Duncan Dam Project Water Use Plan

Duncan Reservoir Kokanee Stock Assessment

Implementation Year 2

Reference: DDMMON-17

Duncan Reservoir Kokanee Stock Assessment – Year 2 (2017)

Study Period: 2017

T. Weir and D. Johner
Ministry of Forests, Lands, Natural Resources Operations and Rural Development

April 2019

Duncan Reservoir Kokanee Stock Assessment –*Year 2 (2017)*

Duncan Dam Project Water Use Plan - DDMMON#17

Study Period: 2017

T. Weir and D. Johner

British Columbia Fish & Aquatic Habitat Branch

Ministry of Forests, Lands, Natural Resource Operations and Rural Development

This is a progress report for an ongoing monitoring program and, as such, contains preliminary data. Conclusions are subject to change and any use or citation of this report or the information herein should note this status.

EXECUTIVE SUMMARY

In August of 2017, the second year of a proposed three year study to evaluate kokanee status in the limnetic habitat of Duncan Reservoir was undertaken by the Fish & Aquatic Habitat Branch of the Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNRORD) in collaboration with BC Hydro (BCH). The Duncan Dam Water Use Plan Consultative Committee recommended this monitoring program in order to provide baseline data on the in-lake kokanee population, from which future evaluations of reservoir operations can be derived. This report presents summary data and results of the 2017 field survey, which included a hydroacoustic survey, mid-water trawling, and pelagic gillnetting in conjunction with a limited limnological survey of water quality parameters. Zooplankton sampling was attempted but not completed in 2017 due to equipment failure.

The kokanee fry population was estimated at 1.02 (95% CI 0.85-1.20) million, and the age 1-3 kokanee population was estimated at 0.25 (95% CI 0.20-0.30) million. The reservoir was thermally stratified and the nighttime kokanee layer was located primarily below the thermocline with the highest densities occurring between 15 – 25m. Densities were slightly higher in the northern half of the reservoir for both fry and adult kokanee.

A total of 155 kokanee, 1 pygmy whitefish, and 4 bull trout were captured by gillnet sampling and the trawl captured 50 fish, all of which were kokanee; confirming the pelagic zone was dominated by kokanee. The combined gillnet and trawl catch indicated the larger of the age 2 cohort were maturing to spawn in the fall of 2017. Similar to 2016, trawl sampling was limited by safety concerns related to large amounts of woody debris.

Table of Contents

List of Figures

List of Tables

INTRODUCTION

This monitoring program was initiated in partial fulfilment of requirements ordered by British Columbia's Comptroller of Water Rights, and will specifically address clause 6(f) of BC Hydro's Duncan Dam Conditional Water License 27027, to monitor kokanee populations in Duncan Reservoir. The project is intended to provide baseline data on the Duncan Reservoir in-lake Kokanee population from which future evaluations of reservoir operations can be derived.

This report presents summary data and results of the 2017 field survey, which included a hydroacoustic survey, mid-water trawling, and pelagic gillnetting in conjunction with a limited limnological survey of water quality parameters. Zooplankton sampling did not occur in 2017 due to an equipment malfunction which was not resolvable within the sampling window.

Upon completion of the monitoring program (Year 11 of the review period, Year 3 of this monitoring program), a comprehensive final synthesis report will be prepared for use in the next review of the Duncan Dam Water Use Plan. The final synthesis report will incorporate relevant information from DDMMON 10 with a focus on answering the management questions and hypotheses identified in the DDMMON 17 TOR.

Data collected during the three years of the project will be evaluated in conjunction with information collected through DDMMON 10 - Duncan Reservoir Fish Habitat Use Monitoring, in order to meet the following overall objectives:

- Provide baseline information on the biological characteristics, distribution and abundance of kokanee populations in Duncan Reservoir, and
- Provide information required to link the effects of reservoir operation to population levels.

The Monitoring Program Terms of Reference for DDMMON 17 (BC Hydro, 2008) provides further details on the project rationale and approach. The Duncan Dam Water Use Plan Consultative Committee recommended this monitoring program to address the following key management question:

What is the baseline population level for kokanee in Duncan Reservoir?

This monitoring program is intended to provide this information in consideration of the following questions for future planning processes:

1) *How does the kokanee population compare with other reservoirs and natural lakes in the Columbia-Kootenay area?*

2) *In consideration of the habitat use and stock assessment information collected over the review period, what are the possible bottlenecks to productive success for kokanee in Duncan Reservoir?*

The objectives and management questions identified above will be addressed within a final synthesis report upon completion of the three-year study period of DDMMON 17.

SITE OVERVIEW

Duncan Reservoir is part of the Columbia Basin drainage and is located in south eastern British Columbia, immediately north of Kootenay Lake and Nelson, BC and south of Golden, BC. At full pool it has a surface area of 7,350 ha at an elevation of 576.68 m and at low pool has an area of 2,190 ha at an elevation of 546.87m (de Zwart et al. 2011). Figure 1 identifies sampling locations during late August, 2017.

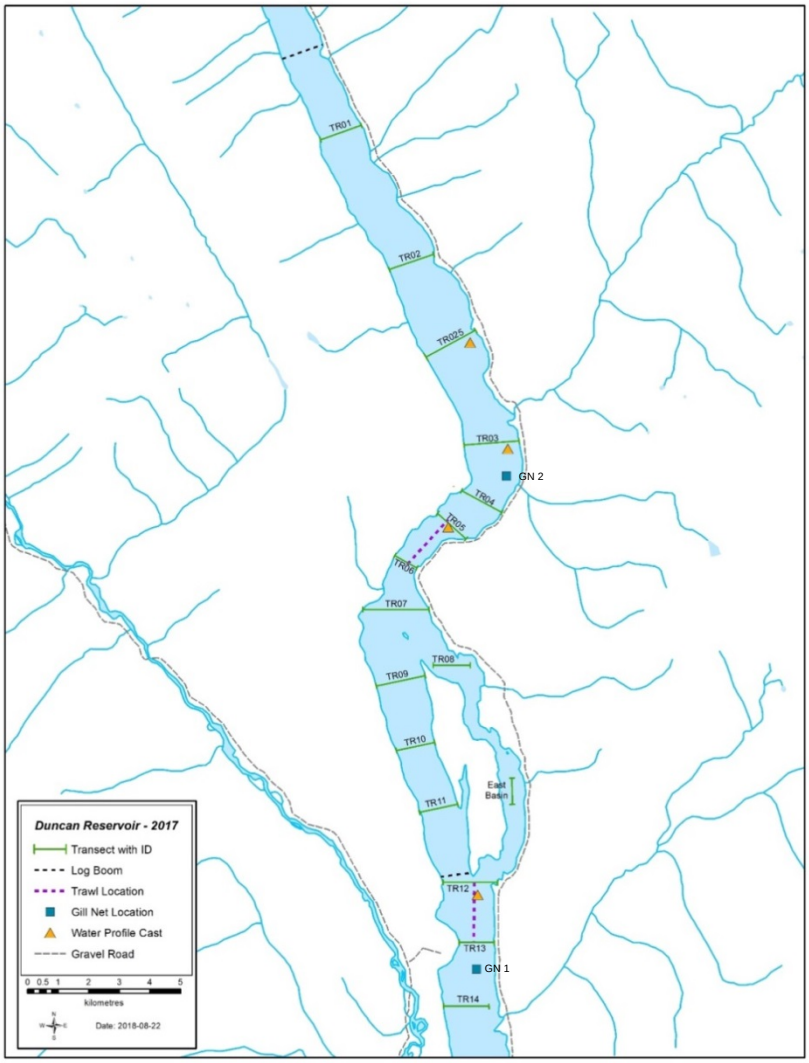

Figure 1. Duncan Reservoir hydroacoustic, trawl, gillnet and water profile sampling locations, August 22-24, 2017.

METHODS

Hydrology

Reservoir level data was obtained from the Water Survey of Canada water office (https://wateroffice.ec.gc.ca/mainmenu/real_time_data_index_e.html) and from the Spring 2018 BC Hydro operations summary (https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/community/columbia-river-operations-summary.pdf).

Water Column Profile

A Seabird SBE 19Plus was used to collect water column profiles at four locations on Duncan Reservoir (Figure 1). The instrument was activated via the manual switch and placed in the water for a soaking period for one minute. After the soaking period, the instrument was lowered through the water column at a constant rate of 0.5 m/s using a hydraulic winch. Only data collected on the way down (downcast) are presented here. The Seabird is equipped with multiple probes:

- Pressure, Strain Gauge [db]
- Temperature [ITS-90, deg C]
- Oxygen, SBE 43 [mg/l]
- Fluorescence, Turner SCUFA [µg/L]
- Conductivity [µS/cm]

Trawl

Trawling occurred from an 8 m boat outfitted with a dual drum hydraulic winch and boom arm, towing a 7 m deep by 3 m wide and 21 m long graduated mesh (92 mm down to 6 mm, stretched) trawl net. Acoustic data collected during the nights immediately prior to trawl sampling were evaluated to determine the vertical fish distribution and the highest density layers were targeted during trawl sampling. The net depth and distance from the boat were measured in real-time using a Notus trawl depth sensor system attached to the top trawl bar. Trawl speed was 2.7 kph to 3.0 kph (0.75 – 0.83 m/s) and was measured using a GPS chart plotter with external antenna for improved accuracy. Trawl sampling occurred during the nighttime hours and began a minimum of 1 hour after civil sunset, and targeted the mid-water fish layer.

Trawl sampling occurred on the night of August 23, 2017 at the north end between acoustic transects TR05-TR06 and at the south end between transects TR12-TR13 (Figure 1). These locations were chosen to maximize sampling of higher density targets (based on acoustic data) where the bottom depth allowed for safe maneuvering of the trawl net. At location TR05-TR06 the first haul was sixty minutes in duration; 30 minutes fishing the 20-

27 m layer and 30 minutes fishing 13-20 m layer. A second haul was initiated at the same location but after 20 minutes fishing at 21-28 m the net encountered an underwater obstruction (assumed to be a submerged log) and was immediately retrieved. Although we were able to retrieve the net immediately and no equipment damage occurred, we left the location due to safety concerns. At location TR12-TR13 the haul was 34 minutes in duration; 17 minutes fishing the 21-28 m layer and 17 minutes fishing the 14-21 m layer. We were limited by the log boom to the north and shallow water to the south at this location, so there was not sufficient space to complete a 60 minute trawl.

Captured fish were dispatched if required by cerebral contusion then kept on ice and sampled within 18 hours of capture for fork length, weight, sex and maturity. Scales and otoliths were retained from kokanee ≥100 mm fork length to determine age. The preferred scale collection area was approximately 2-3 scale rows above the lateral line and behind a line running between the posterior edge of the dorsal fin and leading edge of the anal fish above the lateral line. Scales from each individual were placed on rain proof paper and stored in marked envelopes. Otoliths were stored in vials in a 95% ethanol solution.

Gillnetting

Sampling using mid-water gillnets occurred to validate species composition of acoustic targets and to obtain other biological data. Gillnet sampling was not identified in the DDMMON 17 terms of reference, however observation of real-time acoustic data indicated significant densities of fish targets oriented in close proximity to the bottom in the north arm of the reservoir, where trawling was not possible due to safety concerns.

Each gillnet consisted of 6 panels of variable sized mesh ranging from 25-89 mm stretched mesh according to RIC (1997) standards; a seventh panel of 32 mm mesh added to each RIC standard net to improve effectiveness for capturing age 1 kokanee in the 130-160 mm size. Each seven panel modified RIC standard gillnet was 106.4 m long (15.2 m per panel) by 2.4 m deep.

Gillnets were set at two locations; at the south end between acoustic transects TR13 and TR14 (hereafter called set 1) and at the north end between acoustic transects TR03 and TR04 (hereafter called set 2) (Figure 1). Gillnet set 1 consisted of two 7 panel nets set end to end to create a 2 net continuous gang, with one net suspended at 15 m and the other at 20 m. Acoustic data suggested higher kokanee densities at the north end at the site of gillnet set 2, so only one seven panel net was set there at 15 m deep (top line depth). The ends of the gillnet (set 2) or gang (set 1) was anchored to the bottom with 30 lb. weights using up to 100 m of line (dependent on bottom depth). The gillnets were set parallel to the prevailing wind (generally parallel to shore) and were submerged to the pre-determined depths using a series of clip on bullet floats with pre-measured lines of 15 or 20 m, attached between each net panel. At each end of each gillnet, a larger 20" buoy was attached instead of a bullet float, and the 20" buoys were fitted with small water activated strobe lights for nighttime visibility.

The gillnets were set in the evening on August 23, 2017 with the intent to pull them approximately 14-18 hours later on the morning of August 24th; however, due to inclement

weather they could not be pulled until the evening of the 24th. Complete net set details are found in Appendix 1.

The catches from each depth section of net were bagged separately. Captured fish, dispatched if required by cerebral contusion, were kept on ice and processed in the same manner as the trawl captured fish. Bull trout were released alive if possible, in which case fork lengths were roughly estimated prior to release.

Ages for trawl and gillnet caught kokanee were determined through scale or otolith analyses at the BC Provincial Ageing Laboratory in Abbotsford, BC. In 2017 a total of 8 otoliths and 78 scales were submitted for age analysis.

Hydroacoustics

The hydroacoustic survey was conducted on August 22 & 23rd, 2017, during the night-time hours beginning 1.5 hours after civil sunset. Vertical beaming acoustic data were collected from 16 transects along the reservoir (Figure 1), one more than during the initial 2016 survey. The additional transect (TR025) was added between the TR02 and TR03 in 2017 to increase coverage in the shallow north portion of the reservoir. The majority of transects were positioned generally along the shortest distance shore to shore where the bottom depth was 20m and greater. Transects TR08 and East Basin are exceptions to this, they ran parallel to shore down the middle of their respective basins to allow for sufficient data to be collected (approximately 15 minutes of data collection). Survey data were obtained using a Simrad model EK60 transceiver with a 120 KHz split beam transducer and interfaced via a lap top computer as a processor using ER60 software. See Appendix 2 for echosounder equipment settings. The echosounder system, consisting of the processor, transceiver, and transducer, was calibrated in the field prior to the survey following the procedure described by Kongsberg Maritime AS (2008). During data collection the transducer was towed on a planer alongside the boat at a depth of 1 m, and data were collected continuously along survey transects at 3–5 pings/s while cruising at approximately 2 m/s. Navigation was by radar and GPS.

Echo counting using Sonar 5Pro software was used to generate target densities for unit area by depth stratum. See Appendix 2 for data processing specifications. Echo counting is considered suitable based on low fish densities, high single echo detection (SED) probability, and a low amount of false SED detections (Balk and Lindem, 2011). Area by depth stratum was estimated based on the known surface areas of full pool and low pool (7,350 ha at an elevation of 576.68 m and 2,190 ha at an elevation of 546.87 m; de Zwart et al. 2010) and 5 m habitat layers between them extrapolated. Echograms for each transect were analyzed from surface to 50 m depth in 10 equal depth layers (allowing two exclusion zones; surface to 3 m and 0.2 m above the bottom). Target sizes assumed to encompass the entire fish population were estimated using the split beam method, as described by Simmonds and MacLennan (2005). The fish densities in number/ha for each transect and depth stratum were output in 1-decibel (dB) size groups and compiled on an Excel spreadsheet. Two population components are reported herein, the kokanee fry (age 0) and age 1-3 kokanee. The population components were separated by visually identifying the inflection point where the dominant mode of smaller targets (kokanee fry) met the

remainder of the larger acoustic targets (age 1-3 kokanee). A stochastic simulation (a Monte Carlo method) approach approximated 95% confidence. For each depth stratum, 30,000 random realizations of normal distribution were calculated with a mean being the stratum mean and the standard deviation being the standard error of the population mean estimate. The 0.05 and 0.95 quantiles were taken as the 95% confidence intervals. Simulations were done in the statistical programming environment R 3.4.0 (R Core Team, 2016). Confidence intervals were produced for the entire fish population (>-62 dB; equivalent to >13 mm fork length), the kokanee fry population (-62 dB to -48 dB; equivalent to 13 mm to 76 mm fork length), and for the age 1-3 kokanee (>47 dB; equivalent to >76 mm fork length). Decibel to fork length conversions are approximate and were estimated using the dorsal aspect ratio for 120 KHz frequency (Love 1977).

RESULTS

Hydrology and Water Column Profile

The elevation of Duncan reservoir during the acoustic, trawl and gillnet surveys on August 22 & 23rd, 2017, was 575.8 m; which was similar to the reservoir elevation during the 2016 survey, and near the full pool elevation of 576.6 m. Duncan Reservoir reached a maximum elevation in 2017 on August 13th at 576.5 m and reached a minimum elevation in 2017 of 547.3 m on April 11th.

Duncan Reservoir was thermally stratified during late summer sampling in 2017(Figure 2), which was optimal for the hydroacoustic survey of the limnetic kokanee population. The thermal profiles appear relatively similar across all four sampling locations in 2017, with no evidence of a deepening thermocline from north to south as was evident in the 2016 sampling. Warm surface water (19-21°C) extended down to the thermocline which began at ~6-8 m among all stations. Oxygen levels ranged from 9-11 mg/L throughout the sampled water column at each profile location.

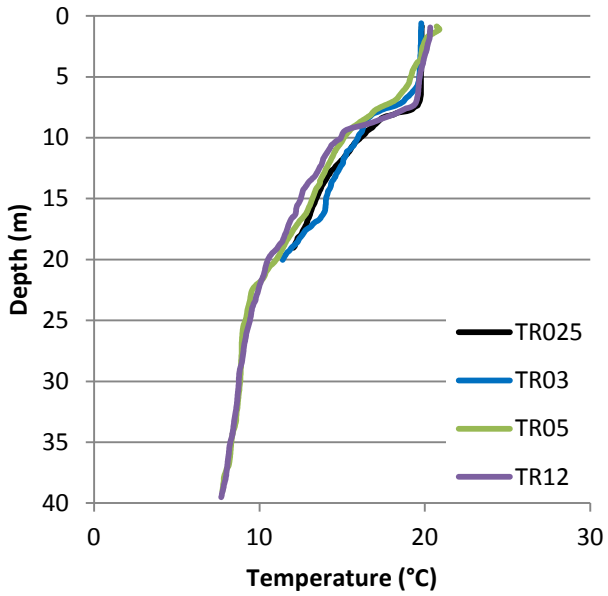

Figure 2. Temperature (degrees Celsius) profiles at three stations on Duncan Reservoir in late August, 2017

Fish Capture

Trawl & Gillnet Sampling

A total of 155 kokanee, 4 bull trout, and 1 pygmy whitefish were captured in the combined catch for both gillnet stations (Table 1; Appendix 3), confirming that the vast majority (98%) of acoustic targets in the pelagic area were kokanee. The trawl captured 50 fish, all of which were kokanee (Table 1; Appendix 4). Trawling occurred at two locations within the reservoir in 2017, however due to disproportionate effort and low catches, the data presented are the combined catch. Mysis shrimp were also captured as by-catch in the trawl in both 2016 and 2017 sampling.

Table 1. Numbers of kokanee (KO) fry and age 1-3, bull trout (BT) and pygmy whitefish (PWF) caught in trawl and gillnet sampling at Duncan Reservoir, late August 2017.

Method	BT	PWF	KO Fry	KO age 1-3
Trawl	**0**	**0**	**34**	**16**
Gillnet (Set 1)	2	0	0	102
Gillnet (Set 2)	2	1	0	53
Gillnet Total	**4**	**1**	**0**	**155**
Trawl and GN	**4**	**1**	**34**	**171**

Trawl 1 and 2 catches are combined due to disproportionate effort and low catch.

Further details for the age 1-3 kokanee catch are provided in Table 2. The proportion of maturing kokanee in the age 1-3 catch was greater in the northern gillnet location (51%, Set 2) compared to the southern location (26%, Set 1). The majority of the trawl sample came from the northern trawl location, although the percentage of maturing age 1-3 kokanee in the trawl sample (12.5 %) was much lower than in the gillnet catch in the same vicinity (set 2; 51%), and also lower than the combined gillnet catch (35 %). The average fork length of maturing fish was larger than immature age 1-3 kokanee, at 216 mm and 153 mm respectively.

Table 2 Catch statistics of age 1-3 kokanee, separated by maturity category, sampled by trawl and gillnet in Duncan Reservoir in late August 2017.

Method	Maturing[1] (%)	Count	Mean FL (mm)	SD	Immature (%)	Count	Mean FL (mm)	SD
Trawl	**12.5**	**2**	**226**	**2.1**	**87.5**	**14**	**150**	**20.3**
Gillnet (Set 1)	26	27	216	12.4	74	75	145	11.1
Gillnet (Set 2)	51	27	216	9.1	49	26	180	21.1
Gillnet	**35**	**54**	**216**	**10.8**	**65**	**101**	**157**	**20.9**
Total	***33***	***56***	***216***	***10.7***	***67***	***115***	***153***	***20.8***

[1] Kokanee in an advanced state of maturity that would have spawned in 2017

Length at age statistics for the kokanee captured in the trawl and gillnet sampling in 2016[1] and 2017 are presented in Table 3. An independent samples t-test was conducted to

[1] Ageing data were unavailable at the time of writing the 2016 data report (Weir et al., 2018) and are initially presented in this report.

compare mean lengths by age class between 2016 and 2017. Age 1 kokanee were statistically greater in length in 2016 ($\overline{x}$=163mm, SD=15.0) compared to 2017 ($\overline{x}$=147mm, SD=12.7); t (171)=7.4, p<0.01. The age 2 kokanee were not found to be significantly different in length between years (t (208)=0.7, p=0.5), and small sample sizes compromised comparison of length at age for age 0 and age 3 between years.

In 2016, the age 1, 2 and 3 kokanee length distributions each overlapped with the adjacent age classes, and a sizeable proportion of age 3 were present (Figure 3). Conversely, in 2017 there was no overlap in length at age and a substantially smaller proportion of age 3 kokanee was captured (Figure 4).

Table 3. Length at age (mm) statistics of kokanee caught in trawl and gillnet sampling at Duncan Reservoir during late August 2016 and 2017.

Age	2016				2017			
	Mean (mm)	**Count**	**SD**	**Range**	**Mean (mm)**	**Count**	**SD**	**Range**
0	51	4	16.3	36-74	48	32	10.2	38-85
1	163	70	15.0	105-184	147	103	12.7	103-172
2	214	142	12.3	180-233	212	68	11.0	185-240
3	239	26	13.3	228-298	263	1	-	-

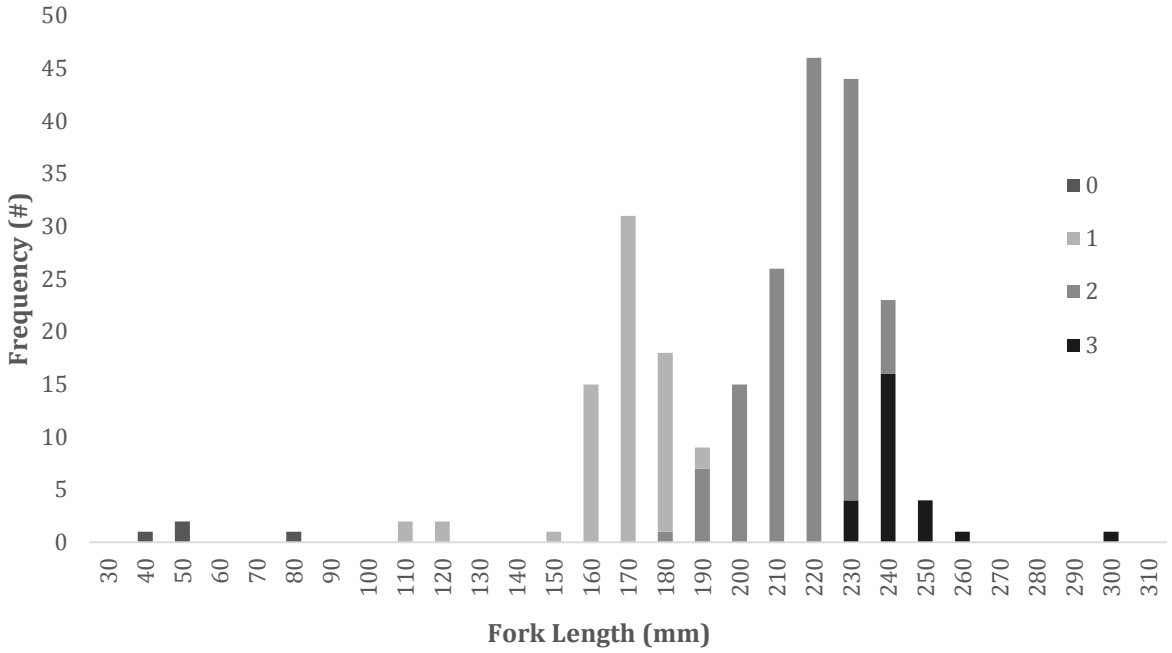

Figure 3. Length frequency by age of all trawl and gillnet caught kokanee from late August sampling, 2016. The bins are labeled by the upper value of the range. As an example, the 160mm bin includes all fish with lengths between 151 and 160mm.

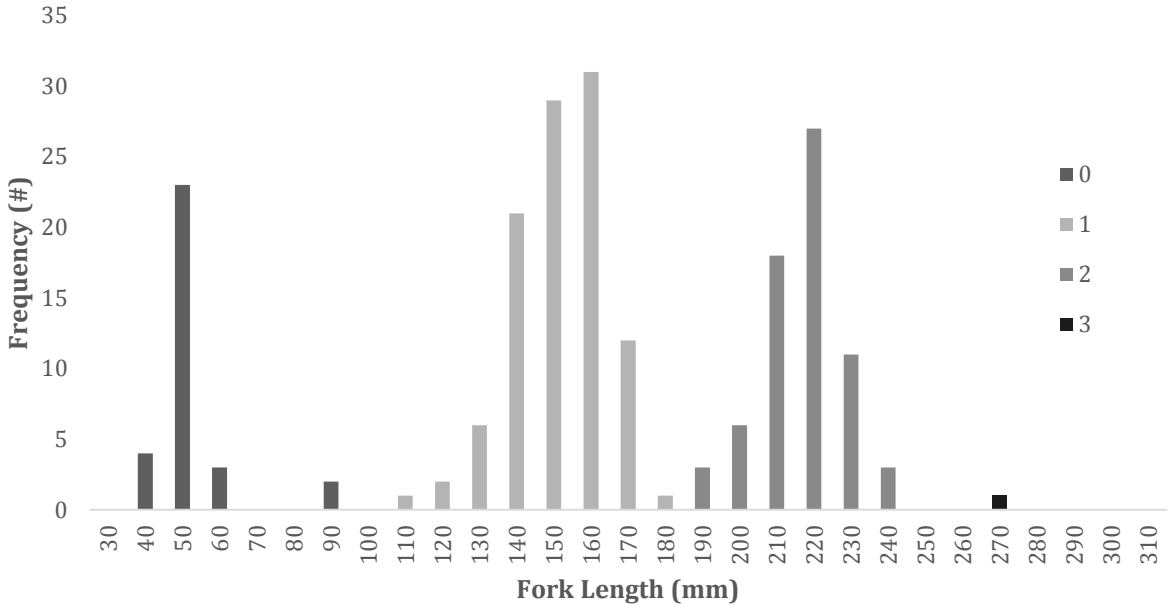

Figure 4. Length frequency by age of all trawl and gillnet caught kokanee from late August sampling, 2017. The bins are labeled by the upper value of the range. As an example, the 160mm bin includes all fish with lengths between 151 and 160mm.

Length frequency distributions of kokanee captured in the 2017 gillnet sets are compared to those captured in trawl sampling in Figure 5. Kokanee fry are not vulnerable to gillnets so were only captured in the trawl sampling. The trawl sampling captured proportionally more age 1 kokanee than age 2 and 3 (>180mm) compared to the gillnet sampling.

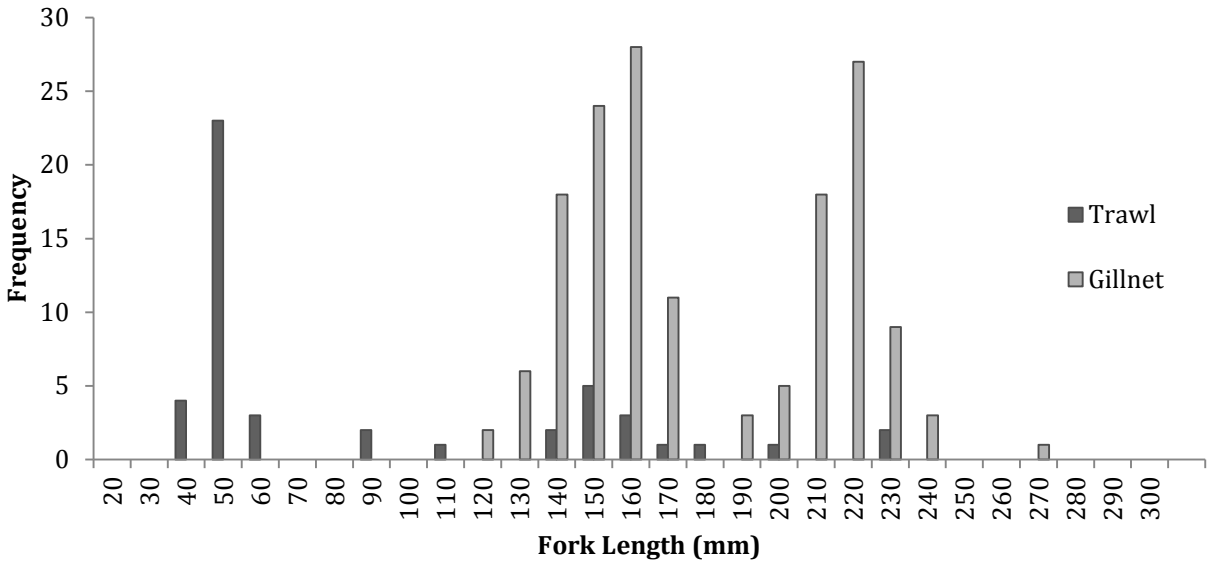

Figure 5. Fork length (mm) frequency distribution of trawl and gillnet caught kokanee in Duncan Reservoir in late August 2017. The bins are labeled by the upper value of the range. As an example, the 160mm bin includes all fish with lengths between 151 and 160mm.

All trawl and gillnet caught kokanee from 2017 sampling are combined and displayed as immature and maturing groups in Figure 6, the latter being fish of an advanced state of maturation that we assume would have spawned in the fall of 2017. Evaluation of Figure 6, in relation to Figure 4, identifies the majority of the age 2 cohort (81%; n=55) and all of the age 3 cohort (n=1) were maturing kokanee. On average, the maturing age 2 kokanee were larger than the immature age 2 kokanee. All kokanee of the age 1 cohort were immature. Assuming our catch accurately represented the spawner age structure; these results indicate the spawner escapement in Duncan Reservoir in 2017 would have been dominated by age 2 kokanee.

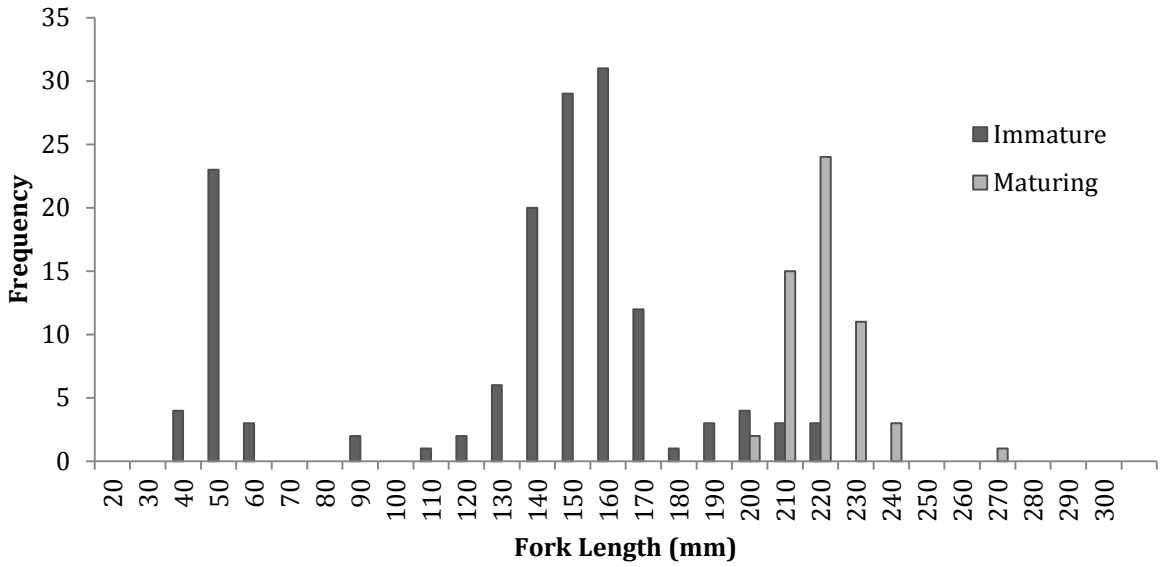

Figure 6. Length frequency of all trawl and gillnet caught kokanee based on state of maturation. Maturing kokanee were considered those in an advanced state of maturity expected to spawn in the fall of 2017. The bins are labeled by the upper value of the range. As an example, the 160mm bin includes all fish with lengths between 151 and 160mm.

Kokanee Abundance

The kokanee fry population in 2017 was estimated at 1.02 million (95% CI 0.85-1.20), which was 9% lower than the 2016 fry estimate of 1.12 million (95% CI 0.81-1.44). The age 1-3 kokanee population was estimated at 0.25 million (95% CI 0.20-0.30) in 2017, which was 20% higher than the 2016 age 1-3 population estimate of 0.20 million (95% CI 0.13-0.28) (Figure 7). The 95% confidence intervals overlapped considerably between years for both the fry and age 1-3 kokanee populations.

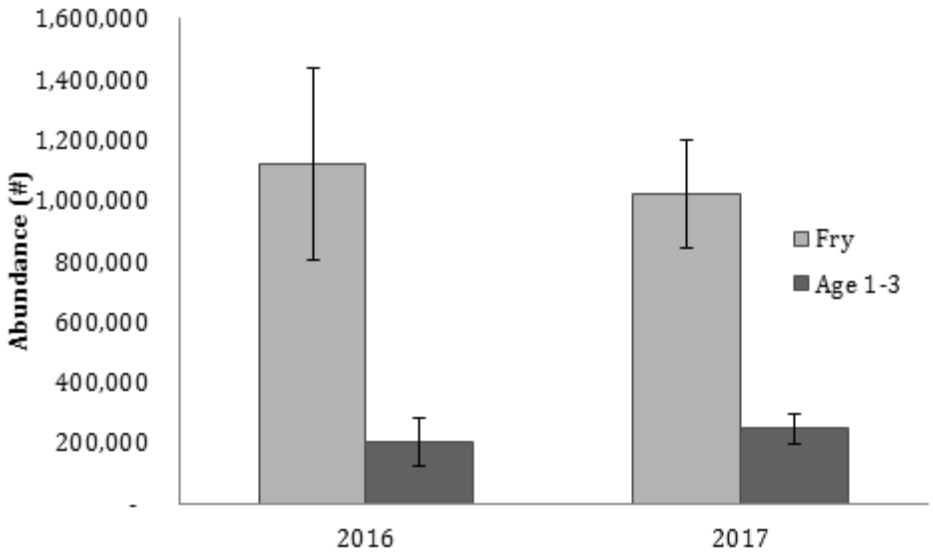

Figure 7. Hydroacoustic abundance estimates and 95% CI for kokanee fry and age 1-3 populations in Duncan Reservoir from late August sampling in 2016 and 2017.

The kokanee were distributed primarily below the thermocline during the nighttime hydroacoustic survey, with the highest densities occurring between 15 – 25 m (Appendix 5). Figure 8 illustrates the density distribution by transect, separated by age 0 and age 1-3 kokanee groups. Both population components were present, in general, at higher densities towards the northern end of the reservoir (transect TR01) compared to the southern end (towards transect TR14), and both population components were below average in the East Basin. The density distribution in 2017 was notably different from that of 2016, when very low densities were observed in the middle transects. Fry densities ranged from 78 to 442 fish/ha with an average of 244 fish/ha. Age 1-3 kokanee densities ranged from 28 to 104 fish/ha with an average of 61 fish/ha.

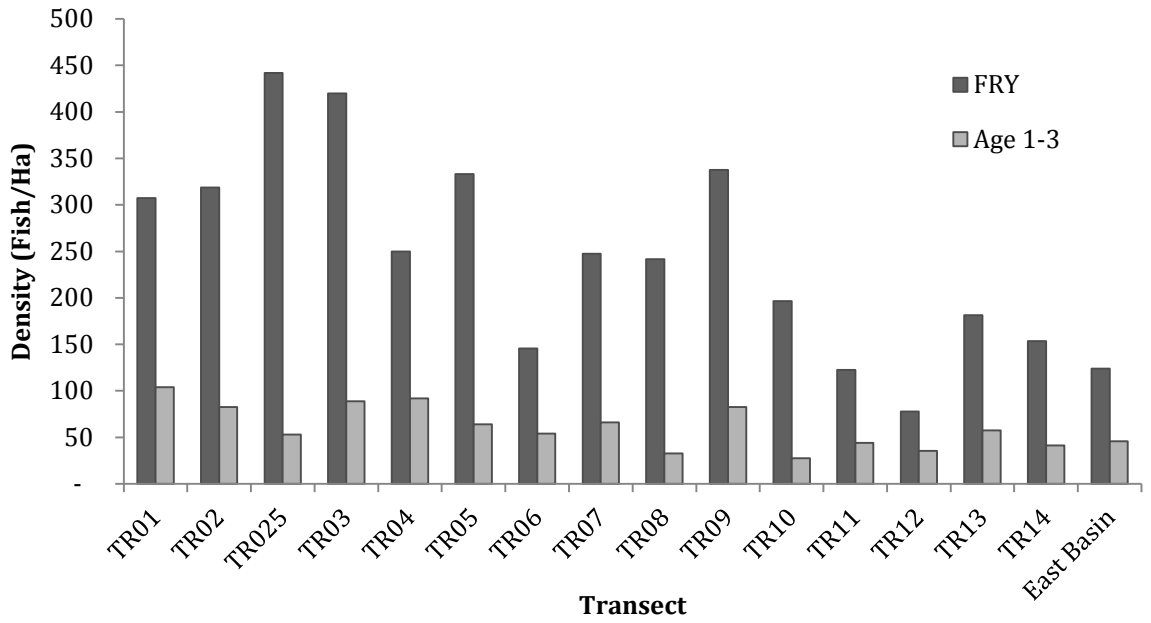

Figure 8. Kokanee fry and age 1-3 density distribution (fish/ha) by hydroacoustic transect in Duncan Reservoir in late August, 2017. The northernmost transect was TR01 and the southernmost transect was TR14 (see Figure 1).

Discussion

The August 2017 field surveys met the primary objective of acquiring the second year of baseline information on the biological characteristics, distribution and abundance of the in-lake kokanee population in Duncan Reservoir. The hydroacoustic survey conditions were very similar to 2016, with a well stratified water column and calm nighttime winds which are optimal for hydroacoustic surveys of kokanee in limnetic habitat. The hydroacoustic survey revealed a minor numerical (9%) decrease in the fry population in 2017 compared to 2016, and a modest numerical increase (20%) in age 1-3 kokanee abundance in 2017. There was a common pattern across both years of higher densities of kokanee fry and age 1-3 at the north end of the reservoir; however, two annual data points are insufficient to make inferences about factors that control kokanee distribution within or between years.

We conducted trawl and pelagic gillnet sampling to validate species composition of the acoustic targets, and to provide biological information on kokanee size, age, and maturity. Trawling provides samples of kokanee fry which are not vulnerable to capture by gillnet, and gillnetting provides an opportunity to sample in locations which are not safe for trawling or where densities are too low for trawling to be effective. Conditions for trawl sampling were not optimal in 2017 due to excessive large woody debris distributed across the reservoir, which posed an equipment and safety hazard. We successfully completed one 60 minute haul at the northernmost trawl location (south of transect 5; figure 1),

however during our attempt at a second haul at that location the net encountered an underwater obstruction (assumed to be a submerged log) part way through the trawl. Although we were able to retrieve the net immediately and no equipment damage occurred, we left the location due to safety concerns. In 2017 sampling we also trawled at the southern end of the reservoir to validate small target species composition. The space available for trawling at the southern end of the reservoir was confined by the log boom and shallowing water south of transect TR13, so we were limited to a 34 minute haul. The shorter duration and low densities at that location resulted in a limited catch of only three fish, all of which were kokanee. Our experience indicates that space limitations and variable debris conditions at Duncan Reservoir preclude trawl sampling as a reliable sampling approach for collecting standardized kokanee age structure and size information, as it is in other large lakes and reservoirs in BC (e.g. Kootenay Lake, Arrow Reservoir, Okanagan Lake).

Our approach to gillnet sampling in 2017 was to set one net at the north end of the reservoir in the same location as in 2016 and move the second north end set to the southern end of the reservoir (where we did not gillnet in 2016) in order to validate species composition and expand the spatial coverage of our sampling for age and maturity structure. Gillnetting was successful in capturing a large number of age 1-3 kokanee with a limited by-catch of bull trout (n=4 including two released), and is the recommended sampling approach for acquiring age 1-3 kokanee. The combined gillnet and trawl data confirmed that the vast majority of fish in the ensonified pelagic zone were kokanee (98% of captured fish) and as such acoustic data were not corrected for species composition and all acoustic targets were considered kokanee.

While not a component of this study, spawner escapement estimates and size information are important biological parameters. In 2016 survey reporting, we noted that trawl and gillnet sampling in late August provided size data from a significant number of fish showing clear evidence of advanced sexual maturity, and suggested that the size data was likely very comparable to biological data collected from terminal spawning locations given the temporal proximity to spawning. Evaluation of data collected from kokanee on the spawning grounds as well as those captured in late August in-lake sampling within the same year would confirm the comparability between the two datasets, however lacking that information we expect maturing fish captured in-lake in late August to be generally representative of actual spawner size, and should be valid as an index. We did note, however, that the maturing kokanee in the 2017 sampling displayed subdued development of secondary sexual characteristics (namely colouration and scale resorption) relative to the maturing fish from 2016 sampling even though the sampling occurred only one week earlier in 2017.

Kokanee biomass estimates are another useful metric to represent kokanee productivity, however the BC provincial standard for estimating biomass requires a reliable annual estimate of age structure to which size at age information can be applied. In other data rich systems such as Kootenay and Arrow Lakes, located near Duncan Lake, these data are collected through comprehensive standardized trawl sampling, which is not viable for Duncan Reservoir as discussed above. However, methodology to estimate biomass using acoustic data in conjunction with size data from gillnetting and trawling has been

developed for application to Kinbasket and Revelstoke data, and will be applied to generate kokanee biomass estimates for Duncan Reservoir in future reporting.

Zooplankton sampling was not conducted in 2017 due to an equipment malfunction, and therefore is not available to support interpretation of the kokanee data in accordance with the DDMMON-17 terms of reference. We acknowledge that a single zooplankton sampling period per season is not sufficient to provide in-depth insight into zooplankton dynamics in the reservoir, so we do not anticipate that the data gap in 2017 will influence the overall outcome of this Water Use Planning study. Zooplankton sampling will be conducted during the third and final survey of this study period in 2018.

Recommendations

- Develop acoustic size-based biomass estimates to facilitate comparisons in kokanee productivity between Duncan Reservoir and other nearby systems such as Kootenay Lake and Kinbasket, Revelstoke, and Arrow Lakes Reservoirs.
- Maintain consistency in survey timing (mid-late August), within the constraints of new moon timing, in order to ensure kokanee spawners are present in the ensonified pelagic area for consistency and comparability of biological and acoustic data over time.

Acknowledgements

Direct funding was provided by BC Hydro and in-kind support by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) for this monitoring.

Assistance with field surveys was provided by Vicki Lewis and Trevor Davies of the MFLNRORD in Victoria. Thanks to Karen Bray and Beth Manson of BC Hydro for providing assistance with organization and provision of gillnetting equipment. Marley Bassett with MFLNRORD was kind enough to lend us zooplankton sampling equipment. Otolith and scale analyses were done by Morgan Davies of the Freshwater Fisheries Society of BC at the Provincial ageing lab in Abbotsford, BC. Accommodation was provided by BC Hydro at Meadow Creek. Katy Jay of BC Hydro provided a helpful review and comments on this document.

References

Balk and Lindem, 2011. Sonar4 and Sonar5-Pro post processing systems, Operator manual version 6.0.1, 464p. Lindem Data Acquisition Humleveien 4b. 0870 Oslo Norway.

BC Hydro. 2008. Duncan Dam Water Use Plan; Monitoring Program Terms of Reference. Prepared for the Consultative Committee for the Duncan Dam Water Use Plan. Burnaby, BC.

de Zwart, I, G. Andrusak, J. Thorley, R. Irvine & S. Masse. 2010. Duncan Reservoir Fish Habitat Use Monitoring (DDMMON-10). Year 2 (2009) Data Report. Report prepared for BC Hydro, Water License Requirements. Prepared by Masse Environmental Consultants Ltd., Redfish Consulting Ltd. and Poisson Consulting Ltd. 57 pp + 2 App.

de Zwart, I, G. Andrusak, J. Thorley, R. Irvine & S. Masse. 2011. Duncan Reservoir Fish Habitat Use Monitoring (DDMMON-10). Year 3 (2010) Data Report. Report prepared for BC Hydro, Water License Requirements. Prepared by Masse Environmental Consultants Ltd., Redfish Consulting Ltd. and Poisson Consulting Ltd. 89 pp + 2 App.

Kongsberg Maritime AS. 2008. Simrad ER60 scientific echosounder reference manual for software version 2.2.0. Kongsberg Maritime, Horten, Norway. 221p.

Love, R. H. 1977. Target strength of an individual fish at any aspect. J. Acoust. Soc. Am. 62(6): 1397-1403.

Simmonds, J., and D. MacLennan. 2005. Fisheries acoustics: Theory and practice. Blackwell, Oxford, UK.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria

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).

Weir, T, D. Johner & S. J. Albers. 2018. Duncan Reservoir Kokanee Stock Assessment –Year 1 (2016). Prepared for BC Hydro under the Duncan Dam Project Water Use Plan, Water License Requirements Study No. DDMMON#17. 29p

Appendix

Appendix 1. Gillnet set data from 2017 Duncan Reservoir sampling.

Attribute	GN1	GN2
Set date	23-Aug-17	23-Aug-17
Retrieval date	24-Aug-17	24-Aug-17
General location	TR04	TR13
Net depth(s) in meters	15,20	15
Lake depth (m) start/end	57/45	27/26
Start Latitude	50 18.302	50 26.212
Start Longitude	116 55.743	116 55.853
Set time (24:00hr)	20:10	20:50
Retrieval time (24:00hr)	15:31	17:05
Total time (hrs)	19.3	20.25

Appendix 2. Equipment and data processing specifications.

Echosounder Specifications and Field Settings

Category	Parameter	Value
Echosounder	Manufacturer	Simrad EK60
Transceiver	Frequency	120 kHz
	Max power	100 W
	Pulse duration	0.256 ms
	Band width	8.71 kHz
	Absorption coefficient	4.11 dBKm
Transducer	Type	split-beam
	Depth of face	1.0 m
	Orientation, survey method	vertical, mobile, tow foil
	Sv, TS transducer gain	27.0 dB
	Angle sensitivity	23.0
	nominal beam angle	7.0 deg
	Data collection threshold	-70 dB
	Ping rate	3 – 5 pps

Data Processing Specifications: SONAR 5 software version 6.0.1

Data conversion	Amplitude/ SED thresholds	-70 dB (40 Log R TVG)
	Sv, TS gain (correction)	-27.3 dB (from field calibration)
Single target filter	analysis threshold[1]	-70 to -24 dB (47 1dB bins)
	Min echo length	0.7 – 1.3
	Max phase deviation	0.30
Density determination	Integration method	20 log r density (total) from Sv/Ts
	Echo counting method	40 log r density based on SED
	Fish size distributions	From *in situ* single echo detections

[1] Lower threshold for fish population estimation was -62dB.

Appendix 3. Gillnet catch data from August 24, 2017 sampling in Duncan Reservoir.

Set	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
1	1	KO	210.0	120.02	M	Maturing	1		
1	2	KO	210.0	109.37	M	Immature	2		
1	3	KO	197.0	97.23	F	Immature	3		
1	4	KO	210.0	120.52	F	Maturing	4		
1	5	KO	210.0	117.13	M	Maturing		5	
1	6	KO	202.0	91.28	M	Immature	6		
1	7	KO	159.0	49.85	F	Immature	7		
1	8	KO	219.0	138.45	M	Maturing	8	8	
1	9	KO	200.0	121.71	M	Maturing	9		
1	10	KO	212.0	135.82	M	Maturing	10		
1	11	KO	168.0	56.71	M	Immature	11		
1	12	KO	220.0	145.03	M	Maturing		12	
1	13	KO	217.0	124.15	M	Maturing	13		
1	14	KO	170.0	59.26	M	Immature	14		
1	15	KO	221.0	138.17	M	Maturing	15		
1	16	KO	212.0	106.47	F	Immature	16		
1	17	KO	157.0	44.29	F	Immature	17		
1	18	KO	220.0	142.74	M	Maturing	18		
1	19	KO	185.0	73.18	M	Immature	19		
1	20	KO	197.0	99.23	M	Immature	20		
1	21	KO	208.0	106.25	F	Maturing	21		
1	22	KO	221.0	150.20	M	Maturing		22	
1	23	KO	240.0	170.14	M	Maturing	23		
1	24	KO	217.0	126.11	M	Maturing	24		
1	25	KO	224.0	127.37	F	Maturing	25		
1	26	KO	232.0	153.45	F	Maturing	26		
1	27	KO	207.0	119.23	M	Maturing		27	
1	28	KO	213.0	109.17	F	Maturing			
1	29	KO	205.0	104.04	F	Maturing	29		
1	30	KO	216.0	116.33	M	Immature			
1	31	KO	215.0	132.10	M	Maturing			
1	32	KO	228.0	154.83	M	Maturing	32		
1	33	KO	188.0	79.23	F	Immature	33		
1	34	KO	157.0	43.97	M	Immature	34		
1	35	KO	160.0	53.25	F	Immature	35		
1	36	KO	195.0	102.08	F	Immature	36		
1	37	KO	165.0	43.91	M	Immature	37		

Appendix 3. Continued

Set	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
1	38	KO	205.0	103.92	F	Immature	38		
1	39	KO	185.0	76.97	F	Immature	39		
1	40	KO	210.0	119.83	F	Maturing			
1	41	KO	204.0	115.66	M	Maturing	41		
1	42	KO	209.0	110.66	F	Maturing	42		
1	43	KO	161.0	44.53	M	Immature	43		
1	44	KO	212.0	105.31	M	Immature		44	
1	45	KO	158.0	47.51	F	Immature	45		
1	46	KO	207.0	105.61	F	Maturing	46		
1	47	KO	165.0	57.49	F	Immature	47		
1	48	KO	161.0	52.42	M	Immature	48		
1	49	KO	217.0	122.80	F	Maturing			
1	50	KO	165.0	50.70	F	Immature	50		
1	51	KO	155.0	46.57	F	Immature		51	
1	52	KO	224.0	124.64	F	Maturing		52	
1	53	KO	165.0	51.84	M	Immature	53		
1	54	PW	137.0	20.59	F	Maturing			
1	55	BT*	450.0			Released			
1	56	BT*	420.0			Released			
2	57	BT	365.0		F	Immature			
2	58	BT	420.0		M	Immature			
2	59	KO	220.0	132.12	M	Maturing	59		
2	60	KO	148.0	36.60	M	Immature		60	
2	61	KO	142.0	33.76	F	Immature	61		
2	62	KO	139.0	30.73		Immature			
2	63	KO	127.0	22.57		Immature			
2	64	KO	151.0	36.16		Immature	64		
2	65	KO	132.0	24.66		Immature	65		
2	66	KO	142.0	33.53		Immature	66		
2	67	KO	152.0	38.45		Immature	67		
2	68	KO	120.0	19.58		Immature			
2	69	KO	149.0	34.43		Immature	69		
2	70	KO	146.0	36.01		Immature		70	
2	71	KO	136.0	26.09		Immature		71	
2	72	KO	140.0	28.73		Immature		72	

Appendix 3. Continued

Set	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	73	KO	121.0	18.32		Immature			
2	74	KO	224.0	131.04	F	Maturing	74		
2	75	KO	224.0	125.02	F	Maturing	75		
2	76	KO	221.0	138.45	M	Maturing			
2	77	KO	211.0	112.85	M	Maturing			
2	78	KO	204.0	117.78	M	Maturing	78		
2	79	KO	236.0	165.46	F	Maturing	79		
2	80	KO	206.0	98.33	F	Maturing			
2	81	KO	130.0	28.53		Immature	81		
2	82	KO	135.0	28.06		Immature	82		
2	83	KO	211.0	112.92	F	Maturing			
2	84	KO	145.0	33.08		Immature	84		
2	85	KO	142.0	32.58		Immature	85		
2	86	KO	143.0	34.03		Immature	86		
2	87	KO	205.0	106.61	F	Maturing			
2	88	KO	202.0	96.52	F	Maturing			
2	89	KO	148.0	36.97		Immature	89		
2	90	KO	123.0	18.08		Immature			
2	91	KO	140.0	32.03		Immature			
2	92	KO	158.0	46.49		Immature	92		
2	93	KO	139.0	29.32		Immature			
2	94	KO	129.0	24.38		Immature			
2	95	KO	220.0	131.32	M	Maturing			
2	96	KO	135.0	26.17		Immature			
2	97	KO	206.0	110.21	F	Maturing			
2	98	KO	212.0	119.34	M	Maturing			
2	99	KO	211.0	116.17	F	Maturing			
2	100	KO	150.0	38.49		Immature	100		
2	101	KO	143.0	33.64		Immature			
2	102	KO	220.0	139.95	M	Maturing			
2	103	KO	219.0	136.25	F	Maturing			
2	104	KO	137.0	26.29		Immature			
2	105	KO	136.0	27.95		Immature			
2	106	KO	219.0	145.02	M	Maturing			
2	107	KO	217.0	120.30	F	Maturing			

Appendix 3. Continued

Set	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	108	KO	215.0	128.56	F	Maturing			
2	109	KO	213.0	126.04	M	Maturing			
2	110	KO	215.0	111.91	F	Maturing			
2	111	KO	263.0	194.02	M	Maturing		111	
2	112	KO	211.0	118.19	M	Maturing			
2	113	KO	131.0	26.42		Immature			
2	114	KO	158.0	50.05		Immature	114		
2	115	KO	197.0	101.29	M	Maturing	115	115	
2	116	KO	159.0	55.97		Immature			
2	117	KO	139.0	31.93		Immature			
2	118	KO	168.0	61.64	M	Immature	118		
2	119	KO	133.0	26.97		Immature			
2	120	KO	162.0	50.67		Immature	120		
2	121	KO	151.0	38.40		Immature			
2	122	KO	157.0	48.91		Immature			
2	123	KO	142.0	33.46		Immature			
2	124	KO	147.0	34.00		Immature			
2	125	KO	216.0	123.59	M	Maturing			
2	126	KO	147.0	38.03		Immature			
2	127	KO	154.0	44.23		Immature			
2	128	KO	159.0	48.18		Immature			
2	129	KO	166.0	54.77		Immature			
2	130	KO	145.0	37.15		Immature			
2	131	KO	144.0	35.03		Immature			
2	132	KO	157.0	42.00		Immature			
2	133	KO	160.0	48.23		Immature			
2	134	KO	153.0	38.71		Immature			
2	135	KO	130.0	24.72		Immature			
2	136	KO	134.0	27.01		Immature			
2	137	KO	223.0	127.01	F	Maturing			
2	138	KO	160.0	46.21		Immature			
2	139	KO	145.0	36.25		Immature			
2	140	KO	146.0	36.09		Immature			
2	141	KO	158.0	48.82		Immature			
2	142	KO	151.0	39.30		Immature			
2	143	KO	155.0	43.32		Immature			

Appendix 3. Continued

Set	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	144	KO	146.0	37.00		Immature			
2	145	KO	136.0	28.92		Immature			
2	146	KO	136.0	28.37		Immature			
2	147	KO	152.0	38.59		Immature			
2	148	KO	133.0	27.65		Immature			
2	149	KO	153.0	43.07		Immature			
2	150	KO	144.0	34.48		Immature			
2	151	KO	150.0	36.49		Immature			
2	152	KO	154.0	40.21		Immature			
2	153	KO	143.0	35.79		Immature			
2	154	KO	133.0	25.97		Immature			
2	155	KO	159.0	45.54		Immature			
2	156	KO	146.0	33.70		Immature			
2	157	KO	156.0	48.09		Immature			
2	158	KO	120.0	18.68		Immature			
2	159	KO	156.0	48.16		Immature			
2	160	KO	141.0	28.80		Immature			

* Both bull trout captured in set 1 were released alive and fork length was estimated

Appendix 4a. Trawl data from the north station (near TR05-06) on August 23rd, 2017 on Duncan Reservoir.

Trawl 1		
Trawl Duration – 60 minutes (two layers at 30 minutes each)	**Location – ~acoustic transect TR05-06**	
Trawl Depth – 13 to 27m	**Start 50˚ 25'.229 / 116˚57'.777**	**End 50˚ 23'.961 / 116˚58'.598**
Trawl 2		
Trawl Duration – 20 minutes	**Location – ~acoustic transect TR05-06**	
Trawl Depth – 21m to 28m	**Start 50˚ 24'.137 / 116˚58'.382**	**End 50˚ 24'.599 / 116˚58'.153**

Trawl No	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Condition Factor
1	1	KO	223.0	138.60	M	Maturing	1.25
1	2	KO	172.0	59.69	F	Immature	1.17
1	3	KO	143.0	35.08	F	Immature	1.20
1	4	KO	144.0	36.84	F	Immature	1.23
1	5	KO	155.0	46.15	M	Immature	1.24
1	6	KO	148.0	36.70		Immature	1.13
1	7	KO	142.0	34.34		Immature	1.20
1	8	KO	135.0	29.39		Immature	1.19
1	9	KO	103.0	11.02		Immature	1.01
1	10	KO	165.0	47.34		Immature	1.05
1	11	KO	138.0	32.42		Immature	1.23
1	12	KO	82.0	5.27		Immature	0.96
1	13	KO	50.0	1.26		Immature	1.01
1	14	KO	51.0	1.13		Immature	0.85
1	15	KO	50.0	1.15		Immature	0.92
1	16	KO	41.0	0.42		Immature	0.61
1	17	KO	49.0	1.21		Immature	1.03
1	18	KO	44.0	0.71		Immature	0.83
1	19	KO	46.0	0.86		Immature	0.88
1	20	KO	46.0	0.84		Immature	0.86
1	21	KO	57.0	1.71		Immature	0.92
1	22	KO	46.0	0.89		Immature	0.91
1	23	KO	44.0	0.84		Immature	0.99
1	24	KO	45.0	0.89		Immature	0.98
1	25	KO	49.0	1.01		Immature	0.86
1	26	KO	44.0	0.75		Immature	0.88
1	27	KO	38.0	0.37		Immature	0.67
1	28	KO	43.0	0.65		Immature	0.82
1	29	KO	39.0	0.48		Immature	0.81
1	30	KO	40.0	0.46		Immature	0.72
1	31	KO	48.0	0.89		Immature	0.80
1	32	KO	47.0	0.88		Immature	0.85

1	33	KO	50.0	1.00		Immature	0.80
1	34	KO	41.0	0.63		Immature	0.91
1	35	KO	45.0	0.69		Immature	0.76
1	36	KO	44.0	0.59		Immature	0.69
1	37	KO	43.0	0.73		Immature	0.92
1	38	KO	46.0			Immature	0.00
1	39	KO				Immature	
1	40	KO				Immature	
2	41	KO	192.0	88.60	F	Immature	1.25
2	42	KO	226.0	129.69	F	Maturing	1.12
2	43	KO	160.0	48.61	F	Immature	1.19
2	44	KO	147.0	35.35	F	Immature	1.11
2	45	KO	85.0	6.25		Immature	1.02
2	46	KO	50.0	1.31		Immature	1.05
2	47	KO	38.0	0.42		Immature	0.77

Appendix 4b. Trawl data from south station (near TR12-13) on August 23rd, 2017 on Duncan Reservoir.

Trawl 1

Trawl Duration – 34 minutes (two layers at 17minutes each)
Trawl Depth – 14m to 28m

Location – ~acoustic transect TR12-13

Start 50˚ 19'.044 / 116˚55'.996

End 50˚ 18'.206 / 116˚56'.017

Trawl No	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Condition Factor
1	1	KO	155.0	38.22	F	Immature	1.03
1	2	KO	50.0	1.30		Immature	1.04
1	3	KO	51.0	1.41		Immature	1.06

Appendix 5. Duncan Reservoir fish density by depth and transect for a) kokanee fry, and b) age 1-3 kokanee from the hydroacoustic survey on August 22-23, 2017. Shaded cells indicated bottom depth.

a) Kokanee Fry

Depth	TR01	TR02	TR025	TR03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TR11	TR12	TR13	TR14	East Basin
3	60	47	39	49	14	96	-	-	45	-	-	21	-	47	42	-
5	16	3	46	28	18	-	-	7	71	11	-	16	16	25	17	26
10	148	26	57	49	35	13	20	70	29	63	43	29	5	5	29	9
15	188	199	136	173	99	126	67	149	65	208	115	33	22	47	38	26
20		127	191	163	142	114	77	48	39	86	30	27	24	40	49	31
25			26	47	35	48	32	24	15	38	30	16	16	26	20	27
30							3	9	10	11	4	20	21	20		32
35							-	3	2	-	1	6	8	4		8
40							-	2	-	2	-	-	-	10		7
45							-	2	-	2	1	-	2	16		3
Sum	**411**	**401**	**495**	**509**	**342**	**397**	**200**	**314**	**274**	**420**	**224**	**166**	**113**	**239**	**195**	**170**

b) Age 1-3 Kokanee targets

Depth	TR01	TR02	TR025	TR03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TR11	TR12	TR13	TR14	East Basin
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	41	-	-	5	1	-	-	4	-	9	-	-	-	-	7	-
15	59	44	21	37	40	27	25	32	8	31	6	13	9	5	16	-
20		38	29	32	51	31	24	17	17	23	10	14	9	17	15	8
25			3	15		6	2	9	5	11	12	7	4	12	4	16
30							3	3	4	6	-	7	12	10		14
35							-	-	-	-	-	3	2	1		5
40							-	1	-	-	-	-	-	5		2
45							-	1	-	2	-	-	-	8		1
Sum	**104**	**83**	**53**	**89**	**92**	**64**	**54**	**66**	**33**	**83**	**28**	**44**	**35**	**57**	**41**	**46**