Peace Project Water Use Plan: Monitoring Programs for the Peace Spill Protocol (GMSMON-4 WAC Bennett Dam Entrainment Study)

Williston Fish Index in the Vicinity of W.A.C. Bennett Dam

An index of fish distribution and abundance in the Peace Arm of Williston Reservoir close to W.A.C. Bennett Dam based on hydroacoustic and gillnet surveys

Study Period: July 14 – July 19, 2012

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EXECUTIVE SUMMARY

As part of the Peace Project Water Use Plan (WUP), the GMSMON-4 Bennett Dam Entrainment (BC Hydro 2008) Monitoring Program Terms of Reference and the Peace Spill Protocol, four mobile hydroacoustic and one gillnet surveys were carried out in the forebay area of the Williston Reservoir Peace Reach from July 15th to 18th 2012. The mobile hydroacoustic study described in this report and the stationary hydroacoustic survey carried out by Biosonics Incorporated (Biosonics 2012) at the W.A.C. Bennett Dam spillway entrance had the goal to determine the species composition and abundance of fish that were entrained over the spillway during the 2012 spill. The mobile survey closely followed transects and fishing locations established as part of the 2008 Williston Fish Index Study (GMSMON-13, Sebastian et al. 2008). Species composition of the hydroacoustic fish targets was determined using gillnetting and the combined results were used to suggest species composition and percentage of the forebay area fish population that was entrained over the W.A.C. Bennett Dam spillway.

The three transects surveyed over four nights were all within 15 km of W.A.C. Bennett Dam and were monitored for fish abundance in depths from 3-60 m and allowed for the calculation of average fish densities per transect. The average transect densities were then expanded to defined zones in the vicinity of W.A.C. Bennett Dam or the whole Peace Reach to calculate population estimates.

In accordance with Sebastian et al.'s (2008) zone naming convention, the combined fish population estimate for Zones 31 and 32 (the two zones closest to the dam and including the forebay area) was 1,064,311fish (± SD 427,989) in 2012 versus 582,343 (± SD 85,408) fish in 2008. Within this population estimate the proportion of very small fish (<36 mm) decreased from 2008 to 2012 while the proportion of medium lengths fish (37-324 mm) increased and the proportion of larger fish (>325 mm) decreased over the same period of time. The fish population estimates for the Peace Reach did not appear to have changed from 2008 (3,239,700 ± SD 515,112) (Sebastian et al. 2008) to 2012 (3,743,744 ± SD 1,534,935), while the 2000 Peace Reach fish abundance estimate (1,410,900 ± SD 197,526) (Sebastian et al. 2003) appeared to be lower. During the 2012 July spill an estimated ~455,000 fish (or ~12% of the total estimated Peace Reach fish population) were entrained over the spillway and an estimated ~82% of these fish were in the 40–75 mm size class (Biosonics 2012).

Based on 2012 gillnetting, the composition of the fish targets detected in the mobile and likely also in the stationary hydroacoustic surveys was mainly composed of Kokanee and Peamouth Chub and to a lesser degree of Lake Whitefish for the 30,051 entrained fish in the size class from 75–465 mm. Kokanee, Peamouth Chub and Lake Whitefish were the most abundant in the gillnet catch of the forebay area in the shallow depths strata from 0-10 m. The minimum gillnet mesh size did not sample fish <80 mm and therefore the species composition of the majority of the fish that were entrained and that were in the 40–75 mm size class could not be directly determined. Nevertheless, of the three most abundant species Kokanee, Peamouth Chub and Lake Whitefish, based on their preference for shallow littoral areas at Age 0+ Peamouth Chub and Lake Whitefish, likely represented the majority of the small fish that were entrained while Age 0+

Kokanee were likely also entrained but to a lesser degree based on their preference for the pelagic zone.

When compared to the 1974, 1988, 2000 and 2008 results, the species composition in the Peace Reach and the vicinity of W.A.C. Bennett Dam appeared to be shifting from a Lake Whitefish dominated fish fauna to a Kokanee and Peamouth Chub dominated one. Over the same period of time, Rainbow Trout, and other foremost abundant species such Longnose Sucker and Artic Grayling appeared to have decreased to very low numbers.

ACKNOWLEDGEMENTS

The authors are grateful to BC Hydro for the opportunity to carry out this interesting project and we thank Michael McArthur (Natural Resource Specialist, Water License Requirements, BC Hydro, Burnaby) for his patient and friendly supervision. The close collaborations with Randy Zemlak (Fisheries Technician, BC Hydro, Prince George) and Rebecca Brough (Fisheries Technician, BC Hydro, Hudson's Hope) in executing the field work for this project are appreciated. Use of the BC Hydro boat, *Williston Ranger*, for all reservoir-based work facilitated safe and effective field work. We also appreciated Jim Dawson's (Biosonics Incorporated, Seattle Washington) input and feedback on the analysis of the hydroacoustic data.

Lucia Ferreira (LGL Limited) participated in all aspects of the field work and assisted with data entry. Mike Demarchi (LGL Limited) reviewed a draft of this report and provided helpful comments.

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INTRODUCTION

This study was carried out July 15-18th 2012 to assess the fish population size and species composition in the Peace Reach of the Williston Reservoir with particular emphasis on the W.A.C. Bennett Dam forebay area during spillway operations. Spill events over large dams can entrain fish and force them to be flushed downstream of the dam and out of the reservoir. A combination of a stationary hydroacoustic survey monitoring fish entrainment over the Bennett Dam spillway and a mobile hydroacoustic survey to estimate the population size and species composition in the forebay area can be used to assess the percentage and species composition of the fish entrained over the spillway.

Information presented in this section builds upon the Peace Reach fish population index study (GMSMON-13) presented by Sebastian et al. (2008) in compliance with the Peace Project Water Use Plan.

The 2012 study repeated the approaches described in past Williston Reservoir Peace Arm Fish Index studies (Sebastian et al. 2003, 2008) and addressed recommendations made in the Peace Project Water Use Plan's, Bennett Dam Entrainment Study (GMSMON-4) (BC Hydro 2008). These recommendations were developed to assess the impacts of flood pulse events and/or spills on the reservoirs' fish populations. Information collected from these studies over time are intended to guide future decision making related to spill risk and flood pulse strategies in an attempt to minimize environmental impacts. The overall purpose of the 2012 study was to collect baseline information on pelagic fish populations within 15 km of W.A.C. Bennett Dam during a major spill event. This study, along with information collected from the fixed hydroacoustic station study (Dawson, 2012) are expected to fulfil the objectives of the W.A.C. Bennett Dam Entrainment study (also part of the Peace Spill Protocol) and assist in quantifying the fisheries effects of the 2012 spills on the Williston reservoir fish populations.

The fundamental management question of this study is:

What are the species composition, abundance, and spatial distribution of fish in the pelagic zone of the Peace Arm of the Williston Reservoir in the vicinity of W.A.C. Bennett Dam?

As outlined in the Monitoring Program Terms of Reference (BC Hydro 2008; page 7, Pargraph 2.3.2), the specific task for this study is:

"…a survey (e.g. 3–4 transects) will be conducted in the immediate forebay near the spillbays using fish finder/hydroacoustic equipment to estimate the number of fish in the area."

Based on this general statement we set out to address the following objectives in the Peace Reach of Williston Reservoir in the vicinity of W.A.C. Bennett Dam:

1. Determine fish species composition and abundance and produce an estimate of the population size of fish in the pelagic zone;
2. Determine the spatial distribution with regards to depth and location of fish in the pelagic zone; and
3. Determine the age and size distributions of fish species in the pelagic zone.

In addition to these objectives, data collected in this study was compared with results reported by Sebastian et al. (2008) to assess any changes in the fish populations in the vicinity to Bennett Dam since 2008.

BACKGROUND

Williston Reservoir

Portions of the following section are based on material in Sebastian et al. (2008):

Williston Reservoir is located in north-central British Columbia ~200km north of Prince George (Figure 1). Williston Reservoir was created by the construction of the W.A.C. Bennett Dam in 1967 across the Peace River. The reservoir is comprised of the Parsnip River Reach, Finlay River Reach and the Peace River reach, with total catchment area being 69,930 km^2. Depending on reservoir pool elevation, Williston Reservoir covers a surface area that ranges from ~1,647–1,800 km^2. During the July 15-18th 2012 study dates, the reservoir elevation ranged from 671.4 – 671.6m (full pool = 672m), hence the reservoir area would have been very close to 1,800 km^2. The reservoir had been filling during the study in 2012 since conditions during the survey were within ~0.5m of the 2012 peak elevation on July 30th (671.97m).

The W.A.C. Bennett Dam has 10 Francis generation units and 3 radial arm spillway gates. In response to a rapidly filling reservoir and increasing risk of an uncontrolled spill, the spillway gates were operated June 26th – August 2nd with a median discharge of 1,495 m^3/s and a peak discharge of 2,896 m^3/s (June 28th). The result of these spills was reduction in reservoir filling rates, however there were no decreases in reservoir elevation during the 2012 spills. Normal, licenced reservoir drawdown is less than 17m. For a description of the construction and operational challenges of Williston Reservoir, see Sebastian et al. (2008).

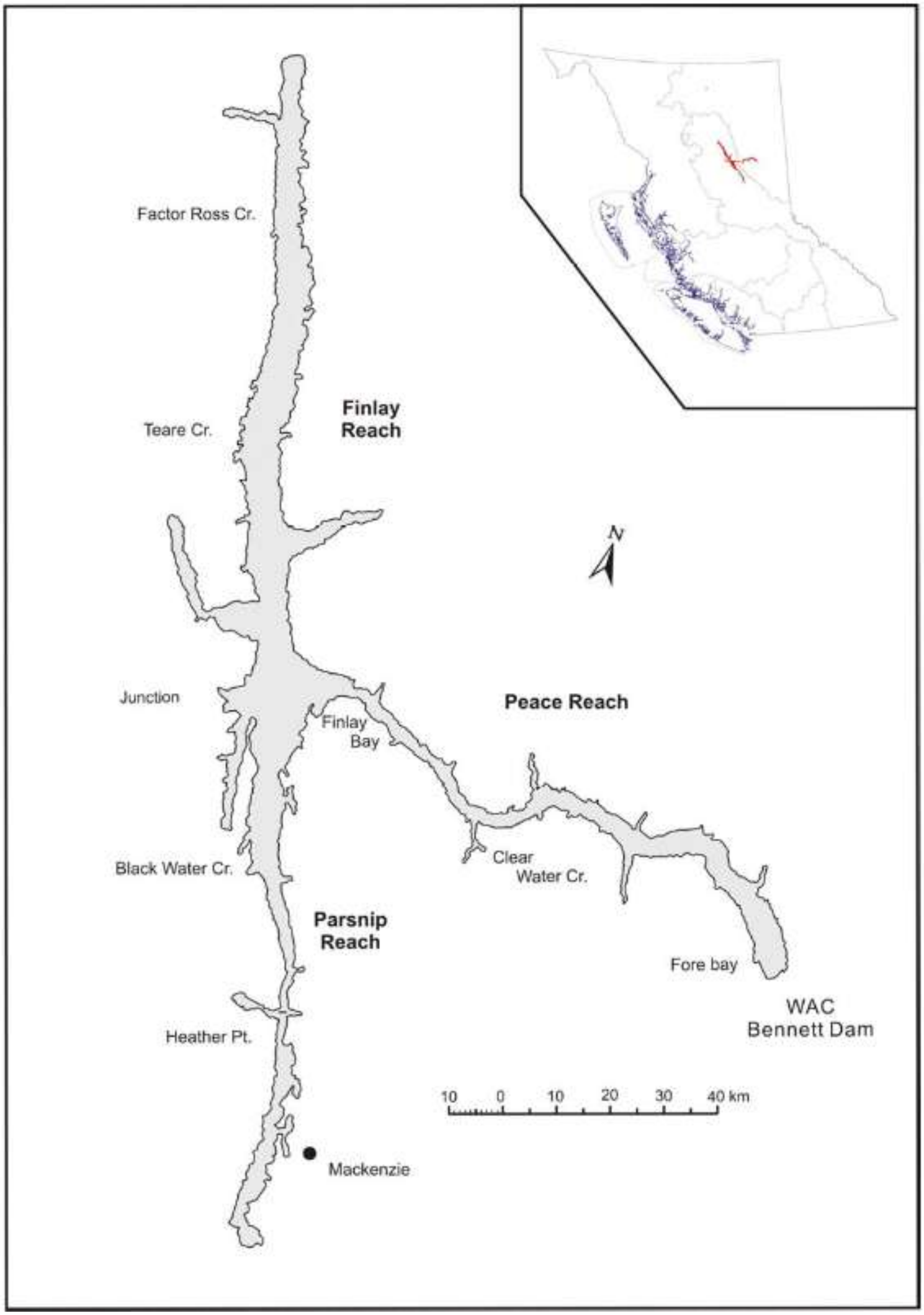


Figure 1 Map of Williston Reservoir showing Finlay, Parsnip and Peace reaches (from: Sebastian et al. 2008).

Williston Reservoir Pelagic Fish Species Composition and Distribution

This section is based on material in Sebastian et al. (2008):

Based on studies of fish assessment (Barrett and Halsey 1985; Blackman 1992) and spatial distribution (Ford et al. 1995 and McPhail 2007), Williston Reservoir is inhabited by a variety of fish species including: Lake Whitefish (*Coregonus clupeaformis*), Bull Trout (*Salvelinus confluentus*), Rainbow Trout (*Oncorhynchus mykiss*), Kokanee (*Oncorhynchus nerka*), Arctic Grayling (*Thymallus arcticus*), Lake Trout (*Salvelinus namaycush*), Burbot (*Lota lota*), Mountain Whitefish (*Prosopium williamsoni*), Longnose Sucker (*Catostomus commersoni*), Largescale Sucker (*Catostomus macrocheilus*), White Sucker (*Catostomus catostomus*), Peamouth Chub (*Mylocheilus caurinus*), Northern Pikeminnow (*Ptychocheilus oregonensis*) and Redside Shiner (*Richardsonius balteatus*). Despite the variety of fish species that inhabit the reservoir, Pillipow and Langston (2002) indicated that only a few of these species comprise the pelagic fish community. In decreasing order of abundance in 2000, fish species in the pelagic zone of Williston Reservoir included: Lake Whitefish, Kokanee, Peamouth Chub, Rainbow Trout, Bull Trout and Lake Trout.

For Bulltrout, Kokanee, Lake Whitefish and Peamouth Chub, a detailed description of life history and distribution throughout the Williston Reservoir is given in the following paragraphs. This information is also based on material in Sebastian et al. (2008).

<u>Bulltrout</u>

Bulltrout, native to western North America, are widely distributed throughout much of BC (McPhail 2007). They generally display three common life history patterns which consist of fluvial, adfluvial and resident populations distributed throughout their entire geographic range. Bulltrout spawn in the fall and depending on the life history, reach sexual maturity between 5-6 years of age. At this age Bulltrout in the Williston Reservoir are ~400mm long (Blackman 1992). This char species is considered slow growing and long lived, often exceeding 10 years of age. As well, depending on the life history pattern, size at age can exceed 400 mm, with adfluvial forms attaining >600 mm at maturity.

Bulltrout are known to utilize the Williston Reservoir extensively, based on past gillnetting. They are considered apex predators within the reservoir and are highly piscivorous, utilizing Kokanee as their main prey base. Although Bulltrout utilize the pelagic area in Williston Reservoir in search of prey, they are not considered to be a major contributor (< 5% of the total catch) to the pelagic fish community. Since juveniles of the adfluvial form of Bulltrout have not been observed to leave their natal stream for their rearing lake before they are 2-4 years old and about 200mm in length (McPhail 2007), Bulltrout <200 mm are not expected to be found in Williston Lake.

<u>Kokanee</u>

Kokanee, evolved post glacially from Sockeye Salmon, are widely distributed within BC. From the two basic life history patterns presented by Sockeye, non-anadromous Kokanee generally have colonized lacustrine habitats of many large lakes within BC and have been introduced to numerous small lakes in the central interior. Kokanee have been introduced to Williston Reservoir (Langston and Murphy 2008). Although Kokanee can express variable life history traits, they remain in freshwater throughout their entire life history (McPhail 2007). Kokanee spawn in the fall and generally mature as 2+ or 3+, depending on the population and lake productivity. Kokanee in the Williston Reservoir typically spawn at age 3+ and an average length of 231 ± 11 mm STDEV (Sebastian et al. 2008). Williston Kokanee are therefore very similar in length at maturity to Kokanee in other ultra-oligotrophic lakes in British Columbia, such as Powell Lake where age 3+ Kokanee spawned at an average length of 216 ± 9 mm STDEV and 231 ± 8 mm STDEV in 2011 and 2012, respectively (Plate et al. 2012 and LGL Limited unpublished data) and such as Coquitlam Lake where age 3+ Kokanee spawned at an average length of 244 ± 8 mm STDEV (Plate et al. 2011). Kokanee of all ages (fry-adult) are known to utilize the pelagic habitat of the Williston Reservoir, based on historic gillnetting and trawl surveys. Much of the time Kokanee are distributed throughout all water layers in other lakes and often rear near the thermocline. In Williston Reservoir however, Kokanee have always been vulnerable to gillnetting in the top 3 m of the water column (Sebastian et al. 2008, Pillipow and Langston 2002, Blackman 1992). By 2000, it was estimated that Kokanee contributed up to 14% of the pelagic fish abundance in Williston Reservoir (Sebastian et al. 2003) and by 2008 this contribution had increased to 45% of the pelagic fish abundance (Sebastian et al. 2008) at least for the Peace Arm of the Williston Reservoir.

<u>Lake Whitefish</u>

Lake Whitefish occur throughout much the upper Fraser, Skeena, Mackenzie and Yukon systems. Little is known about their life history, however, many populations dwell in lacustrine habitats within lake systems in BC. Lake Whitefish spawn in the fall and generally mature between 4-10 years of age. In the Williston Reservoir Lake Whitefish have been observed to be mature at an average length of 278 mm and from age 5 to age 10 (Sebastian et al. 2008). Often slow growing, Lake Whitefish can live >12 years and adults usually attain sizes exceeding 250 mm in length. In Williston Lake, Lake Whitefish showed rapid growth from age 1 to age 3 and then very slow growth after that with very few fish exceeding 300 mm in length (Sebastian et al.2008 and Blackman 1992). Lake Whitefish are known to utilize the Williston Reservoir extensively, based on past gillnetting results (Sebastian et al. 2008, Pillipow and Langston 2002, Blackman 1992). Previous surveys indicate that Lake Whitefish preferred near-surface habitat and were found in similar numbers in surface sets both near shore and off-shore. Lake Whitefish have a wide range of tolerance for temperatures (0 - 26°C) and an optimum for growth of 8-14 ºC (Ford et al. 1995). McPhail (2007) indicates that Lake Whitefish juveniles tolerate higher temperatures than adults so tend to occupy shallower water preferably with a temperature close to 17ºC during their first summer. The 1974 (Barrett and Halsey 1975), 1989 (Blackman 1992) and 2000 (Pillipow and Langston 2002) studies confirmed that Lake Whitefish were the dominant planktivorous species in Williston Reservoir, including Peace Arm but also showed a declining trend.

Peamouth Chub

Peamouth Chub, from the minnow family (Cyprinidae) are a widely distributed species within the interior of BC (McPhail 2007). Based on general life history patterns, Peamouth Chub have colonized lacustrine habitats of most large lakes, including riverine habitats of many large rivers within BC. They are considered to be mainly insectivorous, feeding on a wide variety of aquatic insects and terrestrial insects. Although, Scott and Crossman (1973) indicated that Peamouth Chub can selectively feed upon planktonic crustaceans.

Peamouth Chub spawn in early summer and typically mature in their fourth summer in most areas. In Willliston Reservoir, Peamouth Chub appear to be maturing in their fifth summer and a at an average length of 216 mm ± 16 mm STDEV based on the Peamouth Chub catch and age information collected in this study. While some Peamouth Chub populations are known to spawn in shallow areas (beaches) of lakes, most lacustrine populations utilize inlet or outlet streams proximate to the lake or reservoir in which they reside. Juvenile Peamouth Chub typically school in shallow littoral areas in the daytime and disperse into deeper water at night. Adult Peamouth in the summer have a diel migration which brings them near the surface and into shore in the evenings (McPhail, 2007). After hatching, newly emerged fry are found in nearshore and littoral areas of most lakes and reservoirs, often associated in mixed schools of Redside Shiner, and Northern Pike Minnow. Therefore, juvenile Peamouth Chub are not likely to contribute to the pelagic community of fish that are <120mm and that is detected in hydroacoustic surveys. However, based on previous gillnetting, Peamouth >120 mm (sub-adult-adult) are known to utilize the pelagic habitat of the Williston Reservoir (Blackman 1992; Pillipow and Langston 2002, Sebastian et al. 2008). Their patchy distribution indicated by high variability in gillnet catches is consistent with known schooling behavior and may result in biased estimates for this species. The lack of Peamouth in midwater trawling compared with surface gillnetting suggests that they are vertically distributed within the upper few meters (< 5 m) of the water column based on data from Sebastian et al. (2003 and 2008).

Limnology of the Peace Arm of Williston Reservoir

This section is based on material in Sebastian et al. (2008):

Stockner and Langston (2000) and Stockner et al. (2005) describe the Williston Reservoir’s limnology in detail as follows: the reservoir has a mean depth of 41.7 m and maximum depth of 166 m at maximum operating level of 672.08 m elevation. According to Wetzel (2001), the reservoir is considered an ultraoligotrophic (i.e., very nutrient poor) system with average concentrations of total dissolved phosphorus (TDP) ranging from 3–5 ug/L, nitrate-nitrogen (NO-N) ranging from 60–65 ug/L and low photosynthetic rates (PR) similar to many coastal and northern lakes.

The Peace Reach is much deeper, narrower and more wind-mixed than either Parsnip or Finlay reaches. Within the Peace Reach, the easternmost portion (near the dam) is the deepest. There appears to be an east to west gradient of decreasing biological productivity within the Peace Reach. This gradient is associated with greater epilimnetic depth (>40 m), higher maximum water temperatures, and a higher turbidity at the forebay. The reduction in productivity near the forebay is attributed to increased turbidity which limits light penetration. Erosion of fine alluvial soils due to wind and wave action on steep, exposed shores comprised of glacio-fluvial deposits at the extreme eastern portion of the Peace Arm are the primary causes for increased turbidity in the pelagic area of the forebay. Basic chemical limnology (TP, TDP, NO_3 and NO_3:TDP ratio) support the hypothesis that light limitation rather than nutrient limitation is the cause for reduced productivity in the Peace Arm compared to the main portion of the reservoir.

MATERIALS AND METHODS

Study Area and Transect Naming Convention

The area for this study was limited in the east by the W.A.C. Bennett Dam and in the west by a line across the reservoir between transects 31 and 31.5 (~15 km from the dam) as shown in Figure 2 and based on Sebastian et al's (2008 and 2003) and transect naming convention and Pillipow and Lanston's (2002) gillnet location naming convention.

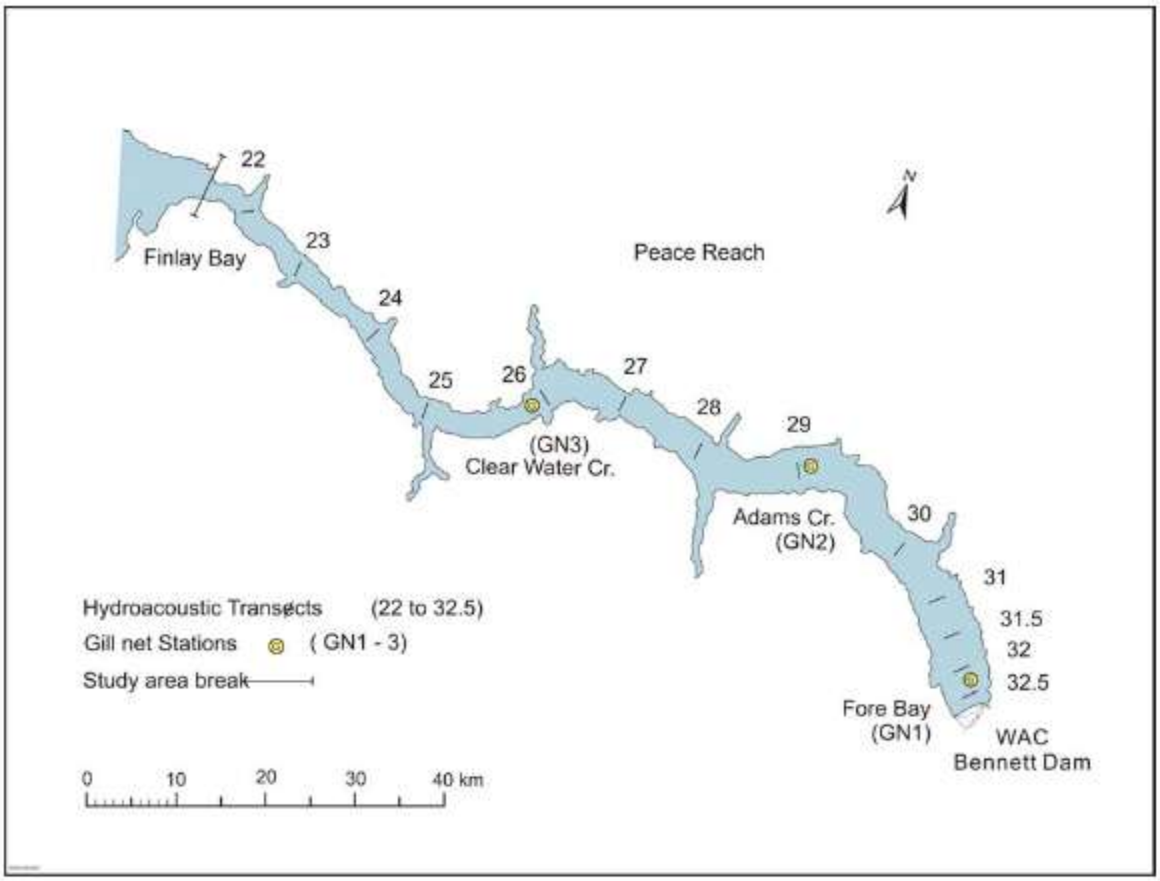


Figure 2 Map of the Peace Reach of the Williston Reservoir showing the locations of all hydroacoustic transects and gillnet stations used by Sebastian et al.

(2008) (from Sebastian et al. 2008) including Transects 31.5, 32 and 32.5 as well as GN1used in this study.

The coordinates of the southernmost end of the three transects sampled for the present study were based on transect coordinates used by Sebastian et al. (2008) and are shown in (Table 1).

Table 1 Hydroacoustic transect locations, and UTM coordinates from Sebastian et al. (2003 and 2008). Transects 31.5, 32 and 32.5 were used in 2012.

Year	Location	Transect	UTM Coordinates
2000, 2008	Near Junction	22	10U.0458476.6210429
2000, 2008		23	10U.0467668.6208282
2000, 2008		24	10U.0476824.6206865
2000, 2008	Clearwater Creek	25	10U.0486553.6203705
2000, 2008		26	10U.0496286.6210709
2000, 2008		27	10U.0505060.6215272
2000, 2008	Carbon Creek	28	10U.0512855.6214730
2000, 2008		29	10U.0524102.6219373
2000, 2008	Dunlevy	30	10U.0534120.6217991
2000, 2008		31	10U.0540047.6215729
2008, 2012		31.5	10U.0544377.6213287
2008, 2012		32	10U.0547338.6209892
2008, 2012	Forebay	32.5	10U.0548465.6209137

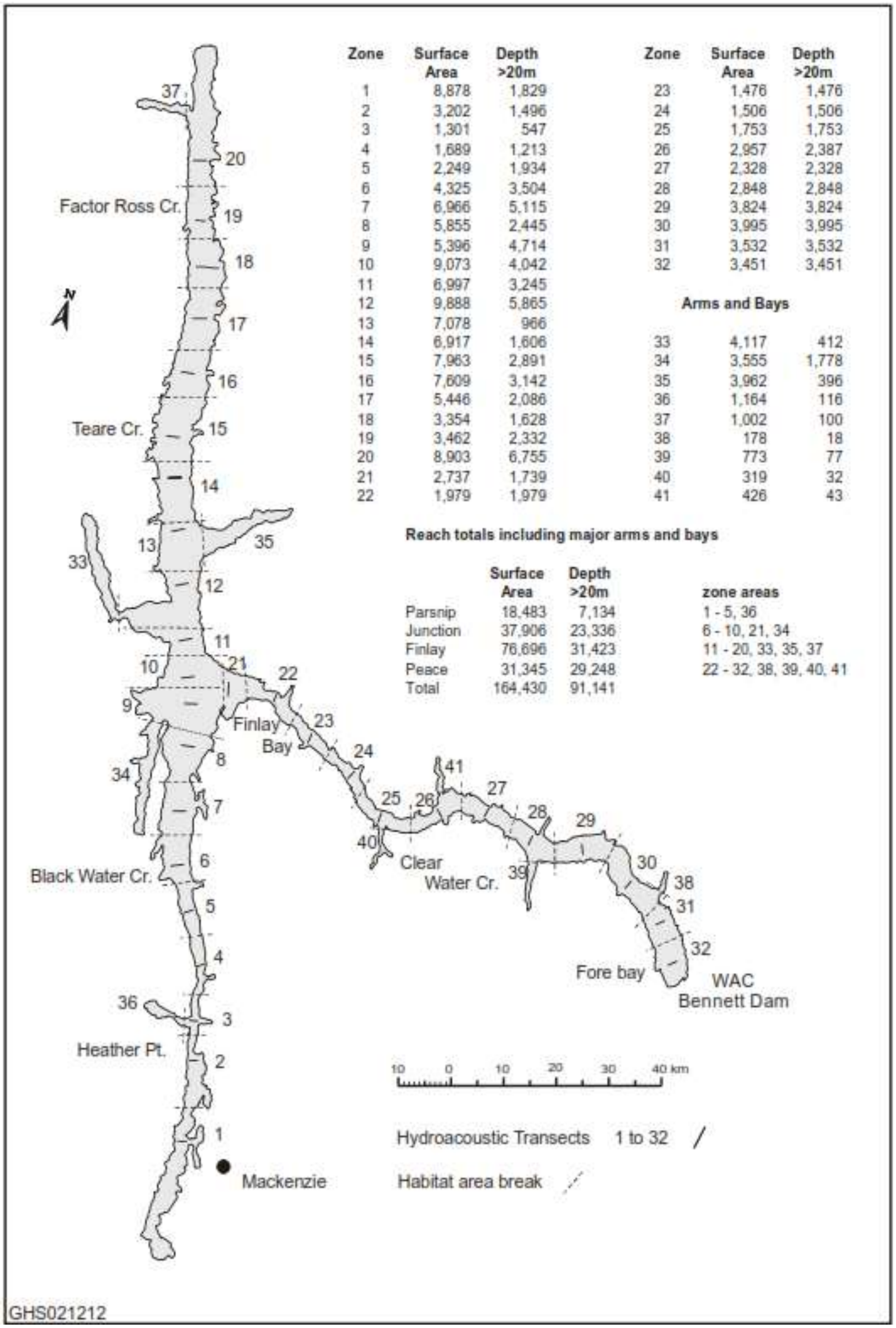
Note: UTM coordinates mark south end of transect

Transect 32.5 is located closest to the Bennett Dam and fish along this transect are the most likely to be entrained through the spillways into Dinosaur Reservoir. Therefore, Transect 32.5 was surveyed three times to achieve a population estimate with higher confidence, while Transects 31 and 31.5 were surveyed twice.

The gillnetting location used in this study was also based on Sebastian et al’s (2008) forebay gillnetting location named Gillnet Station 1 (GN1) as shown in (Figure 2). In this study, GN2 and GN3 were not repeated due to limited time to mobilize within the time window of spillway operations. GN1 was the closest to the spillway and hence was expected to be representative of the fish assemblage that was most likely to be affected by spillway operations.

Zone Definitions and Habitat Areas

To calculate fish populations, we expanded the average hydroacoustic density estimates for Transects 31.5, 32 and 32.5 of fish per hectare to the total area for Zones 31 and 32 (Figure 3). The calculations for the total area of Zones 31 (3,532 ha) and 32 (3,451 ha) were provided by Sebastian et al.(2003) (Figure 3). Sampling of those transects and the expansion of the transect densities to the total areas of defined zones was aimed at achieving consistency with the methods of Sebastian et al. (2008).



Zone	Surface Area	Depth >20m	Zone	Surface Area	Depth >20m
1	8,878	1,829	23	1,476	1,476
2	3,202	1,496	24	1,506	1,506
3	1,301	547	25	1,753	1,753
4	1,689	1,213	26	2,957	2,387
5	2,249	1,934	27	2,328	2,328
6	4,325	3,504	28	2,848	2,848
7	6,966	5,115	29	3,824	3,824
8	5,855	2,445	30	3,995	3,995
9	5,396	4,714	31	3,532	3,532
10	9,073	4,042	32	3,451	3,451
11	6,997	3,245			
12	9,888	5,865		**Arms and Bays**	
13	7,078	966			
14	6,917	1,606	33	4,117	412
15	7,963	2,891	34	3,555	1,778
16	7,609	3,142	35	3,962	396
17	5,446	2,086	36	1,164	116
18	3,354	1,628	37	1,002	100
19	3,462	2,332	38	178	18
20	8,903	6,755	39	773	77
21	2,737	1,739	40	319	32
22	1,979	1,979	41	426	43

Reach totals including major arms and bays

	Surface Area	Depth >20m	zone areas
Parsnip	18,483	7,134	1 - 5, 36
Junction	37,906	23,336	6 - 10, 21, 34
Finlay	76,696	31,423	11 - 20, 33, 35, 37
Peace	31,345	29,248	22 - 32, 38, 39, 40, 41
Total	164,430	91,141	

Figure 3 Sampling zones in Williston Reservoir from Sebastian et al. (2003).

Physical Parameter Profiles

Using a YSI 600 XL multi-meter with a 60-m cable and a YSI 650MDS data display and logging system, we measured:

- depth;
- water temperature;
- dissolved oxygen; and
- pH.

These parameters were recorded at depths of 1 m, and then from 2–15m in 1-m intervals, and from 15–60 m in 5-m intervals.

Mobile Hydroacoustic Surveys

In 2012, we completed four acoustic night-time surveys in the vicinity of W.A.C. Bennett Dam. All surveys occurred at night starting on July 15 and ending on July 18. The new moon phase in July occurred on July 16 and therefore all surveys were conducted with minimal light that could have influenced the behavior of fish. The initial survey was affected by high levels of noise and may have underestimated fish densities. Results from that survey were therefore disregarded and the survey was repeated the following night.

The survey was conducted from the "Williston Ranger"; a closed cabin 9m research boat operated at a speed of 7 km/h or 2 m/s to repeat Sebastian et al.'s (2008) boat speed. Navigation was by radar, a Lowrance LCX27C GPS with Freedom Maps Canada Topo Series software. Acoustic survey data was collected using a 200 kHz BioSonics DTX echo sounder with one 6.2° circular split-beam transducer. The transducer was mounted on the swim platform in the stern of the boat (Figure 4, right panel), positioned 0.5 m below the water surface and aimed vertically to sample from 2.5 m below the surface to 60 m. During the four surveys the same three transects were sampled.

As a quality assurance measure, data was send to Don Degan, Aquacoustics, Inc., 29824 Birdie Haven Court, PO Box 1473, Sterling, AK 99672, U.S.A. every morning after data collection and quickly visually analyzed in the "playback mode" of Biosonics' Visual Acquisition (Version 6.0) software. Don Degan of Aquacoustics Inc. specializes in hydroacoustic surveys and data analysis and has more than 30 years and hundreds of projects of experience to base his advice on.

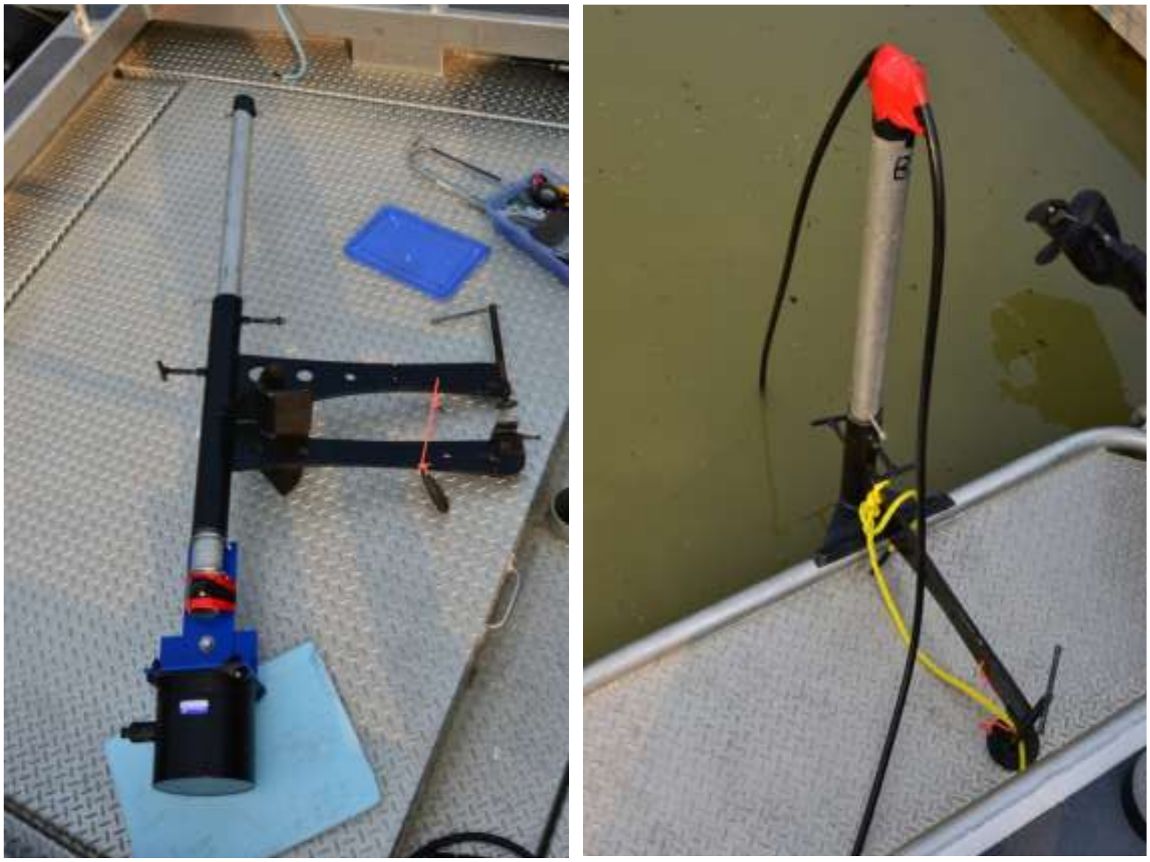


Figure 4 Biosonics transducer and transducer mount on the transom of the study vessel.

Initially, we used the echosounder settings used by Sebastian et al. (2008) but the slow ping rate (3 pings/sec) and long pulse duration (1 msec) used in 2008 did not allow us to record data properly and resulted in an unacceptable signal to noise ratio. Therefore the sample rate for the transducer was set to 10 pings per second, and pulse duration was set to 0.2 msec which resulted in good target recognition and a good signal to noise ratio. The faster ping rate and shorter pulse duration used in this study may have led to a higher number of fish targets detected when compared with Sebastian et al. (2008).

The threshold for the system during data collection was set to -75 dB with a 0 dB power level. Data were automatically geo-referenced through a handheld GPS connected to the BioSonics DTX system. The acoustic system was calibrated using a standard (36-mm diameter) tungsten carbide calibration sphere. The calibration sphere was lowered to ~10 m below the transducer, positioned in the beam, and several thousand pings were recorded to estimate target strength of the sphere. The post calibration indicated that the target strength data from the calibration sphere were equal to the expected target strength for the transducer type and no offset had to be applied to the data.

The maximum pinging depth was set to 60 m to facilitate the high ping sampling rates that led to a high resolution in the depths to 60 m. The focus of this study was the enumeration of fish that may be entrained and fish at depth >60 m are unlikely to be entrained and moreover very few fish were detected in depths >60 m in the 2008 hydroacoustic survey carried out by Sebastian et al. (2008) at the same of year.

Processing of Hydroacoustic Data

Acoustic data were processed using Echoview V4.90 by echo tracking to combine individual echoes into fish tracks. The tracks were filtered by off-axis angle to include only those tracks within 5° of the center of the 6.2° beam. The effective beam width then varied by fish depending on the fish size relative to the analysis threshold of -60 dB.

For each transect, fish density values were estimated as follows: each observed fish was weighted by the effective width of the beam at the range of the fish. The weighted fish count was then summed over each transect and divided by the transect length using the formula:

$$D_i = \frac{\sum_j \frac{1}{b_j}}{l_i}$$

Where D_i is the fish density (fish/m^2) of transect i, the summation is over all fish j observed in transect i, b_j is the beam diameter (m) at range of fish j, and l_i is the length (m) of transect i.

We assumed Love's (1977) equation for all aspects was representative of the target strength distribution:

$$\text{TS} = 20 \log \text{L} - 69.23$$

where,TS = target strength in decibels; and L = fork length in centimeters.

Fish Sampling

A four-person crew conducted the gillnetting operation on 17 and 18 July 2012 (Figure 5). The gillnetting sites corresponded to Gillnet Station 1 used by Sebastian et al. (2008) (see Figure 2).

Figure 5 Setting gillnets on the Peace Reach of the Williston Reservoir, July 17, 2012.

Gillnets

All gillnetting in this study was carried out under the British Columbia, Ministry of Forest, Lands and Natural Resource Operations Fish Collection Permit Number: FJ12-80221 (a copy of the permit can be found in Appendix 3 of this report). We used gillnetting to sample the fish species present in accordance with Resource Inventory Standards Committee (RISC) standards (Anon. 2001). Within the water column, we focused sampling efforts on the upper 15 m of the pelagic zone since the scope of this project was limited to the collection of fish that were likely to be entrained through the W.A.C. Bennett Dam spillway. The center of Gillnetting Station 1 was located 1.45 km from the entrance to the spillway of W.A.C Bennett Dam.

To hold the nets in place, we used 8 pound Danforth anchors on both ends of a gang of nets. The gang of nets used in this study consisted of six multi-panel nets. Each multi-panel gillnet was constructed of double knotted, light-green or transparent monofilament nylon mesh, and with a hang ratio of 2:1. Between every multi-panel net we used two high-volume (140 L) buoys to float the net and one additional high-volume buoy in the center of each net to keep it at the desired depth over its whole length. Net depth was regulated by the length of the line sections between the buoys and the float lines of the nets.

We used two different multi-panel and multi-mesh gillnet types. Five nets consisted of five panels, four of which were 15 m long while the fifth one was 25 m long. Thread diameter of the mesh ranged from 0.2 to 0.25 mm, with mesh sizes of 12, 88, 50, 25 and 18 mm, strung together in a "gang" to form a net 96 m long and 3.6 m deep (Figure 6). In addition to the gillnet type described in Figure 6, we used one smaller multi-mesh net composed of three 2.4 x 15 m panels with mesh sizes of 19, 25 and 50 mm made from the same materials and hung at the same ratio as the five-panel net. Lastly, we used one gillnet that had a uniform mesh size of 60 mm over its 100 m length and 5 m depth. The gang of nets in this study was set at a 45º angle to shore and left in place overnight.

Data from previous studies in British Columbia (Hamley 1972; Plate 2007) indicated a relationship between mesh sizes and the lengths of fish that are expected to be caught (Figure 7) and based on this relationship, we selected the mesh sizes for this study. A 12 mm minimum mesh size should catch fish with a minimum fork length of 60–80 mm and thus be able to catch age-1+ Kokanee, Lake Whitefish and Peamouth Chub, the expected dominant fish species, from early summer on.

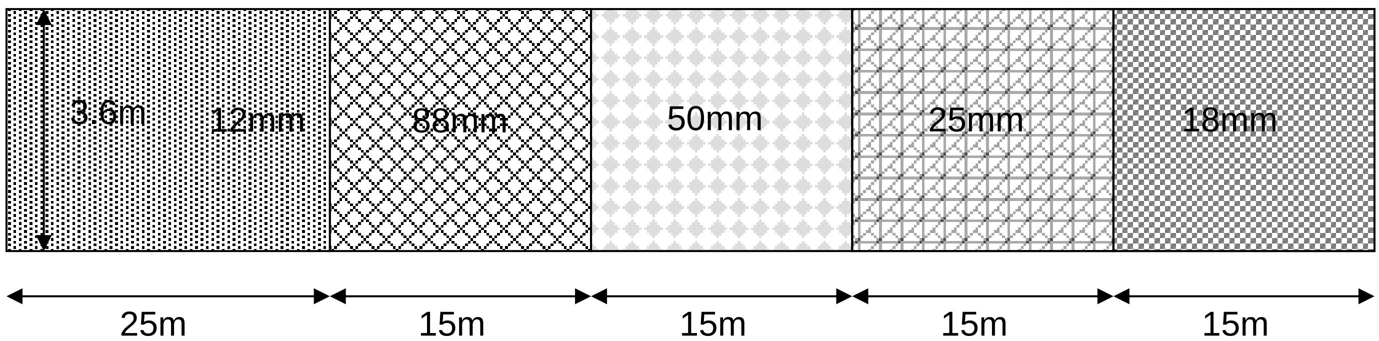


Figure 6 Conceptual depiction of the multi-panel and multi-mesh size net used in 2012.

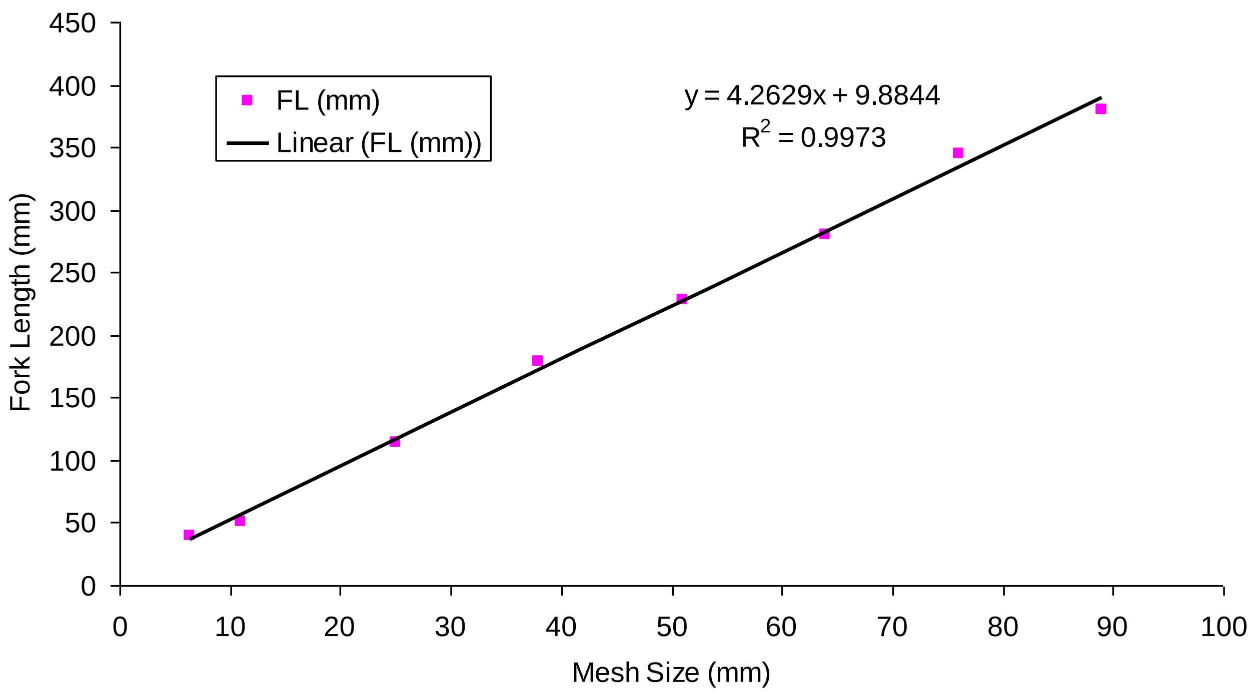


Figure 7 Plot and linear relation between fork lengths and net mesh size for fish caught in freshwater lakes in British Columbia (Hamley 1972, Plate 2007).

Gillnets were deployed on July 17, 2012 and all details of the gillnet set data are summarized in (Table 2).

Table 2 Gillnet set data for 2012 Williston Fish Index Study. UTM Zone for all coordinates is U10.

Date In (dd/mm)	Date Out (dd/mm)	Set #	Mesh & Panel Sizes	Net Depth From (m)	Net Depth To (m)	Gear In (24 hour)	Gear Out (24 hour)	Total Soak Time (h)	3 Net Centre UTM Easting	3 Net Centre UTM Northing
17-Jul	18-Jul	1	Modified RIC 3.6 x 83m	1	4.6	18:00	13:30	19.50	548464	6210071
17-Jul	18-Jul	2	Modified RIC 3.6 x 83m	1	4.6	18:05	13:40	19.58	548464	6210071
17-Jul	18-Jul	3	Modified RIC 3.6 x 83m	5	8.6	18:10	13:50	19.67	548464	6210071
17-Jul	18-Jul	4	Modified RIC 2.4 x 45m	5	7.4	18:15	14:00	1.75	548983	6210014
17-Jul	18-Jul	5	Uniform 60mm, 5 x 83m	10	13.6	18:20	15:10	20.83	548983	6210014
17-Jul	18-Jul	6	Modified RIC 3.6 x 83m	10	13.6	18:25	15:40	21.25	548983	6210014

The net depths in Table 2 were based on the length of line between the surface buoys and the float line or top edge of the nets but all nets were lifted by approximately 5 m by a thunderstorm that asserted a large amount of pressure on the lines that connected the buoys with the anchors and the nest with the buoys.

Effort and Catch Per Unit Effort

Gillnetting effort for each set was measured as fishing time in hours and was calculated in MS Excel as follows:

$$E = (HOUR(TR-TD)*60+MINUTE(TR-TD))/60$$

where,
E = effort in hours;
TD = time of net deployment in 24 hour format;
TR = time of net retrieval in 24 hour format

Catch-per-unit-effort (CPUE) for a given set (j) was standardized to a fishing area of 100 m^2 and one hour was calculated as:

$$CPUEj = Nj/(Aj/100)/TFj$$

where,
Nj= catch in set j;
Aj= total area of gillnets in set j;
TFj= total time fished in hours for set j.

Fish Handling
All captured fish were removed from the nets by hand. Those that were still alive were immediately killed by a blow to the head, placed in plastic bags numbered with the set number, and moved to a central location on a barge located at the BC Hydro boat ramp close to W.A.C. Bennett Dam for processing within 3h.

Biological Sampling
All fish captured were identified to species, classified as adult or juvenile using RISC standards (Anon. 2001), and enumerated. For each fish caught, the following data were recorded: date, time, gear type, set number, fishing depth, fishing location coordinates, fish species and life stage. The samples were processed by measuring fork length (FL, mm) and wet weight (g) for each fish. Scales were also taken from all fish, stored in DFO scale books and sent for scale ageing to Birkenhead Scale Analysis (Lone Butte, BC, Canada). For Bulltrout otoliths were taken in addition to scales for ageing. Scale were aged from images that were prepared by placing acetate on top of gummy surface of the scale books and creating a negative of the scales by compression under a hydraulic press for three minutes. The negatives of the scale images were read using a microfilm scanner at a magnification of 30-55 times. A digitial image of the best scale from each representative age class was taken. For otolith ageing, whole otoliths were placed in a black plastic container with water, and aged under a reflective microscope at a magnification of 25 or 50 times. Ages were reported as Age-0+, Age-1+ and so on. The plus sign indicates that growth since last winter or the last "check" had been added to the full age classes.

RESULTS AND DISCUSSION

Profiles of Physical Parameters

The temperature profile measured on July 21, 2012 showed a distinct temperature drop from 16.5 ºC to 10 ºC across a thermocline that existed at a depth of ~6–13 m. Below the thermocline, the temperature continued to drop at a slower rate from 10 ºC to 5 ºC between 15–45 m, with very small changes in temperature from 45–60 m (Figure 8).

The dissolved O_2 profile also showed a distinct pattern for the thermocline depths from 5–13m which corresponds with the increased solubility of oxygen in colder water. O_2 concentrations increased rapidly from 9.8–10.5 mg/L at depths of 5–8m and increased at a lower rate to a depth of 50 m were the maximum concentration of 12.1 mg/L was reached. From there the O_2 concentration dropped back to 11 and 11.3 mg/L at 55 and 60 m, respectively (Figure 8).

The pH values decreased throughout the thermocline from pH 9–8.1 between 1–20 m and only fluctuated lightly between 20–60m (Figure 8).

In summary, on July 21, 2012 the forebay region of the Peace Reach close to W.AC. Bennett Dam was highly stratified and the epilimnion (zone above the thermocline) reached to a depth of 18 m, typical for the dimictic Williston Reservoir that experiences periods of deep mixing in May and November and periods of stratification from June to October and February to April (Stockner et al. 2005).The surface temperature of 17 ºC was also typical for this time of the year (Stockner et al. 2005) and would drive Kokanee to a minimum depth of 5 m to rear in their preferred temperature range of 10–15ºC (Scott & Crossman 1973).

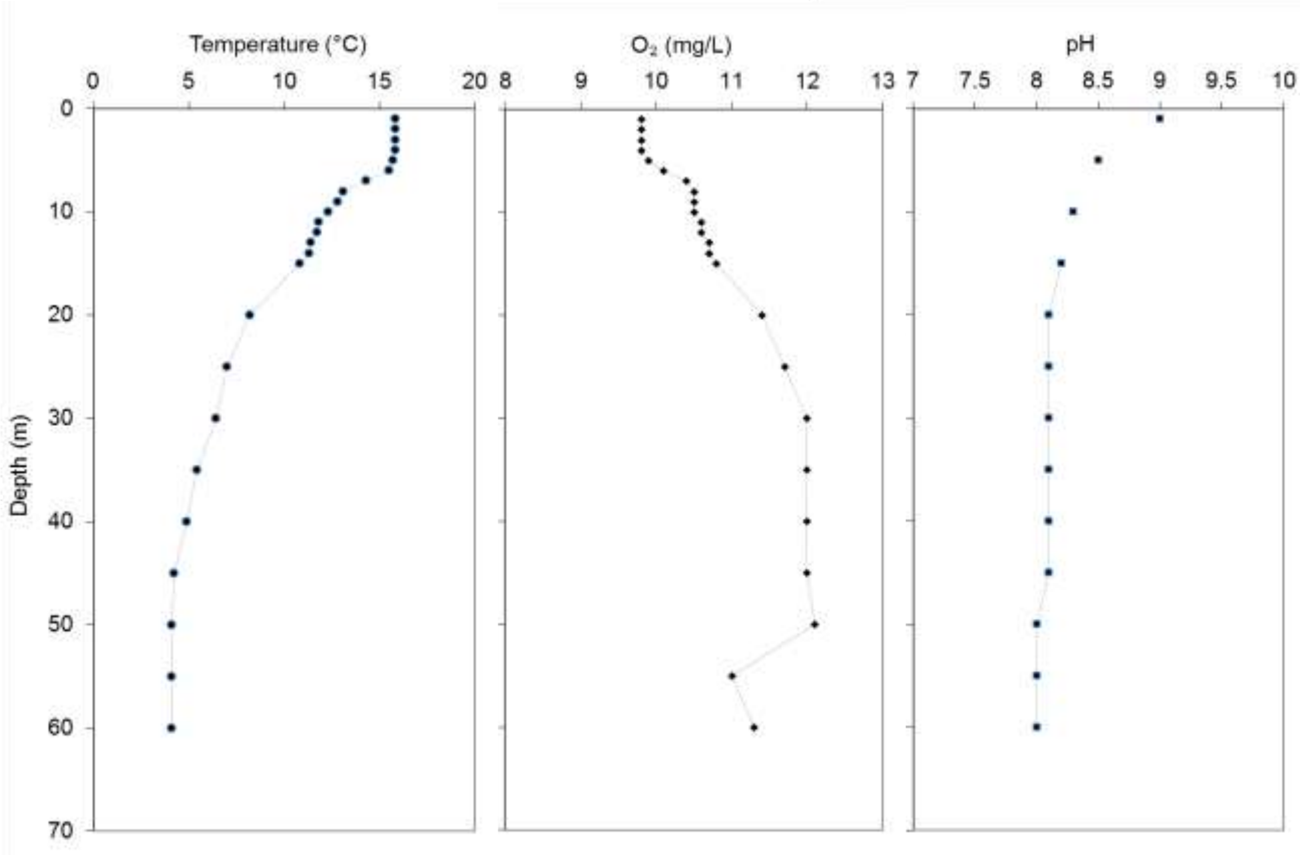


Figure 8 Water temperature, dissolved oxygen (O_2) and pH profiles taken on July 21, 2012 in the center of transect 31.5 in the Peace Reach of Williston Reservoir.

Fish Abundance and Distribution – Hydroacoustics

Between July 15–18, 2012 we surveyed 11 transects (Transect 32.5 five times, Transects 31.5 and 32 three times each) using hydroacoustics at night and within two days of the new moon (July 16) for minimal light. The same approach was taken by Sebastian et al. (2008) who carried out all surveys at night-time and with minimal light. The four transects (Transect 32.5 twice and Transects 32 and 31.5 once each) surveyed during the night from July 15–16 had unusually high noise levels and therefore likely masked an unknown number of fish targets and would have led to the underestimation of the fish population. Therefore the July 15-16 results were disregarded and the hydroacoustic surveys were repeated on July 16–18 without any noise problems.

In general, the hydroacoustic targets detected during all surveys and over all transects showed a distinctive fish layer from 5–18 m with relatively fewer fish outside the layer (Figure 9). This fish layer was therefore located just below the thermocline (Figure 8) and likely in a zone of high zooplankton density that can also be typically found just below the thermocline (Cantin et al. 2011).

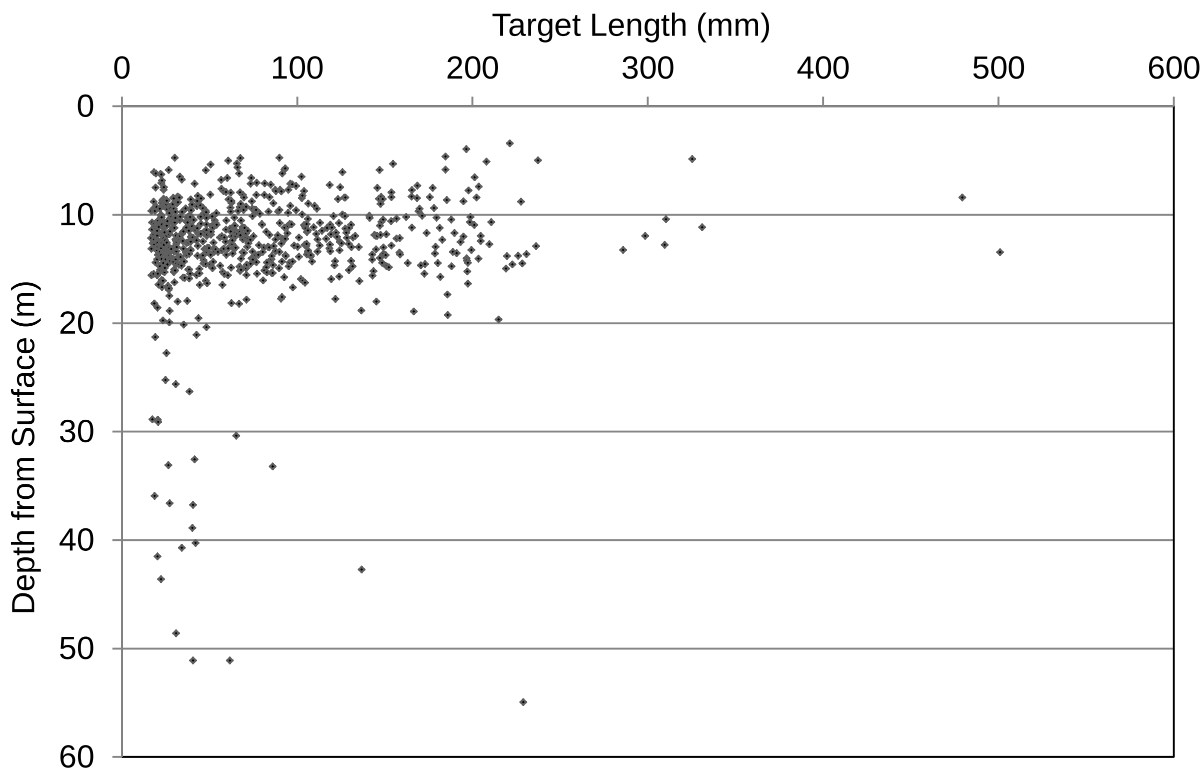


Figure 9 Distribution of individual targets (fish) by length and depth for all transects surveyed by hydroacoustics during night-time from July 16–18, 2012.

Regarding length-specific depth preferences, smaller fish with a length <80 mm showed the largest depth range from 5–62m while fish >80 mm were found mainly in the depth layer of 5–18 m (Figure 9).

As in 2008, very few targets with a strength <30 dB and a corresponding length >500 mm were detected but the main fish layer (5–18 m) in 2012 was mostly shallower than in 2008 (10–35 m) (Sebastian et al. 2008). This difference in the target depth distribution may be based on the shallower epilimnion in 2012 (0–15m) (Figure 8) when compared with the deeper epilimnion in 2008 (0–35 m) (Sebastian et al. 2008) in the Bennett Dam Forebay area. In 2012, we also found less fish in the deeper hypolimnion (below the thermocline) from 40–60 m, while a higher percentage of fish was found in this zone in 2008 (Sebastian et al. 2008). The reasons for this discrepancy may have resulted from different patterns of temperature stratification between the two study years (i.e., 2008 and 2012).

The abundance of fish shallower than 3 m was underestimated because fish have a tendency to avoid the boat and are reflecting too few echoes for a reliable estimate when they are closer than 2 m to the down-looking transducer. Our aggregate gillnet catches suggest that Kokanee, Lake Whitefish and Peamouth Chub were holding at depths <5 m during the period of the hydroacoustic surveys (Figure 19).

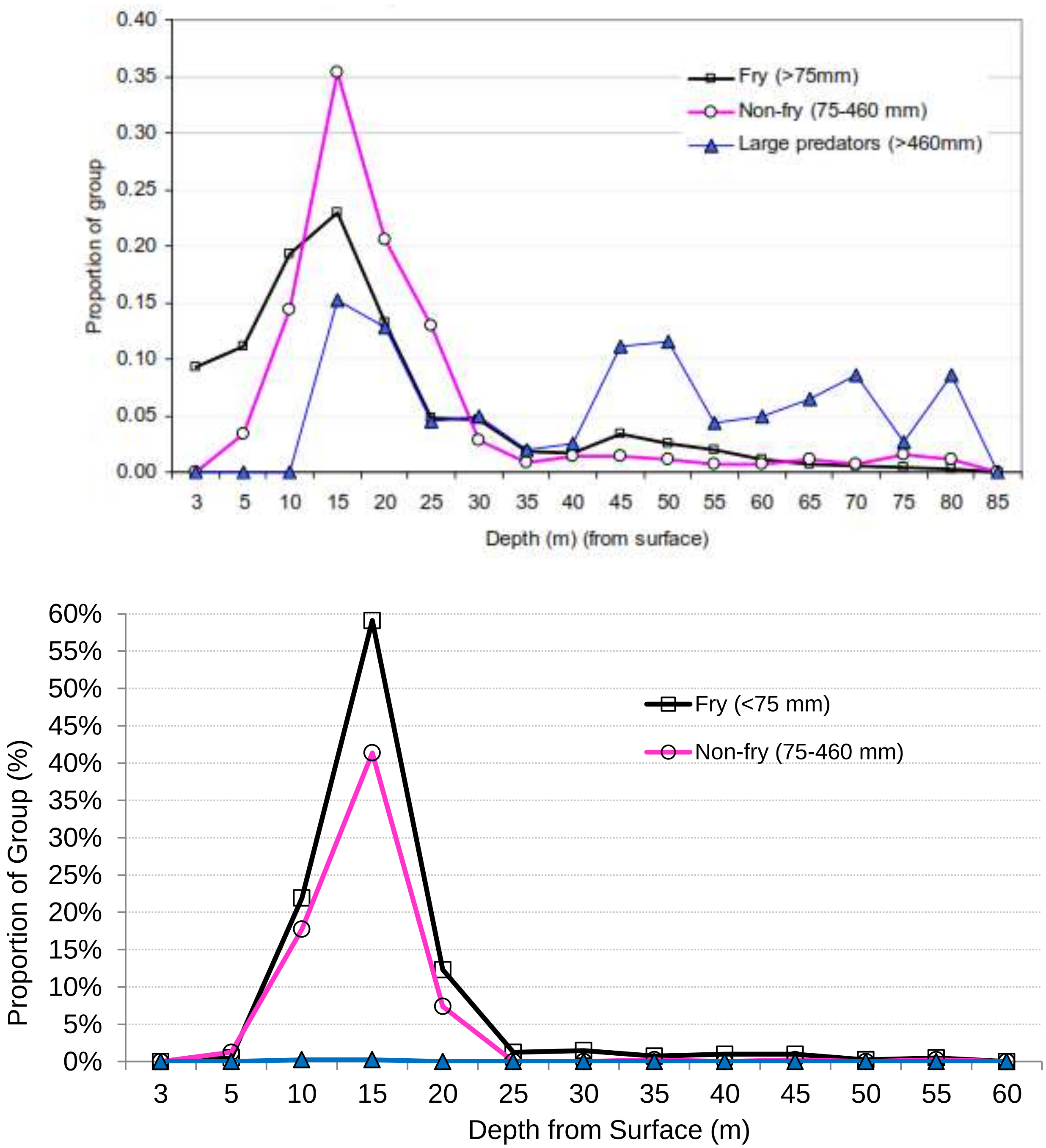


Figure 10 Relative vertical distribution of fish by three size groups in 2008 (top; from Sebastian et al. 2008) and 2012 (bottom; this study).

In 2008 and in 2012, the highest density of fry (<75 mm) and non-fry (75–460 mm) was detected in the depths range from 10–17 m and in 2008 large predators (> 460 mm) were detected in the depth range 45–80 m while very few large predators were detected overall in 2012 (Figure 10). Note that we limited the hydroacoustic depths range to a maximum of 60 m in 2012 based on the very low numbers of targets detected below 60 m as reported by Sebastian et al. (2008) and as shown in typical density distribution plots from Sebastian et al. (2003) and Johnson and Yesaki (1989) in Figure 11 for transects throughout Williston Rservoir .

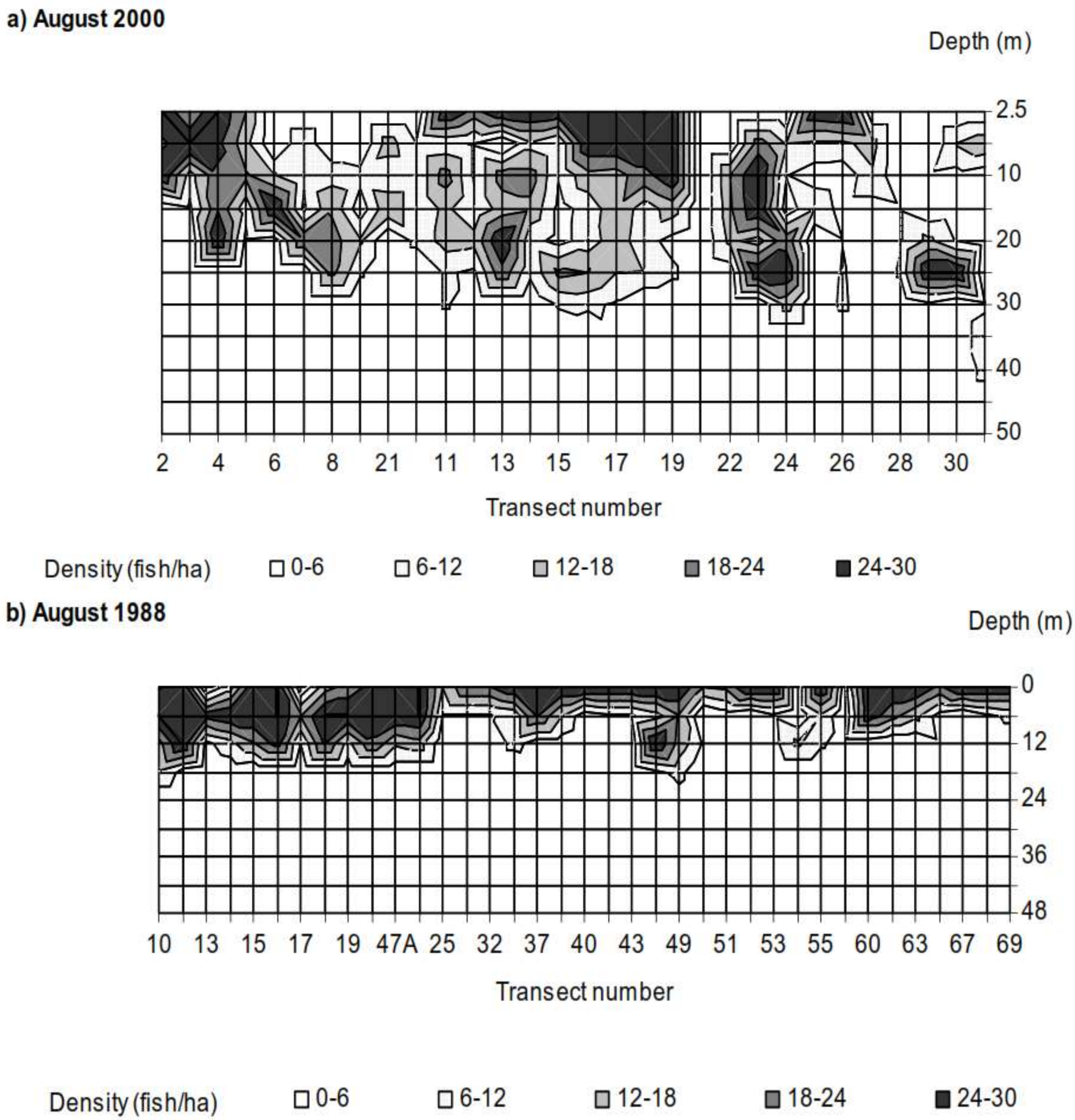


Figure 11 Vertical (and horizontal) fish target density distributions by transect number for all Williston Reservoir found in, a. August of 2000 (Sebastian et al. 2003) and September of 1988 (Johnson and Yesaki 1989).

The comparison between the average fish target densities on Transects 31.5, 32 and 32.5 between 2008 and 2012 are summarized in Figure 12. Fish target density for

Transect 32 was similar between 2008 (80 fish/ha) and 2012 (100 fish/ha) and was higher in 2012 for Transect 31.5 (108 fish/ha in 2008 versus 208 fish/ha ± SD 98 in 2012) and Transect 32.5 (45 fish/ha in 2008 versus 92 fish/ha ± SD 33 in 2012). Consequently, the mean fish target density of all transects was also higher in 2012 (128 fish/ha) than in 2008 (78 fish/ha). The different hydroacoustic depth ranges between 2008 (3–100 m) and 2012 (2–60 m) were unlikely to affect these differences because very few fish were detected below 60 m in 2008 (Sebastian et al. 2008). Statistical analyses of differences between the 2012 and the 2008 results were not possible as the raw hydroacoustic data from 2008 were unavailable and in 2008 each transect was sampled only once (Sebastian et al. 2008).

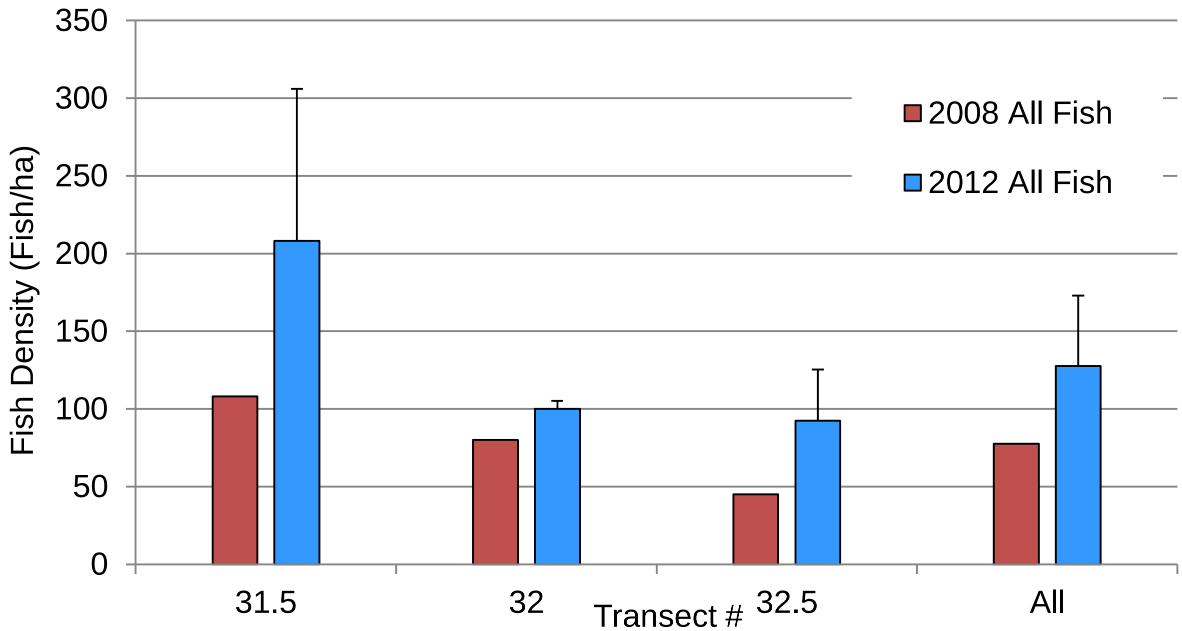


Figure 12 Mean fish density estimates ± SD in 2012 (all species and ages) from 3 - 60 m (2012) and 3 - 100 m (2008) depth ranges by transect number (2008 values from Sebastian et al. 2008 without error bars since transects were only surveyed once).

In 2000 and 2008 along transects 21–32 and in 1988 along transects 48-69 approximately the same area of the Peace Reach was hydroacoustically surveyed by Sebastian et al. (2003 and 2008) and by Johnson and Yesaki (1989), respectively. Also in 2000 along transects 31 and 32, in 2008 along transects 31.5, 32 and 32.5 and in 1988 along transects 67–69 approximately the same forebay area close to W.A.C. Bennett Dam was hydroacoustically surveyed by Sebastian et al. (2003 and 2008) and by Johnson and Yesaki (1989), respectively. The average fish densities per hectare from these studies for the Peace Reach and the forebay area were compared with the average fish density per hectare for the forebay area surveyed in the 2012 study in Figure 13.

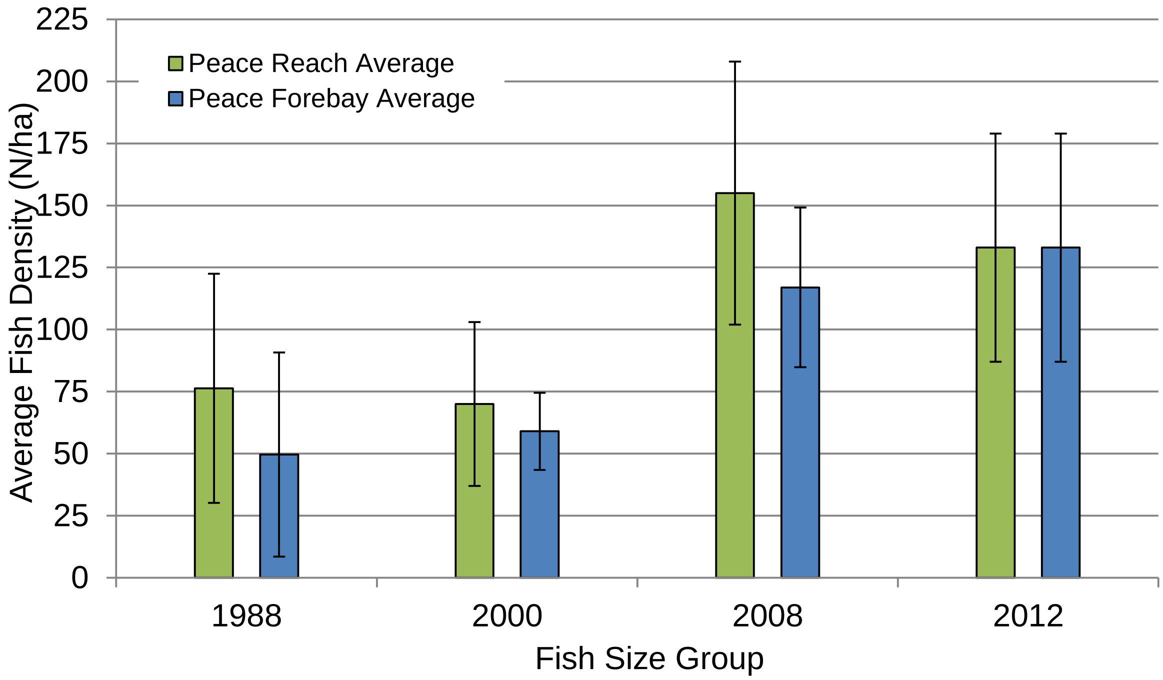


Figure 13 Comparison of the mean fish transect densities ± SD for the Peace Reach (green bars) and the forebay area (blue bars) from the 1988, 2000, 2008 and 2012 hydroacoustic studies (Johnson and Yesaki 1989, Sebastian et al. 2003 and 2008).

This comparison shows that average fish densities in the Peace Reach decreased by a small amount (9.2%) from 1989 to 2000 but increased by 121% from 2000 to 2008 and decreased by 14 % from 2008 to 2012 (Figure 14, green bars). Over the same period of time, the fish densities for the forebay area also increased by a small amount (18%) from 1988 to 2000 but increased by 98% from 2000 to 2008 and kept on increasing by 14% from 2008 to 2012 (Figure 14, blue bars).

The break-down of these fish densities into the three size groups chosen for the analysis of hydroacoustic data was only possible for a comparison between the 2008, the 2000 data (Sebastian et al.2008 and 2003) and the data form this study and is shown in Figure 14. Hydroacoustic raw data from earlier studies was not available for analysis and analyzed data was broken into other size classes. While the fry (<75 mm) size group was strongest in 2008, the non-fry (75–465 mm) size group was strongest in 2012 and the large predator (>465 mm) size group was low in numbers throughout. Sebastian et al. (2008) stated based on the 2000 and 2008 hydroacoustically determined fish densities in the Peace Reach that transect densities close to W.A.C. Bennett Dam in zones 31 and 32 were lower than transect densities in the zones further west and the border to the main reservoir. Based on this trend, we suggest that fish densities throughout the Peace Reach may have not decreased since we found the 2012 densities in the easterly and previously fish-poor zones 31 and 32 to be at the same level as 2008 fish densities for the whole of the Peace Reach including the more productive zones to the west.

A statistical analysis for the significance of differences between the 2000, 2008 and 2012 results is not possible as we had no access to the raw hydroacoustic data from 2000 and 2008.

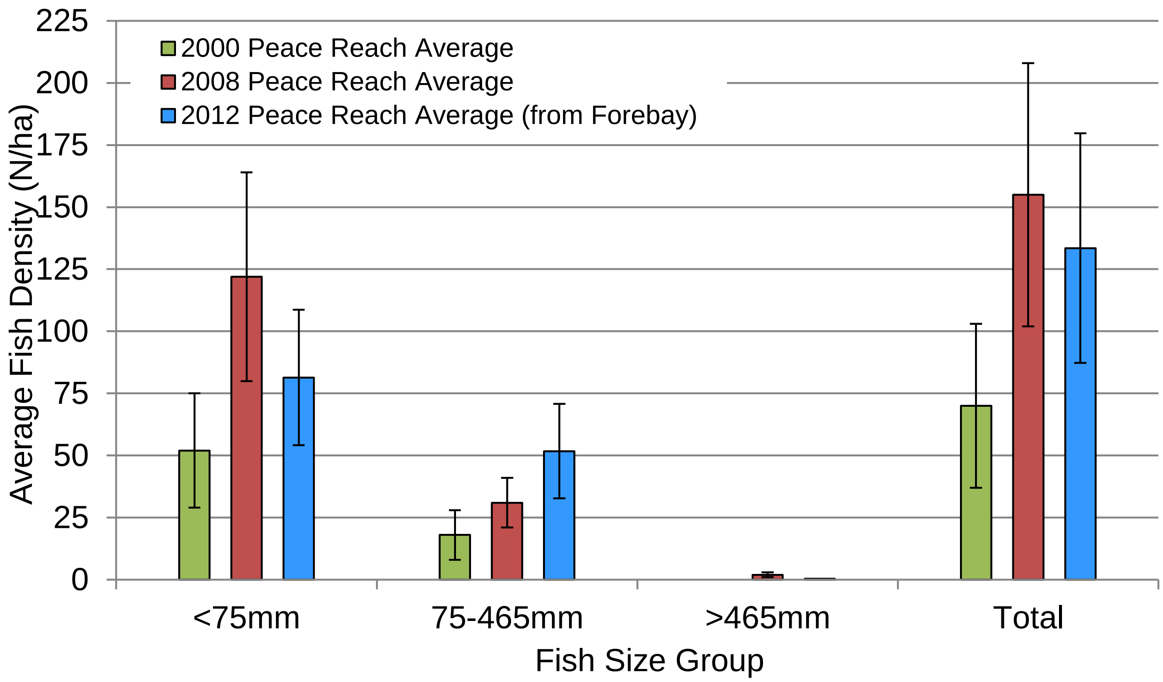


Figure 14 Average transect density (error bars for standard deviation) for all transects in the Peace Arm in 2000 and 2008 (data from Sebastian et al. 2008) compared with average transect densities for zones 31 and 32 from this study.

Overall, the average fish densities recorded in the 2012 hydroacoustic surveys in the Peace Reach of the Williston Reservoir are similar to fish densities recorded in oligotrohphic and ultra-oligotrophic lakes and reservoirs elsewhere in British Columbia. Examples are, densities of 102 , 60, and 85 fish/ha in the Coquitlam Reservoir in 2005, 2010, and 2011, respectively (Bussanich et al. 2006, Plate et al. 2011, Plate et al. 2012) and a density of 93 fish/ha in Powell Lake in 2012 (LGL Limited, unpublished data).

Total Catch, Catch Composition and CPUE from Gillnetting

Pelagic gillnetting provided an indication of the fish species composition present and an index of relative abundance of fish in zones 31 and 32 of the study area in 2012. The relative species composition for the 2012 gillnet catch is shown in Figure 15. Kokanee dominated the catch (65%), while Peamouth Chub (24%), Lake Whitefish (8%) and Bulltrout (3%) were less represented in the catch. The species apportioning shown in Figure 15, is likely representing the species apportioning of the fish in the size class from 75–465 mm that were entrained over the W.A.C. Bennett Dam spillway in 2012. This size class represented 18.2% of all fish that were entrained (Biosonics, 2012). The species apportioning of the small size class of fish 45–75 mm that represented 81.5% of all fish that were entrained cannot be derived from the gillnet catch since the smallest mesh size used in 2012 (12 mm) only samples fish >80 mm.

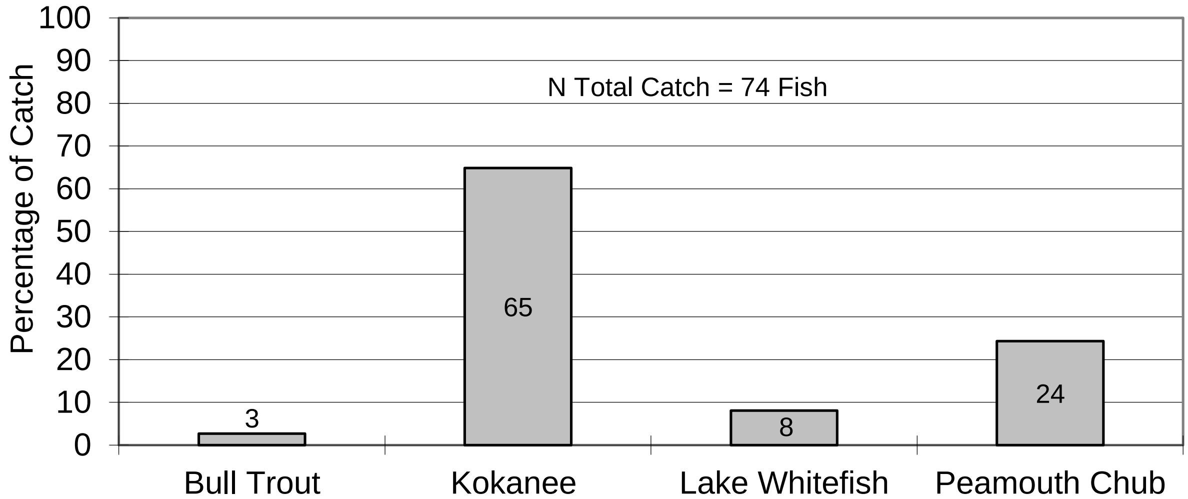


Figure 15 Relative fish species composition in the gillnet catch of the 2012 study in the W.A.C Bennett Dam forebay area.

In 2012, all gillnets were set around the Gillnet Station 1 also used in 2000 and 2008 (Sebastian et al. 2008). Gillnet station 1 was also within 5 km of gillnet locations used in earlier studies by Barrett and Halsey (1975) and Blackman (1992). Based on the vicinity of gillnet sets over the four earlier studies and the location used in 2012, a comparison could be drawn for the total catch, CPUE ($N/100m^2/h$) and the relative species composition. These comparisons are summarized in Figure 16, Figure 17, Figure 18 and Table 3.

Total number of fish caught in the forebay area over time changed from higher catches in 1974, 1988 and 2000 to lower catches in 2008 and 2012 for all species combined (Figure 16). The higher catches in 1974 were likely based on the netting location in the littoral zone which also added a variety of other species (e.g. Longnose Sucker and Arctic Grayling) that are not caught in the pelagic zone (Barrett and Halsey 1975). Higher catches in 1988 and 2000 were based on the complete focus of all pelagic fishing effort on the top 2.4 m of the water column were a high abundance of Lake

Whitefish were encountered in 1988 (Blackman 1992) and a high abundance of Peamouth Chub was encountered in 2000 (Sebastian et al. 2003). Total catch in 2008 and 2012 was similar and mainly composed of Lake Whitefish in 2008 and Kokanee in 2012 (Sebastian et al. 2008).

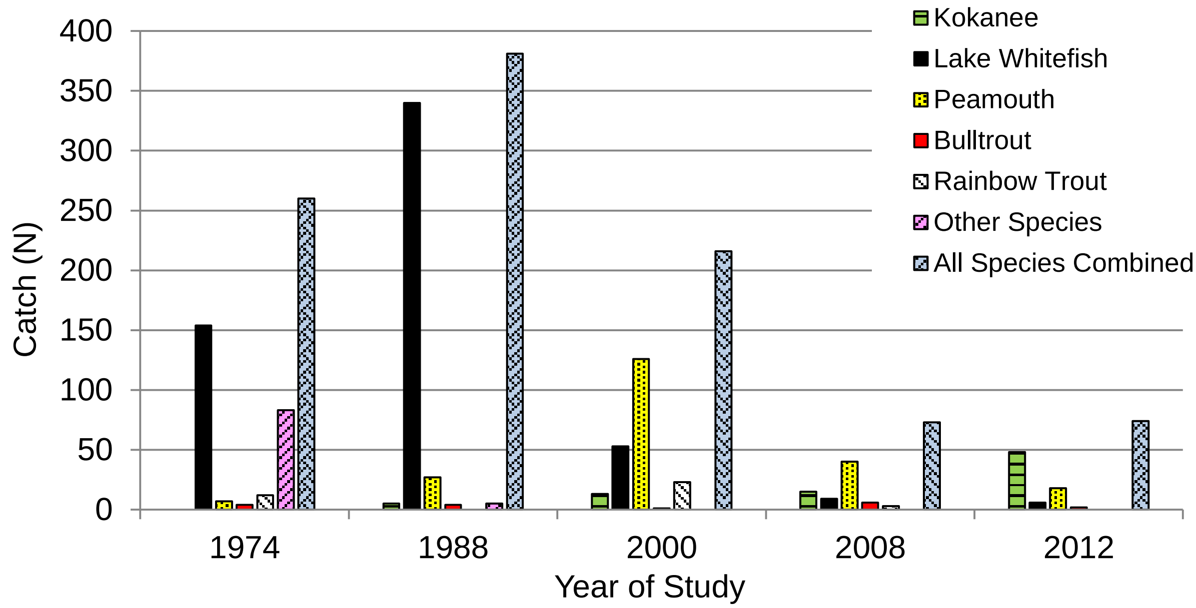


Figure 16 Number of fish captured within 15 km of W.A.C. Bennett Dam by species and year of study (1974 data from Barrett and Halsey 1975, 1988 data from Blackman 1992, 2000 and 2008 data from Sebastian et al. 2008).

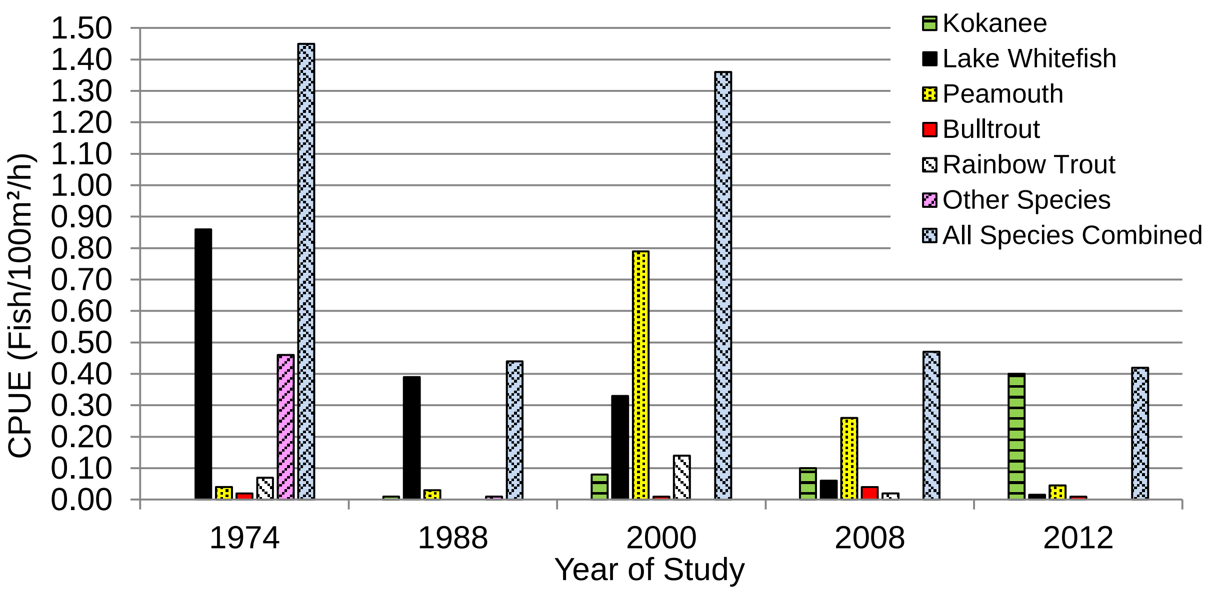


Figure 17 CPUE based on gillnet catches within 15 km of W.A.C. Bennett Dam by species and year of study (1974 data from Barrett and Halsey 1975, 1988 data from Blackman 1992, 2000 and 2008 data from Sebastian et al. 2008).

Similar trends as for the total catch were also apparent for the CPUE (Figure 17) and the relative species composition within the catch (Figure 18). CPUE in the littoral area was higher than in pelagic areas (1974 versus 1988) and catch in the upper 2.4 m of the water column was higher than in deeper water (2000 versus 2008 and 2012). The high abundance of fish in the upper 2.4 m of the water column also has implications for the analysis of hydroacoustic surveys that are missing to record fish in the upper 2.5 m of the water column when only a down-looking transducer is used as practiced in all studies from 1974 to 2012. The addition of a side-looking transducer is highly recommended for all future hydroacoustic studies given the high density of fish in the surface-near water layer.

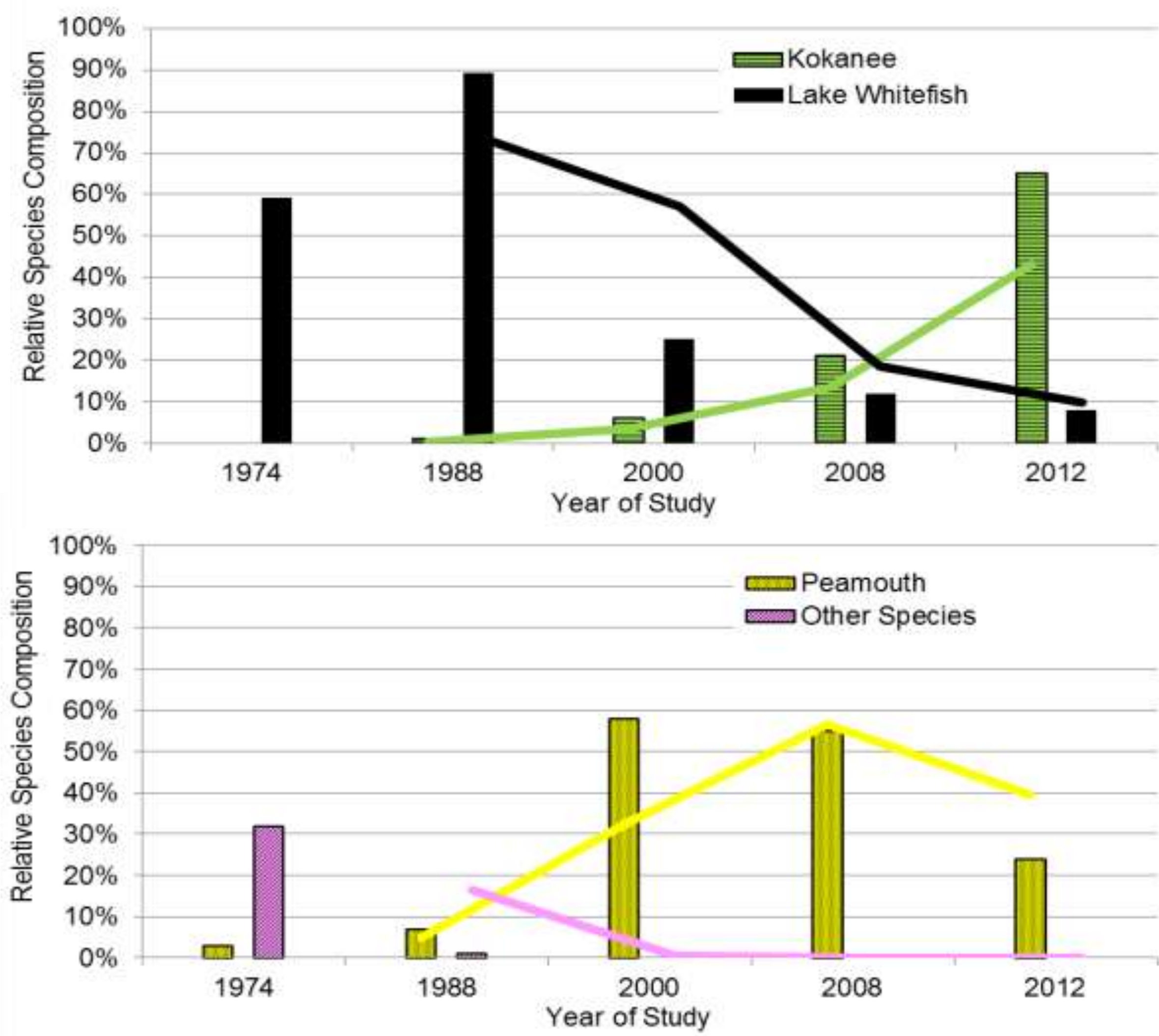


Figure 18 Contribution of Kokanee and Lake Whitefish (top panel) and Peamouth Chub and other species (bottom panel) to the relative species composition based on gillnet catches within 15 km of W.A.C. Bennett Dam from 1974 to 2012 (trendlines are second period moving averages between years) (1974 data Barrett and Halsey 1975, 1988 data Blackman 1992, 2000 and 2008 from Sebastian et al. 2008).

Over the same period of time from 1974 to 2012, the contribution of Lake Whitefish and a variety of species summarized under the “other species” umbrella (e.g. Longnose Sucker and Arctic Grayling) to the catch decreased while the contribution of Kokanee and Peamouth Chub increased (Figure 18). Although the catch species composition was definitely affected by the different lake zones and depths fished, results still suggest that the pelagic fish species composition in the Peace Reach of Williston Reservoir may be in the process of changing from a Lake Whitefish and Peamouth Chub dominated fish community to a Kokanee dominated fish community. This trend was already suggested by Sebastian et al. (2008) based on 2008 catch results and appears to be continuing based on 2012 catch results.

Table 3 CPUE (N/100m^2/h), catch (N) and relative species composition based on the catch in five fisheries studies within 15 km of W.A.C. Bennett Dam from 1974 to 2012 (1974 data from Barrett and Halsey 1975, 1988 data from Blackman 1992, 2000 and 2008 data from Sebastian et al. 2003 and 2008, 2012 data this study)

		1974	1988	2000	2008	2012
CPUE	Kokanee	0	0.01	0.08	0.1	0.400
	Lake Whitefish	0.86	0.39	0.33	0.06	0.016
	Peamouth Chub	0.04	0.03	0.79	0.26	0.05
	Bulltrout	0.02	0	0.01	0.04	0.01
	Rainbow Trout	0.07	0	0.14	0.02	0
	Other Species	0.46	0.01	0	0	0.00
	All species Combined	1.45	0.44	1.36	0.47	0.419
Catch	Kokanee	0	5	13	15	48
	Lake Whitefish	154	340	53	9	6
	Peamouth Chub	7	27	126	40	18
	Bulltrout	4	4	1	6	2
	Rainbow Trout	12	0	23	3	0
	Other Species	83	5	0	0	0
	All species Combined	260	381	216	73	74
Relative Species Composition	Kokanee	0	0.01	0.06	0.21	0.65
	Lake Whitefish	0.59	0.89	0.25	0.12	0.08
	Peamouth Chub	0.03	0.07	0.58	0.55	0.24
	Bulltrout	0.02	0.01	0	0.08	0.03
	Rainbow Trout	0.05	0	0.11	0.04	0
	Other Species	0.32	0.01	0	0	0

Fish Species Depth Distribution

The assumptions about the depth distribution made here are limited to the upper 10 m of the water column since no nets were initially set deeper than 15 m and all nets were lifted by approximately 5 m by a thunderstorm that asserted a large amount of pressure on the lines that connected the buoys with the anchors and the nets with the buoys.

The two Bull Trout that were caught in the nets preferred the deeper water between 5–10 m, while Kokanee and Lake Whitefish were caught in both depth strata between 0–10 m. The majority of Peamouth Chub were caught in the depth stratum from 5–10 m while the remainder of the Peamouth Chub was caught in the shallow depth stratum from 5–10 m.

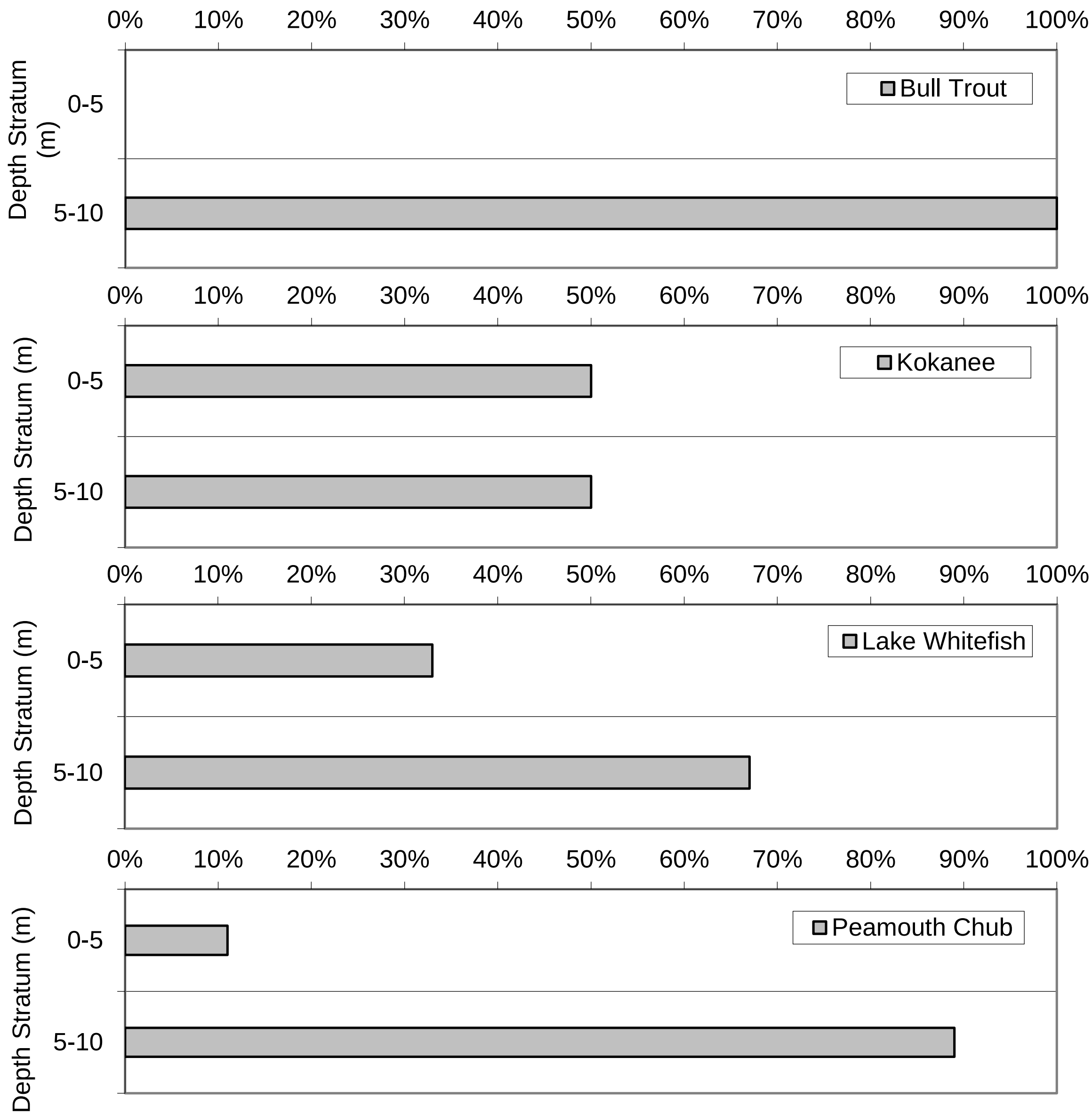


Figure 19 Depth distributions of fish species from gillnet catch at W.A.C. Bennett Dam Forebay Gillnet Station 1.

It appears that Kokanee, Lake Whitefish and Peamouth Chub would have been the three species most likely to be entrained over the spillway in 2012 in the size class from 75–465 mm since they were caught in the shallow depths strata. For the size class <75 m, that represented 85% of the fish entrained in 2012 (Biosonics, 2012) we do not know the species composition since fish of that size were not sampled with the mesh size used in this study.

For all three species it appeared reasonable to rear in the upper 10 m of the water column based on the Williston specific life cycle information summarized for the species in the background section of this report (page 11). How many additional specimen <80 mm of all three species were in the pelagic zone of the forebay area remains unknown since the minimum mesh size used in this study did not sample fish <80 mm.

Age and Growth

A summary of length, weight and condition factor at age from the gillnet catch for Kokanee, Peamouth Chub, Lake Whitefish and Bull Trout is given in Table 4, Table 5, Table 6 and Table 7, respectively.

Table 4 Kokanee length, weight and condition factor at age in 2012

Age	Sample (N)	Average Length (mm)	± SD (mm)	Average Weight (g)	± SD (g)	Length Range (mm)	Weight Range (g)	Condition Factor	± SD
1+	41	105	12	12	4	83–123	6–19	1.00	0.07
2+	7	177	21	69	20	160–218	43–96	1.04	0.06
3+	0	-	-	-	-	-	-	-	-

Table 5 Peamouth Chub length, weight and condition factor at age in 2012

Age	Sample (N)	Average Length (mm)	Average Weight (g)	Length Range (mm)	Weight Range (g)	Condition Factor
3	1	145	34	145	34	1.15
4	1	160	42	160	42	1.03
6	2	234	143	233–235	141–145	1.12
7	1	210	105	210	105	1.13

Table 6 Lake Whitefish length, weight and condition factor at age in 2012

Age	Sample (N)	Average Length (mm)	± SD (mm)	Average Weight (g)	± SD (g)	Length Range (mm)	Weight Range (g)	Condition Factor
5+	1	227	-	114	-	227	114	0.97
6+	5	255	25	171	56	228–288	119–261	1.01

Table 7 Bull Trout length, weight and condition factor at age in 2012

Age	Sample (N)	Average Length (mm)	± SD (mm)	Average Weight (g)	± SD (g)	Length Range (mm)	Weight Range (g)	Condition Factor
6+	1	340	-	346	-	-	-	0.88
7+	1	463	-	966	-	-	-	0.97

Kokanee in 2012, at Age 1+ and Age 2+ appeared shorter and lighter and had a lower condition factor when compared with 2008 (2008 data from Sebastian et al. 2008) but this result is likely based on the additional smaller mesh size used in 2012. In addition to the standard RIC net mesh sizes, we used one smaller mesh size panel in four of the six nets that formed the net gang. When tested for statistical differences (t-test, 2-tailed, unequal variance assumed) while excluding all fish <110 mm, the cut-off length suggested by Sebastian et al. (2008) for the nets used in the 2008 study, neither length (Age 1+ p = 0.26, Age 2+ p = 0.40), nor weight (Age 1+ p = 0.17, Age 2+ p = 0.26) nor Fulton's condition factor (Age 1+ p = 0.17, Age 2+ p = 0.18) were different for the two study years. It is unknown why no Kokanee in Age class 3+ were caught in 2012 while they were caught in the 2000 and the 2008 gillnetting efforts by Pillipow and Langston (2002) and Sebastian et al. (2008). Age 3+ Kokanee leave the pelagic zone for tributary and beach spawning in September and October in Williston Reservoir and should have therefore still been caught in July when nets were set in 2012. Alternatively, a recruitment failure may have occurred in the 2009 Kokanee broodyear but no such occurrence has been reported in the literature. As an alternate explanation, the ageing of the 2012 Kokanee was not verified by age validation in a mark recapture experiment as suggested by Beamish and McFarlane (1983), who found that scale ageing was only validated in 3% of hundreds of studies reviewed by the authors. Especially in cold-water regions like the Williston Reservoir growth in year 1 of a fish's life can be slow and an annual check can be hard to detect. Since mark and recapture experiments for Kokanee in the Williston Reservoir would be cost-prohibitive, it is recommended that in addition to the scale, to take otoliths as a second ageing structure for Kokanee in all future studies to increase the reliability of ageing.

The fork length, weight and condition factor at age for Peamouth Chub (length p = 0.92, weight p = 0.66, condition factor p = 0.72) and the Age 6 Lake Whitefish (length p = 0.07, weight p= 0.13, condition factor p = 0.44) was also not significantly different when 2008 and 2012 results were compared. Other Lake Whitefish age classes could not be compared because no other age overlap between the 2008 and 2012 studies existed.

The condition factor for Bulltrout was low and <1 in 2012 and in 2008 which is typical for Bulltrout that grow mainly in length but do not add as much weight per year as other fish species do. Bulltrout develop a typical long and thin or "snaky" body shape once they have reached maturity in years 5-8 of their life (Mc Phail 2007).

Length Frequencies in Gillnet Catch and Hydroacoustic Targets

The length frequencies of all fish species caught at Gillnet Station 1 in 2000, 2008 and 2012 is shown in Figure 20 and the 2000 and 2008 panels are taken from Sebastian et al. (2008).

To relate the 2012 catch results to the apportionment of fish in the catch as well as the mobile and the stationary hydroacoustic surveys, cutoff lengths between juvenile and mature life stages can be suggested for the three dominant fish species found in Williston Reservoir. Based on Sebastian et al's (2008) observations, maturity in Williston Kokanee occurs in fish that have a minimum age of three summers, are ~210 mm long and are classified as age 2+ fish. The majority of Kokanee spawners are classified as age 3+ fish and have an average length of 231 mm (Sebastian et al. 2008). For Peamouth Chub, the second most abundant species in this study, the minimum age and length at maturity are age 5 and 200 mm, respectively (this study) and for Lake Whitefish the minimum age and length are ~250 mm and age 5+, respectively (Sebastian et al. 2008). In summary, specimen of the three most prominent pelagic fish that <200 mm can safely be categorized as juveniles and non-mature adults while specimen >200 mm can be categorized as spawners.

While the 2000 and 2008 gillnet catch was dominated by fish with lengths close to 200 mm (right at the length limit between immature and mature fish), the 2012 catch was dominated by fish with lengths 90–130 mm or fish that are immature (Figure 20). Sebastian et al. (2008) stated that no fish <110 mm were vulnerable to capture in the 2008 nets with a minimum mesh size of 25 mm, while the smallest mesh size used in this study caught fish down to a minimum length of 80 mm with a minimum mesh size of 12 mm (Figure 7). As in most fish populations and as shown in the Williston Reservoir W.A.C. Bennett Dam Forebay area in 2000, 2008 (Sebastian et al. 2008) and in 2012 (this study) through hydroacoustics, fish <110 mm are more abundant than fish >110 mm and the smaller fish were likely more underrepresented in the 2008 catch with the bigger minimum mesh size. The most abundant length groups in the 2000 and 2008 catch were ranging from 170–230 mm and from 270–320 mm roughly representing adult and mature Kokanee and mature Lake Whitefish, respectively.

The observed decrease in the Lake Whitefish population from 2008 to 2012 may be the reason for the smaller number of fish in the 270–320 mm size groups in 2012. The smaller number of fish in the 170–230 mm size groups appears contrary to the hydroacoustic results that indicated an increase of fish in theses size groups from 2008 to 2012. The explanation of the smaller catch may be found in the unexpected high winds that pushed all nets closer to the surface and possibly out of the main fish layer for fish in these size groups.

The comparison of specific length-frequencies for Kokanee and Lake Whitefish support the notion that older Age 3+ Kokanee were underrepresented in the 2012 gillnet catch (Figure 21, Figure 22) and the reasons for this underrepresentation is unknown but several hypothesis were discussed in the previous chapter.

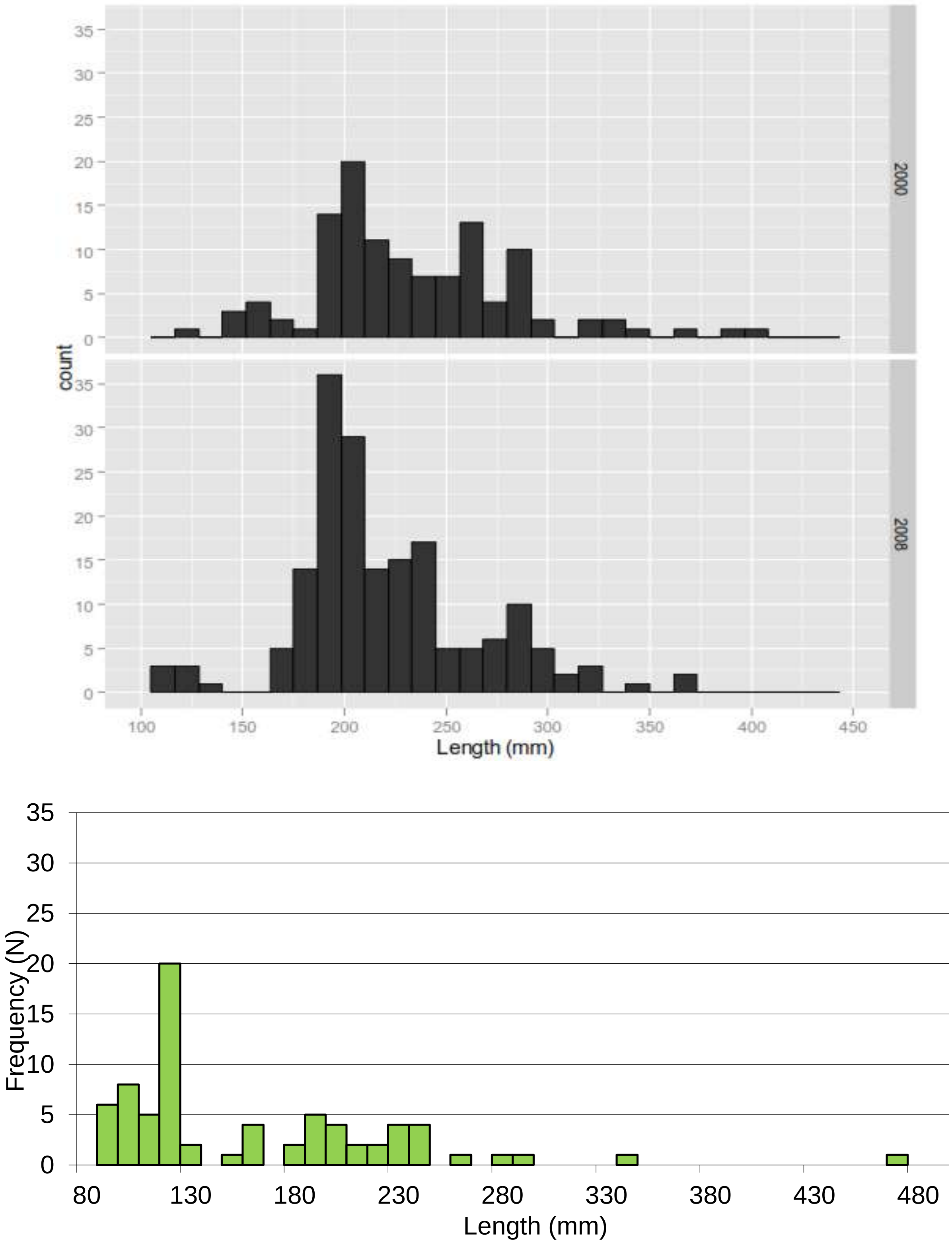


Figure 20 Length frequency of gillnet catches for all species in Peace Reach W.A.C. Bennett Dam Forebay Gillnet Station 1 for 2000 (top panel), 2008 (middle panel) and 2012 (bottom panel) (data for 2000 and 2008 from Sebastian et al. 2008).

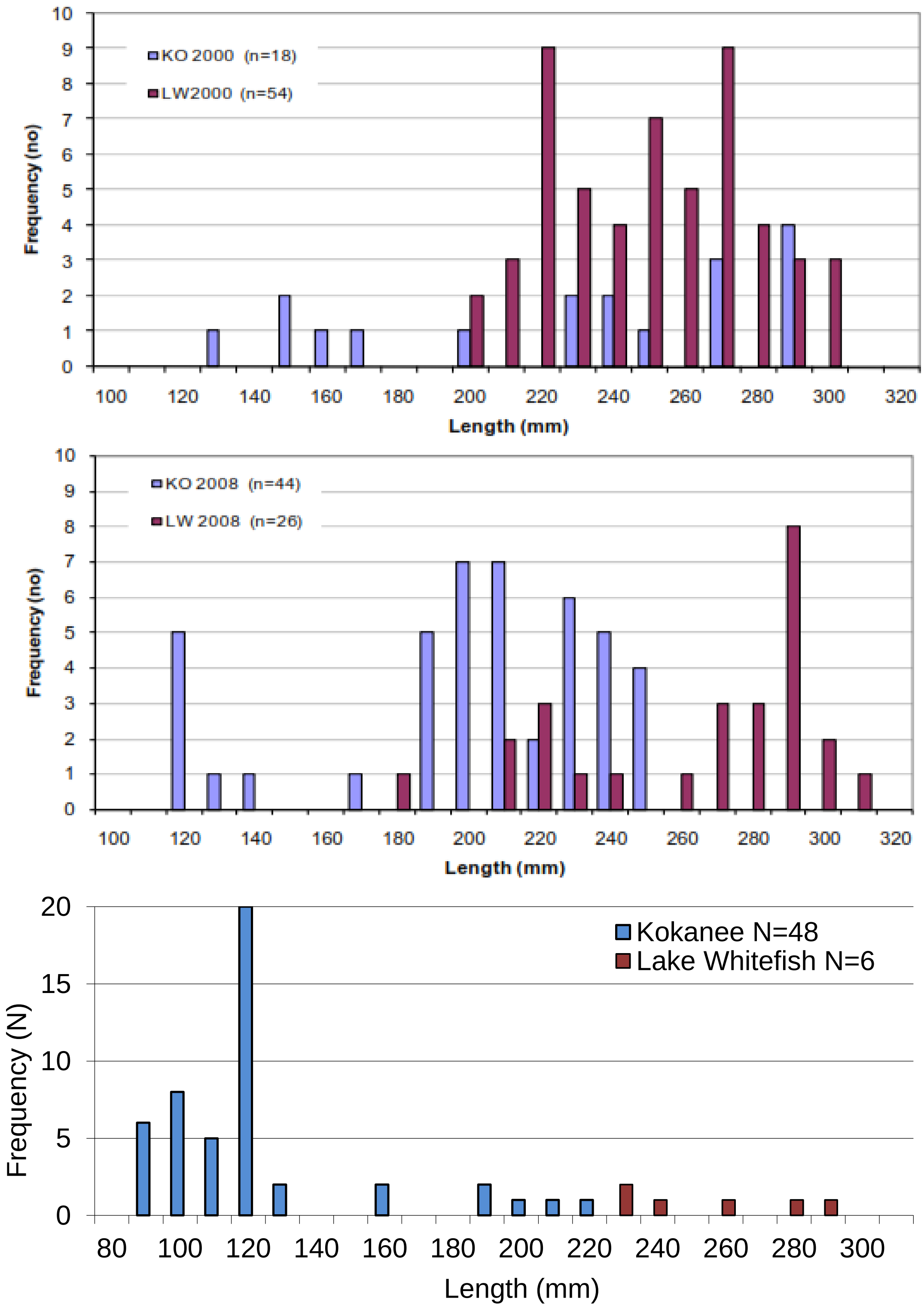


Figure 21 Comparison of length frequency distribution between Kokanee and Lake Whitefish caught in 2000 (top panel), 2008 (middle panel) and 2012 (bottom panel) (data for 2000 and 2008 from Sebastian et al. 2008).

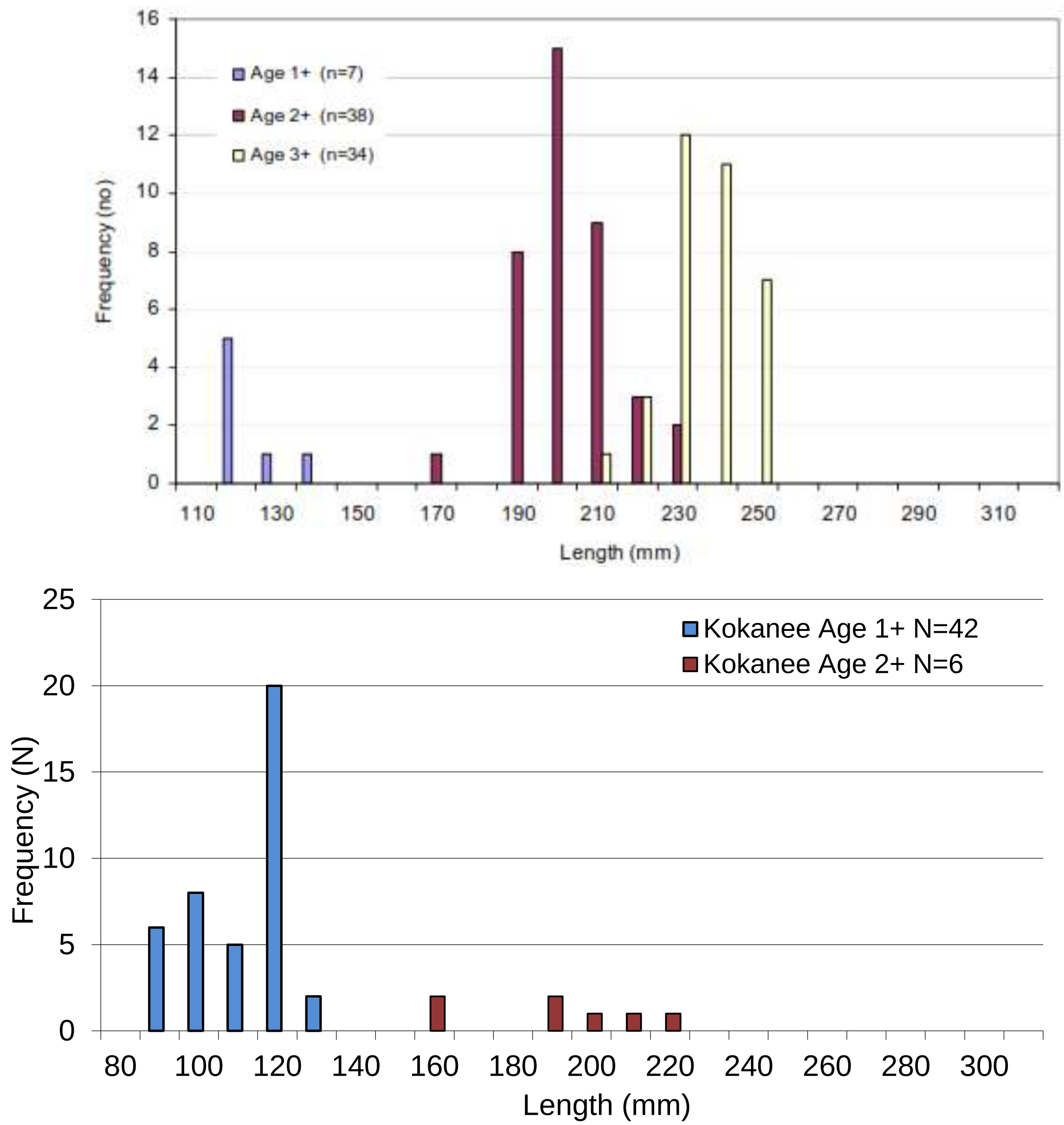


Figure 22 Kokanee length frequency by age from gillnet samples in 2008 (top panel) and 2012 (bottom panel) (2008 data from Sebastian et al. 2008).

Hydroacoustic Abundance and Population Estimates

The hydroacoustically determined size distributions of fish targets was applied to the total fish population estimated by multiplying the transect fish densities with the total area in each zone based on Sebastian et al's (2008) zone area calculations (Figure 3). The result of this exercise is shown in Table 8 and while a higher proportion of fish targets 17–52 mm and 324–465 mm were detected in 2008, more fish targets 52–225 mm were detected in 2012 (Figure 23, bottom panel). Overall the combined population estimate for Zones 31 and 32 (Sebastian et al. 2008) appeared much higher in 2012 (N=1,064,311 ± 427,989 SD) than in 2008 (N=582,343, no SD given). The higher total population estimate in 2012 was based on the higher estimate for fish in the size groups from 25–226 mm, while the smallest size group of fish <25 mm was much stronger represented in 2008 (Figure 23, top panel).

Fish <25 mm were likely juvenile Lake Whitefish or Peamouth Chub which are both known to occupy the littoral near-shore areas as well as pelagic areas of a lake in their first summer after hatching (Scott & Crossman 1973) while Age 0+ Kokanee in July even under oligotrophic conditions would be much larger with a minimum size of 40–60 mm (Quinn 2005). We therefore speculate that prior to the 2008 hydroacoustic surveys, a strong Lake Whitefish or Peamouth Chub hatch could have occurred and that this phenomenon was less pronounced in 2012.

Table 8 Abundance estimate by size class and total population estimate for zones 31 and 32 and for the 2008 and 2012 study years from acoustic size distribution (2008 data from Sebastian et al. 2008).

TS[1](dB)	FL[2] (mm)	2012 Abundance by Size	2012 ± SD	2012 Proportion	2008 Abundance by Size	2008 Proportion
-60	17	6,206	2,496	0.01	58,234	0.10
-57	25	145,838	58,646	0.14	133,939	0.23
-54	36	155,147	62,389	0.15	110,645	0.19
-51	52	155,147	62,389	0.15	110,645	0.19
-48	75	167,559	67,380	0.16	34,941	0.06
-45	109	170,662	68,628	0.16	34,941	0.06
-41	157	138,081	55,526	0.13	34,941	0.06
-39	225	102,397	41,177	0.10	34,941	0.06
-36	324	17,066	6,863	0.02	11,647	0.02
-33	465	3,103	1,248	0.00	5,823	0.01
-30	669	3,103	1,248	0.00	0	0.00
-27	>670	0	0	0.00	0	0.00
2012 Total Pop Estimate		1,064,311	427,989	1.00		1.00
2008 Total Pop Estimate		582,343				

[1] TS = Acoustic target strength; numbers represent higher bin boundaries (eg. -60dB group includes all fish between -60dB and -62.9dB)

[2] FL = Fork lengths are based on Love's (1977) dorsal aspect formula; numbers represent higher bin boundaries

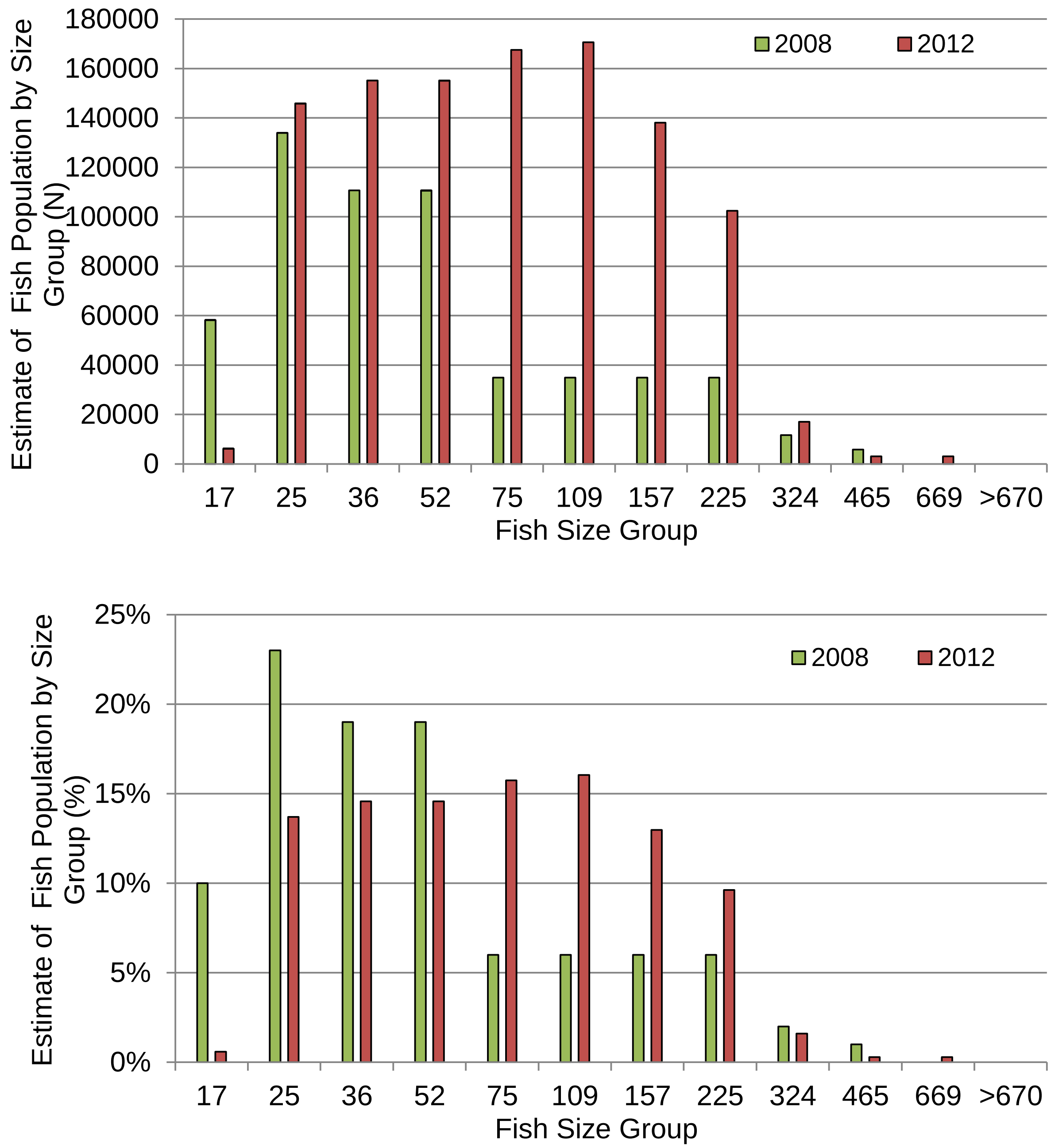


Figure 23 Absolute (top panel) and relative (bottom panel) estimates of fish population by size group in 2008 (total estimate N = 582,343) and 2012 (total estimate N = 1,064,311 ± SD 427,989) based on hydroacoustic surveys carried out in 2008 (Sebastian et al. 2008) and 2012 (this study).

The absolute number as well as the proportion of fish in size groups from 52–225 mm that are mainly representing Kokanee (based on gillnet catch composition) appears much larger in 2012 (Figure 23). This suggestion is supported by the gillnet catch composition that showed a much higher proportion of Kokanee in the 2012 catch when compared to 2008 (Figure 16).

The difference in these results cannot be tested for significance since the authors had no access to the 2008 hydroacoustic raw data.

It can be speculated that the apparently higher 2012 population estimate for fish in the size groups from 75–225 mm may be related to one or more strong recruitment years in the Kokanee population that appears to become the dominant pelagic fish population in the Peace Reach of the Williston Reservoir.

Biomass based on the hydroacoustic size distributions and population estimates can only be determined if a known length-weight correlation exists since hydroacoustic surveys can only detect fish length (and not shape or weight). In the 2012 study, we did only capture Age 1+ and Age 2+ Kokanee and Age 5+ and Age 6+ Lake Whitefish. Based on this limited data set, reliable length-weight relationships could not be calculated. In addition, the gillnet catch underrepresented or did not represent at all the size classes >75 mm and we therefore neither know the species composition of ~24% of the 2012 and ~77% of the 2008 targets nor their related length-weight relationships.

Although length-weight relationships for Kokanee or Lake Whitefish from the 2008 or 2000 hydroacoustic surveys could be used to calculate biomass based on species composition, fish growth and conditioning factor can change from year to year and the calculated biomasses would potentially not be representative of conditions in 2012. This is especially true for a system such as Williston Reservoir with a fish species composition that still appears to be changing towards an ecosystem based equilibrium in which some species thrive while others decrease in abundance.

The W.A.C. Bennett forebay area fish population estimates gradually increased from 1988 to 2012 (Figure 24) and similarly following a decrease from 1998 to 2000 were increasing in 2008 and 2012 for the whole of the Peace Reach (Figure 25).

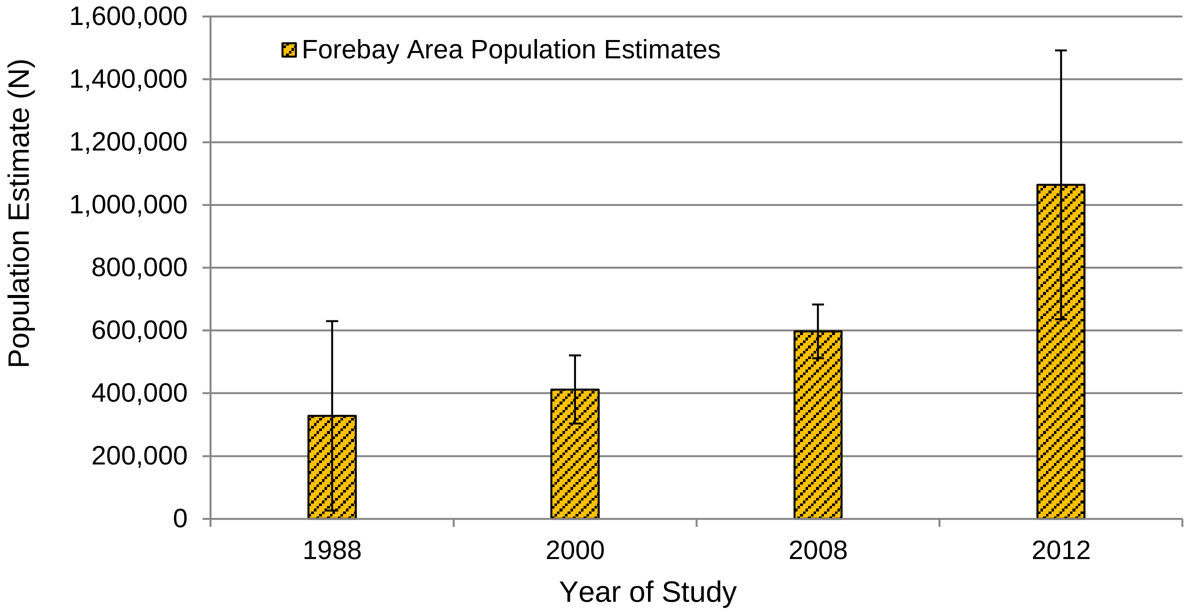


Figure 24 Fish population estimates based on hydroacoustic surveys in the W.A.C. Bennett Dam forebay area for 1988 (Blackman 1992), 2000 (Sebastian et al. 2003), 2008 (Sebastian et al. 2008) and 2012 (this study).

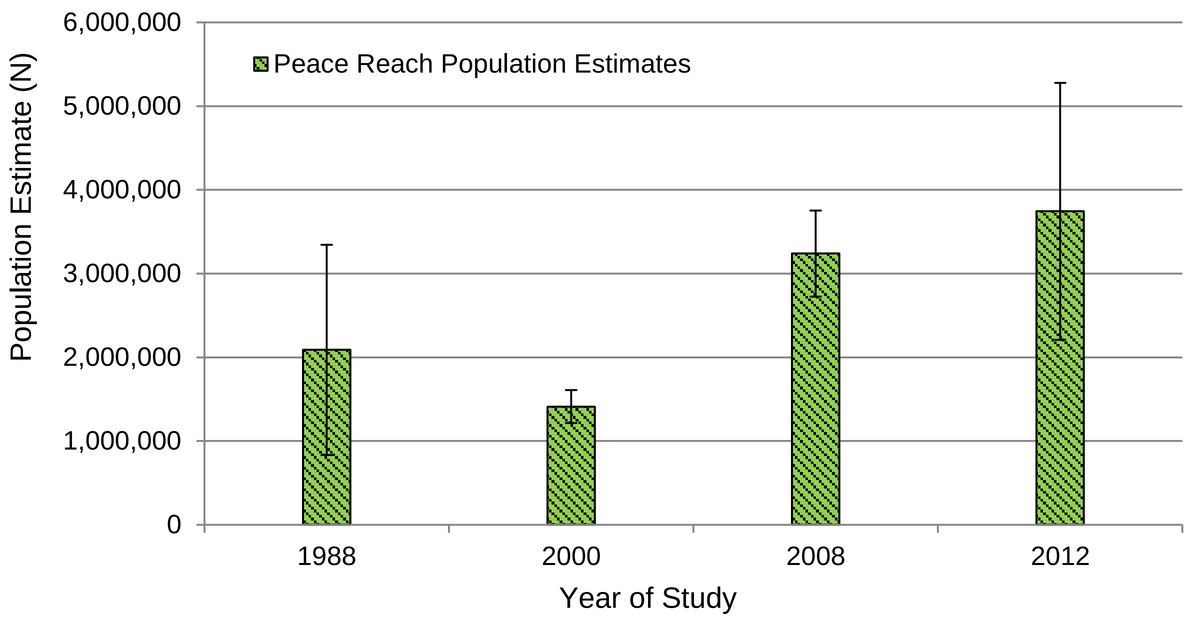


Figure 25 Fish population estimates based on hydroacoustic surveys in the Peace Reach for 1988 (Blackman 1992), 2000 (Sebastian et al. 2003) and 2008 (Sebastian et al. 2008). The estimate for 2012 was based on the expansion of the transect density found in the forebay area to all of the Peace Reach.

The observed increases in the population estimates are likely based on a real increase in the fish population over the 1988–2012 period but may have also been affected by technical differences in the execution of the surveys and the analysis of the data. A summary of the hydroacoustic survey detail for all years is provided in Table 9. While the different operating frequencies as well as the make and model of the sounders should have had no effect on the number of targets detected, ping frequency and pulse width could have influenced the minimum target detection distance and the minimum separation distance between individual targets. When "target tracking" is used, faster ping rates reduce the minimum target detection distance and in the example of the Williston Reservoir would have likely led to more fish detected in 2012 when a higher ping frequency was used. This effect is less pronounced when simple "echo counting" is used to enumerate targets and target size is determined during data analysis rather than data recording. It is unclear whether in 2008, echo counting or target tracking where used to enumerate target numbers. If echo counting was used in 2008 as the target enumeration tool, it is unclear how double detection of targets in deeper areas with an overlapping beam width was detected and accounted for. In retrospect, it was hard to compare all of the factors that could have biased population estimates over the years but it was assumed that all previous studies were carried out with adequate diligence to calculate realistic population estimates.

For future studies, it is recommended to standardize all settings and data analysis procedures for hydroacoustic surveys based on latest advances in hydroacoustics.

Table 9 Comparison of technical details for hydroacoustic surveys carried out on Williston Reservoir between 1988 and 2012.

Source	Year	Reach (all or Reach Name)	Make and Model	Frequency (kHz)	Depth of Face (m)	Pings/Second	Pulse Width (ms)	Boat Speed (m/s)	Sampling Threshold (dB)	Processing Theshold (dB)	Beam Width Nominal (^{0})	Beam Width Effective (^{0})	Minimum Fish Detection Range (m)
Johnson & Yesaki 1989	1988	Peace	Biosonics	420	1	3.25	0.4	2			6	10	7
Sebastian et al. 2003	2000	Peace	Simrad EY 500	120	1.5	2	0.3	2	70	65	6	10	10
Sebastian et al. 2008	2008	Peace	Simrad EY 500	120	1	3	1	2	70	70	6	10	8
Plate et al. 2013	2012	Peace/ Forebay	Biosonics DTX	200	0.5	10	0.2	1.7	75	60	6	12	3

Discussion of the Quantitative and Qualitative Aspects of the 2012 Spillway Fish Entrainment over the W.A.C. Bennett Dam Spillway

The target strength (Figure 26) and the vertical distribution of targets (Figure 27) in the mobile and the stationary hydroacoustic surveys were very similar and appeared to be representing the same fish populations. Based on this similarity between the forebay area where gillnets were set and the spillway entrance where fish were entrained, it could be assumed that the species composition in the gillnet catch also represented the species composition of the total of the ~455, 000 fish (Biosonics 2012) that were entrained. Unfortunately, the minimum gillnet mesh size used in this study, although smaller than in all previous studies (12 mm versus 25 mm), still only catches fish >80 mm as shown in Figure 7 of the "Methods" section of this report. Therefore the gillnet catch species composition with high likelihood represented the ~82,000 entrained fish (Biosonics 2012) or 18.2% of the total number of entrained fish that fitted into the size class from 75–465 mm. The relative species distribution for this size class was shown in Figure 15.

Very few fish over 465 mm (a total of 455 fish or 0.01% of the total number entrained, Biosonics 2012) were entrained and they must have been either Bulltrout or Lake Trout since no other species found in Williston Reservoir reach length over 465 mm.

Unfortunately, for the ~373,000 fish (or 81.5% of all entrained fish) that were 40–75 mm long, the species composition cannot be simply derived from the gillnet catch, since fish <80 mm were not sampled or from their size alone, since at least three species, namely Lake Whitefish, Kokanee and Peamouth Chub could have been entrained at this size and time of year.

Peamouth Chub of the 2012 broodyear were surely not detected in the July 2012 hydroacoustic survey since they typically hatch at a length of 7 mm (McPhail 2007) and had likely not hatched in 2012 in Williston Reservoir since all of the larger Peamouth Chub were found to be in spawning colours and with unspawned gonads. Peamouth Chub at Age1+ typically reach 35–65 mm at the end of their first year (McPhail 2007) and were therefore surely one species and age class that was entrained as part of the small fish size class from 40–75 mm. Peamouth also typically forage in the littoral and the pelagic zone and close to the surface (McPhail 2007).

Juvenile Lake Whitefish can reach lengths of 40–75 mm in their first summer and tend to occupy the littoral zone and shallower water preferably around 17ºC before they start to occupy the pelagic zone in the fall (McPhail 2007). During the July 2012 hydroacoustic survey, the water temperature in the top 3 m of Williston Reservoir was ~16.5 ºC and therefore likely a large portion of the Age 0+ Lake Whitefish were in the top 3m of the water column and the littoral zone were they could easily be entrained.

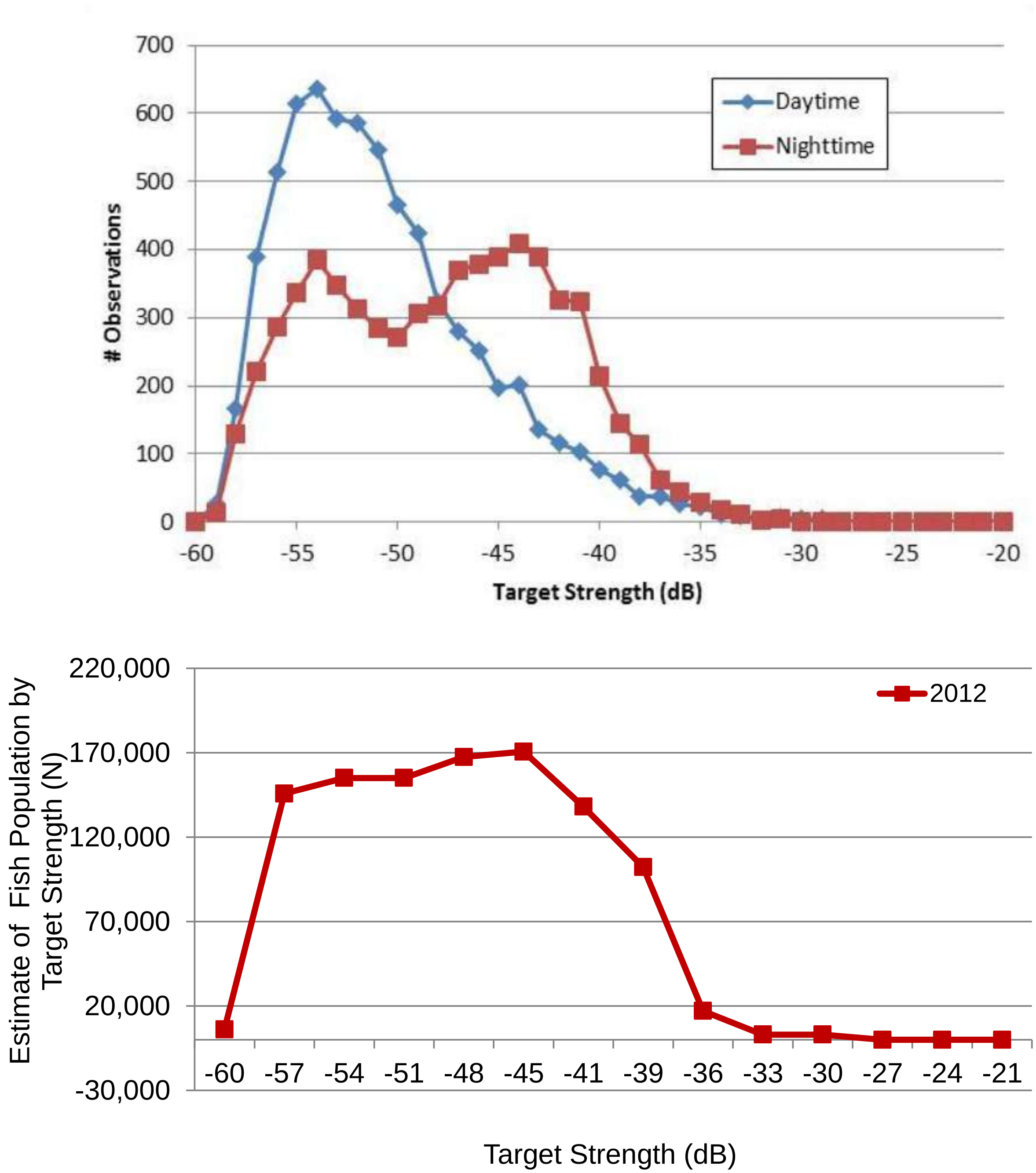


Figure 26 Comparison between the target strength distribution of the stationary hydroacoustic survey carried out at the spillway entrance (top panel, from Biosonics 2012) and the mobile hydroacoustic surveys carried out in the forebay area (bottom panel) in 2012.

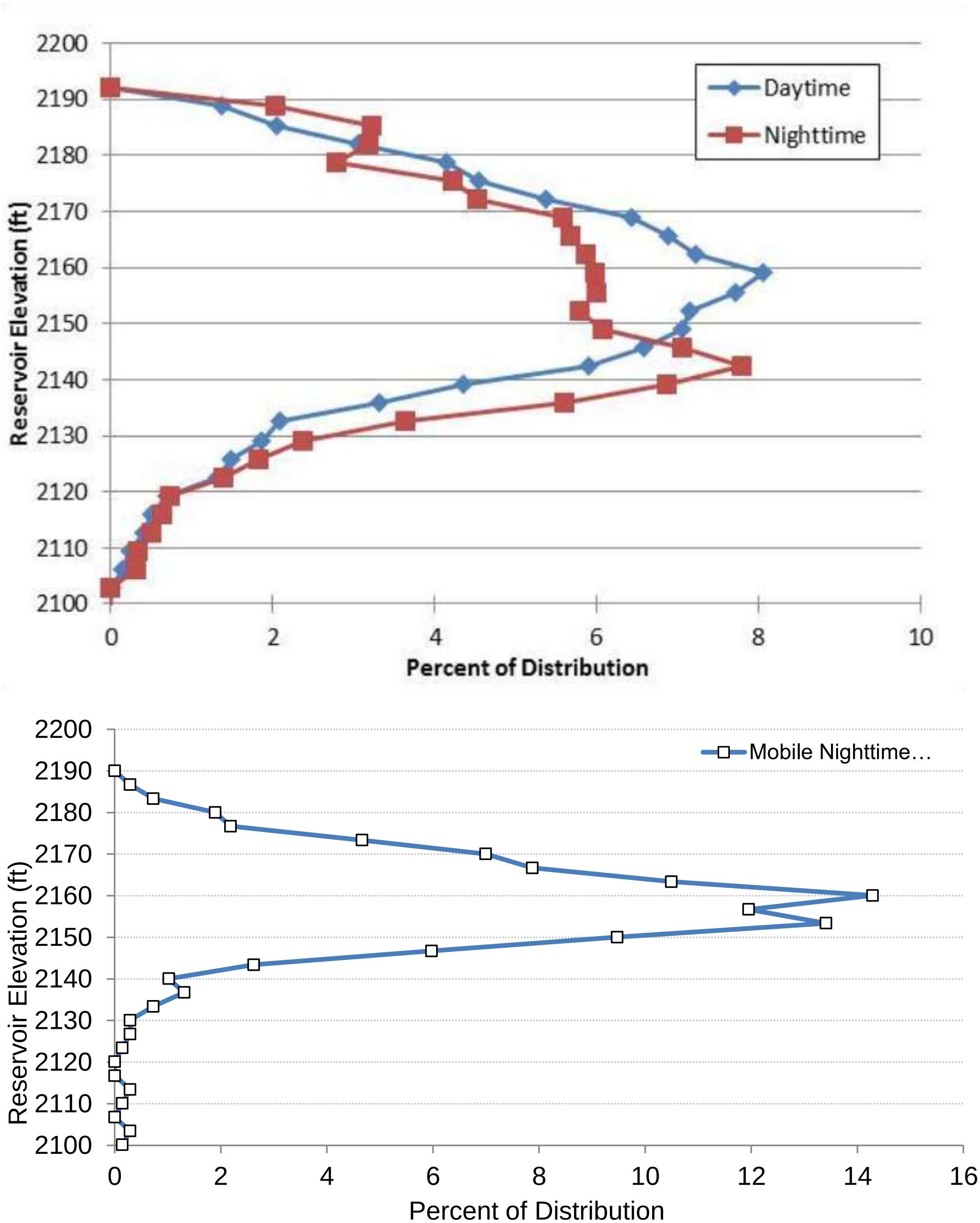


Figure 27 Comparison of vertical distribution of hydroacoustic targets between the stationary survey carried out at the spillway entrance (top panel, from Biosonics 2012) and the mobile hydroacoustic survey forebay area (bottom panel) in 2012.

Juvenile Kokanee also reach lengths from 40–75 mm within their first summer but typically move away from their spawning creeks or beaches and into the pelagic zone directly following emergence from the spawning substrate (Mc Phail 2007). Age 0+ Kokanee just as Peamouth Chub and Lake Whitefish likely also occupied the upper 3 m of the water column in Williston Reservoir in July of 2012 but have been reported to also occupy deeper water elsewhere (McPhail 2007). In the ultra-oligotrophic Alouette Reservoir and Powell Lake in southern British Columbia Age 0+ Kokanee preferably occupied the upper 10m of the water column (Plate, unpublished data).

In summary, and based on habitat and foraging preferences the two most likely juvenile fish species in the 40–75 mm size class entrained over the W.A.C Bennett Dam spillway were Peamouth Chub (age 1+) and Lake Whitefish (age 0+) and a smaller number of juvenile Kokanee (age 0+). A precise apportionment between these species cannot be suggested based on the lack of sampling of fish <80 mm in the gillnet catch and general habitat and foraging preferences for juveniles of all three species In Williston Reservoir.

RECOMMENDATIONS

For future mobile hydroacoustic surveys in Williston Reservoir the following recommendations should be considered:

1. All hydroacoustic surveys should be carried out using a side-looker in addition to the down-looker used in all surveys up to now. It is likely that large numbers of fish occupy the top 3 m of the water column where their numbers are underestimated by down-lookers because fish within the zone 2–5 m (depending on ping frequency) below the transducer face and the boat cannot be reliably detected and because fish in this zone also avoid the boat.
2. For all future hydroacoustic surveys “fish tracking” rather than “echo counting” should be used to enumerate fish targets to standardize methods and simplify data analysis.
3. Settings of the echosounder during all future surveys should be standardized to maximize ping rate (a minimum ping rate of 10 pings/s is recommended) and minimize pulse width (a maximum pulse width of 0.2 ms is recommended) to minimize the distance from the transducer face of reliable target detection and to decrease background noise while minimizing separation distance between individual fish targets. In addition, the maximum range of the down-looker should be set to 60 m since very few fish have been detected below this depth in the past and a smaller depth range allows for faster ping rates.
4. To verify the species composition of the hydroacoustic targets, nets with a minimum mesh sizes of 10 mm should be set close to the surface and as close as safely possible to the W.A.C. Bennett Dam before and after spilling to apportion the species composition of the small fish that get entrained over the spillway. The same small mesh nets should be set at increasing distances from the dam to develop an understanding of the differences in juvenile fish species composition between the littoral and the pelagic zones of Williston Reservoir close to W.A.C. Bennett Dam.

5. Trawling will not likely be an effective method of fish capture in the forebay area in the future since it has not been effective in the past.

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APPENDICES

Appendix 1 Gillnetting catch raw data sheet Page 1

Fishing Data Sheet Page	Date (dd/mm)	Data Taker Initials	Set #	Fish ID #	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Scale Book # or Otolith Bag #	Scale #	Depth Caught	Age from Scale or Otoliths
4	18/79	LF	6	73	Bull Trout	340	346	0.880318		****		11.8	6+
2	18/35	LF	5	29	Bull Trout	463	966	0.973272	F	237	23,23	11.8	7+
3	18/51	LF	6	45	Kokanee	83	6	1.049342		238	12,12	11.8	1+
2	18/36	LF	6	30	Kokanee	84	6	1.01231		237	24,24	11.8	1+
3	18/49	LF	6	43	Kokanee	88	8	1.173929		238	??	11.8	
1	18/07	LF	1	1	Kokanee	90	8	1.097394		237	1,1	3.8	1+
2	18/29	LF	3	23	Kokanee	90	7	0.960219		237	18,18	7.5	1+
2	18/43	LF	6	37	Kokanee	90	6	0.823045		238	6,6?	11.8	1+
2	18/28	LF	3	22	Kokanee	92	8	1.027369		237	17,17	7.5	1+
2	18/37	LF	6	31	Kokanee	93	7	0.87026		***		11.8	
3	18/47	LF	6	41	Kokanee	93	8	0.994583		238	9,9?	11.8	1+
3	18/48	LF	6	42	Kokanee	94	8	0.963178		238	10,10?	11.8	1+
1	18/21	LF	3	15	Kokanee	96	8	0.904225		237	13,13	7.5	1+
2	18/27	LF	3	21	Kokanee	98	9	0.956234		237	16,16	7.5	1+
2	18/39	LF	6	33	Kokanee	98	9	0.956234		238	2,2?	11.8	1+
3	18/50	LF	6	44	Kokanee	98	10	1.062482		238	11,11	11.8	1+
2	18/41	LF	6	35	Kokanee	104	11	0.977896		238	4,4?	11.8	1+
1	18/16	LF	2	10	Kokanee	105	14	1.209373		****		3.8	
2	18/44	LF	6	38	Kokanee	107	13	1.061187		238	7,7?	11.8	1+
2	18/40	LF	6	34	Kokanee	108	14	1.111365		238	3,3?	11.8	1+
1	18/10	LF	2	4	Kokanee	109	14	1.081057		237	5,5	3.8	1+
1	18/20	LF	1	14	Kokanee	111	14	1.023668		237	2,2	3.8	1+
1	18/22	LF	3	16	Kokanee	112	14	0.996492		237	14,14	7.5	n/a
2	18/38	LF	6	32	Kokanee	112	12	0.854136		238	1,1?	11.8	1+
2	18/46	LF	6	40	Kokanee	112	15	1.06767		238	8,8?	11.8	1+
2	18/45	LF	6	39	Kokanee	113	13	0.900965		****?	?	11.8	
1	18/13	LF	2	7	Kokanee	114	13	0.877463		237	8,8	3.8	1+
1	18/15	LF	2	9	Kokanee	114	16	1.079954		237	9,9	3.8	1+
2	18/42	LF	6	36	Kokanee	114	14	0.94496		238	5,5?	11.8	1+
1	18/09	LF	2	3	Kokanee	115	15	0.986274		237	4,4	3.8	1+
2	18/34	LF	4	28	Kokanee	115	14	0.920523		****		6.2	
1	18/08	LF	2	2	Kokanee	116	17	1.089118		237	3,3	3.8	1+
1	18/23	LF	3	17	Kokanee	116	16	1.025052		237	15,15	7.5	1+
1	18/24	LF	3	18	Kokanee	116	15	0.960987		****		7.5	
3	18/58	LF	6	52	Kokanee	116	15	0.960987		238	19,19	11.8	1+
1	18/12	LF	2	6	Kokanee	117	17	1.06143		237	7,7	3.8	1+
1	18/25	LF	3	19	Kokanee	117	15	0.936556		****		7.5	
3	18/59	LF	6	53	Kokanee	117	16	0.998993		238	20,20	11.8	1+
1	18/11	LF	2	5	Kokanee	119	17	1.008807		237	6,6	3.8	1+

Appendix 1 Gillnetting catch raw data sheet Page 2

Fishing Data Sheet Page	Date (dd/mm)	Data Taker Initials	Set #	Fish ID #	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Scale Book # or Otolith Bag #	Scale #	Depth Caught	Age from Scale or Otoliths	Main Stomach Contents
1	18/14	LF	2	8	Kokanee	119	17	1.008807		****		3.8		
1	18/17	LF	2	11	Kokanee	119	17	1.008807		237	10,10	3.8	1+	
1	18/26	LF	3	20	Kokanee	121	17	0.959606		****		7.5		
3	18/57	LF	6	51	Kokanee	123	19	1.021029		238	18,18	11.8	1+	
3	18/55	LF	6	49	Kokanee	160	45	1.098633		238	16,16	11.8	2+	
3	18/56	LF	6	50	Kokanee	160	43	1.049805		238	17,17	11.8	2+	
3	18/53	LF	6	47	Kokanee	183	63	1.027986		238	14,14	11.8	2+	
2	18/31	LF	3	25	Kokanee	190	76	1.108033		237	20,20	7.5	2+	Zooplankton & Insects
3	18/52	LF	6	46	Kokanee	193	79	1.098892		238	13,13	11.8	2+	
2	18/30	LF	3	24	Kokanee	201	81	0.997463		237	19,19	7.5	2+	Zooplankton
3	18/54	LF	6	48	Kokanee	218	96	0.92662		238	15,15	11.8	2+	
4	18/75	LF	6	69	Lake Whitefish	227	114	0.974602	M	239		11.8	5+	
1	18/18	LF	2	12	Lake Whitefish	228	119	1.00402		237	11,11	3.8	6+	Zooplankton
1	18/19	LF	2	13	Lake Whitefish	233	138	1.090966		237	12,12	3.8	6+	
4	18/76	LF	6	70	Lake Whitefish	253	149	0.920078	M	239		11.8	6+	Zooplankton
4	18/78	LF	6	72	Lake Whitefish	272	187	0.929255	F	239		11.8	6+	
4	18/77	LF	6	71	Lake Whitefish	288	261	1.092605	F	239		11.8	6+	Zooplankton
4	18/80	LF	6	74	Peamouth Chub	200		0		****		11.8		
3	18/60	LF	6	54	Peamouth Chub	145	34	1.115257		238	21,21	11.8	3+	
3	18/62	LF	6	56	Peamouth Chub	151	40	1.161794		****		11.8		
2	18/32	LF	3	26	Peamouth Chub	160	42	1.025391		237	21,21	7.5	4+	
4	18/71	LF	6	65	Peamouth Chub	173	56	1.081558		****		11.8		
3	18/61	LF	6	55	Peamouth Chub	175	64	1.194169		****		11.8		
4	18/74	LF	6	68	Peamouth Chub	185	74	1.168736		****		11.8		
3	18/64	LF	6	58	Peamouth Chub	187	76	1.162221		****		11.8		
3	18/65	LF	6	59	Peamouth Chub	190	76	1.108033		****		11.8		
3	18/63	LF	6	57	Peamouth Chub	195	83	1.119372		238	22,22	11.8	n/a	
3	18/66	LF	6	60	Peamouth Chub	196	89	1.182012		****		11.8		
4	18/70	LF	6	64	Peamouth Chub	210	105	1.133787		238		11.8	7+	
2	18/33	LF	3	27	Peamouth Chub	213	111	1.148641		237	22,22	7.5	n/a	Zooplankton & Insects
4	18/72	LF	6	66	Peamouth Chub	221	113	1.046891		****		11.8		
4	18/73	LF	6	67	Peamouth Chub	225	145	1.272977		****		11.8		
4	18/69	LF	6	63	Peamouth Chub	233	145	1.146305		238		11.8	6+	
4	18/67	LF	6	61	Peamouth Chub	235	141	1.086464		238		11.8	6+	
4	18/68	LF	6	62	Peamouth Chub	239	127	0.930272		****		11.8		

Appendix 2 Hydroacoustic transect raw data

Filename	Date-time	Transect #	Distance (m)	density(#/ha)
Wil_20120716_231813	7/16/2012 23:18	T1-32.5	3396	62.59
Wil_20120716_235113	7/16/2012 23:51	T2-32.5	3375	86.75
Wil_20120717_003624	7/17/2012 0:36	T1-32	4216	103.71
Wil_20120717_015021	7/17/2012 1:50	T1-31.5	3694	277.30
Wil_20120717_224836	7/17/2012 22:48	T3-32.5	3394	127.84
Wil_20120718_232240	7/18/2012 23:22	T2-32	4692	96.30
Wil_20120719_003416	7/19/2012 0:34	T2-31.5	3681	138.87
			Average	127.62
Fish < 75 mm			STDEV	70.69
Filename	Date-time	Transect #	Distance (m)	density(#/ha)
Wil_20120716_231813	7/16/2012 23:18	T1-32.5	3396	38.12
Wil_20120716_235113	7/16/2012 23:51	T2-32.5	3375	64.93
Wil_20120717_003624	7/17/2012 0:36	T1-32	4216	62.32
Wil_20120717_015021	7/17/2012 1:50	T1-31.5	3694	165.00
Wil_20120717_224836	7/17/2012 22:48	T3-32.5	3394	77.87
Wil_20120718_232240	7/18/2012 23:22	T2-32	4692	57.51
Wil_20120719_003416	7/19/2012 0:34	T2-31.5	3681	82.88
			Average	78
Fish 75 - 465 mm			STDEV	41
Filename	Date-time	Transect #	Distance (m)	density(#/ha)
Wil_20120716_231813	7/16/2012 23:18	T1-32.5	3396	22.70
Wil_20120716_235113	7/16/2012 23:51	T2-32.5	3375	21.82
Wil_20120717_003624	7/17/2012 0:36	T1-32	4216	41.39
Wil_20120717_015021	7/17/2012 1:50	T1-31.5	3694	111.30
Wil_20120717_224836	7/17/2012 22:48	T3-32.5	3394	49.97
Wil_20120718_232240	7/18/2012 23:22	T2-32	4692	38.79
Wil_20120719_003416	7/19/2012 0:34	T2-31.5	3681	55.99
			Average	49
Fish > 465 mm			STDEV	30
Filename	Date-time	Transect #	Distance (m)	density(#/ha)
Wil_20120716_231813	7/16/2012 23:18	T1-32.5	3396	1.77
Wil_20120716_235113	7/16/2012 23:51	T2-32.5	3375	0.00
Wil_20120717_003624	7/17/2012 0:36	T1-32	4216	0.00
Wil_20120717_015021	7/17/2012 1:50	T1-31.5	3694	0.99
Wil_20120717_224836	7/17/2012 22:48	T3-32.5	3394	0.00
Wil_20120718_232240	7/18/2012 23:22	T2-32	4692	0.00
Wil_20120719_003416	7/19/2012 0:34	T2-31.5	3681	0.00
			Average	0.4
			STDEV	0.7

Appendix 3 Fish Collection Permit

BRITISH COLUMBIA | Ministry of Forests, Lands and Natural Resource Operations

FISH COLLECTION PERMIT
Inventory

File: 34770-20

Permit No.: FJ12-80221

Permit Holder: LGL Limited – Elmar M. Plate
9768 Second Street
Sidney BC V8L 3Y8

Client No.: 12118

Authorized Persons: Elmar M. Plate, Lucia Ferreira

Pursuant to section 19 of the *Wildlife Act*, RSBC 1996, Chap. 488, and section 18 of the Angling and Scientific Regulations, BC Reg. 125/90, the above named persons are hereby authorized to collect fish for scientific purposes from non-tidal waters subject to the conditions set forth in this Permit:

Permitted Sampling Period: July 17, 2012 to July 20, 2012
Permitted Waterbodies: Peace Region – Williston Reservoir (WA25100110)
Permitted Sampling Techniques: GN (subject to permit terms and conditions)
Potential Species: KO, LW, PCC, RB (subject to permit terms and conditions)
Permitted Lethal Sampling: Up to 200 KO and up to 100 LW from Williston Reservoir (WA25100110) (subject to permit terms and conditions)

Provincial Conditions: (Permit holders must be aware of all terms and conditions):
See Appendix A.
Region Specific Conditions:
See Appendix A.

Authorized by:
Chris Addison
Regional Manager
Recreational Fisheries & Wildlife Programs
Peace Region

Chris Addison

Date: July 17, 2012 Permit Fee $25

Any contravention or failure to comply with the terms and conditions of this permit is an offense under the *Wildlife Act*, RSBC 1996, Chap. 488 and B.C. Reg. 125/90.

Ministry of Forests, Lands & Natural Resource Operations
Fish, Wildlife & Habitat Management Branch
Permit & Authorization Service Bureau
PO Box 9372 Stn Prov Gov