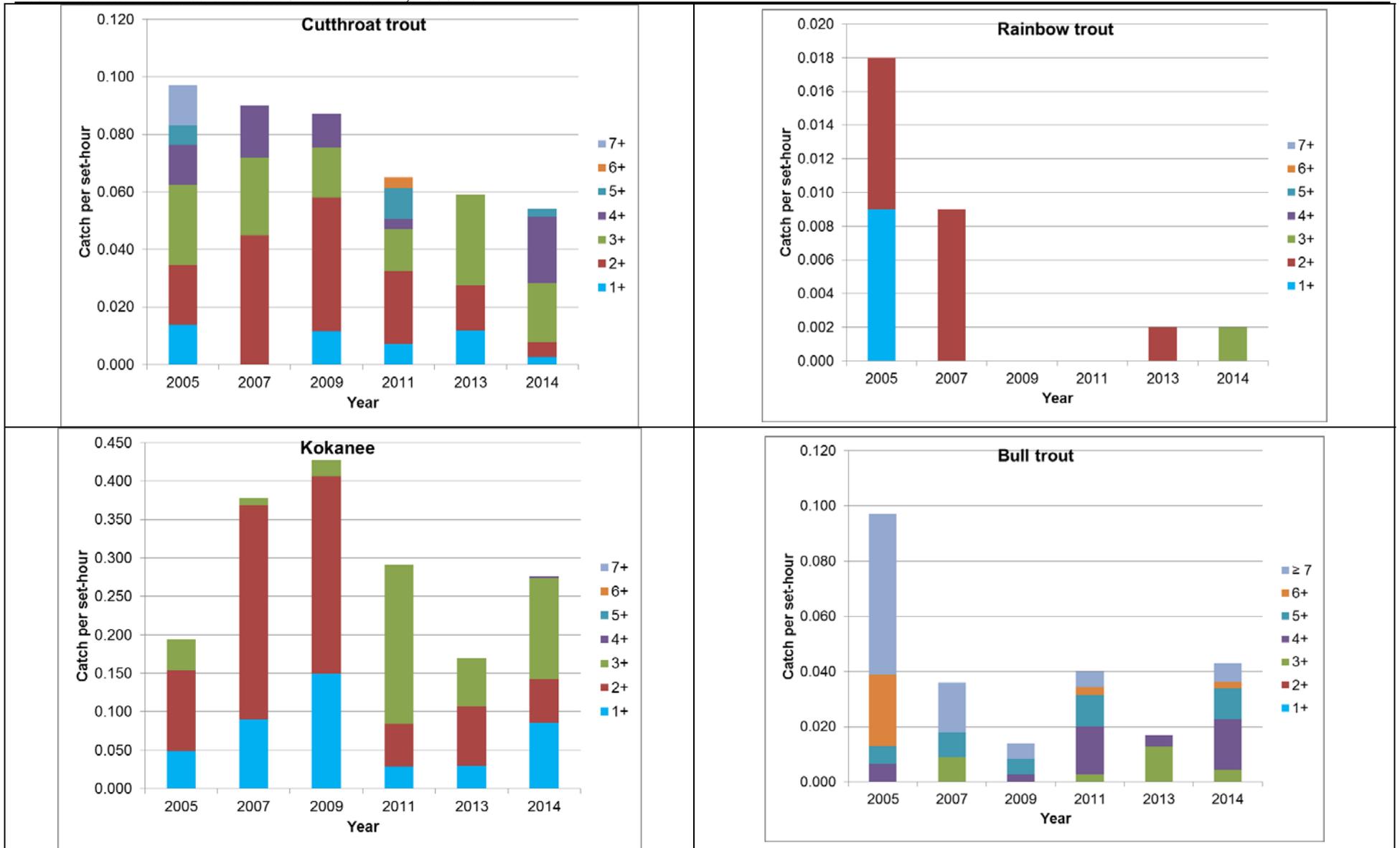


Figure 19. Age composition of Salmonids > 100 mm in length from catch rates (CPUE) of RISC gill nets from nearshore & offshore stations combined. Data are from the 2005-2014 Stave Reservoir Fish Biomass Study.

#### **4.2.4 Stomach contents**

Analysis of stomach contents (percentage of composition by numbers among major food categories) from a sample of Salmonids captured in RISC gill nets (~ 7 fish per species per year, when available) showed distinct differences in diet among species that were quite consistent over all years of the study. Cutthroat Trout had the most balanced diet of the salmonids in most years, consuming appreciable numbers of terrestrial and benthic invertebrates as well as fish (Figure 20, Appendix 7.8). The only exception was in 2005 when their diet was > 80% terrestrial invertebrates. Rainbow Trout, from which stomachs were sampled in just three years, fed mostly on terrestrial invertebrates (> 80% of numbers), with a small amount of each other category in their diet at times. Kokanee consumed mainly zooplankton in all years (> 85%), however, the predominance of zooplankton increased steadily over time, from 85% in 2005 to 99.9% by 2011. Terrestrial and benthic invertebrates that comprised 15% of their diet at the beginning of the study were almost entirely absent from it by the end. Bull Trout consumed mainly fish in all years (50-100%), with occasional items from each other food category in some years. It is important to note that because of the small number of stomachs processed these results were not stratified by size of fish from which the stomachs came, so size dependent piscivory no doubt contributed to some of the inter-annual differences in percentage of fish consumed by Cutthroat Trout and Bull Trout. These salmonids are typically not highly piscivorous until they reach a length of about 250 mm (Quinn 2005).

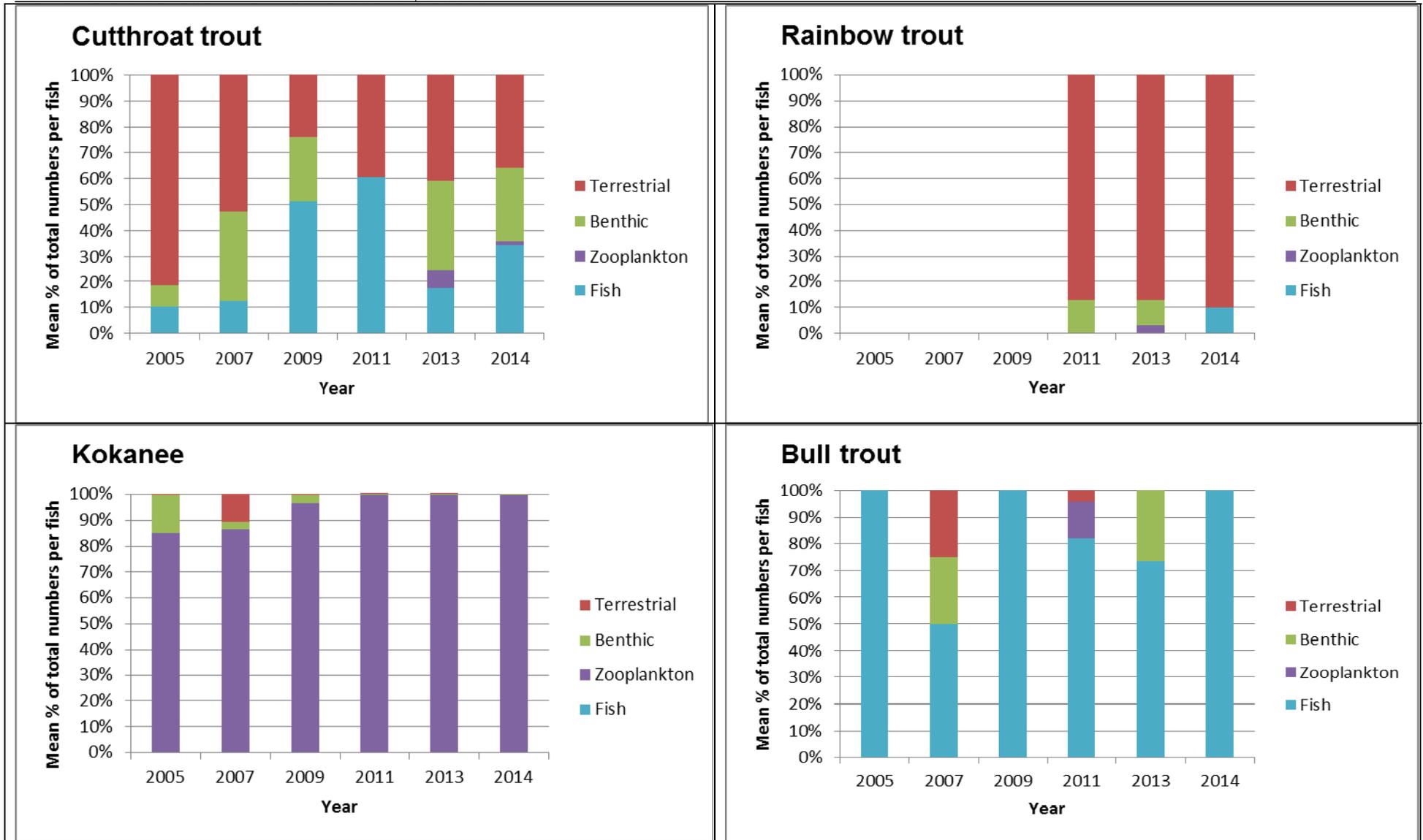


Figure 20. Contents of salmonid stomachs expressed as mean percentage of composition by numbers for major food categories (terrestrial, benthic, zooplankton, fish). Data are from all years of gill netting during the Stave 2005-2014 Fish Biomass Study.

#### 4.2.5 Parasitization by gill lice

From 2005-2009, gill lice were not observed on fish captured from Stave Reservoir, indicating that these parasites were absent from fish or too rare to notice. In 2011 gill lice, probably *Salmincola californiensis*, were frequently observed attached at the base of fins and in the opercular cavity of kokanee (Figure 21), but no attempt was made to quantify the infestation in that year. Inspection of all captured trout and kokanee for gill lice in 2013 and 2014 showed that a high percentage of kokanee were parasitized (> 66% for all ages combined), whereas the percentage of trout and Bull Trout infested was much lower (< 30% for all ages combined, Table 7). None of the few Rainbow Trout sampled carried gill lice. The percentage of fish with parasites increased with age for kokanee, but not for cutthroat or Bull Trout, and this was the case in both years. For all age groups sampled, the percentage of fish with gill lice was the same or lower in 2013 than in 2014 for all species.

The mean number of gill lice carried by fish that were parasitized by them was similar for Cutthroat Trout in both years (1.5-2.3 gill lice/fish), and higher for kokanee in 2013 than in 2014 (8.0 and 4.9 gill lice/fish, respectively, Table 8). The mean number of gill lice per fish increased with age for kokanee, but not for Cutthroat Trout. The number of lice per fish was not determined for Bull Trout, which were rarely parasitized by them, and Rainbow Trout in the sample were not parasitized by them at all.



Figure 21. A kokanee from Stave Reservoir with several parasitic copepods, tentatively *Salmincola californiensis*, in its gill cavity (photo from October 2011).

Table 7. Presence or absence of gill lice on salmonids in 2013 and 2014, the two years that these parasites were quantitatively monitored during the 2005-2014 Stave Reservoir Fish Biomass Study.

Year	Species	Age	Number of fish with lice		Number of Fish examined	% of fish with lice	
			Absent	Present		Absent	Present
2013	C. Trout	1	3	0	3	100.0%	0.0%
"	"	2	3	1	4	75.0%	25.0%
"	"	3	8	0	8	100.0%	0.0%
"	"	NA	9	1	10	90.0%	10.0%
"	"	Combined	23	2	25	92.0%	8.0%
"	R. Trout	2	1	0	1	100.0%	0.0%
"	"	Combined	1	0	1	100.0%	0.0%
"	Kokanee	1	6	0	6	100.0%	0.0%
"	"	2	6	10	16	37.5%	62.5%
"	"	3	1	12	13	7.7%	92.3%
"	"	NA	11	26	37	29.7%	70.3%
"	"	Combined	24	48	72	33.3%	66.7%
"	Bull Trout	3	3	0	3	100.0%	0.0%
"	"	4	1	0	1	100.0%	0.0%
"	"	NA	3	0	3	100.0%	0.0%
"	"	Combined	7	0	7	100.0%	0.0%
2014	C. Trout	1	1	0	1	100.0%	0.0%
"	"	2	1	1	2	50.0%	50.0%
"	"	3	6	2	8	75.0%	25.0%
"	"	4	7	2	9	77.8%	22.2%
"	"	5	0	1	1	0.0%	100.0%
"	"	NA	3	1	4	75.0%	25.0%
"	"	Combined	18	7	25	72.0%	28.0%
"	R. Trout	3	1	0	1	100.0%	0.0%
"	"	Combined	1	0	1	100.0%	0.0%
"	Kokanee	1	30	7	37	81.1%	18.9%
"	"	2	6	19	25	24.0%	76.0%
"	"	3	2	56	58	3.4%	96.6%
"	"	4	0	1	1	0.0%	100.0%
"	"	NA	1	3	4	25.0%	75.0%
"	"	Combined	39	86	125	31.2%	68.8%
"	Bull Trout	3	2	0	2	100.0%	0.0%
"	"	4	8	0	8	100.0%	0.0%
"	"	5	5	0	5	100.0%	0.0%
"	"	6	1	0	1	100.0%	0.0%
"	"	7	1	1	2	50.0%	50.0%
"	"	8	1	0	1	100.0%	0.0%
"	"	Combined	18	1	19	94.7%	5.3%

Table 8. Intensity of infestation (number of lice per fish) on Salmonids with gill lice in years 2013 and 2014 of the 2005-2014 Stave Reservoir Fish Biomass Study. These parasites not observed (2005, 2007, 2009) or not sampled (2011) in other years of gill netting during the study.

Year	Species	Age	Gill lice per fish			Number of Fish examined
			Mean	Min	Max	
2013	C. Trout	2	1.0	1	1	1
"	"	NA	2.0	2	2	1
"	"	Combined	1.5	1	2	2
"	Kokanee	2	6.0	4	10	3
"	"	3	9.4	4	20	9
"	"	NA	7.4	3	15	11
"	"	Combined	8.0	3	20	23
2014	C. Trout	2	1.0	1	1	1
"	"	3	3.0	2	4	2
"	"	4	2.0	2	2	1
"	"	Combined	2.3	1	4	4
"	Kokanee	1	2.0	1	3	4
"	"	2	5.3	1	17	7
"	"	3	6.3	4	9	6
"	"	Combined	4.9	1	17	17

### 4.3 Acoustic surveys

#### 4.3.1 Overview

Acoustic surveys were completed as planned within the required September 15 to October 15 sampling window in all 10 years of the study despite frequent unfavorably windy weather conditions. The target of at least 6 transects sampled was met in 9 of 10 years, and 5 transects were sampled in the remaining year (2008). Especially rough conditions in 2011 required transects to be rerouted quartering downwind to allow completion of the survey, and persistent fall winds in 2012 caused a survey attempt in late September to be aborted and postponed until October 9. Weather was only calm enough such that most side-looking data was usable in 5 of 10 years. However, in all years except 2011, enough side-looking data was usable from various transects to provide a representative sample of 0-5 m fish density around the lake. Unusually rough conditions in 2011 rendered all side-looking data unusable, so fish density in the 0-5 m depth interval was estimated from density in deeper layers of the water column in that year (Stables and Perrin 2012a).

#### 4.3.2 Total annual abundance by habitat zone

Acoustic estimates of total fish abundance (species combined) in the study area showed a pattern of increase through 2010, after which it dropped sharply and remained at relatively low levels since (Figure 22, Appendix 7.9). Inter-year differences were clearly visible on echograms (Figure 23). The peak abundance of 1.69 million fish in

2010 was 4.3 times greater than the initial 2005 value, and 3.6 times greater than the 2014 value. Throughout the study, most fish (78-95%) occurred in the pelagic zone (offshore of the 40 m depth contour, Figure 22). Abundance followed the same pattern of increase and decrease over time in both zones. For all years of sampling, the 95% confidence interval of the total estimate (zones combined) ranged from  $\pm 14\%$  to  $\pm 30\%$  (mean 19%).

### 4.3.3 Size distribution of fish detected with acoustics

Frequency distributions of TS, the acoustic size of fish, showed two to three major peaks in each year of the study (Figure 24). The largest peak in all years was within the small fish size group (TS < the -49.6 dB, representing fish < ~ 100 mm long, this group was too small for capture in RISC gill nets). The medium fish size group (TS  $\geq -46.9$  and  $\leq -34$  dB, fish ~ 100-375 mm long) often contained one clear peak and was the second most abundant size class in all years. Abundance of the large fish size group (TS < -34 dB, fish > ~ 375 mm) that represented large predators was always very low, with no discernible peak. In several years (e.g., 2009) the small fish size group contained two visible peaks that may have represented fry and age-1 kokanee. This finding, like gill net age composition results, suggests that a fair proportion of age 1 kokanee were too small for capture in RISC gill nets.

Estimates of fish abundance (fish/ha, species combined) showed a similar pattern of relative abundance among size groups in all years. Small fish were most numerous (67-86% of total numbers), followed by medium fish (15.3-31.0%), and large fish (0.1-3.5%, Figure 25). In years of high abundance (2009-2011), a relatively large proportion of all fish were of the small size group. Small and medium size fish peaked in abundance in 2009 and 2010, whereas large fish peaked in 2008 and 2009.

### 4.3.4 Vertical distribution of fish

During most years, fish abundance was highest in the 10-30 m depth range, however, in some years, especially 2009, it was high in the upper 10 m of the water column (Figure 26). Only in 2010 and 2011 were an appreciable number of fish found below 30 m. In nearly all years, small fish were concentrated shallower than medium or large fish (Figure 27). In 2010 and 2011, however, the smallest of small fish (< -55dB) were spread widely over the water column, whereas fish > -55 dB were concentrated in the 10-30 m range.

### 4.3.5 Correlation of acoustic abundance estimates with gill net CPUE

Annual acoustic estimates of fish > ~ 100 mm in length were positively correlated with annual mean CPUE in RISC gill nets, although the fit to a power function was modest ( $R^2 = 0.40$ ,  $p=0.18$ ,  $\alpha=0.05$ , Figure 28). A power function was the model of choice because it fit the data slightly better than a linear model (higher  $R^2$ ) and because it implies that CPUE would be zero if fish abundance was zero and that the rate of increase in CPUE would slow as fish abundance increases (i.e., due to gear saturation). The low degree of correlation may be partly explained by the fact that gill netting methods only became consistent after the first two years of the study (there was no offshore gill netting in 2005, and sets were dusk-night rather than overnight in 2007). Although the sample size (years of data) was small and the degree of correlation was low, the presence of some positive correspondence between CPUE and the acoustic estimate supports the use of species composition data from RISC gill netting for apportioning the acoustic estimate of medium and large fish ( $TS \geq -46.9$  dB).

### 4.3.6 Annual abundance by species and age

Plots of annual abundance by species (all ages combined) show that kokanee greatly predominated in the fish community throughout the study (Figure 29, Appendix 7.9). Their densities were 111-584 fish/ha and they comprised from 93 to 99% of total abundance. Age-0 kokanee were by far the most abundant age group in all years (95-504 fish/ha, 69-88% of total kokanee numbers, Figure 30, Appendix 7.10). In the first six years of the study age-2 kokanee were next most abundant, followed by age-1, whereas, from 2011 to 2014 age-3 kokanee most often predominated, followed by age-1 or 2. When considering these species and age specific estimates it is important to remember that 2006, 2008, 2010, and 2012 when no gill netting was conducted are undoubtedly less accurate than other years.

Annual abundance ranges for other species (ages combined) were: Cutthroat Trout 0.04-7.4 fish/ha, Rainbow Trout 0.0-1.72 fish/ha, Bull Trout 0.38-2.53 fish/ha, Northern Pikeminnow 0.58-5.25 fish/ha, Peamouth 0.0-3.5 fish/ha, Redside Shiner 0.0-1.35 fish/ha (Appendix 7.9). For salmonids other than kokanee, the age groups that typically predominated were: ages-2 and 3 for Cutthroat Trout, age-2 for Rainbow Trout, and ages-4 through 7 for Bull Trout. There was no obvious succession of cohorts, strong or weak, for any of the salmonids. However, when considering these species and age specific estimates it is important to remember that 2006, 2008, 2010, and 2012 when no gill netting was conducted are undoubtedly less accurate than other years, and lack of gill netting in alternate years inhibited tracking of cohorts.

#### 4.3.7 Annual biomass by species and age

Annual estimates of biomass by species (ages combined) also followed a pattern of large increase 2005-2010 followed by a sharp decrease in 2011, yet they recovered more over the final two years of the study than did abundance estimates (Figure 31, Appendix 7.11). Kokanee were the largest single contributor to biomass in all years (1.0-5.5 kg/ha, 44-77% of total biomass), however other species with larger mean body size also contributed significantly. In particular, Bull Trout and Cutthroat Trout comprised up to 39% and 30% of total biomass, respectively, in some years, and Bull Trout biomass was especially large in 2009 and 2010 (2.9 and 4.9 kg/ha). However, the certainty of these estimates was reduced by the small sample sizes for some species in gill net catches that were used for species composition and weight estimates (e.g., Bull Trout, see Discussion), and there was no gill netting in 2010.

In the first six years of the study, most kokanee biomass was from age-2 fish (1.3-3.9 kg/ha, 58-82% of kokanee biomass), with ages 1 or 3 next most important, depending on the year (Figure 32). In the last four years age-3 kokanee predominated (0.8-2.7 kg/ha, 52-79%), with age-2 next most abundant. In no year did age-1 fish make up more than 13% of the biomass of this species. For other species, largest contributors to biomass in most years were: ages 2, 3, and 4 for Cutthroat Trout, age 1-3 for Rainbow Trout, and age 5 and older for Bull Trout. Clearly, the large body size of older Bull Trout counterbalanced their low numbers, resulting in the relatively large biomass.

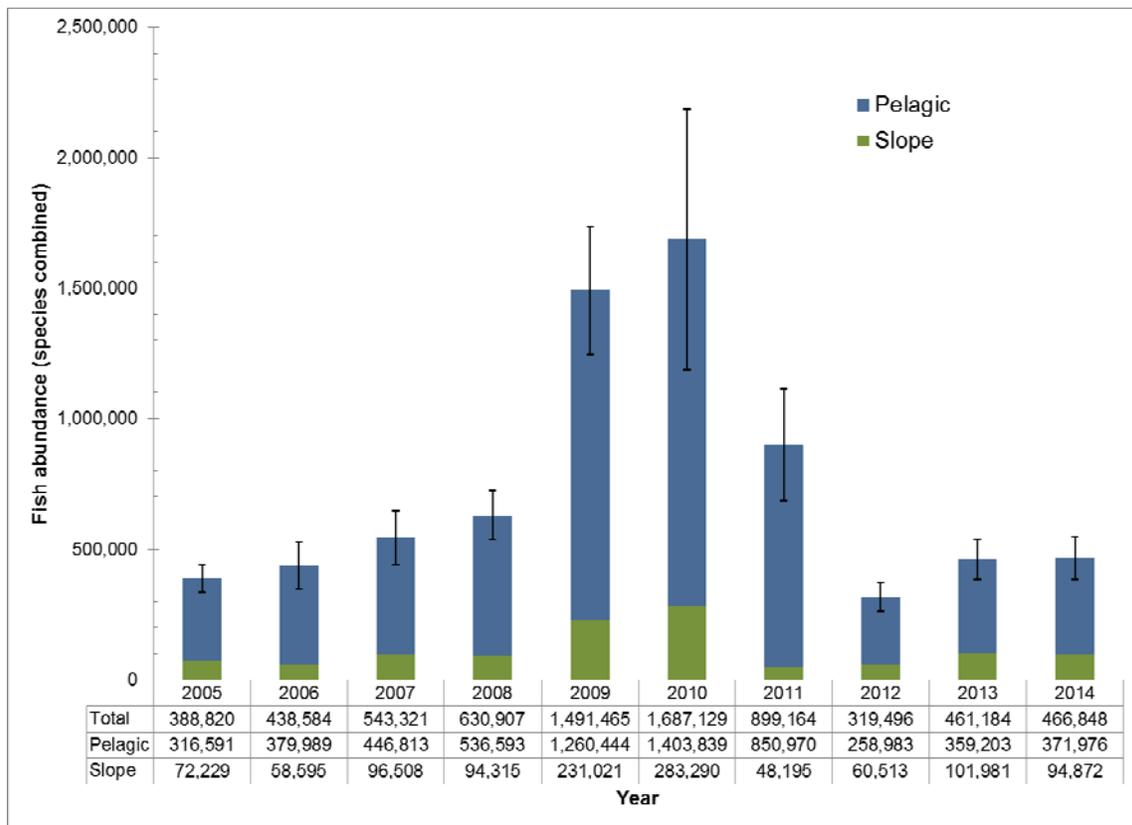


Figure 22. Annual estimates of fish abundance in Stave Reservoir (species combined) by habitat zone (slope and pelagic), from 2005-2014 fall acoustic surveys.

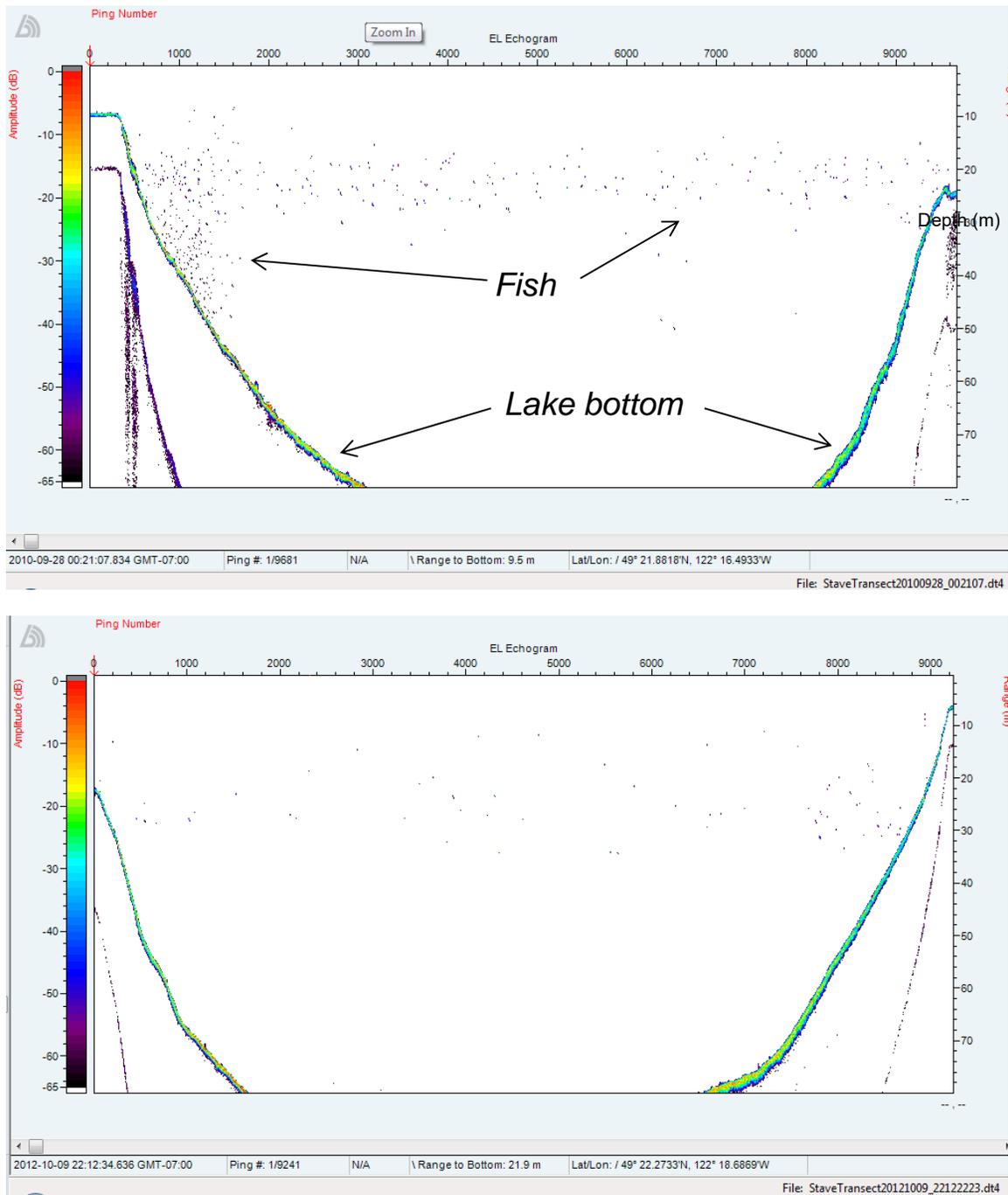


Figure 23. Echograms from a single representative transect (T7) during a high abundance year (Upper frame, 2010, 596 fish/ha) and a low abundance year (Lower frame, 2012, 113 fish/ha), from the Stave Reservoir 2005-2014 Fish Biomass Study.

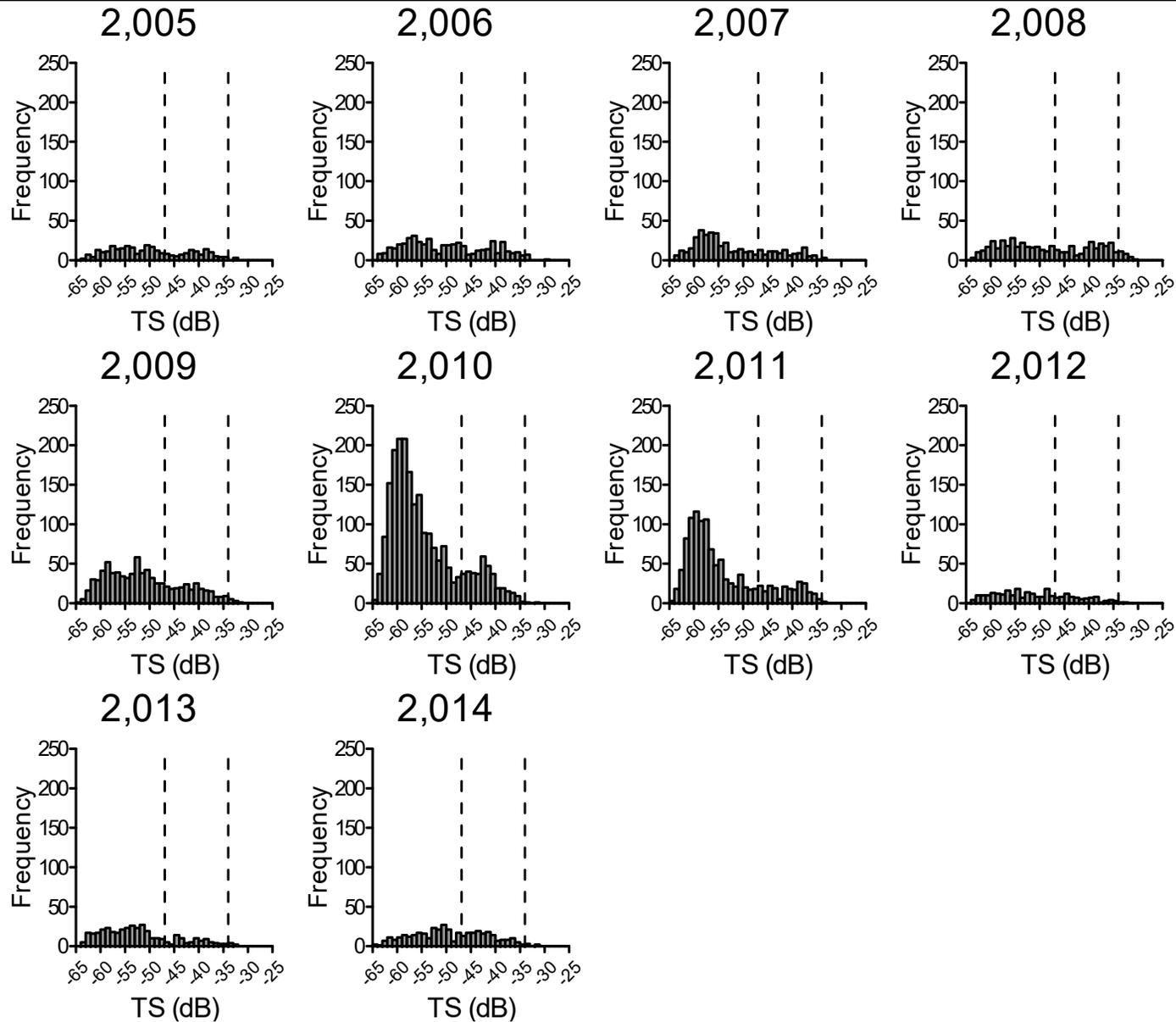


Figure 24. TS Frequency distributions of target strength (TS) from each year of acoustic sampling in Stave Reservoir (transects, habitat zones, and depths pooled). Vertical dashed lines indicate boundaries of small (< -46 dB, < ~ 100 mm), medium (~ 100-375 mm), and large (> ~ 375 mm) fish categories.

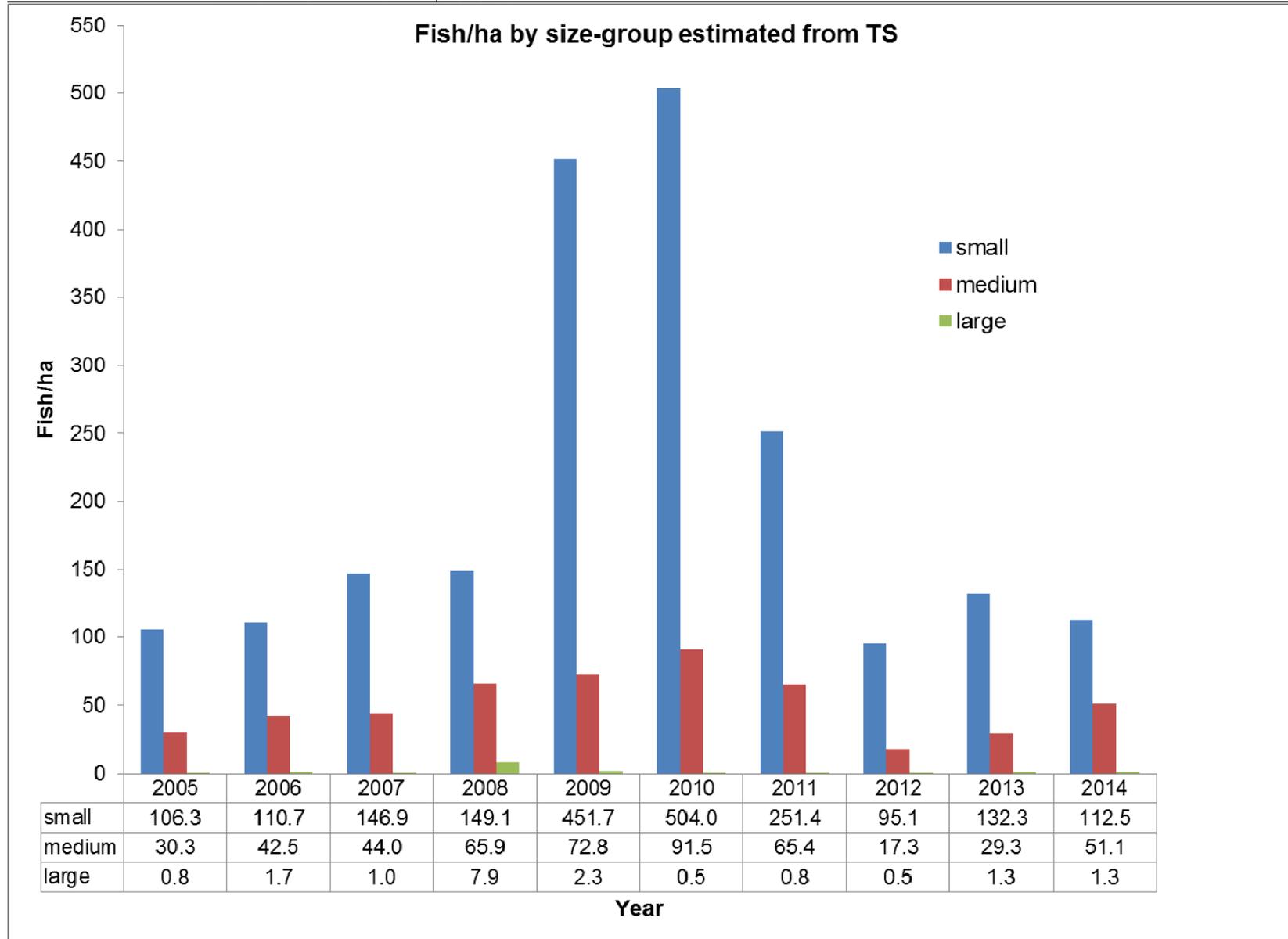


Figure 25. Annual abundance of small, medium, and large fish size-groups (estimated from TS), Stave Reservoir 2005-2014 Fish Biomass Study.

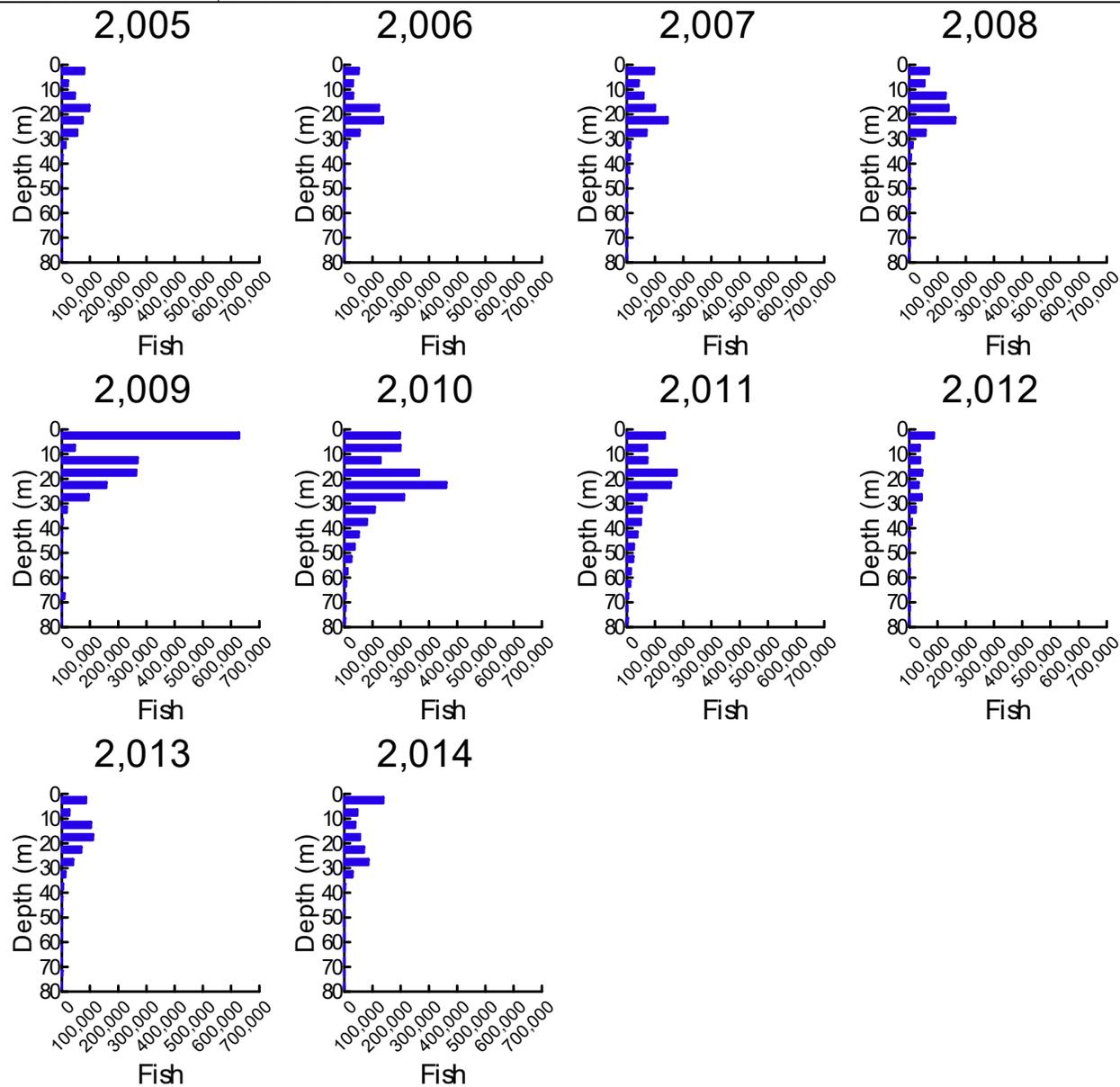


Figure 26. Acoustic estimate of total fish abundance (species and habitat zones combined) by 5 m thick depth intervals in each year of the 2005-2014 Stave Reservoir Fish Biomass Study.

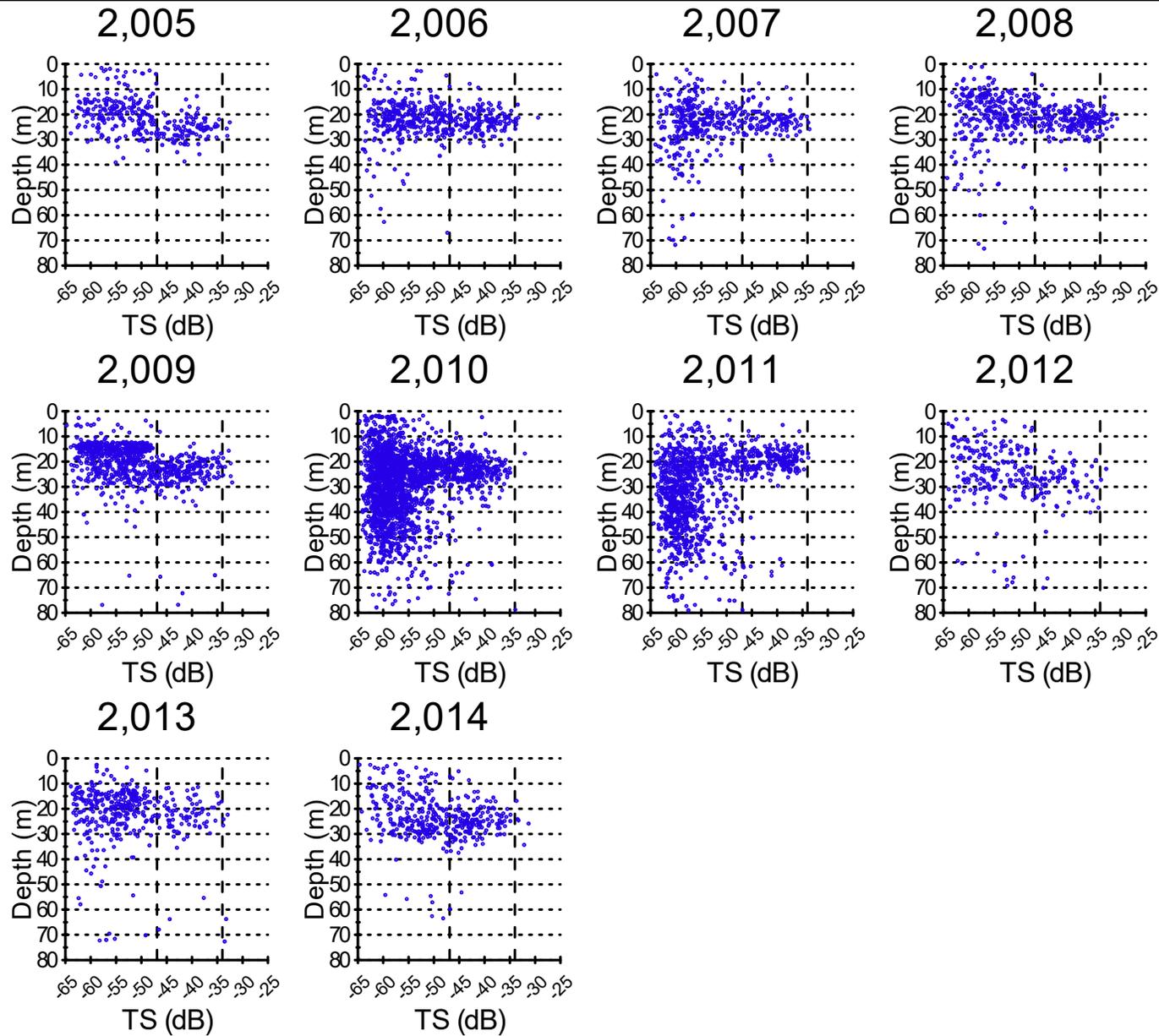


Figure 27. Target strength (TS) of fish traces versus depth in each year of acoustic sampling during the Stave Reservoir 2005-2014 Fish Biomass Study. Vertical dashed lines indicate boundaries of small (< -46 dB, < ~ 100 mm), medium (~ 100-375 mm), and large (> ~ 375 mm) fish categories.

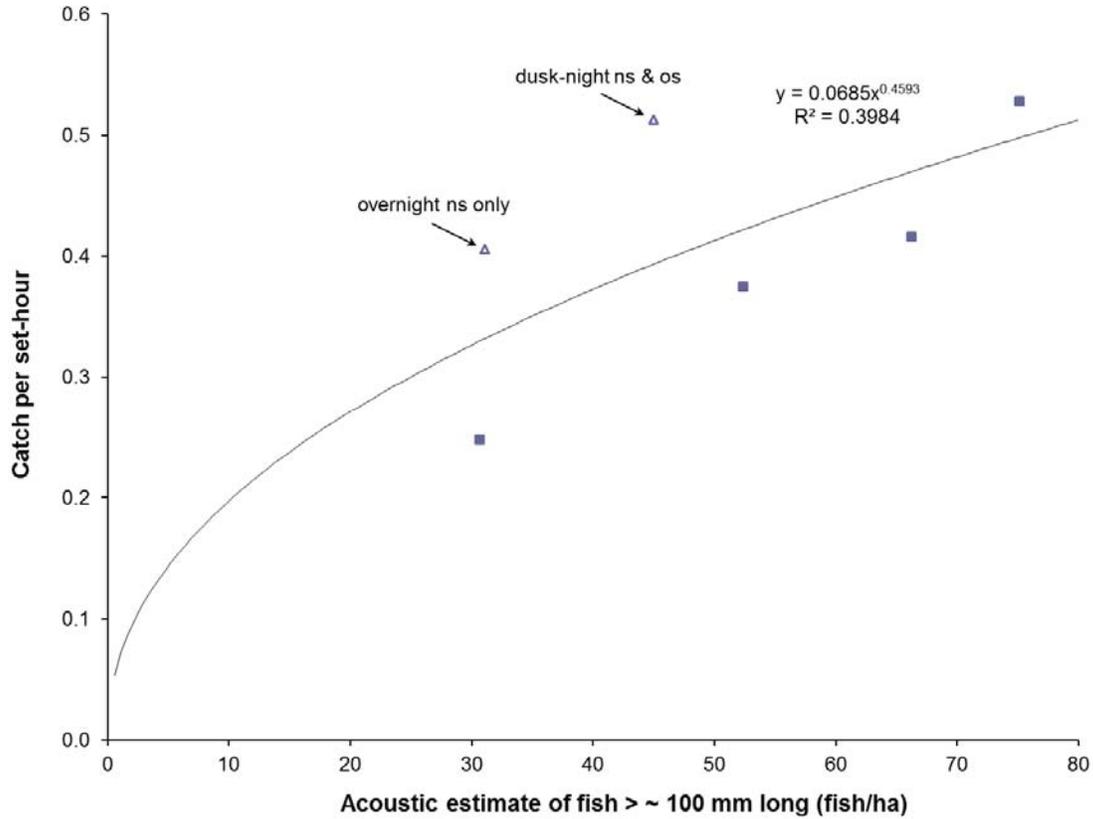


Figure 28. CPUE in RISC gill nets versus acoustic abundance estimates of medium and large fish combined ( $TS \geq 46.9$  dB) with a power function fit to the data points. Data plotted are the six years of the Stave Fish Biomass Study with gill netting. CPUE data are combined catch of all species per set-hour in slope and pelagic zones combined. In four of six years (square symbols), nets were set at nearshore (ns) and offshore (os) stations and all sets were overnight. In the remaining two years (triangles) conditions differed as noted on the plot.

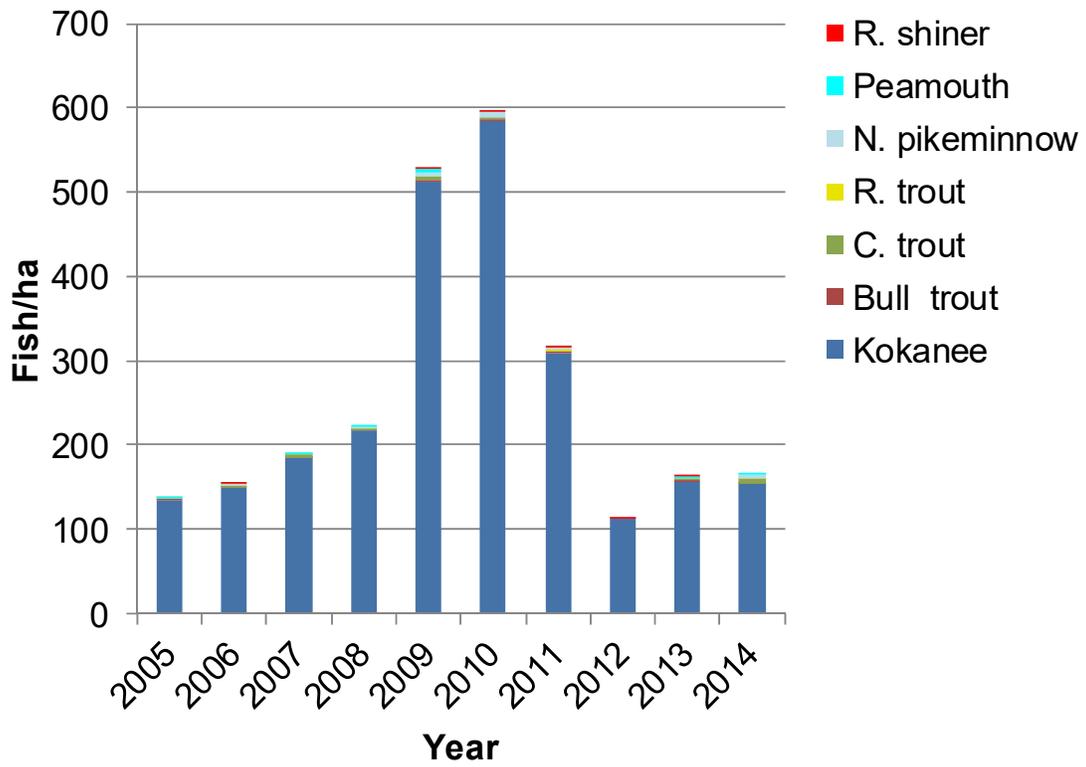


Figure 29. Annual abundance of fish by species (fish/ha) during the 2005-2014 Stave Reservoir Fish Biomass Study. Estimates are from fall acoustic surveys apportioned using fall RISC gill net survey data. Gill netting was only conducted in 2005, 2007, 2009, 2011, 2013, and 2014.

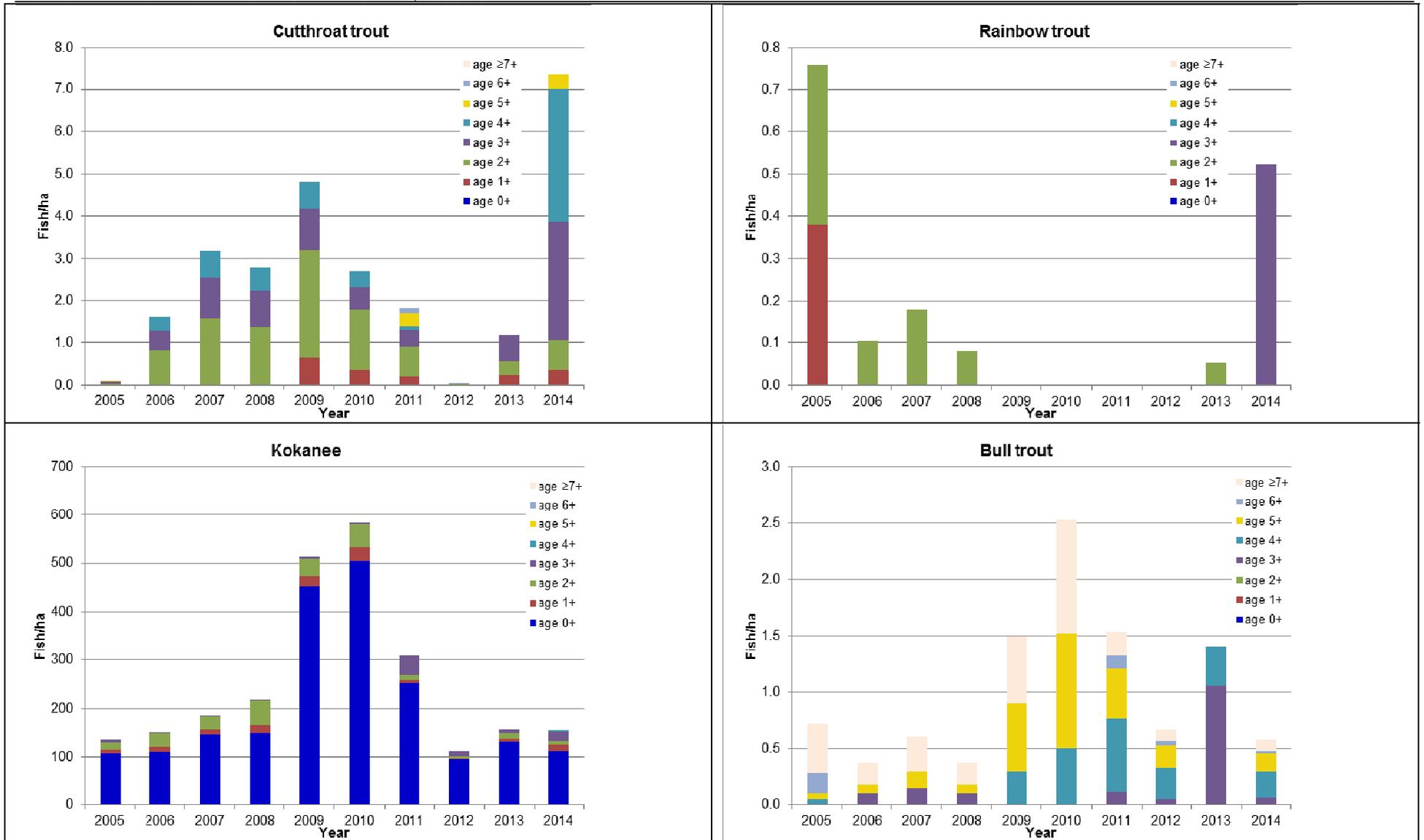


Figure 30. Annual abundance of Salmonids by species and age group (fish/ha) during the 2005-2014 Stave Reservoir Fish Biomass Study. Estimates are from fall acoustic surveys apportioned using fall RISC gill net survey data. Gill netting was only conducted in 2005, 2007, 2009, 2011, 2013, and 2014.

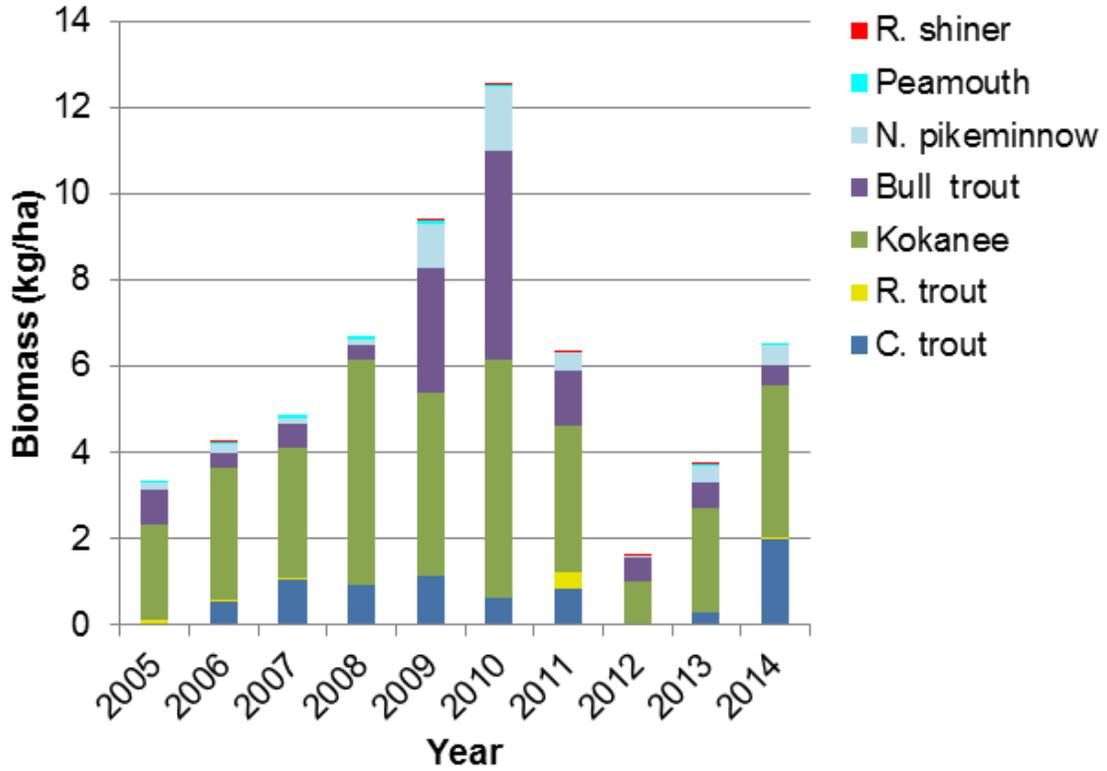


Figure 31. Annual biomass of fish by species (fish/ha) during the 2005-2014 Stave Reservoir Fish Biomass Study. Estimates are from fall acoustic surveys apportioned using fall RISC gill net survey data. Gill netting was only conducted in 2005, 2007, 2009, 2011, 2013, and 2014.

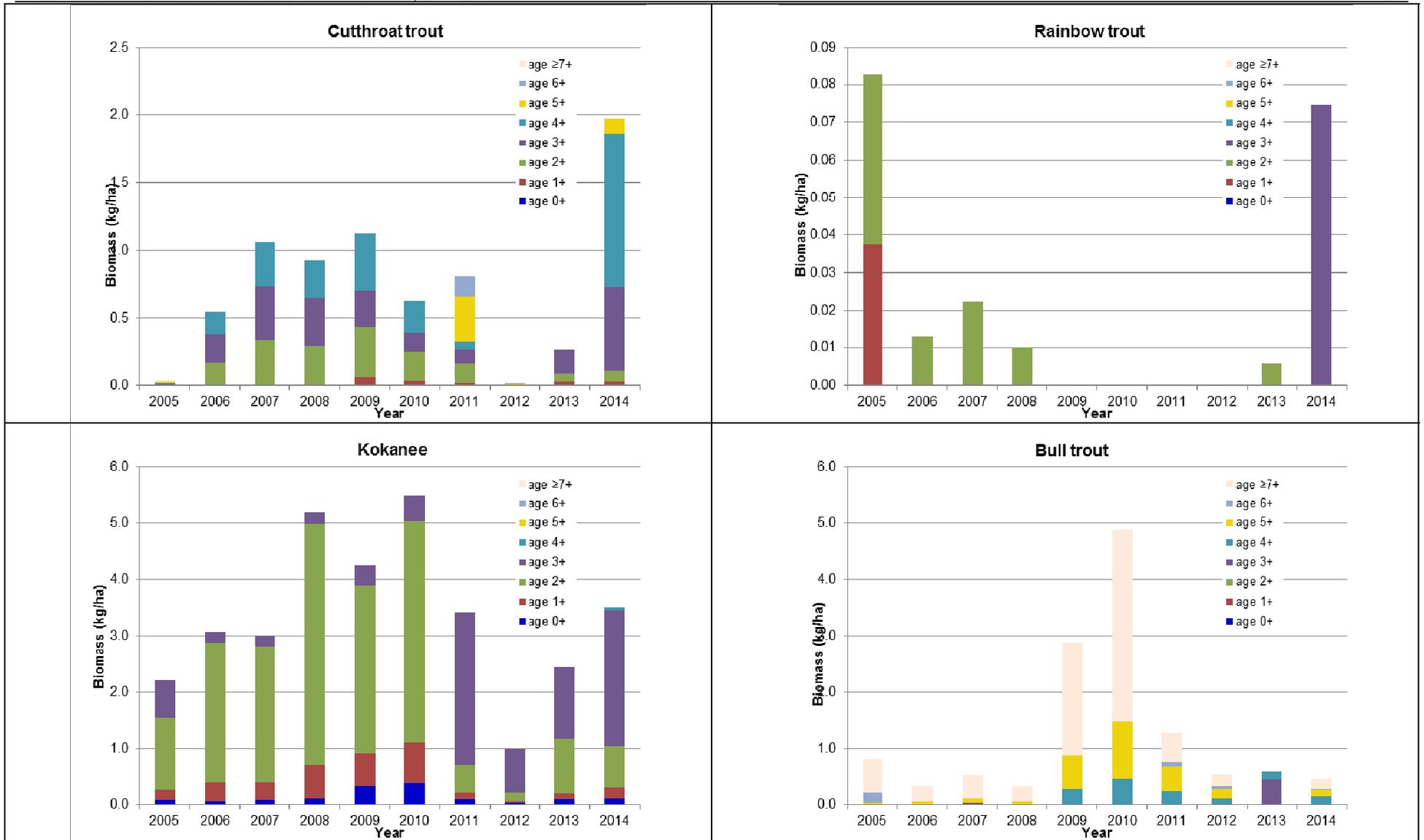


Figure 32. Annual biomass of Salmonids by species and age group (fish/ha) during the 2005-2014 Stave Reservoir Fish Biomass Study. Estimates are from fall acoustic surveys apportioned using fall RISC gill net survey data. Gill netting was only conducted in 2005, 2007, 2009, 2011, 2013, and 2014.

#### **4.4 Answers to management questions**

##### **4.4.1 Relationship between fish metrics and Combo6**

Abundance of 388,820 fish in 2005 increased to 1,687,129 fish in 2010 but then declined to 466,848 fish in 2014, resulting in little net change in fish abundance over the 10 year monitoring period (Figure 22). Most of the temporal changes were related to small fish (based on TS, Figure 25). The time course change in abundance did not follow a consistent rising trend or an increase followed by variation around a mean that was greater than the starting abundance, as hypothesized. Furthermore, relative abundance of most highly littoral species in the gill net catch (CPUE of Largescale Sucker, Northern Pikeminnow, Redside Shiner) decreased rather than increased over time (Figure 11). As a result, there is no evidence that Combo6 produced a time course increase in total fish abundance. This finding does not mean that Combo6 did not produce an effect. It only means that an effect could not be detected in the monitoring layout. There was no mathematical model that would be ecologically useful to fit to these time course fish abundance data.

Without application of regression analysis, we were not restricted by statistical assumptions for examination of time course trends in other fish population metrics including biomass and species-specific abundance. Change in fish abundance over time was mostly due to kokanee (93-99% of total abundance, Figure 29). Again, time course change in this kokanee abundance did not follow a consistent rising trend or an increase followed by variation around a mean that was greater than the starting abundance, as hypothesized. The same was found for species-specific fish biomass estimates (Figure 31).

##### **4.4.2 Relationship between fish, primary production, and other habitat metrics**

Over the 10 years of fish monitoring, only four seasonal measurements of pelagic primary production were available from BC Hydro (2010 through 2013). A scatterplot of these data with total fish abundance shows no pattern (Figure 33). Even if there was a pattern, four data points is not sufficient with which to statistically examine a functional relationship. Hence, no conclusion can be obtained from the available PR data.

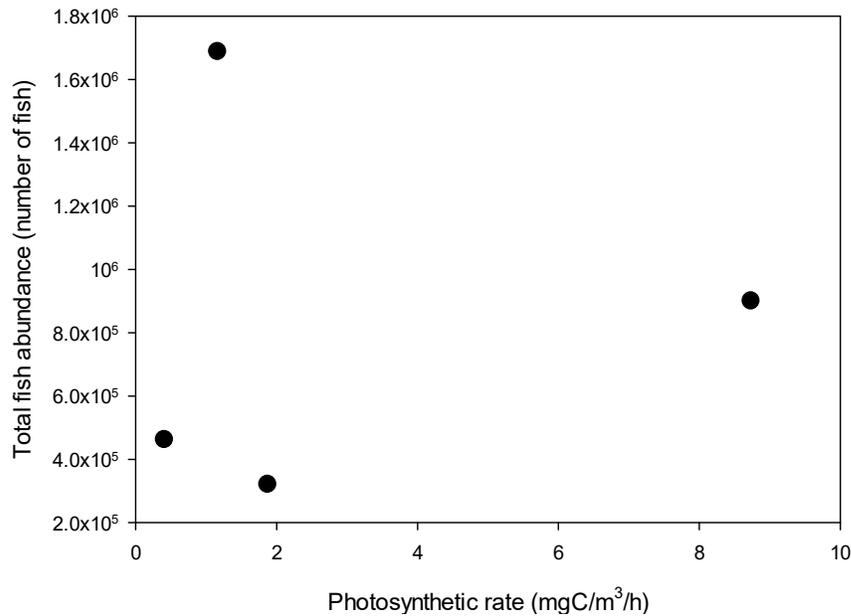


Figure 33. Scatterplot of total fish abundance in Stave Lake Reservoir and pelagic photosynthetic rate among all years.

Two other relationships were explored to provide insight into interactions between fish and Combo6. No pattern was found between condition factor (CF) of kokanee and the minimum water surface elevation during the critical growth period of May 15 – September 7 as defined in Combo6 (Figure 34). Nor was a pattern evident between kokanee CF and the number of days between May 15 and September 7 when the water surface elevation exceeded 80m (Figure 34). Similarly, no pattern was found between phosphorus loading to Stave from Alouette Lake and fish abundance or fish biomass (Figure 35). Regression analysis was not applied to these data because statistics were not needed to show the absence of functional relationships.

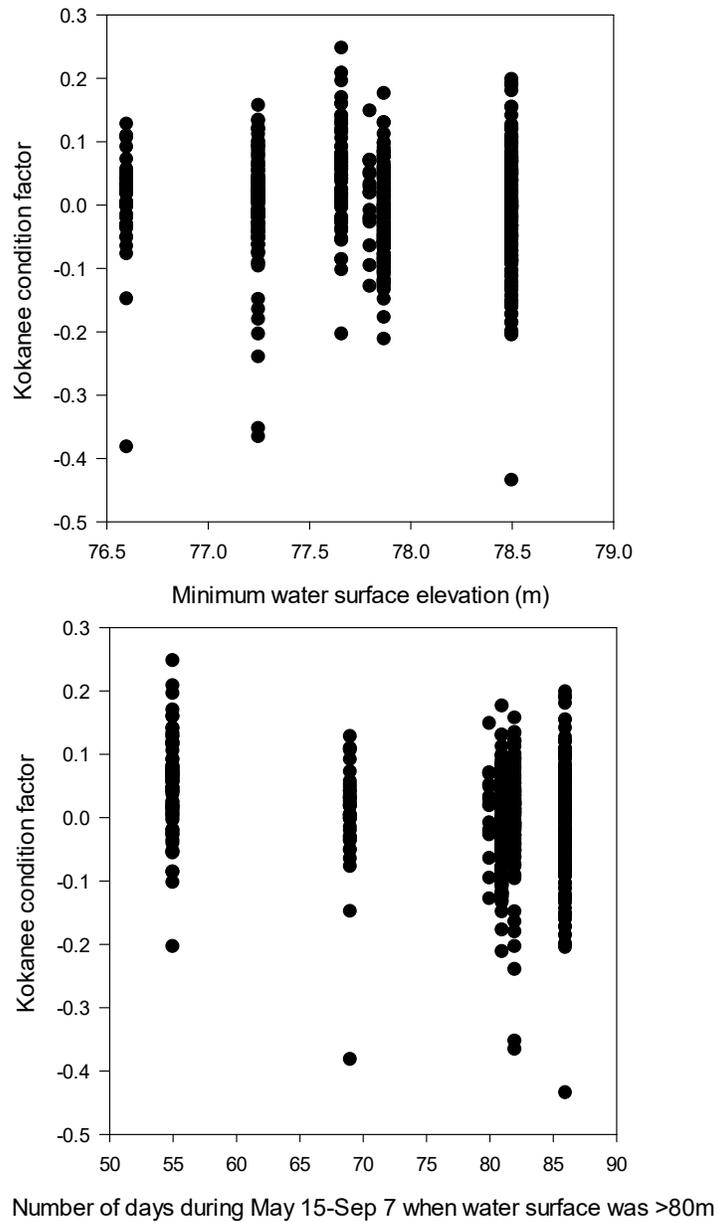


Figure 34. Kokanee condition factor plotted with minimum water surface elevation in Stave Reservoir during the critical period of May 15 – September 7 (top) and the number of days when the water surface elevation was >80m also during the critical period of May 15 – September 7 (bottom) among all study years of 2005 – 2014.

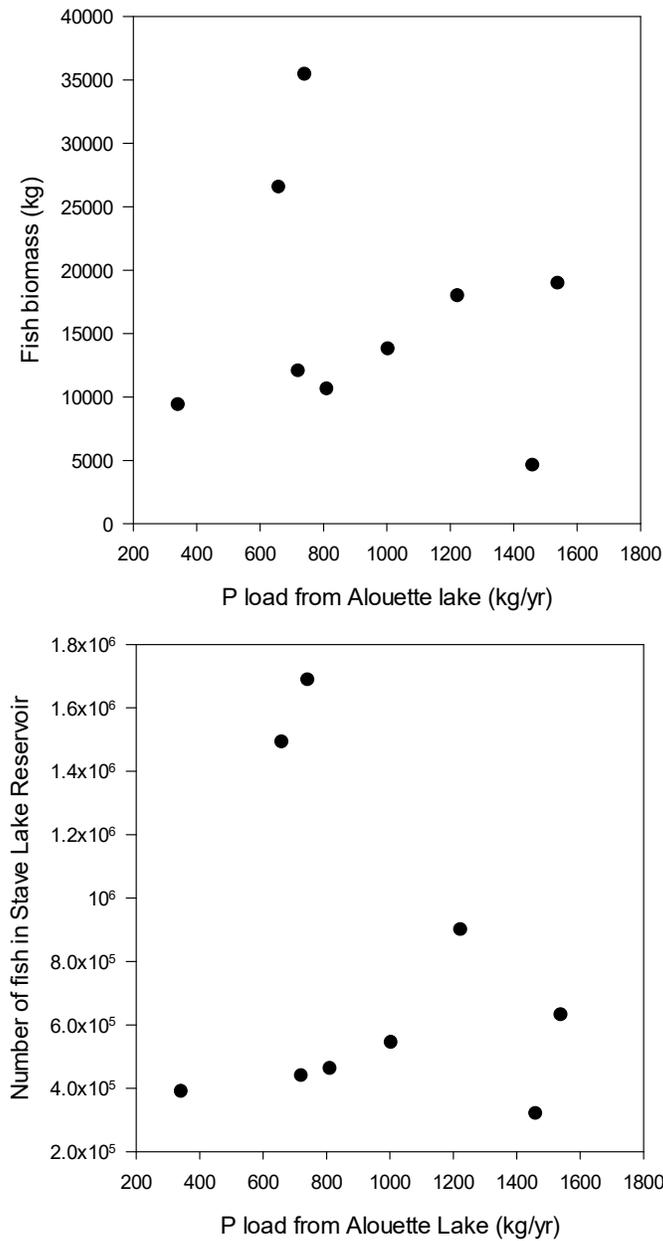


Figure 35. Fish biomass (top) and abundance (bottom) in Stave Reservoir plotted with phosphorus load from Alouette Lake among all years.

## 5 DISCUSSION

### 5.1 Effects of Combo6 on the Stave Reservoir Fish Community

A hypothesis from implementation of Combo6 was that a change in water management in the biologically active growing season would improve conditions for fish

populations, leading to an overall increase in fish abundance and biomass. Without monitoring the limnology and fish populations before Combo6, testing of this hypothesis was constrained to observation of temporal trends after Combo6 was implemented. The abundance or biomass of fish was expected to increase steadily over time or increase to a new equilibrium defined by altered habitat conditions as less variation in summertime water surface elevations prevailed compared to conditions before implementation of the water use plan. Neither of these changes was observed in the fish abundance and biomass data.

This outcome does not mean that Combo6 did not produce an effect on fish populations but rather an effect if present could not be detected. Part of the problem was due to the lack of data from years before implementation of the water use plan with which to make before – after comparisons and lack of control data. Another reason was that for the time period studied, inter-year variation exceeded any time course trend, thus obscuring a temporal trend if it was present.

The ten years of fish population monitoring produced valuable information suggesting there were ecological reasons not to expect a treatment effect in the measured fish populations. The water use plan did not alter the extent of annual drawdown. It only adjusted variability in the water elevations during the high water period. That variation would be expected to only influence benthic production in substrata near the highest littoral elevations. Kokanee that were by far the most abundant of fish populations in Stave Lake Reservoir are a pelagic species occupying habitat that was not affected by any of the hydrologic changes. Their habitat might be reduced during the winter drawdown each year, but the extent of that drawdown did not change with Combo6. Lack of a relationship between kokanee condition and hydrologic metrics of Combo6 further supports this idea. This habitat use by the most abundant fish species and disconnect from habitat affected by Combo6 means there was no reason to expect a response from the numerically dominant kokanee population to Combo6. Inter-annual variation in kokanee abundance and biomass must therefore be related to factors other than variation in the highest of water surface elevations. In addition, all of the fish species that are known to use littoral habitat in Stave Reservoir (e.g. Rainbow Trout, Cutthroat Trout, maybe Bull Trout) and potentially were most affected by Combo6, were found to be opportunistic feeders, ingesting a large amount of terrestrial insects (Cutthroat Trout, Rainbow Trout) and other fish (Cutthroat Trout, Bull Trout) as well as benthic invertebrates. Only the benthos would be affected by change in variation of dewatering of upper elevations of the littoral zone but benthos in lower parts of the littoral zone may not have been affected. The fish stomach contents data suggest that if availability of benthos is limited, the fish species using littoral habitat would ingest food from other sources. The Rainbow Trout, in particular were found to ingest mostly terrestrial insects and little benthos. Any change in availability of benthos may have had little to no effect on availability of food for those Rainbow Trout. Given these lines of evidence, there was not a strong rationale to expect Combo6 to provide a

benefit to fish populations in Stave Reservoir as implied in the fish abundance and biomass data.

We examined two other factors that might have explained the large inter-year variability in fish population size and biomass. Unfortunately, there were insufficient observations of the pelagic photosynthetic rate, a measure of phytoplankton production, with which to examine a relationship with abundance of planktivorous fish (e.g., kokanee). Phytoplankton production is a good predictor of biomass of juvenile sockeye salmon in coastal lakes (Shortreed et al. 2000) and given the similar habitat requirements by kokanee and juvenile sockeye, the same might be expected in Stave Reservoir. Further measurements in future years would be required to determine if the relationship is present. No relationship was found between total fish abundance or biomass and phosphorus load from inflowing Alouette Lake. Nutrient loading, particularly by phosphorus that is known to limit biological production in oligotrophic coastal lakes of British Columbia, is well known to be positively related to production of planktivorous fish populations (Hyatt and Stockner 1985). Lack of this relationship in this study does not mean it does not exist. More correctly, it means that phosphorus load from all sources was not accounted for or that the allochthonous load was not enough to cause a change in biological production to propagate through the food web and change fish production. The high flushing rate of Stave Lake Reservoir (5 times during the growing season (Stockner and Beer, 2004)) would undoubtedly limit the potential effect of any nutrient load in this process.

## **5.2 Evaluation of two other potential influences on fish biomass**

### **5.2.1 Natal stream flows**

Annual differences in fish production from streams where they spawn may have influenced fish abundance and biomass in the reservoir. It is well known that environmental conditions in natal streams can greatly affect the survival of salmonids during incubation, which in turn affects their abundance later in life (Groot and Margolis 1991, Quinn 2005). For example, Thorne and Ames (1987) found that peak daily flows during the “in-gravel” period explained 94% of the variability in the presmolts/spawner ratio of sockeye salmon in the Lake Washington system. Flow records from the upper Stave River for most of the 2005-2014 period (2013 was unavailable) were examined for evidence that flooding during fall or winter when kokanee eggs were in the gravel showed any correspondence with their abundance trends in the reservoir. The upper Stave River and Winslow Creek are thought to be important natal streams for char, kokanee, and possibly Rainbow Trout, and kokanee have actually been observed on their spawning migration in Winslow Creek (in September 1993, Bruce et al. 1994). Discharge patterns of Winslow Creek are thought to be similar to those of the upper Stave River (Bruce et al. 1994). Although nothing is known about the number of

spawners or eggs deposited in any year, a simple comparison of maximum fall and early winter flows (October-January) to age-0 kokanee abundance the following year showed no discernable pattern and no statistical correlation, and discharge was relatively low for the in-gravel periods leading to the major decline in kokanee fry abundance in 2011 and 2012 (Figure 36). This evidence gives no indication that high flows during egg incubation reduced kokanee recruitment to the reservoir.

The previous paragraph points out a fundamental flaw in the Fish Biomass Study design: an unstated assumption of constant salmonid survival among years during the stream-phase of life. A stronger study design would have validated this assumption by monitoring stream production each year (e.g., trapping of juveniles migrating from natal streams, or the addition of early season acoustic surveys of the reservoir to assess recruitment from streams before summer growth and mortality in the reservoir).

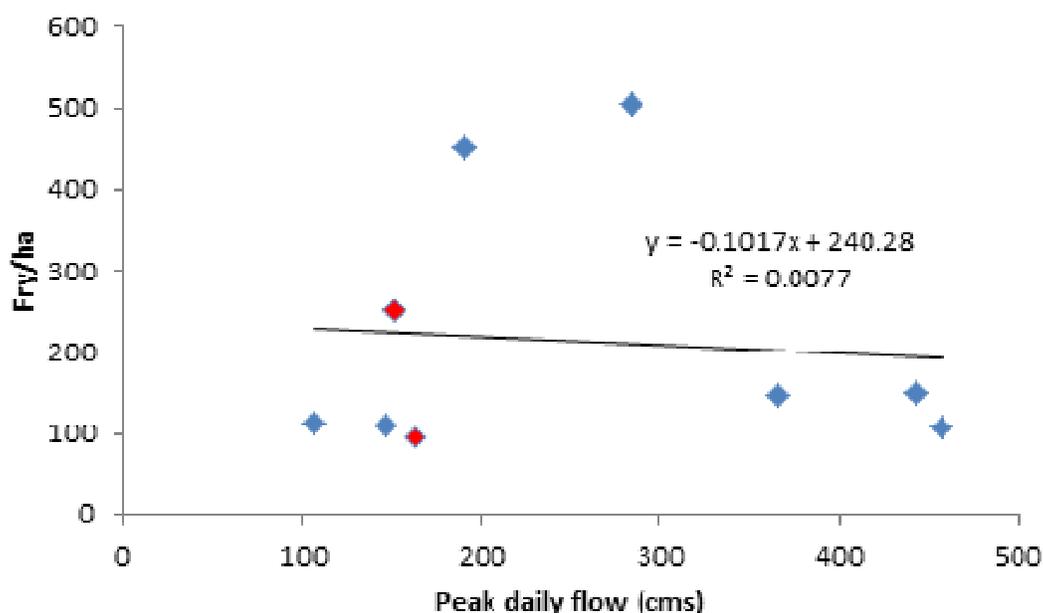


Figure 36. October-January upper Stave River Peak daily flows ( $m^3/s$ ) versus kokanee fry abundance Stave Reservoir the next fall, for years 2005-2012 and 2014 (2013 flow data unavailable). Red symbols indicate 2011 and 2012 fry abundance estimates, during the major kokanee population decline.

### 5.2.2 Parasitic gill lice

Parasitic gill lice, probably *Salmincola californiensis*, were first noticed on kokanee in fall 2011 of this study, which coincided with a sharp decline in kokanee abundance from the peak in 2010. This parasite may have been present in the system beforehand, as Bruce et al. (1994) reported that 50% of Cutthroat Trout in Cardinalis Creek were parasitized by “anchor worms” during 1993 stream surveys (none were reported from the lake then). Severe infestations of *S. Californiensis* can reduce growth,

survival, stamina, fecundity, and tolerance of stress in salmonids (Gall et al. 1972, Kabata and Cousens 1977, Pawaputanon 1980). They spread among fish most readily during crowding that may occur in natural situations such as schooling, spawning, or constriction of suitable habitat by warm temperatures or low dissolved oxygen (Hargis et al. 2014). Warm water temperatures can increase the incidence and spread of gill lice (Sutherland and Wittrock 1985) and gill lice reduce the tolerance of fish to warm water (Pawaputanon 1980); temperatures > 23°C can increase mortality of juvenile sockeye salmon infested with gill lice. Despite these negative effects, mortality and reduced growth due to *S. californiensis* has only been clearly documented in very crowded man-made environments, such as hatcheries. Recently, Hargis et al. (2014) reported that an infestation of *S. californiensis* concurrent with low water levels and warm temperatures was likely a primary cause of decline in adult kokanee in Eleven Mile Reservoir, Colorado. At this time there is no clear evidence that gill lice played a part in the decline of kokanee in Stave Reservoir after 2010. In fact, since gill lice were first noticed in 2011, mean kokanee condition factors have been the same (2011 and 2014) or significantly higher (2013, ANOVA,  $\alpha=0.05$ ,  $P=0.000$ ) than in previous years, which is uncharacteristic of severe *Salmincola* infestations (Pawaputanon 1980). However, if water temperatures increase in the future (e.g., due to global climate change), the impact of this parasite on kokanee and other fish in the community has the potential to increase.

### 5.3 Abundance and biomass of fish in Stave Reservoir compared to other water bodies

Estimates of fish biomass (kg/ha) from Stave Reservoir are low to intermediate compared to several other northwest lakes and reservoirs for which comparable data are available (Figure 37). Mean total biomass (species combined) for the ten years of the study was 5.9 kg/ha compared to 14.5-31.2 kg/ha in John Hart Reservoir (2010 and 2013, Stables and Perrin 2011, Stables et al. 2013) and Coquitlam Reservoir in 2004 (Bussanich et al. 2005), respectively. John Hart is an impoundment of the Campbell River on Vancouver Island that contains mainly Rainbow Trout, Cutthroat Trout, and Three-Spine Sticklebacks. Coquitlam Reservoir, in the Lower Fraser Valley, is dominated by non-salmonids. During this study mean kokanee biomass in Stave Reservoir was 3.4 kg/ha compared to 6.0 kg/ha in Lake Pend Oreille Idaho, in which kokanee are the predominant species (Bassista & Maiolie 2004 and 2005). Mean kokanee biomass in Alouette Reservoir, another kokanee dominated water body adjacent to Stave Reservoir, was 0.4 kg/ha in 1998 before fertilization, and 9.0 kg/ha from 2009-2012 during a fertilization program to enhance kokanee production (Harris et al. 2011, Hebert et al. 2013). Mean trout and char biomass (combined) in Stave Reservoir was 2.02 kg/ha during the study versus 1.36-12.78 kg/ha in Lake Pend Oreille, Ross Lake, and John Hart Reservoir in several years of study. Ross Lake is a US-

Canada transboundary reservoir on the Skagit River that is mainly inhabited by Rainbow Trout and Bull Trout (Loof 1992).

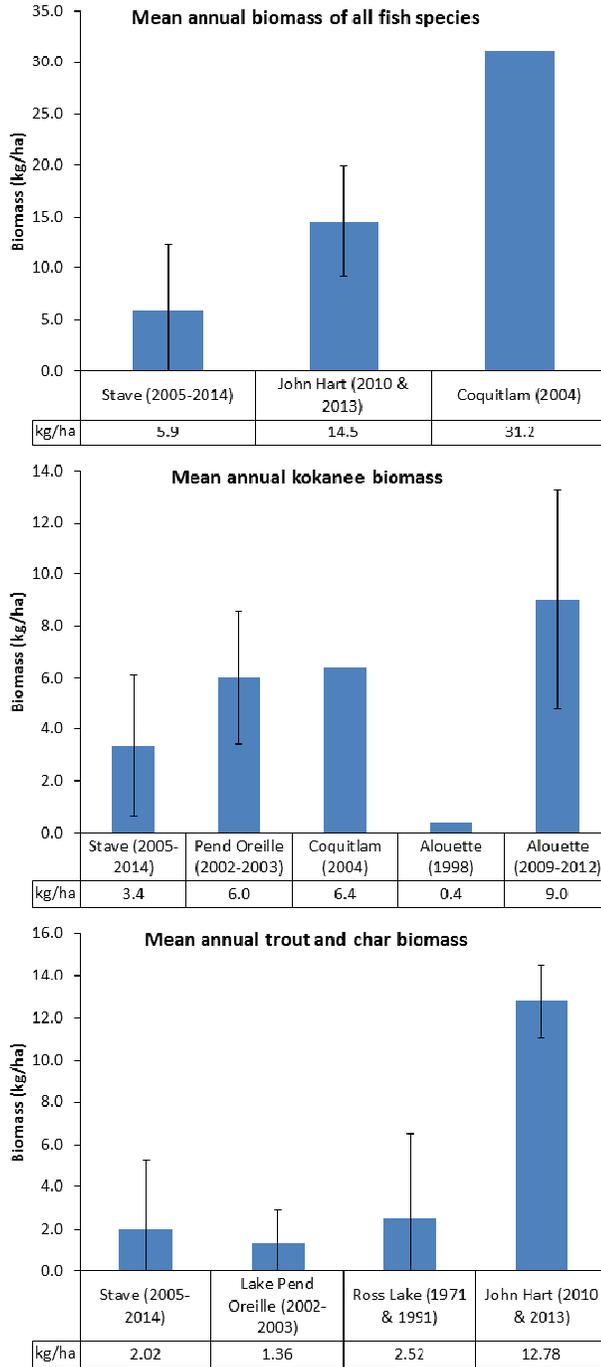


Figure 37. Mean annual fish biomass in Stave Reservoir and other selected northwest reservoirs, for species combined (upper), kokanee (middle), and combined trout and char (lower). Error bars are 2 standard deviations. Alouette 1998 and 2009-2012 are pre-fertilization and during fertilization periods. Pend Oreille includes only pelagic trout and char; Ross Lake data are approximations.

## **5.4 Sources of error and recommendations**

Knowledge gained during this study offers an opportunity to comment on some of its potential sources of error and to make recommendations that may be useful for planning similar studies in the future. The following paragraphs describe a number of factors that affected the quality of fish abundance and biomass estimates and our ability to test the hypotheses of interest.

### **5.4.1 Seasonal timing of surveys**

Surveys took place mid-September to mid-October to follow the period when previous studies suggested that mature kokanee would be migrating from the lake to spawn. It was speculated that abundance and biomass estimates based on the remaining juvenile kokanee age groups would allow more reliable inter-year comparisons. Unfortunately, starting in 2009 mature age-3 fish were commonly captured during our sampling, so this strategy was not effective. Therefore, late summer sampling when all kokanee age groups, including age-3, were consistently in the reservoir may have been a better time to sample the population. This timing may also have been better for sampling Bull Trout before their fall spawning migration into streams. This is another instance (as with natal stream effects above) when the minimal knowledge of the full life history of salmonids of Stave Reservoir hindered study objectives.

### **5.4.2 Alternate year gill netting strategy**

Only gill netting in alternate years and using each sample to represent more than one year (sharing data across years) greatly undermined monitoring of changes in the fish community, estimation of fish abundance and biomass, and testing of key hypotheses. It invalidated for statistical analysis all biomass estimates and species-specific abundance estimates in years without gill netting. Furthermore, it inhibited the tracking of cohort characteristics (e.g., length, weight, abundance) across years in relation to changing operational and environmental conditions. This loss of data greatly weakened the ability to describe changes in the fish community and test hypotheses, so experimental designs like this one that share data across years should not be used.

### **5.4.3 Level of gill netting effort**

Gill netting provided a great deal of useful biological information about the Stave Reservoir fish community, and the positive correlation between CPUE and acoustic estimates of abundance supported the use of species composition data from RISC gill netting for apportioning the acoustic estimates. In recent years a number of others have also shown that acoustics and gill netting can provide complementary data (e.g., Baldwin and McLellan 2008, Winfield et al. 2009, Emmrich et al. 2012). However, for several

species the amount of gill netting effort expended per year in this study (17-22 RISC net sets in most years) was insufficient to catch the minimum of 30 fish per species required to develop statistically useful length, weight, and age relationships (RIC 1997). This level of effort produced ample kokanee (well over 30 fish/year, Table 5), enough Cutthroat Trout sometimes (10-32 fish/year), and never enough Bull Trout (4-20 fish/year) or Rainbow Trout (1-8 fish/year). The experience of others (e.g., Butts 2004) also indicates that on the order of 20 sets/survey is a small number for a water body the size of Stave Reservoir. Based on our catch rates, the target sample size of 30 fish would have always been reached with an increase in effort of 300% (probably less) for Cutthroat Trout and 750% for Bull Trout. Improved efficiency through reallocation of effort among nearshore and offshore stations may have reduced these requirements somewhat. Catching 30 Rainbow Trout per year would have been impractical considering their rarity. Added effort would have also allowed more thorough spatial coverage (more stations and depths) that would have been advantageous. In this study, for large bodied species like cutthroat and Bull Trout where catches were small, a change in catch of a single fish could alter biomass estimates appreciably, meaning that small random differences in catch rates had a large effect on biomass estimates. This may explain the large increase in Bull Trout biomass from 2007 to 2009, which was strongly influenced by a pelagic catch of no Bull Trout in 2007 and one Bull Trout in 2009. Total biomass estimates were subject to the same type of error, since they were constructed from species-specific estimates. Considering the 30 fish per species requirement, the proportion of years with gill netting when biomass estimates were reliable was 1/6 for Cutthroat Trout, 0/6 for Rainbow Trout, 5/6 for kokanee, 0/6 for Bull Trout, 5/6 for Northern Pikeminnow, 4/6 for Peamouth, and 6/6 for Redside Shiner.

#### 5.4.4 Attraction of predators to prey in nets

Catch per unit effort (CPUE) in gill nets may, at times, have overestimated relative abundance of large predators such as cutthroat and Bull Trout. There are two plausible causes for this type of bias. First, large fish have higher cruising speeds and thus higher encounter rates with gill nets than smaller fish (Rudstam et al. 1984). We did not attempt to correct for this potential error. Second, piscivores may be attracted to fish tangled in nets (Lester et al. 2009). In 2007 we made dusk-night gill net sets, pulling the nets during darkness to minimize the opportunity for this bias, however, the difficult logistics of working on Stave Reservoir made this approach impractical and it was not followed thereafter. In later years we occasionally noticed large predators tangled in smaller than optimal mesh sizes among smaller fish, suggesting attraction. Since the number of large predators in the catch was always low but their mean body size was large compared to other species, overestimation of their relative abundance would have had a larger effect on biomass than on abundance estimates.

#### 5.4.5 Lack of trawl sampling

Lack of data from trawling had only a small effect on total and species specific biomass estimates. Although kokanee fry are often the predominant small pelagic fish in large, oligotrophic BC water bodies like Stave Reservoir; their fry typically make up a small fraction of kokanee biomass compared to older age groups with much greater mean body weight. Other species of small fish in the Stave system that are sometimes pelagic are Redside Shiners and Three-Spine Sticklebacks, of which only shiners were encountered during gill netting during this study (both nearshore and offshore). Redside Shiners are usually restricted to the upper water column (e.g., 0-5 or 0-10 m in Alouette Reservoir, Hebert et al. 2013), and our gill netting showed such a distribution for individuals of this species large enough to be caught in this gear (Figure 13). Even in 2009, the year of highest fish abundance 0-5 m when 86% of the whole-lake abundance estimate was fish <100 mm, fish of that size made up < 4% of total biomass, so any error in the assumption that all small fish were kokanee had a minor effect on biomass estimates.

#### 5.4.6 Precision of acoustic estimates

Precision of abundance estimates from acoustic surveys was satisfactory. Although the 5-8 acoustic transects that could be sampled in one night was minimal, variance among transects was small enough that precision of total annual fish abundance estimates was acceptable ( $\pm 14$ -30% of the total). Even so, use of an echo sounder with two transducers to allow simultaneous collection of down and side-looking data would have been advisable to increase survey efficiency, allowing sampling of more transects and requiring just one pass per transect rather than two. Efficiency is advisable on a water body the size of Stave Reservoir because it allows quick completion of sampling when weather conditions are good. Precision of biomass estimates was not computed because it was not necessary for regression or correlation analysis planned for testing key hypotheses, and because of its complexity.

#### 5.4.7 Horizontal stratification by habitat zones

Stratification of the sampling and analysis design into slope (nearshore) and pelagic (offshore) zones as recommended by Beachamp et al. (2009) improved the quality of abundance and biomass estimates. Gill net catches showed that nearshore and offshore fish assemblages existed with relatively stable boundaries over the years (~ the 40 m depth contour). Estimates made without use of this stratification (and without its requisite mid-lake gill netting) greatly underestimated pelagic fish abundance and biomass and overestimated those metrics for slope zone fish. For example, in 2005 kokanee comprised 67% of the stratified biomass estimate versus 13% of the unstratified estimate. The values obtained using stratification were in keeping with the large percentage of the study area that was pelagic zone greatly dominated by kokanee.

#### **5.4.8 Acoustic sampling effort in the slope and pelagic zones**

The chosen acoustic survey design used cross-lake transects where each transect included both the slope and pelagic zones. This was efficient for sampling the whole lake in one night, but it gave little coverage in the slope zone (< 40 m depth contour). A design with cross-lake transects and supplementary transects in the slope zone, such as by zigzags along the shore, would have been a better design for measuring effects of Combo 6, with its greatest effect expected near shore. Supplementary nearshore transects would have required an additional night of sampling.

#### **5.4.9 The need for side-looking acoustic sampling**

Side-looking sampling of the 0-5 m range of the water column was problematic due to its requirement for calm conditions. However, in this multi-species study side-looking observations were necessary for adequate assessment of trout and other species occupying the epilimnion. Improved survey efficiency through use of a dual transducer system for simultaneous down and side-looking data collection would have made side-looking sampling more effective. Using a higher data processing threshold (e.g., -55 dB rather than -65 dB) would have allowed sampling in slightly rougher conditions, but would have excluded more small fish from abundance estimates and often would not have helped. Sampling earlier in the season may have offered more frequent calm weather than the chosen sampling period, although night outflow winds are common in all seasons on many large lakes near mountains. A realistic acoustic sampling plan would include at least one day allowance per year for bad weather to accommodate data quality and safety considerations.

#### **5.4.10 Estimation of fish size in the uppermost water column**

In the upper 10 m of the water column, the sample size for estimating the size distribution of fish was always small. Target strength data from the down-looking transducer were used to apportion the acoustic estimate into fish with TS < -46.9 dB (< ~ 100 mm length) and  $\geq$  -46.9 dB (> ~ 100 mm length) in each 5 m depth interval of the water column. The number of TS measurements above 10 m where the down-looking beam was very narrow was always undesirably small, leading to less reliable size composition estimates in the 0-5 m and 5-10 m layers. This depth range represented the epilimnion and mostly affected estimates of fish that mainly occupied that zone, including trout and Redside Shiners. The situation could only have been improved with increased down-looking sampling or the addition of up-looking sampling.

#### **5.4.11 Effectiveness of acoustics for the species present**

The effectiveness of mobile acoustic sampling varied among fish species in Stave Reservoir. Mobile acoustic sampling is ineffective for benthic and littoral fish species, so suckers and sculpins were excluded from our abundance and biomass

estimates based on their mainly nearshore and benthic distribution in the gill net catch. Abundance and biomass of semi-pelagic species that were somewhat associated with the lake bottom (Cutthroat Trout, Bull Trout, Northern Pikeminnow, Peamouth, and Redside Shiner) were no doubt minimum estimates. Cutthroat Trout showed some association with the bottom and shore, but were often found away from shore in the epilimnion or midwater layers, even at mid-lake gill net stations, so they were quite accessible to acoustics. Bull Trout were often found at mid-depths both near the bottom and at mid-lake stations, so they were also fairly accessible to acoustics. Bull Trout seem to be adaptable in their behavior and their degree of benthic association differs among lakes. For example, Bassista et al. (2005) concluded that Bull Trout in Lake Pend Orielle were too benthic in habits for reliable acoustic assessment, whereas, Bull Trout in Seton and Anderson Lakes, BC, were highly pelagic during summer and fall 2014 (St'at'imc EcoResources Ltd. 2015). For Stave Reservoir, an acoustic survey design with more sampling in the slope zone would probably have better assessed cutthroat and Bull Trout.

#### **5.4.12 Logistics of acoustics and gill netting on Stave Reservoir**

Although many potential challenges were anticipated before field work began, especially difficult access to the study site, frequently unfavorable weather, night operations, and the many aquatic hazards of the reservoir, made the sampling required for this study especially difficult. Weather was considered good for side-looking acoustic sampling (mostly calm and smooth, 75% of side-looking data usable) in only five of ten years. Gill nets were frequently torn by submerged trees and woody debris on the lake bottom and often required extensive repairs. The lack of accommodations on or close to the reservoir coupled with a 10 km long shallow, snag obstructed channel to the study area that had to be negotiated in both directions each day greatly added to field time. In the three years when the gill net crew was able to base operations out of the Zajac Ranch the trip through the channel was reduced to 5 km, and logistics were generally much improved. Future studies of this type on Stave Reservoir can best address these issues by maximizing survey efficiency (e.g., using a dual transducer echo sounder) and allowing more time for safe operations and the collection of high quality data than is necessary on more hospitable water bodies.

## 6 LITERATURE CITED

- Andrusak, H., and T. G. Northcote. 1971. Segregation between adult cutthroat trout (*Salmo clarki*) and Dolly Varden (*Salvelinus malma*) in small coastal British Columbia lakes. *Journal of the Fisheries Research Board of Canada* 28:1259-1268.
- Baldwin, C.M., and J.G. McLellan. 2008. Use of gill nets for target verification of a hydroacoustic fisheries survey and comparison with kokanee spawner escapement estimates from a tributary trap. *North American Journal of Fisheries Management* 28:1744-1757.
- Bassista, T. P., and M. A. Maiolie. 2004. Lake Pend Oreille predation research: Annual progress report, April 1, 2002—March 31, 2003. Idaho Department of Fish and Game Report Number 04-10.
- Bassista, T. P., M.A. Maiolie, and M.A. Duclos. 2005. Lake Pend Oreille predation research: Annual progress report, March 1, 2003 - February 29, 2004. Idaho Department of Fish and Game Report Number 05-04.
- BC Hydro, 2013. Generation Operating Order Stave Falls Project sfn 4G-46 v.2.12. BC Hydro Generation Operating Order. 25 October 2013.
- Beauchamp, D. A., D. L. Parrish, and R. A. Whaley. 2009. Sampling coldwater fish in large standing waters. Pages 97-118 in *Standard Sampling Methods for North American Freshwater Fishes*. S. A. Bonar, W. A. Hubert, and D. Willis (eds.). American Fisheries Society, Bethesda, Maryland.
- Bentley, K.T. and D.E. Schindler. 2013. Body condition correlates with instantaneous growth in stream-dwelling rainbow trout and Arctic Grayling. *Transactions of the American Fisheries Society*. 142: 747-755.
- Brandt, S. B. 1996. Acoustic assessment of fish abundance and distribution. Pages 385-432 in *Fisheries Techniques*, 2nd edition. L.A. Nielsen and D.L. Johnson (eds.). American Fisheries Society, Bethesda, Maryland.
- Bruce, J. A., T. L. Slaney, and R. J. Fielden. 1994. Stave Lake baseline fisheries study and enhancement recommendations. Report from Aquatic Resources Limited to BC Hydro.
- Burgner, R. L. 1991. Life history of sockeye salmon. In Groot and Margolis, eds., *Pacific Salmon Life Histories*. UBC Press, Vancouver.
- Bussanich, R., B. Murray, and R. Bocking. 2005. Assessment of fish population and lakeshore spawning habitat in Coquitlam Reservoir – Year 1: Studies to address fish population and reservoir ecology, 2004. BCRP Report No. 04.Co.03.

- Butts, A. E. 2004. Project 5, lake and reservoir research, Grant F-73-R-26, Annual Performance Report, July 1, 2003 to June 30, 2004. Idaho Fish and Game report number 04-46, 85 pages.
- CCME. 2003. Canadian environmental quality guidelines: update 3.2. Canadian Council of Ministers of Environment. Winnipeg. Manitoba.
- Cochran, W. G. 1977. Sampling Techniques. 3rd edition. Wiley and Sons, New York.
- Crockett, H. J., B. M. Johnson, P. J. Martinez, and D. Brauch. 2006. Modeling target strength distributions to improve hydroacoustic estimation of lake trout population size. Transactions of the American Fisheries Society 135:1095-1108.
- Failing, L. 1999a. Stave River Water Use Plan: Report of the consultative committee. Prepared by Compass Resource Management Ltd for BC Hydro. October 1999. 44 pp. + App.
- Failing, L. 1999b. Stave/Hayward Reservoir monitor summary. Appendix 7 of Stave River Water Use Plan: Report of the consultative committee. Prepared by Compass Resource Management Ltd for BC Hydro. 4 pp.
- Gall, G. A. E., E. L. McClendon, and W. E. Schafer (1972): Evidence on the influence of the copepod (*Salmincola californiensis*) on the reproductive performance of a domesticated strain of rainbow trout (*Salmo gairdneri*), Transactions of the American Fisheries Society, 101:2, 345-346.
- Groot, C., and L. Margolis. 1991. Pacific Salmon Life Histories. UBC Press, Vancouver.
- Hargis, L.N., Lepak, J.M., Vigil, E.M., and Gunn, C. 2014. Prevalence and intensity of the parasitic copepod (*Salmincola californiensis*) on kokanee salmon (*Oncorhynchus nerka*) in a Colorado reservoir. Southwestern Naturalist 59-126:129.
- Harris, S.L., A.Cruickshank, T. Weir, D. Sebastian, G. Andrusak, H. Andrusak, L. Vidmanic, & N.E. Down. 2011. The Alouette Reservoir nutrient restoration program, 2009-2010. Fisheries Project Report No. RD130. BC Ministry of Environment, Ecosystem Sustainability and Protection Branch, 93 p.
- Hebert, A.S., S.L. Harris, G. Andrusak, H. Andrusak, L. Vidmanic, T. Weir, D. Johner, and N.E. Down. 2013. Alouette Reservoir nutrient restoration project 2011-2012. BC Ministry of Environment Fisheries Project Report No. RD141.
- Hyatt, K.D., and J.G. Stockner. 1985. Responses of sockeye salmon (*Oncorhynchus nerka*) to fertilization of British Columbia coastal lakes. Canadian Journal of Fisheries and Aquatic Science. 42: 320-331.
- Johnston, J. M. 1981. Development and evaluation of hydroacoustic techniques for instantaneous fish population estimates in shallow lakes. Washington Department of Game Fishery Research Report No. 81-18, Olympia.

- Johnston, N. T., M. D. Stamford, K. I. Ashley, and K. Tsumura. 1999. Responses of rainbow trout (*Oncorhynchus mykiss*) and their prey to fertilization of an oligotrophic montane lake. *Can. J. Fish. Aquatic. Sci.* 56:1011-1025.
- Kabata, Z., and B. Cousens. 1977. Host-parasite relationships between sockeye salmon, *Oncorhynchus nerka*, and *Salmincola californiensis* (Copepoda: Lernaepodidae). *J. Fish. Res. Board Can.* 34: 191-202.
- Keiser, R., and T. J. Mulligan. 1984. Analysis of echo counting data: A model. *Canadian Journal of Fisheries and Aquatic Sciences* 41:451-458.
- Lester, N. P., P. E. Bailey, and W. A. Hubert. 2009. Coldwater fish in small standing waters. Pages 97-118 in *Standard Sampling Methods for North American Freshwater Fishes*. S. A. Bonar, W. A. Hubert, and D. Willis (eds.). American Fisheries Society, Bethesda, Maryland.
- Loof, A. C. 1992. Ross Lake rainbow trout study 1990-1991 progress report. Washington Department of Fish and Wildlife report 92-15. 95p.
- Love, R. H. 1977. Target strength of an individual fish at any aspect. *Journal of the Acoustical Society of America* 62:1397-1403.
- Emmrich, M., I. J. Winfield, J. Guillard, A. Rustadbakken, C. Verges, P. Volta, E. Jeppesen, T. Lauridsen, S. Brucet, K. Holmgren, C. Argillier, and T. Mehner. 2012. Strong correspondence between gillnet catch per unit effort and hydroacoustically derived fish biomass in stratified lakes. *Freshwater Biology* 57:2436-2448.
- McPhail, J. D. 2007. *The Freshwater Fishes of British Columbia*. The University of Alberta Press, Edmonton, Alberta.
- Neff, B.D. and L. M. Cargnelli. 2004. Relationships between condition factors, parasite load and paternity in bluegill sunfish, *Lepomis macrochirus*. *Environmental Biology of Fishes* 71: 297-304.
- Nilsson, N. A., and T. G. Northcote. 1981. Rainbow trout and cutthroat trout interactions in coastal British Columbia lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 38:1228-1246.
- Norris, J. G., and J. A. Balkwill. 1987. Summary report: Reconnaissance level aquatic biophysical inventory of the tributaries of Stave Lake. MELP habitat division manuscript. 17p.
- Ostberg, C.O. and R.J. Rodriguez. 2002. Novel molecular markers differentiate *Oncorhynchus mykiss* (rainbow trout and steelhead) and the *O. clarki* (cutthroat trout) subspecies. *Mol. Ecol. Notes* 2: 197-202.
- Ostberg, C.O. and R.J. Rodriguez. 2004. Bi-parentally inherited species-specific markers identify hybridization between rainbow trout and cutthroat trout subspecies. *Mol. Ecol. Res.* 4:26-29.

- Parker-Stetter, S.L., Rudstam, L.G., Sullivan, P.J. and Warner, D.M. 2009. Standard operating procedures for fishery acoustics in the Great Lakes. Great Lakes Fisheries Commission Special Publication 09-01. 180 pp. Available at: [http://www.glf.org/pubs/SpecialPubs/Sp09\\_1.pdf](http://www.glf.org/pubs/SpecialPubs/Sp09_1.pdf).
- Pawaputanon, K. 1980. Effects of parasitic copepod *Salmincola californiensis* on juvenile sockeye salmon *Oncorhynchus nerka*. PhD. Thesis, Department of Zoology, University of British Columbia. 181 pages.
- Perrin, C.J., M.L. Rosenau, T.B. Stables, and K.I. Ashley. 2006. Restoration of a montane reservoir fishery via biomanipulation and nutrient addition. *North American Journal of Fisheries Management*. 26: 391-407.
- Quinn, T.P. 2005. The behavior and ecology of Pacific salmon and trout. American Fisheries Society, Bethesda.
- Redenbach, Z. and E.B. Taylor 2003. Evidence for bimodal hybrid zones between two species of char (*Salvelinus*) in northwestern North America. *J. Evol. Biol.* 16(6): 1135-1148.
- Regional Consulting Ltd. 2000. Bridge-Coastal Fish and Wildlife Restoration Program Strategic Plan. 2 vols. Prepared for B.C. Fisheries and Ministry of Environment, Lands and Parks., Fisheries and Oceans Canada., and B.C. Hydro. 393 pages.
- RIC. 1997. Fish Collection Methods and Standards. Prepared by the B.C. Ministry of Environment, Lands and Parks, Fish Inventory Unit for the Aquatic Ecosystems Task Force, Resources Inventory Committee (RIC).
- Rudstam, L.G., J. J. Magnuson, and W. M. Tonn. 1984. Size selectivity of passive fishing gear: A correction for encounter probability applied to gill nets. *Canadian Journal of Fisheries and Aquatic Sciences* 41:1252-255.
- Shortreed, K.S., J.M.B. Hume, and J.G. Stockner. 2000. Using photosynthetic rates to estimate the juvenile sockeye salmon rearing capacity of British Columbia Lakes. In: *Sustainable Fisheries Management: Pacific Salmon*. Ed by E.E. Knudsen, C.R. Steward, D. MacDonald, J.E. Williams, and D.W. Reiser. Pp: 505-521.
- Slaney, T.L. 1989. Fisheries enhancement opportunities in reservoirs of the British Columbia Lower Mainland. Prep. By Aquatic Resources :td. For B.C. Hydro, Vancouver, B.C. 56 pp.
- Simmonds, E. J., and D. N. MacLennan. 2005. *Fisheries Acoustics*. Chapman and Hall, London.
- Sokal, R. R., and F. J. Rohlf. 1969. *Biometry*. W. H. Freeman and Company, San Francisco.
- St'at'imc EcoResources Ltd. 2015. Seton Lake aquatic productivity monitoring (BRGMON6): Progress in 2014-2015. Report prepared by Limnotek Research and Development Inc. on behalf of St'at'imc EcoResources Ltd. for BC Hydro.

- Stables, T. B., and C. J. Perrin. 2004. Abundance and distribution of fish in Duncan Lake at the Kemess Mine: A detailed survey using acoustic technology. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for Hatfield Consultants Ltd. 38p.
- Stables, T. B., and C. J. Perrin. 2006. Abundance and biomass of fish in Stave Reservoir during fall 2005. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 61p.
- Stables, T. B., and C. J. Perrin. 2007. Abundance and biomass of fish in Stave Reservoir in September 2006. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 43p.
- Stables, T. B., and C. J. Perrin. 2008. Abundance and biomass of fish in Stave Reservoir in October 2007. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 55p.
- Stables, T. B., and C. J. Perrin. 2009. Abundance and biomass of fish in Stave Reservoir in October 2008. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 55p.
- Stables, T. B., and C. J. Perrin. 2010. Abundance and biomass of fish in Stave Reservoir in September 2009. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 58p.
- Stables, T. B., and C. J. Perrin. 2011. Abundance and biomass of fish in Stave Reservoir in September 2010. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 17p.
- Stables, T. B., and C. J. Perrin. 2012a. Abundance and biomass of fish in Stave Reservoir in fall 2011. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 34 p.
- Stables, T. B., and C. J. Perrin. 2012b. Abundance and biomass of fish in Stave Reservoir in October 2012. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 21 p.
- Stables, T. B., and C. J. Perrin. 2014. Abundance and biomass of fish in Stave Reservoir in fall 2013. Draft report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 34 pages.
- Stables, T. B., E. B. Taylor, and C. J. Perrin. 2013. John Hart Entrainment Action Plan Monitoring Study 1: John Hart Reservoir fish stock and genetics assessment in August 2013. Draft report prepared by Limnotek Research and Development Inc. for BC Hydro. 61p.
- Stables, T. B., and G. L. Thomas. 1992. Acoustic measurement of trout distributions in Spada Lake, Washington, using stationary transducers. *Journal of Fish Biology* 40:191-203.

- Stables, T. B., G.L. Thomas, S.L. Thiesfeld, G.B. Pauley, and M.A. Wert. 1990. Effects of reservoir enlargement and other factors on the yield of wild rainbow and cutthroat trout in Spada Lake, Washington. *North American Journal of Fisheries Management* 10:305-314.
- Stockner, J. G. and J. Beer. 2004. The limnology of Stave/Hayward reservoirs: with a perspective on carbon production. Prepared for BC Hydro Water Use Plans by Eco-logic Ltd. and University of British Columbia, Institute For Resources, Environment and Sustainability, Vancouver. 33 pp. + App.
- Sutherland, D. R., and D. D. Wittrock. 1985. Effects of *Salmincola californiensis* (Copepoda: Lernaepodidae) on the gills of farm-raised rainbow trout, *Salmo gairdneri*. *Canadian Journal of Zoology* 63:2893–2901.
- Thorne, R. E. 1983. Hydroacoustics. Pages 239-260 in *Fisheries Techniques*. L. Nielsen, and D. Johnson (eds.). American Fisheries Society, Bethesda, Maryland.
- Thorne, R.E. and J.J. Ames. 1987. A note of variability of marine survival of sockeye salmon (*Onchorhynchus nerka*) and effects of flooding on spawning success. *Canadian Journal of Fisheries and Aquatic Sciences* 44:1791-795.
- Winfield I.J., Fletcher J.M., James J.B. & Bean C.W. 2009. Assessment of fish populations in still waters using hydroacoustics and survey gill netting: Experiences with Arctic charr (*Salvelinus alpinus*) in the UK. *Fisheries Research* 96:30–38.
- Yule, D. L. 2000. Comparison of horizontal acoustic and purse-seine estimates of salmonid densities and sizes in eleven Wyoming waters. *North American Journal of Fisheries Management* 20:759-775.

## **7 DATA APPENDICES**

**7.1 Minnow trap data**

Catch, effort, and CPUE (catch per trap-hour) of minnow traps set during the 2005-2014 Stave Reservoir fish biomass study. Traps were only set in 2005 and 2007 and only at nearshore stations where they were fished concurrently with gill nets.

Year	Station	Sampling period	Depth Range (m)	Trap-hours	No. of traps	Catch and CPUE by fish species												Species combined	
						Juvenile Salmonids		Peamouth		Northern Pikeminnow		Prickly Sculpin		Redside shiner					
						Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
2005	north	daytime	4-13	28	5	0	0	0	0	0	0	18	0.64	3	0.11	21	0.75		
"	"	overnight	3-6	24.1	1	0	0	1	0.04	1	0.04	0	0	0	0	2	0.08		
"	"	Total catch and mean CPUE	3-13	52.1	6	0	0	1	0.02	1	0.02	18	0.35	3	0.06	23	0.44		
"	south	daytime	6-15	20.1	4	0	0	2	0.1	5	0.25	23	1.15	0	0	30	1.49		
"	"	overnight	4-5	45.5	2	0	0	0	0	6	0.13	7	0.15	1	0.02	14	0.31		
"	"	Total catch and mean CPUE	6-15	65.6	6	0	0	2	0.03	11	0.17	30	0.46	1	0.02	44	0.67		
"	"	Total catch and mean CPUE for stations & periods combined	3-15	117.7	12	0	0	3	0.03	12	0.1	48	0.41	4	0.03	67	0.57		
2007	North	Overnight	1.0-6.0	74.7	12	0	0	0	0	6	0.08	3	0.04	5	0.07	14	0.19		
"	South	"	0.5-6.3	35.3	12	1	0.03	0	0	13	0.37	5	0.14	1	0.03	20	0.57		
"	"	Total catch and mean CPUE for stations & periods combined	0.5-6.3	110	24	1	0.01	0	0	19	0.17	8	0.07	6	0.06	34	0.31		

## 7.2 Gill net CPUE during this and earlier studies of Stave Reservoir

Gill net CPUE from the 2004-2014 fish biomass study compared to CPUE from earlier studies of Stave Reservoir. CPUE was standardized to Fish · 100 m<sup>-2</sup> · 24 hours<sup>-1</sup> and the general location and period of sets, when known, is described.

Survey details	CPUE (fish · 100 m <sup>-2</sup> · 24 hours <sup>-1</sup> )									Total
	C. Trout	R. Trout	Kokanee	B. Trout	L. Sucker	Pikeminnow	Peamouth	R. Shiner	B. bullhead	
July-1987 <sup>a</sup>	1.74	0.15	3.63	1.16	1.16	12.50	0.00	9.58	0.00	29.9
July-1988 <sup>b</sup>	0.15	0.10	1.49	0.36	0.00	1.08	0.00	0.05	0.00	3.2
Sept-1993 <sup>c</sup>	0.32	1.28	1.61	0.32	11.08	60.35	0.00	2.89	0.96	78.8
Sept-2005 day, nearshore <sup>d</sup>	1.00	0.00	1.00	1.00	0.25	2.49	0.25	0.75	0.00	6.7
Sept-2005 overnight, nearshore <sup>d</sup>	1.06	0.19	2.13	1.06	6.95	11.59	2.61	10.63	0.00	36.2
Oct-2007 night, nearshore <sup>d</sup>	1.13	0.16	4.68	0.65	5.33	8.56	1.45	10.66	0.00	32.6
Oct-2007 night, mid-lake <sup>d</sup>	0.76	0.00	3.31	0.00	0.00	0.25	0.00	0.00	0.00	6.4
Sept-2009 overnight, nearshore <sup>d</sup>	0.79	0.00	4.41	0.21	2.05	4.98	3.10	3.88	0.00	19.4
Sept-2009 overnight, mid-lake <sup>d</sup>	1.16	0.00	5.05	0.07	0.00	0.55	0.00	0.55	0.00	7.4
Sept-2011 overnight, nearshore <sup>d</sup>	1.04	0.05	1.79	0.66	0.80	2.82	2.45	3.81	0.00	13.9
Sept-2011 overnight, mid-lake <sup>d</sup>	0.26	0.45	5.11	0.13	0.00	0.06	0.19	0.65	0.00	6.9
Oct-2013 overnight, nearshored	0.92	0.07	1.13	0.35	3.73	1.90	3.52	4.23	0.00	15.9
Oct-2013 overnight, mid-laked	0.66	0.00	3.35	0.12	0.00	0.06	0.00	0.42	0.00	4.6
Oct-2014 overnight, nearshore <sup>d</sup>	0.59	0.04	2.75	0.80	1.52	3.59	2.79	3.46	0.00	15.6
Oct-2014 overnight, mid-lake <sup>d</sup>	0.85	0.00	4.79	0.08	0.00	0.31	0.00	0.23	0.00	6.3

<sup>a</sup> Source: Norris and Balkwill 1987 in Bruce et al. 1994.

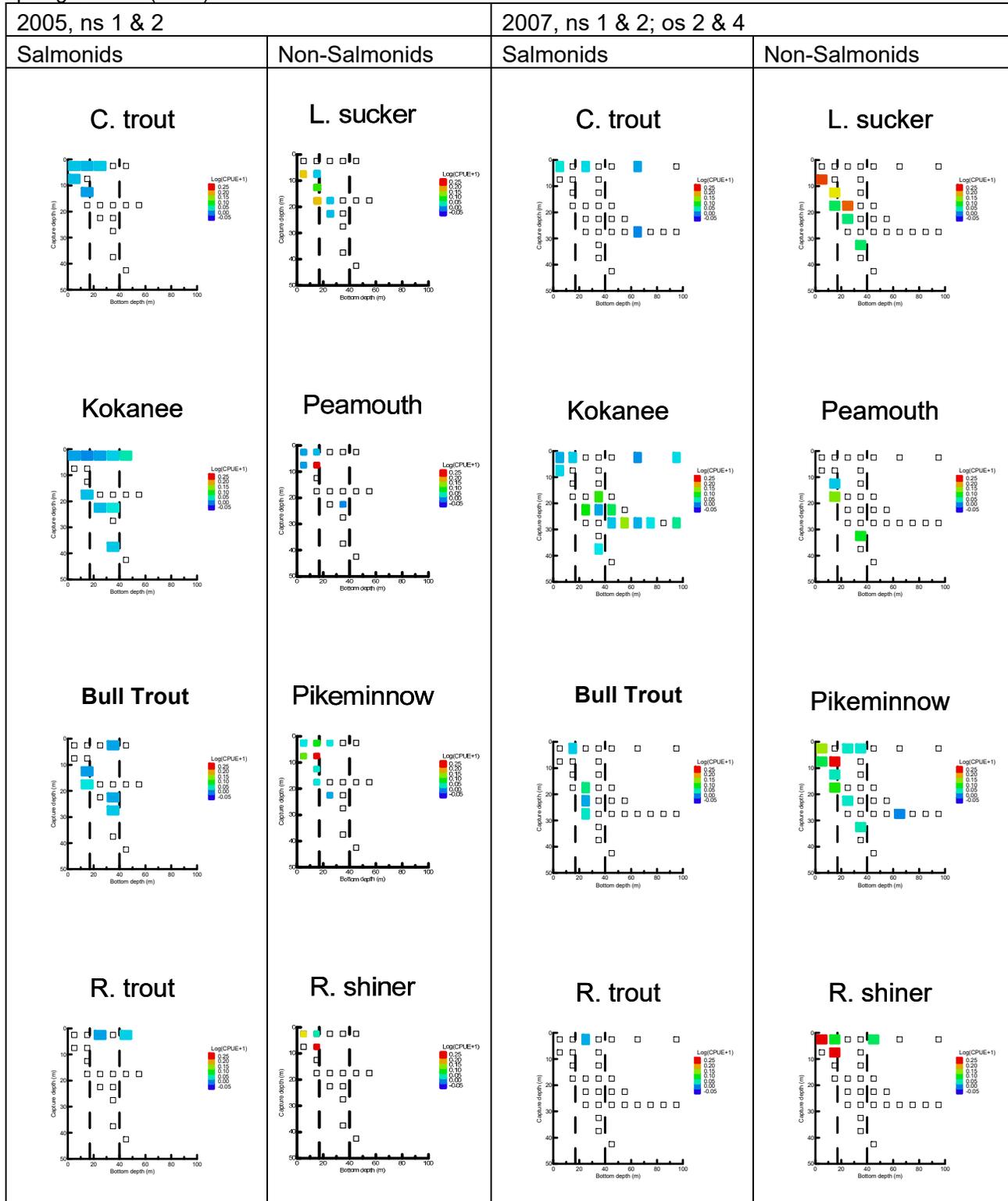
<sup>b</sup> Source: B. Gadbois, B.C. Hydro, personnel communication in Bruce et al. 1994. Targeted open water areas.

<sup>c</sup> Source: Bruce et al. 1994. Targeted timber and debris choked areas.

<sup>d</sup> Source: This study, where sampling was in the main lake basin, away from debris choked areas. Nearshore means all sets that were not in the middle of the lake, including gangs of midwater nets that extended up to 2-3 net lengths out from their point of contact with the lake bottom.

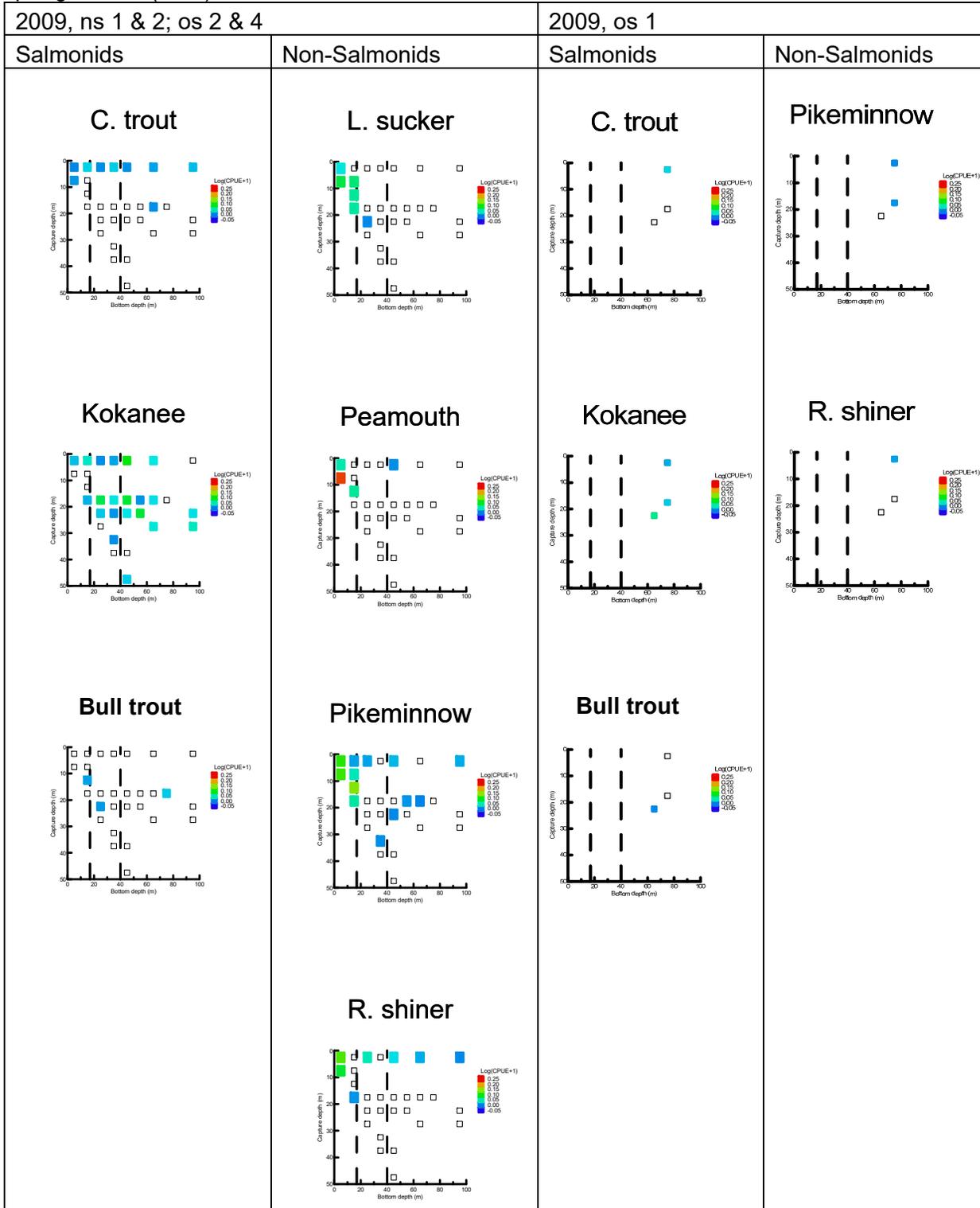
7.3 CPUE vs bottom and capture depths by year of gill netting

2005 & 2007 SURVEYS: Mean CPUE in RISC gill nets versus depth of capture and water column depth, Stave Reservoir Fish Biomass Study. CPUE =  $\log_{10}(\text{catch per panel-hour}+1)$ . Empty boxes indicate panels with no catch. Vertical dashed lines indicate the typical shoreward limit of acoustic coverage (17 m bottom depth) and the boundary between slope and pelagic zones (40 m).



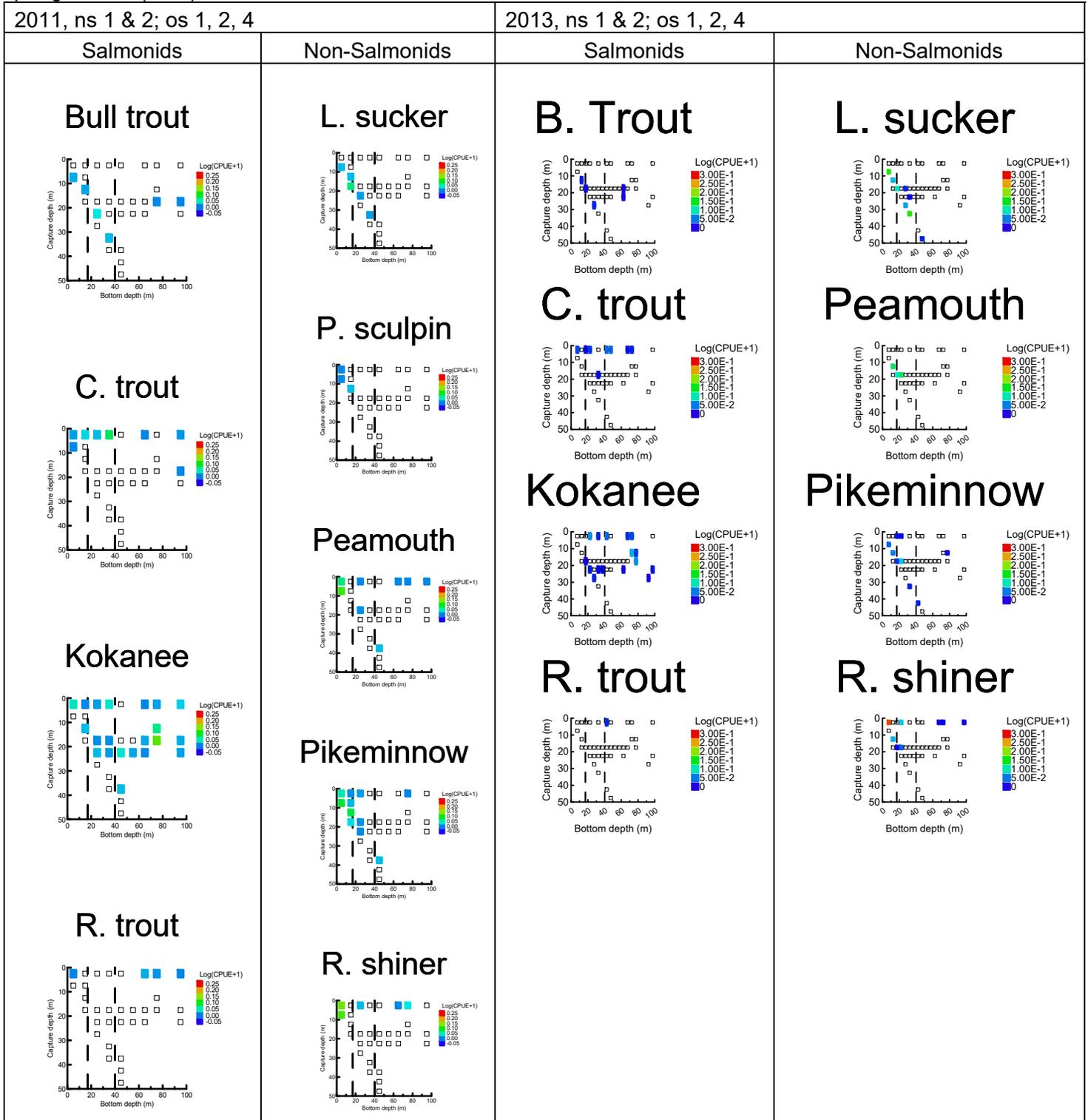
**7.3 (cont) CPUE vs bottom and capture depths by year of gill netting**

**2009 SURVEY:** Mean CPUE in RISC gill nets versus depth of capture and water column depth, Stave Reservoir Fish Biomass Study. CPUE =  $\log_{10}(\text{catch per panel-hour}+1)$ . Empty boxes indicate panels with no catch. Vertical dashed lines indicate the typical shoreward limit of acoustic coverage (17 m bottom depth) and the boundary between slope and pelagic zones (40 m).



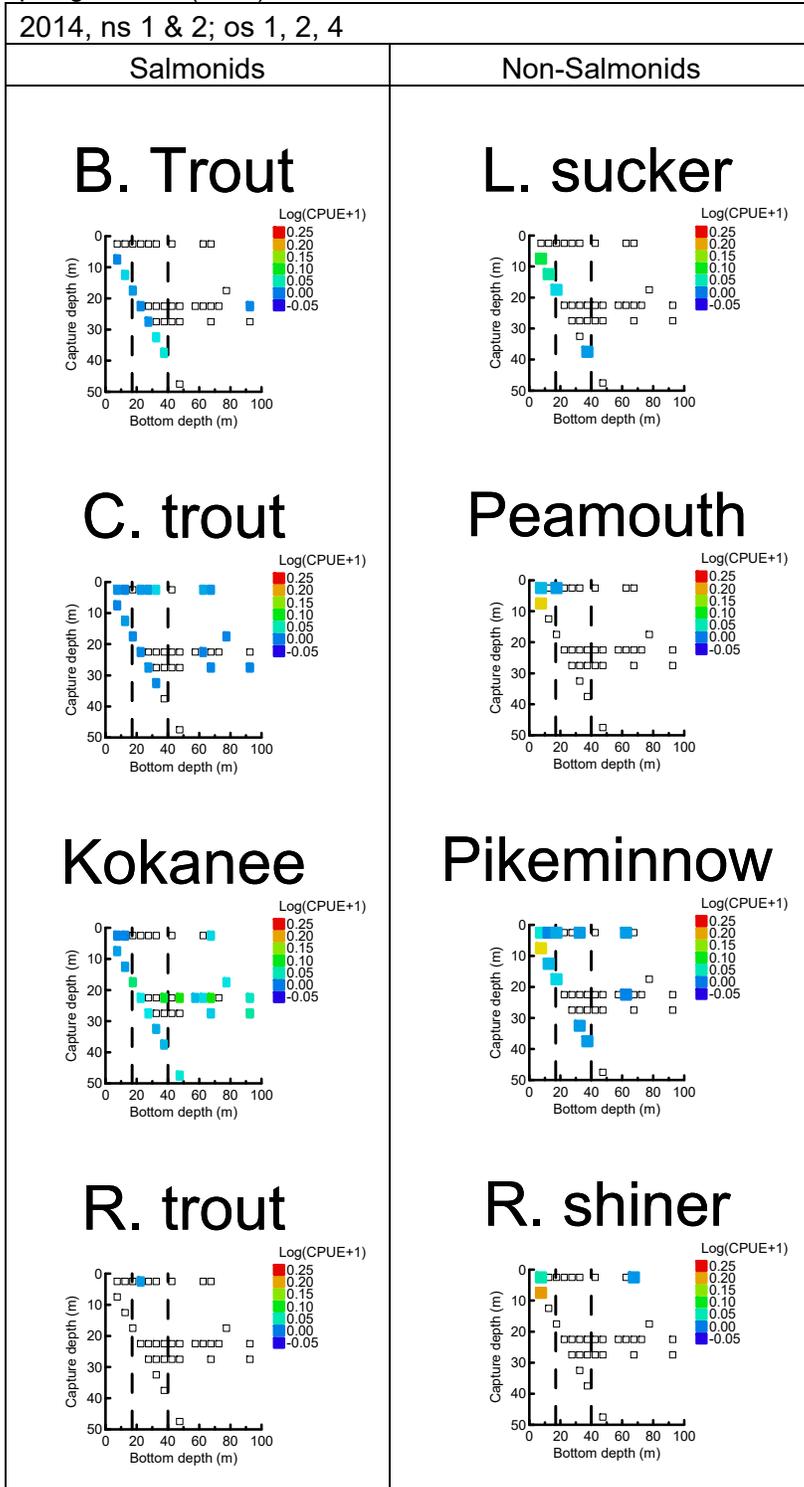
**7.3 (cont) CPUE vs bottom and capture depths by year of gill netting**

2011 & 2013 SURVEYS: Mean CPUE in RISC gill nets versus depth of capture and water column depth, Stave Reservoir Fish Biomass Study. CPUE =  $\log_{10}(\text{catch per panel-hour}+1)$ . Empty boxes indicate panels with no catch. Vertical dashed lines indicate the typical shoreward limit of acoustic coverage (17 m bottom depth) and the boundary between slope and pelagic zones (40 m).



**7.3 (cont) CPUE vs bottom and capture depths by year of gill netting**

**2014 SURVEY:** Mean CPUE in RISC gill nets versus depth of capture and water column depth, Stave Reservoir Fish Biomass Study. CPUE =  $\log_{10}(\text{catch per panel-hour}+1)$ . Empty boxes indicate panels with no catch. Vertical dashed lines indicate the typical shoreward limit of acoustic coverage (17 m bottom depth) and the boundary between slope and pelagic zones (40 m).



## 7.4 Annual species composition estimates for acoustic apportionment

Year	Zone	Depth	C. Trout	R. Trout	Kokanee	Bull Trout	N. Pikeminnow	Peamouth	R. Shiner	Total
2005	slope	0-5 m	22.22%	5.56%	38.89%	5.56%	27.78%	0.00%	0.00%	100%
2005	slope	5-10 m	22.22%	5.56%	38.89%	5.56%	27.78%	0.00%	0.00%	100%
2005	slope	10-15 m	11.11%	2.78%	30.16%	24.21%	31.75%	0.00%	0.00%	100%
2005	slope	15-20 m	0.00%	0.00%	21.43%	42.86%	35.71%	0.00%	0.00%	100%
2005	slope	20-25 m	0.00%	0.00%	64.71%	17.65%	11.76%	5.88%	0.00%	100%
2005	slope	25-30 m	0.00%	0.00%	25.00%	50.00%	25.00%	0.00%	0.00%	100%
2005	slope	30-35 m	0.00%	0.00%	25.00%	50.00%	25.00%	0.00%	0.00%	100%
2005	slope	35-40 m	0.00%	0.00%	25.00%	50.00%	25.00%	0.00%	0.00%	100%
2005	pelagic	0-5 m	0.00%	33.33%	66.67%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	5-10 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	10-15 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	15-20 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	20-25 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	25-30 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	30-35 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	35-40 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	40-45 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	45-50 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	50-55 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	55-60 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	60-65 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	65-70 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	70-75 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2005	pelagic	75-80 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	slope	0-5 m	25.00%	12.50%	0.00%	12.50%	50.00%	0.00%	0.00%	100%
2007	slope	5-10 m	12.50%	6.25%	0.00%	6.25%	25.00%	50.00%	0.00%	100%
2007	slope	10-15 m	0.00%	0.00%	6.25%	0.00%	18.75%	75.00%	0.00%	100%
2007	slope	15-20 m	0.00%	0.00%	12.50%	0.00%	37.50%	50.00%	0.00%	100%
2007	slope	20-25 m	0.00%	0.00%	64.29%	14.29%	21.43%	0.00%	0.00%	100%
2007	slope	25-30 m	0.00%	0.00%	21.43%	38.10%	18.25%	22.22%	0.00%	100%
2007	slope	30-35 m	0.00%	0.00%	0.00%	0.00%	33.33%	66.67%	0.00%	100%
2007	slope	35-40 m	0.00%	0.00%	0.00%	0.00%	33.33%	66.67%	0.00%	100%
2007	pelagic	0-5 m	50.00%	0.00%	50.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	5-10 m	25.00%	0.00%	75.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	10-15 m	13.00%	0.00%	87.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	15-20 m	2.08%	0.00%	95.83%	0.00%	2.08%	0.00%	0.00%	100%
2007	pelagic	20-25 m	2.08%	0.00%	95.83%	0.00%	2.08%	0.00%	0.00%	100%
2007	pelagic	25-30 m	2.08%	0.00%	95.83%	0.00%	2.08%	0.00%	0.00%	100%
2007	pelagic	30-35 m	2.08%	0.00%	95.83%	0.00%	2.08%	0.00%	0.00%	100%
2007	pelagic	35-40 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	40-45 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	45-50 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	50-55 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	55-60 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	60-65 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	65-70 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	70-75 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2007	pelagic	75-80 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%

**7.4 (cont) Annual species composition estimates for acoustic apportionment**

Year	Zone	Depth	C. Trout	R. Trout	Kokanee	B. Trout	N. Pikeminnow	Peamouth	R. Shiner	Total
2013	slope	0-5 m	17.24%	0.00%	31.03%	0.00%	13.79%	0.00%	37.93%	100%
2013	slope	5-10 m	8.82%	0.00%	17.65%	0.00%	17.65%	29.41%	26.47%	100%
2013	slope	10-15 m	2.44%	0.00%	7.32%	2.44%	21.95%	48.78%	17.07%	100%
2013	slope	15-20 m	1.96%	0.00%	1.96%	1.96%	23.53%	60.78%	9.80%	100%
2013	slope	20-25 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	slope	25-30 m	0.00%	0.00%	50.00%	50.00%	0.00%	0.00%	0.00%	100%
2013	slope	30-35 m	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	100%
2013	slope	35-40 m	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	100%
2013	pelagic	0-5 m	34.88%	2.33%	46.51%	0.00%	0.00%	0.00%	16.28%	100%
2013	pelagic	5-10 m	19.23%	0.00%	65.38%	0.00%	3.85%	0.00%	11.54%	100%
2013	pelagic	10-15 m	0.00%	0.00%	93.33%	0.00%	6.67%	0.00%	0.00%	100%
2013	pelagic	15-20 m	0.00%	0.00%	94.12%	5.88%	0.00%	0.00%	0.00%	100%
2013	pelagic	20-25 m	0.00%	0.00%	87.50%	12.50%	0.00%	0.00%	0.00%	100%
2013	pelagic	25-30 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	30-35 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	35-40 m	0.00%	0.00%	50.00%	0.00%	50.00%	0.00%	0.00%	100%
2013	pelagic	40-45 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	45-50 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	50-55 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	55-60 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	60-65 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	65-70 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	70-75 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2013	pelagic	75-80 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	slope	0-5 m	62.50%	12.50%	0.00%	0.00%	25.00%	0.00%	0.00%	100%
2014	slope	5-10 m	33.30%	0.00%	44.40%	0.00%	22.20%	0.00%	0.00%	100%
2014	slope	10-15 m	9.10%	0.00%	72.70%	9.10%	9.10%	0.00%	0.00%	100%
2014	slope	15-20 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	slope	20-25 m	7.10%	0.00%	85.70%	7.10%	0.00%	0.00%	0.00%	100%
2014	slope	25-30 m	14.30%	0.00%	71.40%	14.30%	0.00%	0.00%	0.00%	100%
2014	slope	30-35 m	7.70%	0.00%	23.10%	53.80%	15.40%	0.00%	0.00%	100%
2014	slope	35-40 m	0.00%	0.00%	28.60%	57.10%	14.30%	0.00%	0.00%	100%
2014	pelagic	0-5 m	30.40%	0.00%	43.50%	0.00%	13.00%	0.00%	13.00%	100%
2014	pelagic	5-10 m	19.20%	0.00%	65.40%	0.00%	3.80%	0.00%	11.50%	100%
2014	pelagic	10-15 m	17.60%	0.00%	76.50%	0.00%	5.90%	0.00%	0.00%	100%
2014	pelagic	15-20 m	10.00%	0.00%	90.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	20-25 m	2.40%	0.00%	92.70%	2.40%	2.40%	0.00%	0.00%	100%
2014	pelagic	25-30 m	8.00%	0.00%	92.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	30-35 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	35-40 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	40-45 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	45-50 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	50-55 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	55-60 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	60-65 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	65-70 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	70-75 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2014	pelagic	75-80 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%

**7.4 (cont) Annual species composition estimates for acoustic apportionment**

Year	Zone	Depth	C. Trout	R. Trout	Kokanee	Bull Trout	N. Pikeminnow	Peamouth	R. Shiner	Total
2009	slope	0-5 m	23.08%	0.00%	30.77%	0.00%	15.38%	0.00%	30.77%	100%
2009	slope	5-10 m	23.08%	0.00%	30.77%	0.00%	15.38%	0.00%	30.77%	100%
2009	slope	10-15 m	11.54%	0.00%	45.38%	0.00%	25.19%	0.00%	17.88%	100%
2009	slope	15-20 m	0.00%	0.00%	60.00%	0.00%	35.00%	0.00%	5.00%	100%
2009	slope	20-25 m	0.00%	0.00%	75.00%	25.00%	0.00%	0.00%	0.00%	100%
2009	slope	25-30 m	0.00%	0.00%	62.50%	12.50%	25.00%	0.00%	0.00%	100%
2009	slope	30-35 m	0.00%	0.00%	50.00%	0.00%	50.00%	0.00%	0.00%	100%
2009	slope	35-40 m	0.00%	0.00%	50.00%	0.00%	50.00%	0.00%	0.00%	100%
2009	pelagic	0-5 m	25.40%	0.00%	49.21%	0.00%	3.17%	1.59%	20.63%	100%
2009	pelagic	5-10 m	25.40%	0.00%	49.21%	0.00%	3.17%	1.59%	20.63%	100%
2009	pelagic	10-15 m	16.03%	0.00%	62.94%	1.67%	8.25%	0.79%	10.32%	100%
2009	pelagic	15-20 m	6.67%	0.00%	76.67%	3.33%	13.33%	0.00%	0.00%	100%
2009	pelagic	20-25 m	0.00%	0.00%	94.87%	2.56%	2.56%	0.00%	0.00%	100%
2009	pelagic	25-30 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	30-35 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	35-40 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	40-45 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	45-50 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	50-55 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	55-60 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	60-65 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	65-70 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	70-75 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	75-80 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	80-85 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	85-90 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	90-95 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2009	pelagic	95-100 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
Year	Zone	Depth	C. Trout	R. Trout	Kokanee	Bull Trout	N. Pikeminnow	Peamouth	R. Shiner	Total
2011	slope	0-5 m	52.17%	0.00%	17.39%	0.00%	8.70%	4.35%	17.39%	100%
2011	slope	5-10 m	52.17%	0.00%	17.39%	0.00%	8.70%	4.35%	17.39%	100%
2011	slope	10-15 m	26.09%	0.00%	28.70%	0.00%	24.35%	12.17%	8.70%	100%
2011	slope	15-20 m	0.00%	0.00%	40.00%	0.00%	40.00%	20.00%	0.00%	100%
2011	slope	20-25 m	0.00%	0.00%	38.46%	53.85%	7.69%	0.00%	0.00%	100%
2011	slope	25-30 m	0.00%	0.00%	27.56%	51.92%	12.18%	8.33%	0.00%	100%
2011	slope	30-35 m	0.00%	0.00%	16.67%	50.00%	16.67%	16.67%	0.00%	100%
2011	slope	35-40 m	0.00%	0.00%	16.67%	50.00%	16.67%	16.67%	0.00%	100%
2011	pelagic	0-5 m	11.11%	25.93%	40.74%	0.00%	3.70%	11.11%	7.41%	100%
2011	pelagic	5-10 m	11.11%	25.93%	40.74%	0.00%	3.70%	11.11%	7.41%	100%
2011	pelagic	10-15 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	15-20 m	1.96%	0.00%	94.12%	3.92%	0.00%	0.00%	0.00%	100%
2011	pelagic	20-25 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	25-30 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	30-35 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	35-40 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	40-45 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	45-50 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	50-55 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	55-60 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	60-65 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	65-70 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
2011	pelagic	70-75 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%

2011	pelagic	75-80 m	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100%
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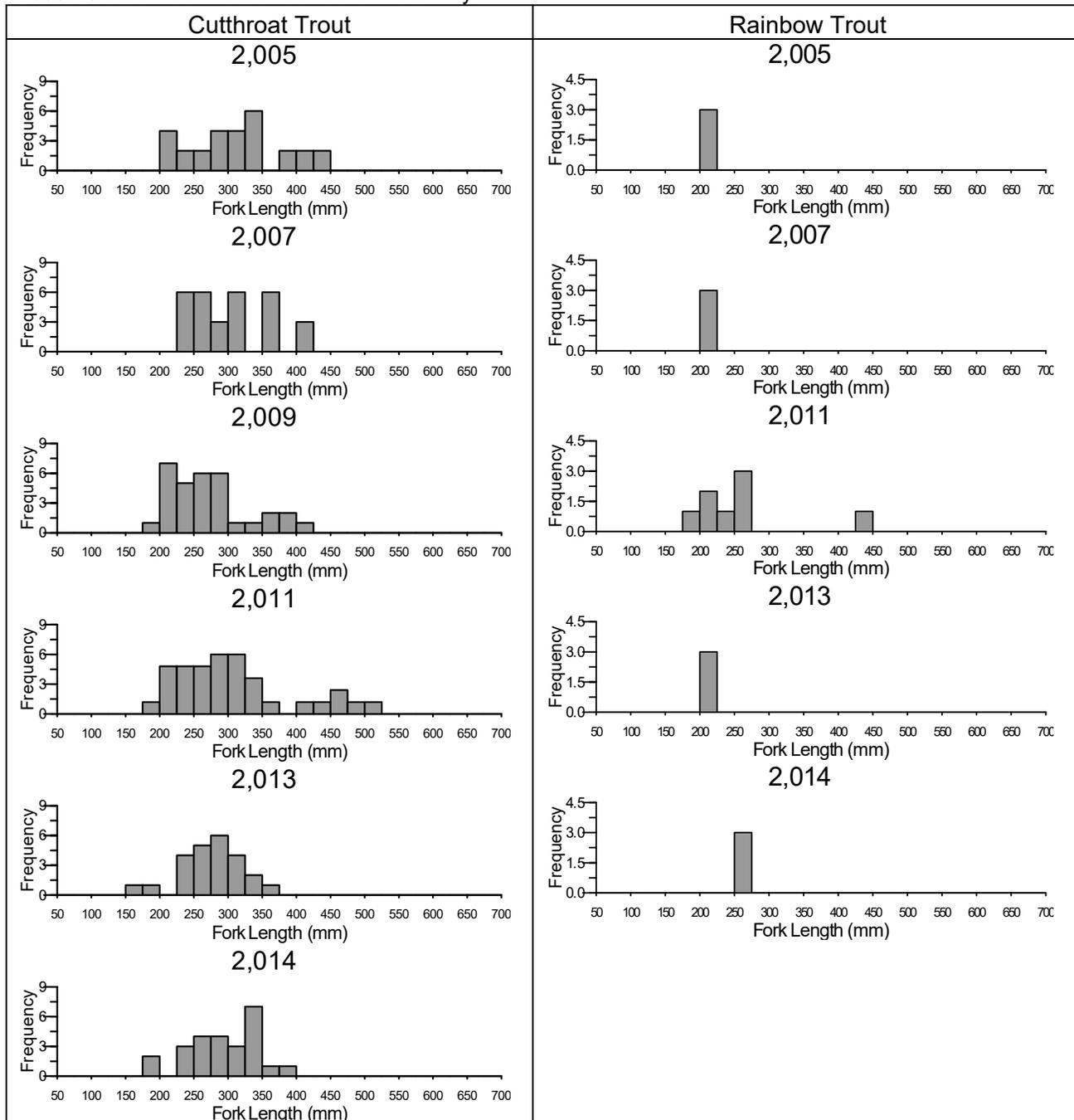
## 7.5 Mean and range of fish lengths and weights in each year

Mean and range of lengths and weights of fish captured in all gears during the 2005-2014 Stave Reservoir Fish Biomass Study.

Year	Species	Length (mm)				Weight (g)			
		Mean	Minimum	Maximum	Sample size	Mean	Minimum	Maximum	Sample size
2005	C. Trout	311.8	200.0	434	14	368.8	87.0	1,090.0	14.0
"	R. Trout	220.0	216.0	224	2	119.0	119.0	119.0	1
"	Kokanee	180.8	120.0	243	23	76.2	20.0	166.0	18
"	Bull Trout	456.9	320.0	636	15	844.9	362.0	1,149.0	11
"	L. Sucker	300.5	160.0	393	73	341.6	51.0	660.0	30
"	N. Pikeminnow	183.1	98.0	462	142	251.5	11.0	1,180.0	69
"	Peamouth	123.8	61.0	166	31	26.6	2.8	54.0	13
"	R. Shiner	102.1	63.0	198	117	14.4	10.0	23.0	31
"	P. Sculpin	94.8	52.0	180	48	-	-	-	-
2007	C. Trout	304.5	233.0	402	10	332.8	134.3	707.0	10
"	R. Trout	223.0	223.0	223	1	124.1	124.1	124.1	1
"	Kokanee	180.3	123.0	264	42	73.9	25.0	145.4	42
"	Bull Trout	418.3	257.0	586	4	577.0	187.0	1,040.0	4
"	L. Sucker	249.5	160.0	364	33	217.1	42.0	535.0	33
"	N. Pikeminnow	158.6	59.0	426	73	97.6	2.1	905.0	67
"	Peamouth	147.2	114.0	173	9	38.8	14.1	60.2	9
"	R. Shiner	103.5	55.0	126	72	14.4	1.5	25.8	69
2009	C. Trout	268.4	191.0	405	32	228.5	83.0	747.0	31
"	Kokanee	166.0	105.0	255	156	60.4	13.0	150.0	156
"	Bull Trout	509.0	420.0	645	5	1,927.6	910.0	4,500.0	5
"	L. Sucker	280.1	146.0	415	38	327.8	43.0	823.0	38
"	N. Pikeminnow	232.3	121.0	465	100	282.7	18.0	1,323.0	100
"	Peamouth	127.8	107.0	187	52	25.7	14.0	81.0	52
"	R. Shiner	107.5	96.0	150	74	16.3	11.0	51.0	65
"	P. Sculpin	122.1	95.0	141	7	23.1	9.0	40.0	7
2011	C. Trout	306.4	197.0	510	33	395.1	77.0	1,603.0	33
"	R. Trout	254.1	184.0	430	8	236.1	70.0	946.0	8
"	Kokanee	170.0	112.0	208	114	60.5	16.0	120.0	114
"	Bull Trout	378.8	228.0	595	16	789.4	113.0	2,527.0	16
"	L. Sucker	322.5	156.0	410	17	448.1	45.0	792.0	17
"	N. Pikeminnow	231.8	106.0	480	63	272.8	13.0	1,401.0	63
"	Peamouth	121.6	106.0	162	54	22.0	14.0	53.0	54
"	R. Shiner	106.9	92.0	124	83	16.8	10.0	24.0	83
"	P. Sculpin	120.6	105.0	145	5	19.6	11.0	33.0	5
2013	C. Trout	276.1	168.0	356	25	227.0	51.0	417.0	25
"	R. Trout	216.0	216.0	216	1	107.0	107.0	107.0	1
"	Kokanee	190.6	104.0	260	72	97.8	16.0	180.0	72
"	Bull Trout	323.1	210.0	414	7	463.2	269.0	801.0	7
"	L. Sucker	296.7	115.0	420	53	379.9	18.0	895.0	53
"	N. Pikeminnow	270.2	125.0	455	28	384.3	20.0	1,089.0	28
"	Peamouth	127.1	102.0	165	50	25.3	15.0	54.0	50
"	R. Shiner	105.1	55.0	122	74	15.0	2.0	23.0	74
2014	C. Trout	294.9	195.0	386	25	282.5	81.2	682.0	25
"	R. Trout	259.0	259.0	259	1	143.0	143.0	143.0	1
"	Kokanee	181.6	105.0	238	125	84.8	13.0	159.0	125
"	Bull Trout	403.3	262.0	673	19	813.4	199.0	2,157.0	19
"	L. Sucker	298.2	107.0	436	36	442.4	13.7	939.0	29
"	N. Pikeminnow	185.4	98.0	428	84	197.4	11.5	958.0	35
"	Peamouth	122.8	104.0	160	64	21.1	14.2	30.8	31
"	R. Shiner	106.7	69.0	132	88	14.1	4.2	21.9	32

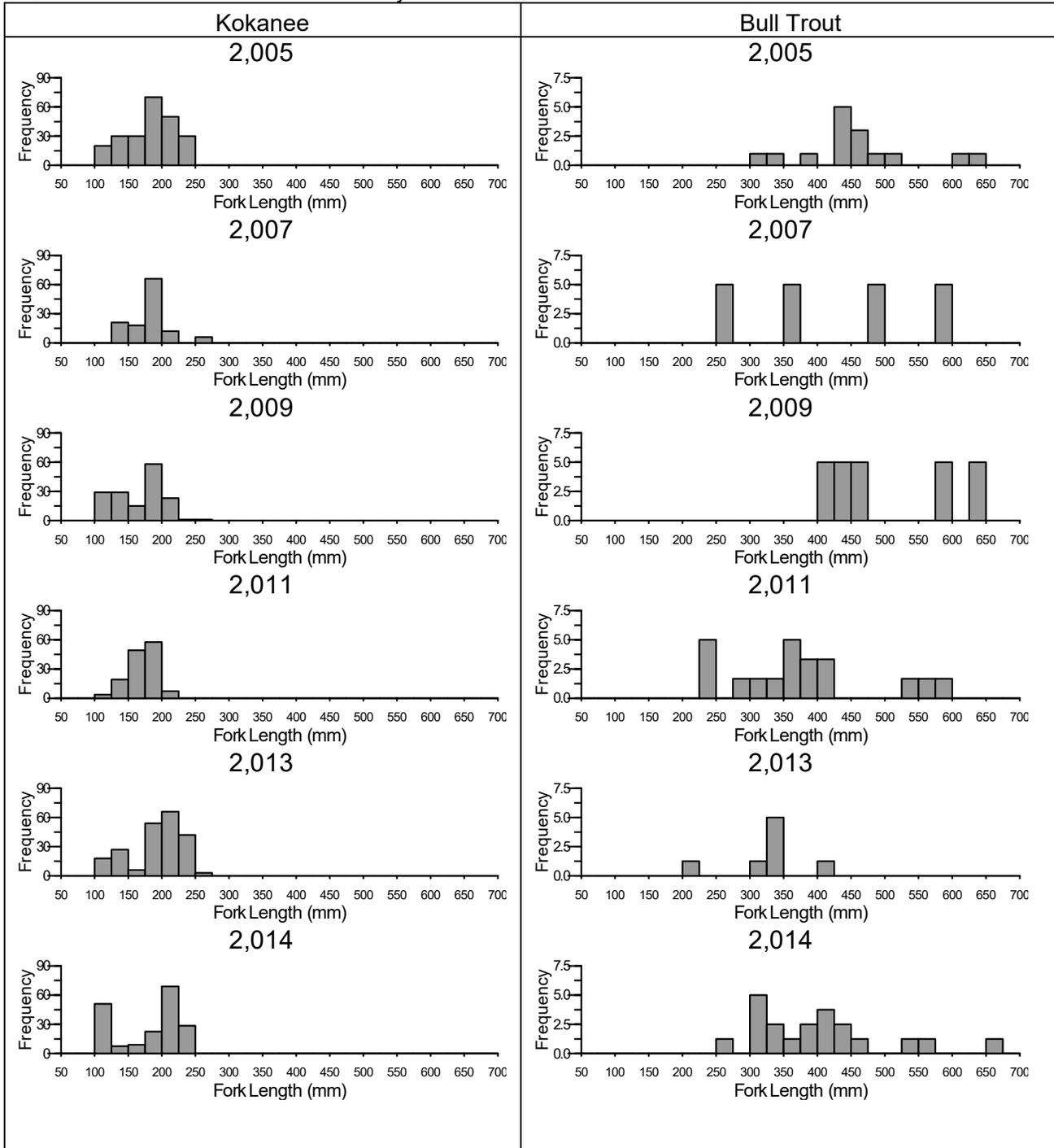
**7.6 Length frequency distributions of fish in each year of gill netting**

Length frequency distributions of Cutthroat and Rainbow trout caught in RISC gill nets in years of gill netting during the 2005-2014 Stave Reservoir fish biomass study.



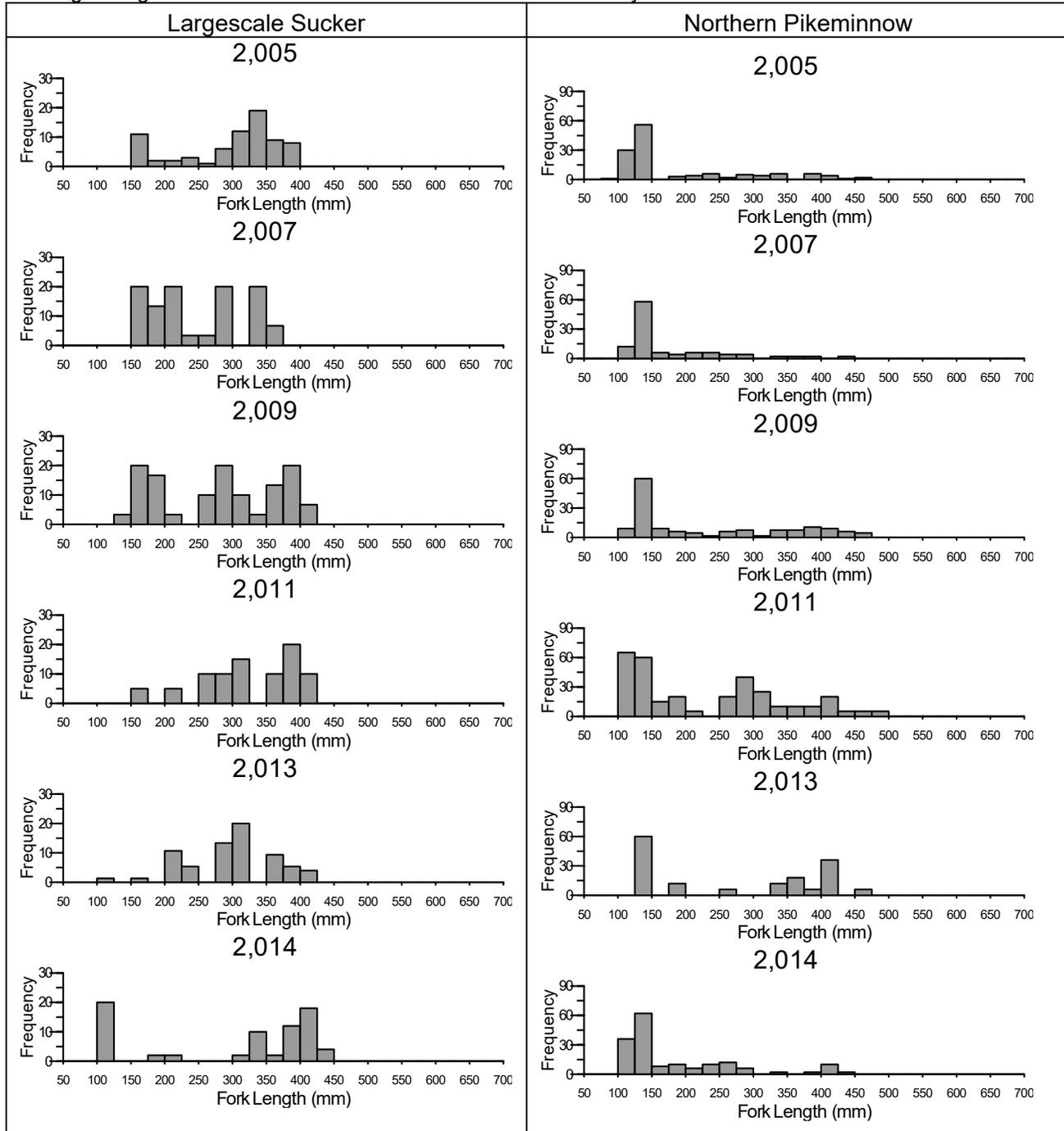
Appendix 7.6 (cont)

Length frequency distributions of kokanee and Bull Trout caught RISC gill nets in years of gill netting during the 2005-2014 Stave Reservoir fish biomass study



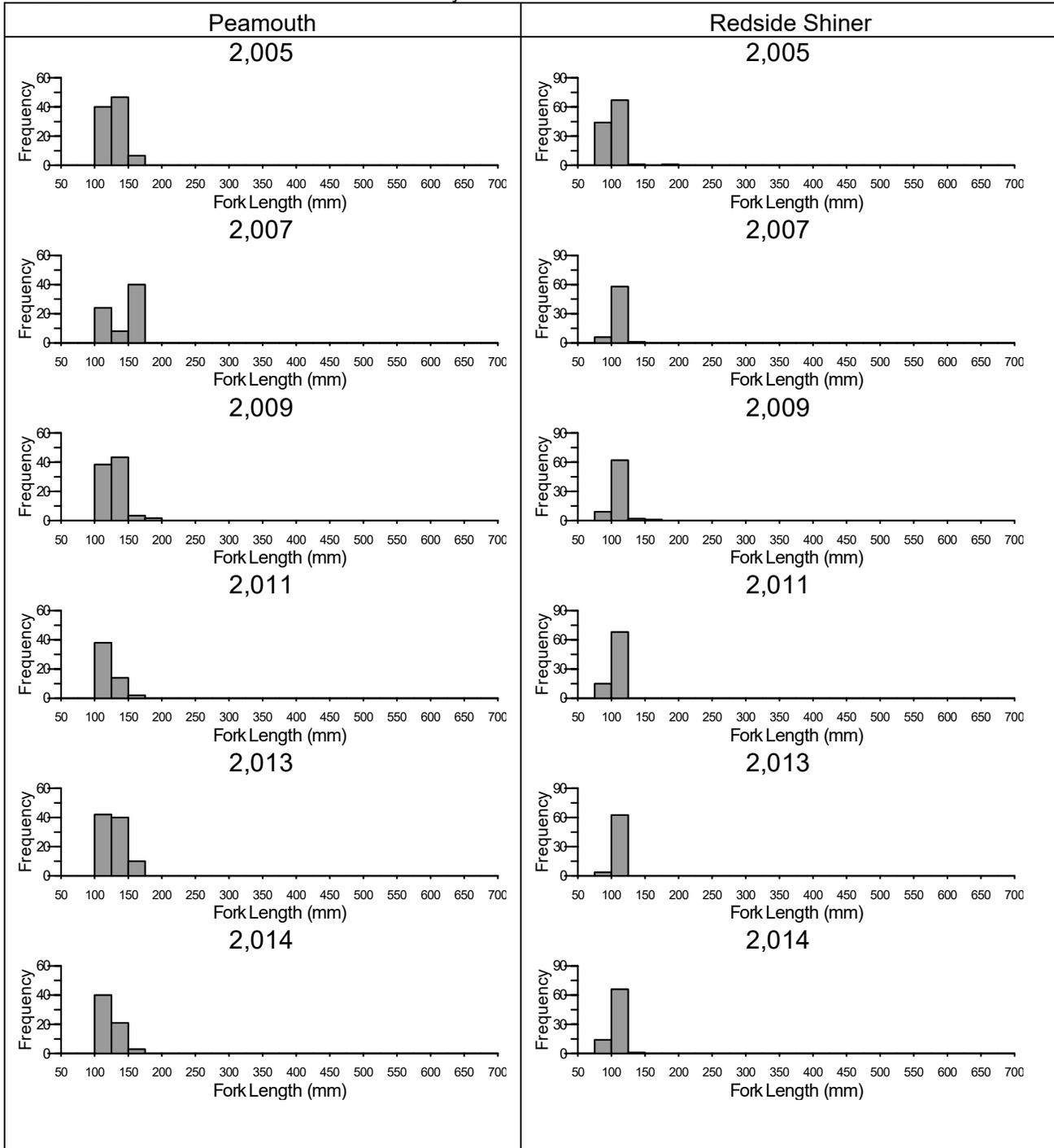
Appendix 7.6 (cont)

Length frequency distributions of Largescale Sucker and Northern Pike minnow caught RISC gill nets in years of gill netting during the 2005-2014 Stave Reservoir fish biomass study.



Appendix 7.6 (cont)

Length frequency distributions of Peamouth and Redside Shiner caught in RISC gill nets in years of gill netting during the 2005-2014 Stave Reservoir fish biomass study.



## 7.7 Age composition of Salmonids in each year of gill netting

Age composition of Salmonids in the RISC gill net catch for each year of gill netting in the 2005-2014 Stave Reservoir Fish Biomass Study.

Species	Year	CPUE (catch per set hour)							Age composition (% of annual catch)						
		1+	2+	3+	4+	5+	6+	7+	1+	2+	3+	4+	5+	6+	7+
C. Trout	2005	0.014	0.021	0.028	0.014	0.007	0.000	0.014	14%	21%	29%	14%	7%	0%	14%
"	2007	0.000	0.045	0.027	0.018	0.000	0.000	0.000	0%	50%	30%	20%	0%	0%	0%
"	2009	0.012	0.046	0.017	0.012	0.000	0.000	0.000	13%	53%	20%	13%	0%	0%	0%
"	2011	0.007	0.025	0.014	0.004	0.011	0.004	0.000	11%	39%	22%	6%	17%	6%	0%
"	2013	0.012	0.016	0.031	0.000	0.000	0.000	0.000	20%	27%	53%	0%	0%	0%	0%
"	2014	0.003	0.005	0.021	0.023	0.003	0.000	0.000	5%	10%	38%	43%	5%	0%	0%
Species	Year	1+	2+	3+	4+	5+	6+	7+	1+	2+	3+	4+	5+	6+	7+
R. Trout	2005	0.009	0.009	0.000	0.000	0.000	0.000	0.000	50%	50%	0%	0%	0%	0%	0%
"	2007	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0%	100%	0%	0%	0%	0%	0%
"	2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0%	0%	0%	0%	0%	0%	0%
"	2011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0%	0%	0%	0%	0%	0%	0%
"	2013	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0%	100%	0%	0%	0%	0%	0%
"	2014	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0%	0%	100%	0%	0%	0%	0%
Species	Year	1+	2+	3+	4+	5+	6+	7+	1+	2+	3+	4+	5+	6+	7+
Kokanee	2005	0.049	0.105	0.040	0.000	0.000	0.000	0.000	25%	54%	21%	0%	0%	0%	0%
"	2007	0.090	0.279	0.009	0.000	0.000	0.000	0.000	24%	74%	2%	0%	0%	0%	0%
"	2009	0.149	0.256	0.021	0.000	0.000	0.000	0.000	35%	60%	5%	0%	0%	0%	0%
"	2011	0.028	0.056	0.207	0.000	0.000	0.000	0.000	10%	19%	71%	0%	0%	0%	0%
"	2013	0.029	0.078	0.063	0.000	0.000	0.000	0.000	17%	46%	37%	0%	0%	0%	0%
"	2014	0.086	0.057	0.131	0.002	0.000	0.000	0.000	31%	20%	48%	1%	0%	0%	0%
Species	Year	1+	2+	3+	4+	5+	6+	≥ 7	1+	2+	3+	4+	5+	6+	≥ 7
Bull Trout	2005	0.000	0.000	0.000	0.006	0.006	0.026	0.058	0.0%	0.0%	0.0%	6.7%	6.7%	26.7%	60.0%
"	2007	0.000	0.000	0.009	0.000	0.009	0.000	0.018	0.0%	0.0%	25.0%	0.0%	25.0%	0.0%	50.0%
"	2009	0.000	0.000	0.000	0.003	0.006	0.000	0.006	0.0%	0.0%	0.0%	20.0%	40.0%	0.0%	40.0%
"	2011	0.000	0.000	0.003	0.017	0.011	0.003	0.006	0.0%	0.0%	7.1%	42.9%	28.6%	7.1%	14.3%
"	2013	0.000	0.000	0.013	0.004	0.000	0.000	0.000	0.0%	0.0%	75.0%	25.0%	0.0%	0.0%	0.0%
"	2014	0.000	0.000	0.005	0.018	0.011	0.002	0.007	0.0%	0.0%	10.5%	42.1%	26.3%	5.3%	15.8%

## 7.8 Stomach contents of Salmonids in each year of gill netting

Contents of salmonid stomachs expressed as mean percentage of composition by numbers for major food categories (terrestrial, benthic, zooplankton, fish). Data are from all years of gill netting during the Stave 2005-2014 Fish Biomass Study.

Species	Year	Mean % of stomach content composition by numbers				Total	No. of stomachs processed
		Terrestrial	Benthic	Zooplankton	Fish		
Cutthroat Trout	2005	81.3%	8.5%	0.0%	10.2%	100.0%	7
"	2007	52.7%	34.9%	0.0%	12.4%	100.0%	6
"	2009	23.8%	25.1%	0.0%	51.1%	100.0%	8
"	2011	39.3%	0.0%	0.0%	60.7%	100.0%	7
"	2013	40.7%	35.1%	6.7%	17.5%	100.0%	13
"	2014	35.8%	28.3%	1.6%	34.3%	100.0%	9
"	Combined	44.9%	23.5%	2.1%	29.5%	100.0%	50
Rainbow Trout	2011	87.1%	12.9%	0.0%	0.0%	100.0%	5
"	2013	87.3%	9.5%	3.3%	0.0%	100.0%	1
"	2014	90.0%	0.0%	0.0%	10.0%	100.0%	1
"	Combined	87.5%	10.6%	0.5%	1.4%	100.0%	7
Rainbow/cutthroat hybrid	2011	0.0%	0.0%	0.0%	100.0%	100.0%	1
Kokanee	2005	0.3%	14.7%	84.9%	0.0%	100.0%	7
"	2007	10.6%	3.0%	86.4%	0.0%	100.0%	12
"	2009	0.3%	3.2%	96.5%	0.0%	100.0%	8
"	2011	0.0%	0.1%	99.9%	0.0%	100.0%	6
"	2013	0.0%	0.2%	99.8%	0.0%	100.0%	7
"	2014	0.0%	0.2%	99.8%	0.0%	100.0%	7
"	Combined	2.9%	3.7%	93.3%	0.0%	100.0%	47
Bull Trout	2005	0.0%	0.0%	0.0%	100.0%	100.0%	8
"	2007	25.0%	25.0%	0.0%	50.0%	100.0%	2
"	2009	0.0%	0.0%	0.0%	100.0%	100.0%	4
"	2011	4.0%	0.0%	14.0%	82.0%	100.0%	5
"	2013	0.0%	26.7%	0.0%	73.3%	100.0%	6
"	2014	0.0%	0.0%	0.0%	100.0%	100.0%	9
"	Combined	2.3%	6.1%	2.3%	89.2%	100.0%	34

## 7.9 Annual fish abundance and biomass estimates by species

Annual estimates of fish abundance (fish/ha) and biomass (kg/ha) by species. Years when gill netting was conducted are in bold.

Abundance (fish/ha)								
Year	Kokanee	Bull Trout	C. Trout	R. Trout	N. Pikeminnow	Peamouth	R. Shiner	Total
<b>2005</b>	135	0.72	0.10	0.76	0.62	0.02	0.00	137
2006	150	0.38	1.64	0.10	1.86	0.82	0.47	155
<b>2007</b>	185	0.60	3.18	0.18	1.21	1.97	0.00	192
2008	216	0.38	2.79	0.08	1.07	2.20	0.00	223
<b>2009</b>	513	1.50	4.81	0.00	3.58	3.50	0.22	527
2010	584	2.53	2.69	0.00	5.25	1.07	0.07	596
<b>2011</b>	309	1.54	1.82	1.72	1.47	0.67	1.35	318
2012	112	0.67	0.04	0.00	0.18	0.00	0.16	113
<b>2013</b>	157	1.40	1.18	0.05	1.04	1.24	1.06	163
<b>2014</b>	153	0.58	7.35	0.52	2.48	0.96	0.00	165
Mean	251	1.03	2.56	0.34	1.87	1.24	0.33	259

Biomass (kg/ha)								
Year	Kokanee	Bull Trout	C. Trout	R. Trout	N. Pikeminnow	Peamouth	R. Shiner	Total
<b>2005</b>	2.21	0.82	0.04	0.08	0.16	0.00	0.00	3.31
2006	3.08	0.34	0.54	0.01	0.23	0.03	0.01	4.25
<b>2007</b>	3.01	0.54	1.06	0.02	0.15	0.08	0.00	4.86
2008	5.19	0.34	0.93	0.01	0.13	0.09	0.00	6.69
<b>2009</b>	4.26	2.88	1.12	0.00	1.01	0.09	0.00	9.37
2010	5.50	4.88	0.63	0.00	1.48	0.03	0.00	12.51
<b>2011</b>	3.41	1.27	0.81	0.40	0.40	0.01	0.02	6.34
2012	1.00	0.55	0.02	0.00	0.05	0.00	0.00	1.62
<b>2013</b>	2.43	0.60	0.26	0.01	0.40	0.03	0.02	3.75
<b>2014</b>	3.49	0.47	1.97	0.07	0.49	0.02	0.00	6.51
Mean	3.36	1.27	0.74	0.06	0.45	0.04	0.01	5.92

## 7.10 Annual abundance of Salmonid species by age group.

Species	Year	Abundance (number/ha) by age group								Total
		age 0+	age 1+	age 2+	age 3+	age 4+	age 5+	age 6+	age 7+	
C. Trout	2005	0.00	0.01	0.02	0.03	0.01	0.01	0.00	0.01	0.10
"	2006	0.00	0.00	0.82	0.49	0.33	0.00	0.00	0.00	1.64
"	2007	0.00	0.00	1.59	0.95	0.64	0.00	0.00	0.00	3.18
"	2008	0.00	0.00	1.39	0.84	0.56	0.00	0.00	0.00	2.79
"	2009	0.00	0.64	2.57	0.96	0.64	0.00	0.00	0.00	4.81
"	2010	0.00	0.36	1.44	0.54	0.36	0.00	0.00	0.00	2.69
"	2011	0.00	0.20	0.71	0.40	0.10	0.30	0.10	0.00	1.81
"	2012	0.00	0.00	0.02	0.01	0.00	0.01	0.00	0.00	0.04
"	2013	0.00	0.24	0.32	0.63	0.00	0.01	0.00	0.00	1.18
"	2014	0.00	0.35	0.70	2.80	3.15	0.35	0.00	0.00	7.35
Species	Year	age 0+	age 1+	age 2+	age 3+	age 4+	age 5+	age 6+	age 7+	Total
R. Trout	2005	0.00	0.38	0.38	0.00	0.00	0.00	0.00	0.00	0.76
"	2006	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.10
"	2007	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.18
"	2008	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.08
"	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	2013	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.05
"	2014	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.52
Species	Year	age 0+	age 1+	age 2+	age 3+	age 4+	age 5+	age 6+	age 7+	Total
Kokanee	2005	106.27	7.22	15.63	6.01	0.00	0.00	0.00	0.00	135.13
"	2006	110.75	9.27	28.73	0.93	0.00	0.00	0.00	0.00	149.67
"	2007	146.94	9.01	27.93	0.90	0.00	0.00	0.00	0.00	184.77
"	2008	149.05	16.02	49.66	1.60	0.00	0.00	0.00	0.00	216.34
"	2009	451.74	21.52	36.90	3.07	0.00	0.00	0.00	0.00	513.24
"	2010	503.98	28.13	48.22	4.02	0.00	0.00	0.00	0.00	584.34
"	2011	251.37	5.58	11.16	40.93	0.00	0.00	0.00	0.00	309.05
"	2012	95.11	1.62	3.23	11.85	0.00	0.00	0.00	0.00	111.80
"	2013	132.26	4.23	11.27	9.16	0.00	0.00	0.00	0.00	156.92
"	2014	112.52	12.61	8.30	19.25	0.33	0.00	0.00	0.00	153.02
Species	Year	age 0+	age 1+	age 2+	age 3+	age 4+	age 5+	age 6+	age ≥7+	Total
Bull Trout	2005	0.00	0.00	0.00	0.00	0.05	0.05	0.19	0.43	0.72
"	2006	0.00	0.00	0.00	0.09	0.00	0.09	0.11	0.19	0.38
"	2007	0.00	0.00	0.00	0.15	0.00	0.15	0.11	0.30	0.60
"	2008	0.00	0.00	0.00	0.09	0.00	0.09	0.11	0.19	0.38
"	2009	0.00	0.00	0.00	0.00	0.30	0.60	0.11	0.60	1.50
"	2010	0.00	0.00	0.00	0.00	0.51	1.01	0.11	1.01	2.53
"	2011	0.00	0.00	0.00	0.11	0.66	0.44	0.11	0.22	1.54
"	2012	0.00	0.00	0.00	0.05	0.29	0.19	0.05	0.10	0.67
"	2013	0.00	0.00	0.00	1.05	0.35	0.19	0.05	0.10	1.40
"	2014	0.00	0.00	0.00	0.06	0.24	0.15	0.03	0.09	0.58

**7.11 Annual biomass of Salmonid species by age group.**

Species	Year	Biomass (kg/ha) by age group								Total
		age 0+	age 1+	age 2+	age 3+	age 4+	age 5+	age 6+	age 7+	
C. Trout	2005	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.04
"	2006	0.00	0.00	0.17	0.21	0.17	0.00	0.00	0.00	0.54
"	2007	0.00	0.00	0.33	0.40	0.32	0.00	0.00	0.00	1.06
"	2008	0.00	0.00	0.29	0.35	0.28	0.00	0.00	0.00	0.93
"	2009	0.00	0.06	0.38	0.26	0.42	0.00	0.00	0.00	1.12
"	2010	0.00	0.03	0.21	0.15	0.24	0.00	0.00	0.00	0.63
"	2011	0.00	0.02	0.14	0.11	0.05	0.34	0.15	0.00	0.81
"	2012	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02
"	2013	0.00	0.02	0.06	0.18	0.00		0.00		0.26
"	2014	0.00	0.03	0.08	0.62	1.13	0.11	0.00	0.00	1.97
Species	Year	age 0+	age 1+	age 2+	age 3+	age 4+	age 5+	age 6+	age 7+	Total
R. Trout	2005	0.00	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.08
"	2006	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
"	2007	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02
"	2008	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
"	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	2013	0.00	0.00	0.01	0.00	0.00		0.00	0.00	0.01
"	2014	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.07
Species	Year	age 0+	age 1+	age 2+	age 3+	age 4+	age 5+	age 6+	age 7+	Total
Kokanee	2005	0.07	0.19	1.29	0.66	0.00	0.00	0.00	0.00	2.21
"	2006	0.06	0.35	2.47	0.21	0.00	0.00	0.00	0.00	3.08
"	2007	0.07	0.34	2.40	0.20	0.00	0.00	0.00	0.00	3.01
"	2008	0.11	0.60	4.27	0.21	0.00	0.00	0.00	0.00	5.19
"	2009	0.35	0.56	2.99	0.37	0.00	0.00	0.00	0.00	4.26
"	2010	0.39	0.73	3.90	0.48	0.00	0.00	0.00	0.00	5.50
"	2011	0.09	0.12	0.50	2.70	0.00	0.00	0.00	0.00	3.41
"	2012	0.03	0.04	0.15	0.78	0.00	0.00	0.00	0.00	1.00
"	2013	0.09	0.11	0.97	1.26	0.00		0.00		2.43
"	2014	0.11	0.22	0.72	2.40	0.05	0.00	0.00	0.00	3.49
Species	Year	age 0+	age 1+	age 2+	age 3+	age 4+	age 5+	age 6+	age ≥7+	Total
Bull Trout	2005	0.00	0.00	0.00	0.00	0.02	0.02	0.17	0.61	0.82
"	2006	0.00	0.00	0.00	0.02	0.00	0.05	0.00	0.28	0.34
"	2007	0.00	0.00	0.00	0.03	0.00	0.08	0.00	0.44	0.54
"	2008	0.00	0.00	0.00	0.02	0.00	0.05	0.00	0.28	0.34
"	2009	0.00	0.00	0.00	0.00	0.28	0.60	0.00	2.01	2.88
"	2010	0.00	0.00	0.00	0.00	0.47	1.01	0.00	3.39	4.88
"	2011	0.00	0.00	0.00	0.01	0.23	0.45	0.09	0.50	1.27
"	2012	0.00	0.00	0.00	0.01	0.10	0.19	0.04	0.22	0.55
"	2013	0.00	0.00	0.00	0.45	0.15	0.00	0.00	0.00	0.60
"	2014	0.00	0.00	0.00	0.02	0.12	0.12	0.04	0.17	0.47

## **7.12 RAW DATA APPENDICES**

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