Duncan Dam Project Water Use Plan

Duncan Reservoir Kokanee Stock Assessment

Implementation Year 1

Reference: DDMMON-17

Duncan Reservoir Kokanee Stock Assessment – Year 1 (2016)

Study Period: August 2016

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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 2016, the first year of a proposed three year study to evaluate kokanee status in the limnetic habitat of Duncan Reservoir was undertaken by the Fish & Wildlife Branch of the Ministry of Forests, Lands and Natural Resource Operations (FLNRO) 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 2016 field survey, which included a hydroacoustic survey, mid-water trawling, and pelagic gillnetting in conjunction with a limited limnological survey of water quality parameters and zooplankton sampling.

The kokanee fry population was estimated at 1.12 (95% CI 0.81-1.44) million, and the age 1-3+ kokanee population was estimated at 0.20 (95% CI 0.13-0.28) 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. Higher densities of kokanee were observed at the northern and southern ends of the reservoir with low densities in the middle transects.

A total of 227 kokanee, 1 mountain whitefish, and 3 bull trout were captured by gillnet sampling and the trawl captured 19 fish, all of which were kokanee; confirming the pelagic zone was dominated by kokanee. The vast majority of fish captured were age 1-3+ kokanee with only four age 0 kokanee captured in the trawl, although trawl sampling was limited due to safety concerns and a large gillnet catch. The combined gillnet and trawl data indicate a large proportion of the age 1-3+ kokanee were maturing to spawn in 2016.

Copepod densities were far higher than densities of daphnia or other cladocera in late August of 2016; however daphnia comprised the vast majority of biomass. Densities and biomass of each taxonomic group were higher at the northern sampling station, and relative proportions of each group were similar between stations.

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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 2016 field survey, which included a hydroacoustic survey, mid-water trawling, and pelagic gillnetting in conjunction with a limited limnological survey of water quality parameters and zooplankton sampling. 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 locations of hydroacoustic transects, zooplankton sampling stations, and water profile casts from 2016.

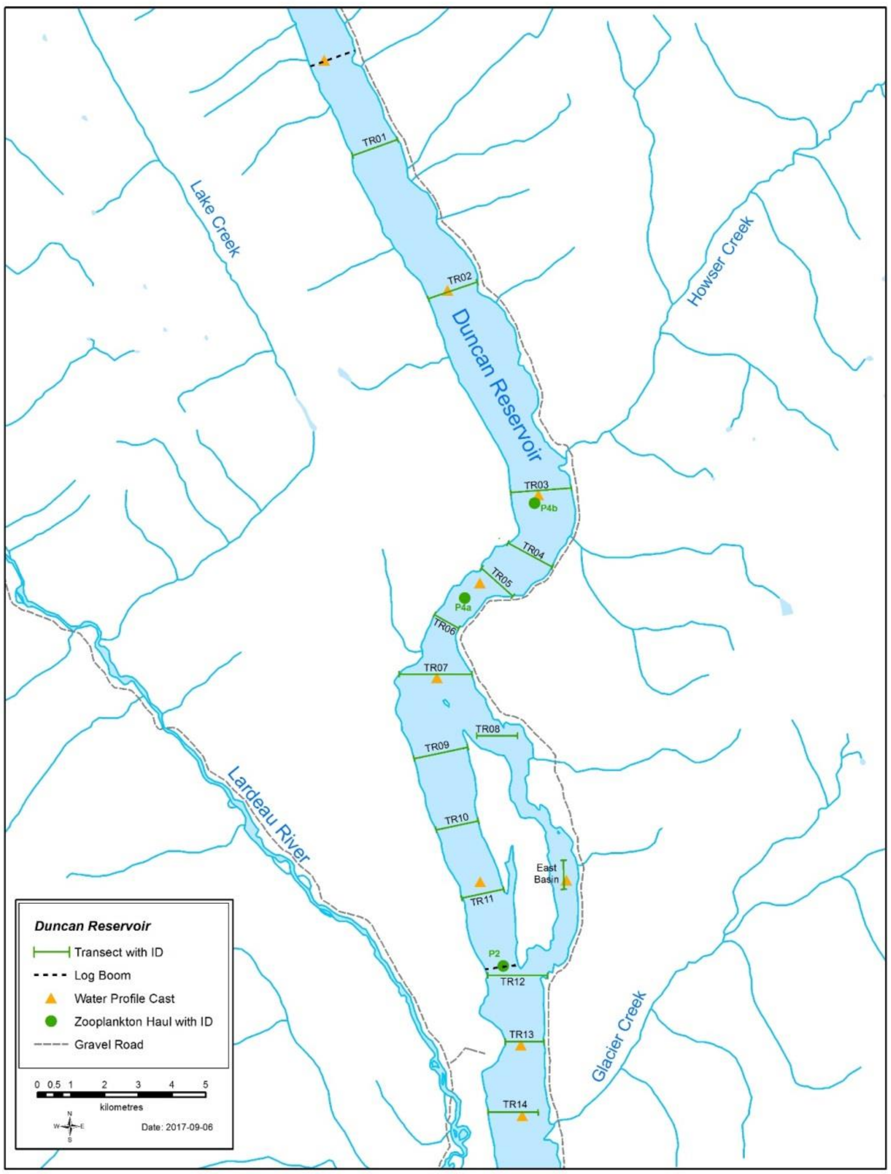

Figure 1. Duncan Reservoir hydroacoustic transect, zooplankton sampling and water column profiling sites from late August 2016.

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 the HYDAT database (http://collaboration.cmc.ec.gc.ca/cmc/hydrometrics/www/).

Water Column Profile

A Seabird SBE 19Plus was used to collect water column profiles at nine 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]

Zooplankton

Zooplankton sampling occurred at three stations, P2 and P4a and P4b (Figure 1) on August 31, 2016. Station P4b was the northernmost station and was located where sampling occurred under in September of 2009 (under DDMMON-10, see de Zwart *et. al*, 2010), then called station P4, to facilitate possible comparisons between years. Station P2 was located in the same location as in 2009 and 2010 September sampling. Station P4a was located where sampling occurred in September 2010 (under DDMMON-10, see de Zwart *et. al*, 2011), also then called station P4, although it was at a different location than P4 sampling in 2009. We designated P4a and P4b to distinguish the variation in P4 locations that occurred in DDMMON-10 in 2009 and 2010 due to differing seasons and water levels.

We observed a bottom depth of only 26 m at station P4b so the sampling was modified to avoid bottom by conducting a 0-20 m haul as opposed to the standard 0-30 m sampling conducted at the other two sites. As such, the estimates for station P4b may not be directly comparable to other stations sampled from 0-30 m, but should be comparable to sampling in other years at the same location with the same haul depth of 0-20 m.

Zooplankton samples were collected with a vertically hauled 153 μm mesh Wisconsin net with a 0.5 m throat diameter on August 31, 2016. Triplicate samples were taken at each site. Samples were analyzed individually and the results presented are the mean value of the three samples. Following collection, the zooplankton samples were rinsed from the dolphin bucket and preserved in 70% ethanol. Zooplankton samples were analyzed for species density (ind/L) and biomass (μg/L) (estimated from empirical length-weight regressions, McCauley 1984) but presented here in three taxa as copepoda, daphnia, and 'other' cladocerans. Samples were re-suspended in tap water that had been filtered through a 74-μm mesh and were sub-sampled using a four-chambered Folsom-type plankton splitter. Splits were placed in gridded plastic petri dishes and stained with Rose Bengal to facilitate viewing with a Wild M3B dissecting microscope (at up to 400X magnification). For each replicate, organisms were identified to species level and counted until up to 200 organisms of the predominant species were recorded. If 150 organisms were counted by the end of a split, a new split was not started. Using a mouse cursor on a live television image, the lengths of up to 30 organisms of each species were measured for use in biomass calculations. Lengths were converted to biomass (μg dry weight) using an empirical length-weight regression from McCauley (1984). See Vidmanic (2013) for more complete methods.

Zooplankton species were identified with reference to taxonomic keys (Pennak 1989, Brooks 1959, Wilson 1959, Sandercock and Scudder 1996).

Trawl

Trawl sampling provided species verification of acoustic data as well as information on age structure, size-at-age, and maturity. A mid-water night-time trawl was completed on Duncan Reservoir on August 31, 2016 near Transect 05 (TR05; Figure 1). This location was chosen to maximize sampling of higher density targets where the bottom depth allowed for safe maneuvering of the trawl net.

A 7 m deep by 3 m wide graduated mesh trawl net was towed for 46 minutes starting near TR05 and headed in a southerly direction toward TR06. Trawling occurred from an 8 m boat outfitted with a dual drum hydraulic winch and boom arm to deploy and retrieve the net. Acoustic data were used to determine vertical fish distribution allowing the highest target density layer to be sampled. The trawl net was deployed to target depth of 19.5 m (top bar) at 22:32 hours. Depth of the top bar was measured using a Notus depth sensor system for real time depth and range readings. 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.

Captured fish were dispatched if required by cerebral contusion then kept on ice and sampled within 12 hours of capture for fork length, weight, sex and maturity. Scales and otoliths were retained from kokanee >100 mm fork length to determine age. 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 was employed 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, with a seventh additional 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 and were set end to end to create a 2 or 3 net gang. Each end of a gang was anchored to the bottom using up to 100 m of line (dependent on bottom depth), The three nets were stretched out parallel to the prevailing wind and were submerged to pre-determined depths of 15, 20 or 25 m (from the surface) using a series of clip on floats with pre-measured lines of 15, 20 or 25 m.

The nets were set in the evening on August 30, 2017 and left until morning; a duration of 15-18 hrs. Set 1 occurred near TR05 (Figure 1) and consisted a two net gang with both set at 25 m depth from surface anchored over a bottom depth of 37 m at start and 67 m at the end. Premeasured 25 m ropes attached to bullet floats were used to keep the nets at the desired depth. Set 2 occurred near TR04 (Figure 1) and consisted of a three net gang, set at 20 m, 15 m, and 15 m. Bottom depth throughout the set was 27 m deep. 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 fork length, weight, sex and maturity were determined within a few hours of capture. Scales and otoliths were retained from kokanee >~100 mm fork length to determine age.

Ages for trawl and gillnet caught kokanee were determined through scale or otolith analyses by specialists under contract to the Ministry of Environment at the Fish Aging lab in Abbotsford, BC. Ageing data were not available at the time of writing this report but will be presented in future reporting.

Hydroacoustics

The hydroacoustic survey was conducted on August 29-30th, 2016, during the night-time hours beginning 1.5 hours after civil sunset. Vertical beaming acoustic data were collected at 15 locations along the reservoir (Figure 1). Prior to the survey, evenly spaced transect locations were approximated throughout the deeper basin of the lake. Based on *in situ* data analysis and exploration of the lake, the survey design was modified in the field to include additional transects throughout the shallower sections of the reservoir to incorporate all habitat utilized by kokanee. Transects at these locations 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. Instead, they paralleled 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 in 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. 2011) and 5 m habitat layers between them extrapolated. This relatively coarse approach to determining habitat areas is preliminary and refined estimates will be developed and applied in future years. 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 and the upper cut off of fry 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 strata were output in 1-decibel (dB) size groups and compiled on an Excel spreadsheet. Decibel to fork length conversion was estimated using the dorsal aspect ratio for 120KHz frequency (Love 1977). The resulting layered fish densities were used to stratify transects of each survey into homogenous zones. 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 (>13 mm fork length), fry sized fish population (13 mm to 76 mm fork length), and for fish larger than fry size (>76 mm fork length).

RESULTS

Hydrology

The 2016 daily elevation profile tracked near the long term (1967-2016) mean for the majority of the year with the exceptions of January-February when the 2016 daily elevation was below average, as well as November-December when the 2016 daily elevation was consistently higher than the long term mean (Figure 2). The 2016 reservoir elevation stayed within 1 SD of the long term mean across the entire year with the exception of a short period in early January when it fell below 1 SD of the long term mean. At the time of the acoustic survey the reservoir elevation was very similar between 2016 and the long term mean.

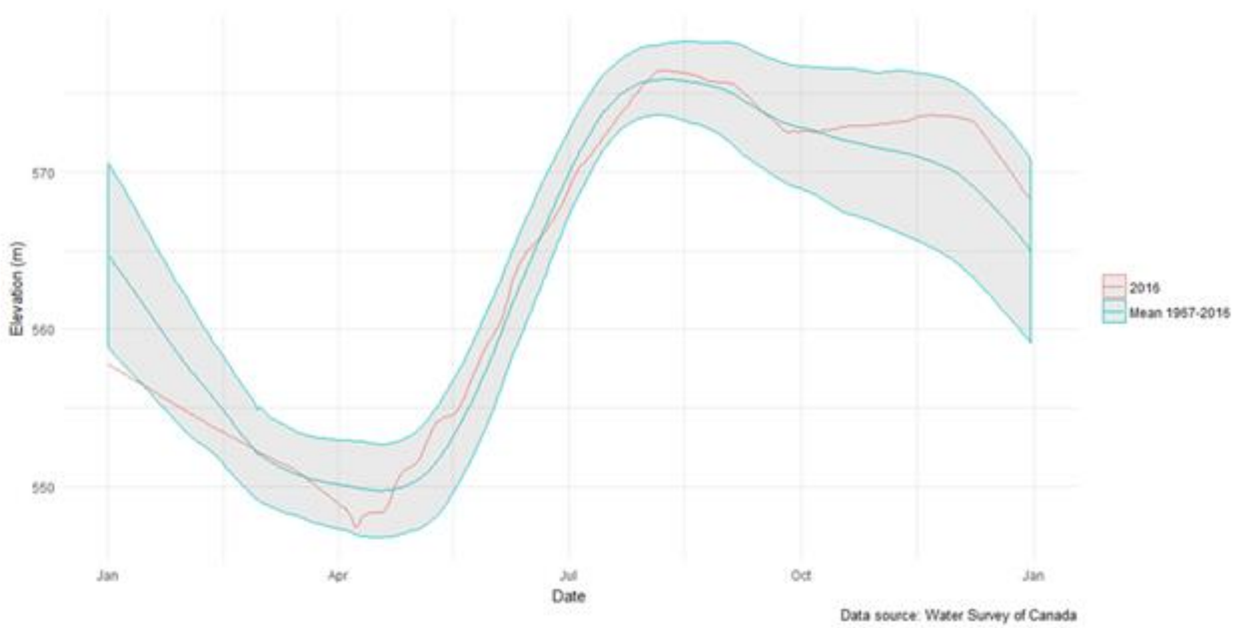

Figure 2. Duncan Reservoir hydrological profile for 2016 and the long term mean (1967-2016; shaded area is ± 1SD). The Duncan Reservoir elevation is captured by a BC Hydro gauge at Duncan Dam.

Water Column Profile

Duncan Reservoir was highly thermally stratified during late summer sampling. We estimate the middle of thermocline at approximately 25 m depth (Figure 3) with a gradual incline from deeper in the North end to slightly shallower in the South end. Fully saturated oxygen levels (Figure 4) and a fluorescence maxima just above the thermocline (approximately 23 m; Figure 5) suggests an actively photosynthesizing phytoplankton community supporting higher trophic levels.

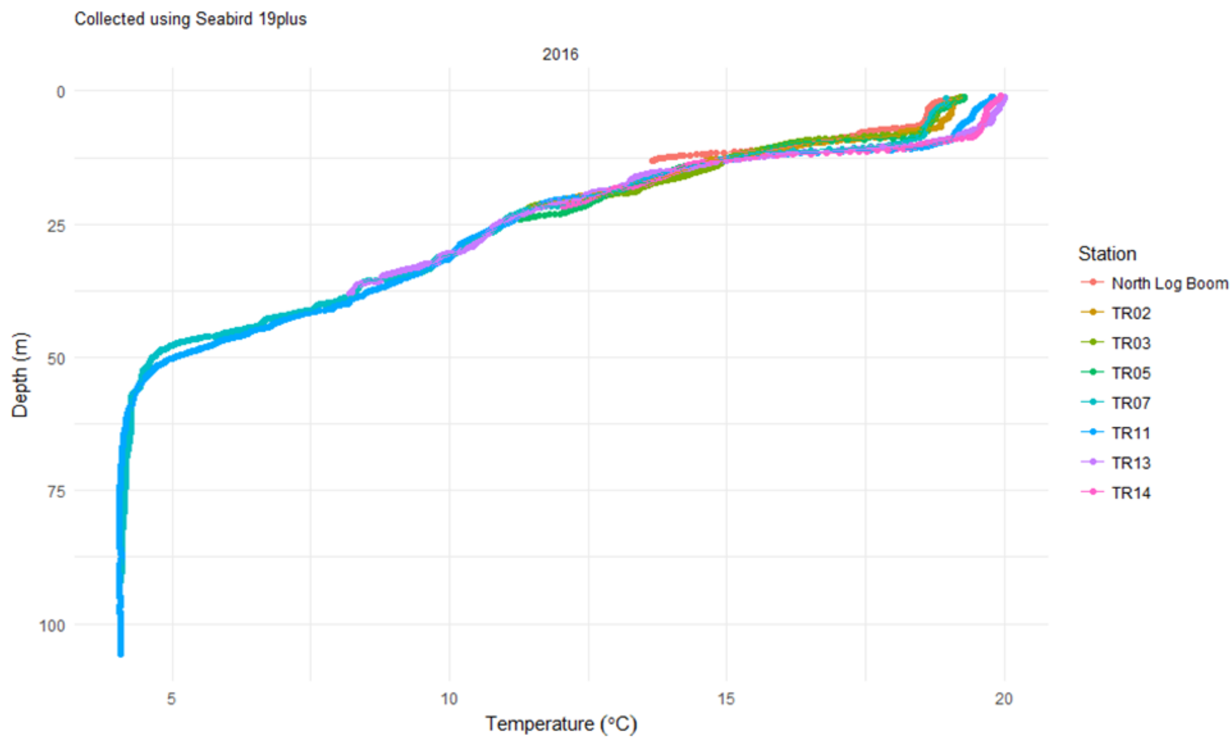

Figure 3. Temperature profiles along a north-south transect for Duncan Reservoir in late August, 2016.

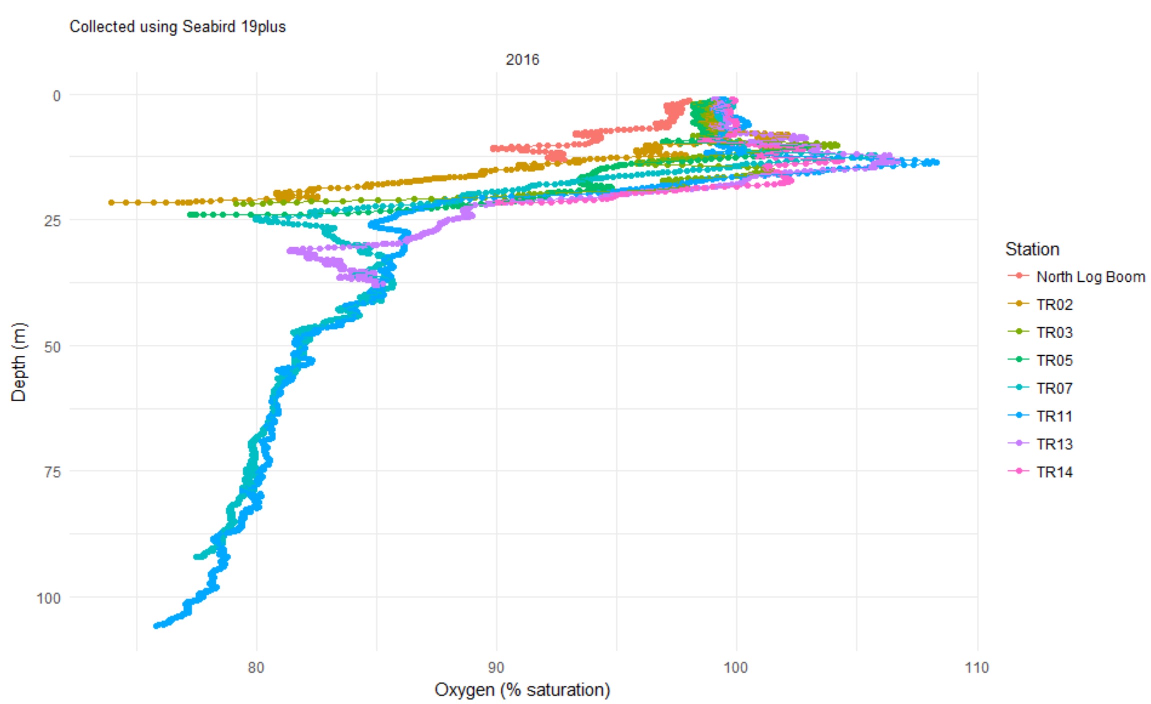

Figure 4. Oxygen profiles along a north-south transect for Duncan Reservoir in late August, 2016.

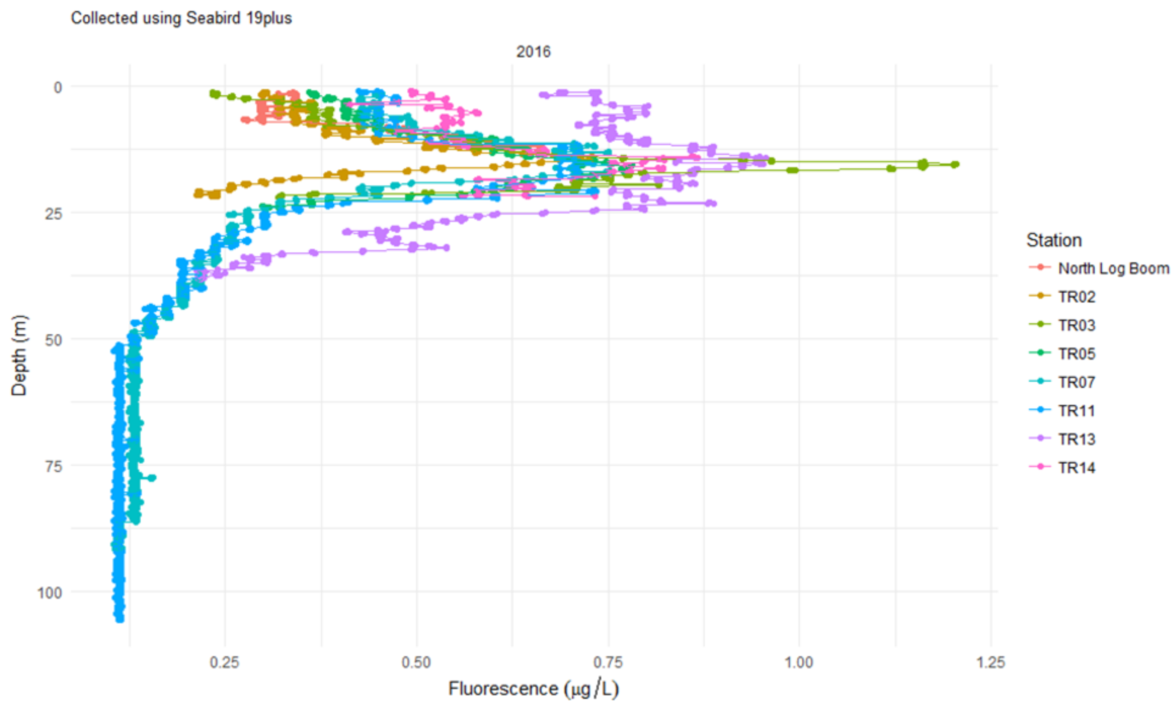

Figure 5. Fluorescence profiles along a north-south transect for Duncan Reservoir in late August, 2016.

Zooplankton

Zooplankton density and biomass density estimates from late August 2016 are presented in Table 1. Sampling occurred at three stations, P2 and P4a and P4b. Sampling at station P4b was modified due to a shallow bottom depth by conducting a 0-20 m haul as opposed to the standard 0-30 m sampling conducted at the other two sites. As such, volumetric densities are not directly comparable between station P4b and the other two stations.

Copepod densities were far higher than densities of daphnia or other cladocera at all three stations in 2016 (Table 1). Densities of each taxa were higher at P4a compared to P2, resulting in a total density at station P4a of 5.51 ind/L vs 4.33 ind/L at P2. The proportional composition of taxa at each station was similar.

Although at much lower numeric densities, daphnia comprised the majority of biomass compared to copepods and other cladocera (Table 1). Biomass densities of each taxa were higher at P4a compared to P2, resulting in a total biomass density at station P4a of 28.00 µg/L vs 19.58 µg/L at P2. The proportional composition of taxa at each station was similar.

Table 1. Average zooplankton density (ind/L) and biomass density (µg/L) by station from late August sampling in Duncan Reservoir.

	Density (ind/L)			Biomass Density (µg/L)		
	P2	**P4a**	**P4b***	**P2**	**P4a**	**P4b***
Copepoda	3.72	4.53	4.07	7.27	8.90	7.96
Daphnia	0.53	0.80	1.43	12.04	18.34	32.54
other Cladocera	0.08	0.17	0.25	0.26	0.76	0.39
Total	**4.33**	**5.51**	**5.75**	**19.58**	**28.00**	**40.89**

** Not directly comparable to other stations due to a shallower bottom depth limiting sampling to 0-20m at P4b vs 0-30m at P2 and P4a.*

Fish Capture

Trawl & Gillnet Sampling

A total of 227 kokanee, 1 mountain whitefish, and 3 bull trout were captured in the combined catch for both gillnet stations (including 5 mature kokanee and 1 bull trout that were released and no physical measurements were collected) (Table 2; Appendix 3). The trawl captured 19 fish, all of which were kokanee (Table 2; Appendix 4). Trawl sampling was limited to a single haul as the gillnet sampling was very effective and the low densities observed in the acoustic data for the majority of the reservoir suggested trawling elsewhere would be of limited value.

Biological statistics including number of fish captured, percent of total catch, percent sexually mature and fork length (mm) by sampling method, location, and depth are shown in Table 2. The combined gillnet and trawl catch confirmed that the vast majority (98%) of acoustic targets in the pelagic area were kokanee. The mean lengths of both mature and immature kokanee were smaller for the trawl samples compared to the gillnet samples, although they were not significantly different for either the immature component ($p = 0.11$) or the mature component ($p = 0.31$). A higher proportion of gillnet captured kokanee were mature at 63% compared to the trawl at 47%.

Figure 6 illustrates the length frequency distributions of kokanee captured in the combined gillnet sets alongside the trawl captured fish (ageing data not available at time of reporting). The vast majority of fish captured were age 1-3+ kokanee (fork length > 100 mm) with only four age 0 kokanee captured in the trawl. The bimodal distribution of kokanee >150 mm suggests two distinct age classes although overlap in size at age is expected and assumedly there were age 1, 2 and 3 kokanee present in the catch. Scale and otolith ageing data is required to confirm this and to determine average size at age; a total of 56 otoliths and 58 scales were submitted for aging but data were not available at the time of this report.

Table 2. Kokanee (KO), bull trout (BT) and mountain whitefish (MWF) catch statistics for gillnet and trawl sampling at Duncan Reservoir, August 2016.

					Kokanee					
							Mature		Immature	
Method	**Depth (m)**[1]	**BT**	**KO**	**MWF**	**% of catch**	**% mature**[3]	**Mean FL (mm)**	**SD**	**Mean FL (mm)**	**SD**
Gillnet (Set 1)	25, 25	1	30	1	94%	43%	228	23.3	169	14.7
Gillnet (Set 2)	15, 15, 20	1	192		99%	66%	221	11.1	171	16.0
Gillnet (Released)[4]		1	5			100%				
Gillnet		**3**	**227**	**1**	**98%**	**63%**	**221**	**12.7**	**170**	**15.7**
Trawl	**19.5**		**19**		**100%**	**47%**[2]	**216**	**13.3**	**160**[2]	**33.7**[2]
Total		***3***	***246***	***1***	***98%***	***61%***[2]	***221***	***12.7***	***164***[2]	***29.9***[2]

[1] *depths are top of net for gillnets and trawl net.*

[2] *statistics ommit age 0 (<100mm; n=4) for comparability to gillnet data*

[3] *'Mature' describes kokanee in an advanced state of maturity that would have spawned in 2016*

[4] *Five mature KO and one BT were released, the gillnet set number was not identified*

The combined gillnet and trawl data indicate a large proportion of the age 1-3+ kokanee (fork length >100 mm) were maturing to spawn in 2016. Figure 7 illustrates the proportional distribution by net depth of mature and immature kokanee by fork length and weight in the gillnet catch in 2016. The distributions at all depths were dominated by 2 distinct primary modes, and while ages were not available, these distributions suggest the likelihood of a majority of immature fish being age 1 fish while the maturing fish were likely primarily age 2+. A third, lesser mode of much larger fish is evident in the mature catch in the 25 m net, which likely represents age 3+ spawners.

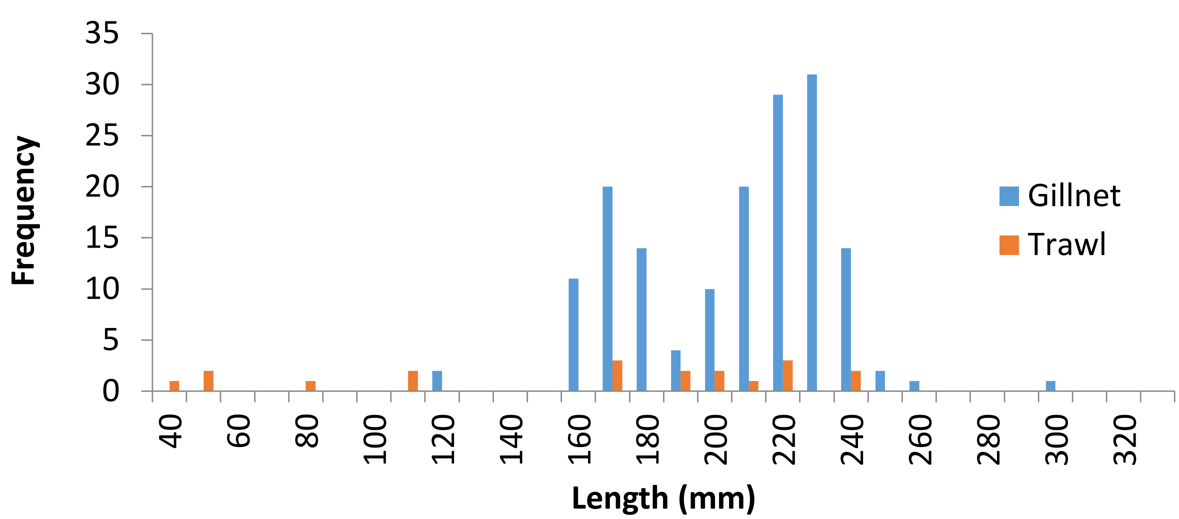

Figure 6. Fork length (mm) frequency distribution of trawl and gillnet caught kokanee in Duncan Reservoir in late August 2016.

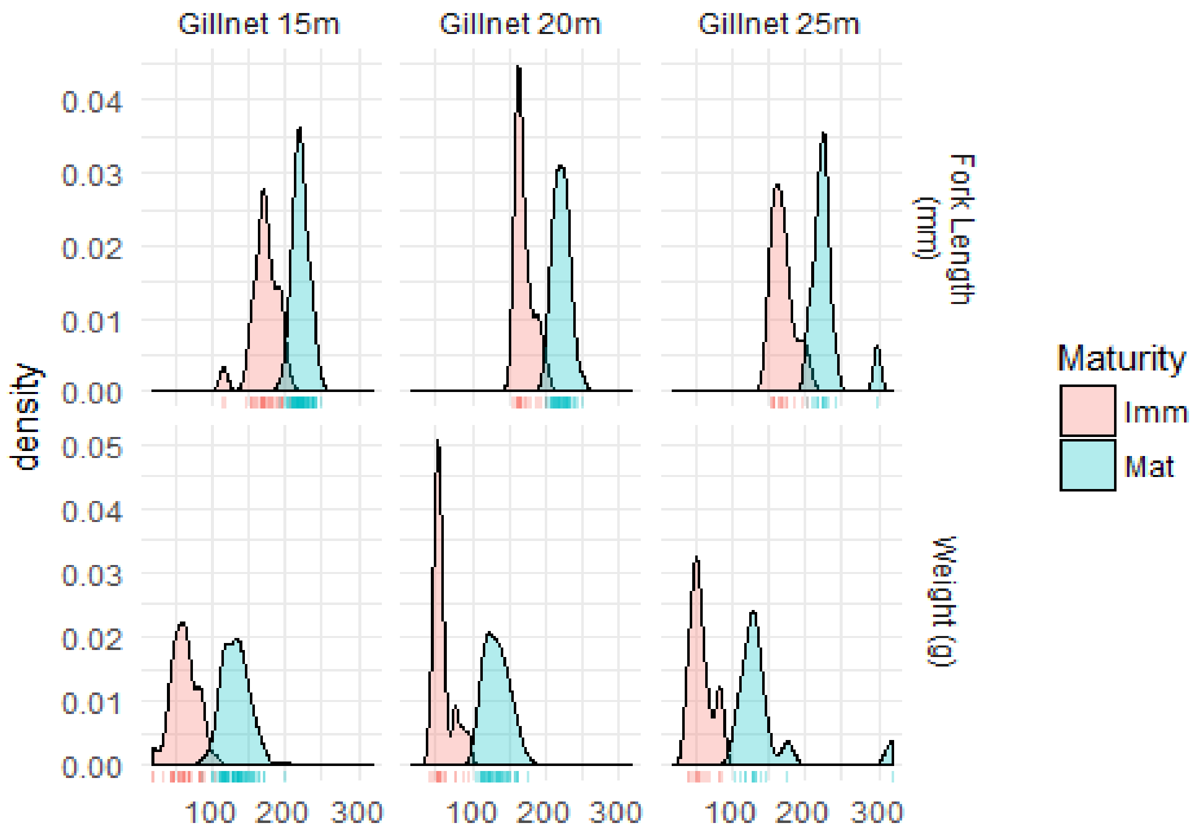

Figure 7. Fork length (mm) and weight (g) statistical density distributions for mature (Mat) and immature (Imm) gillnet caught kokanee in Duncan Reservoir in late August, 2016. Data are provided for each gillnet sampling depth (15m, 20m, and 25m).

Kokanee Abundance

Acoustic targets -62 decibel (dB) to -47 dB (converts to a fork length of approximately 13 – 76 mm using dorsal aspect ratio for 120KHz frequency (Love 1977)), assumed to be kokanee fry, were estimated at 1.12 (95% CI 0.81-1.44) million. Targets larger than -47 dB, assumed to be age 1-3+ kokanee, were estimated at 0.20 (95% CI 0.13-0.28) million (Figure 8).

Distribution of fish during the hours of darkness was primarily below the thermocline with the highest densities occurring between 15 – 25 m (Appendix 5 a & b). Figure 9 illustrates the density distribution by transect separated by age 0 and age 1-3+ kokanee groups. Longitudinal density distributions of both groups follow generally the same pattern, with higher densities at the northern and southern transects and very low densities in the middle transects. The single transect in the east basin (TR15) produced densities of (133 f/ha) and (59 fish/ha) for fry and age 1-3+ kokanee respectively; near the reservoir transect mean for age 1-3+ densities (53m fish/ha) but below mean for fry densities (284 fish/ha). East Basin transect densities were similar to transect 12 densities (135 fish/ha and 67 fish/ha for fry and age 1-3+, respectively) where the east basin connects to the main basin.

Gillnetting targeted the higher density area to the north, with gillnet set 1 between transects 4 & 5 and set 2 just north of transect 4. Trawling occurred in the same general area near transect 5. Both methods would likely have been ineffective at capturing fish at the exceptionally low densities found in the vicinity of ~transects 8-11.

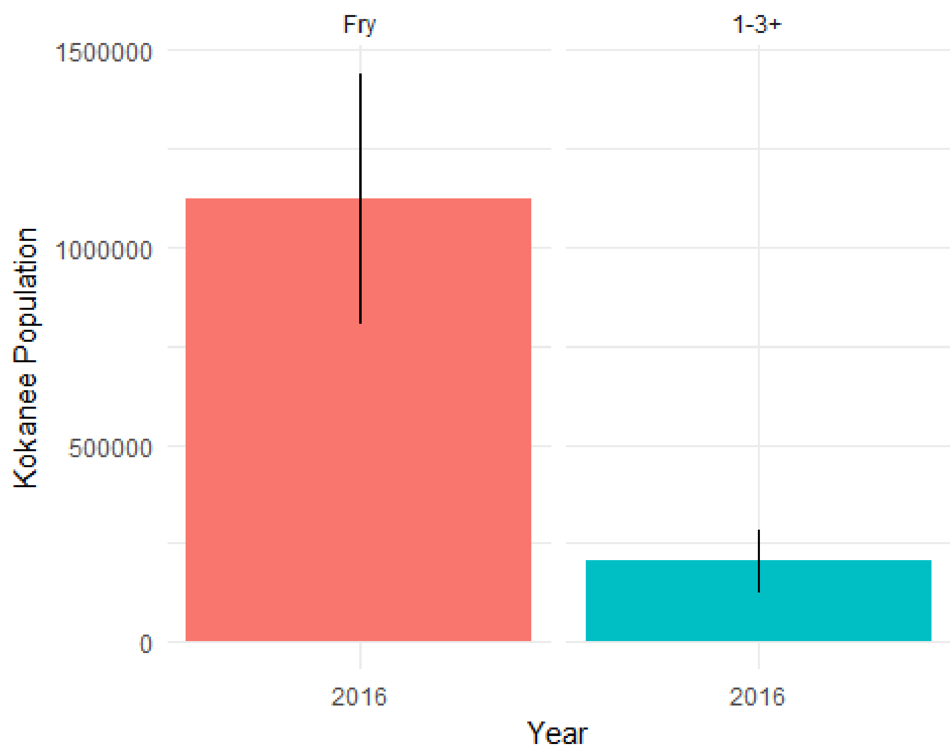

Figure 8. Kokanee estimated abundance and 95% CI in Duncan Reservoir in late August, 2016.

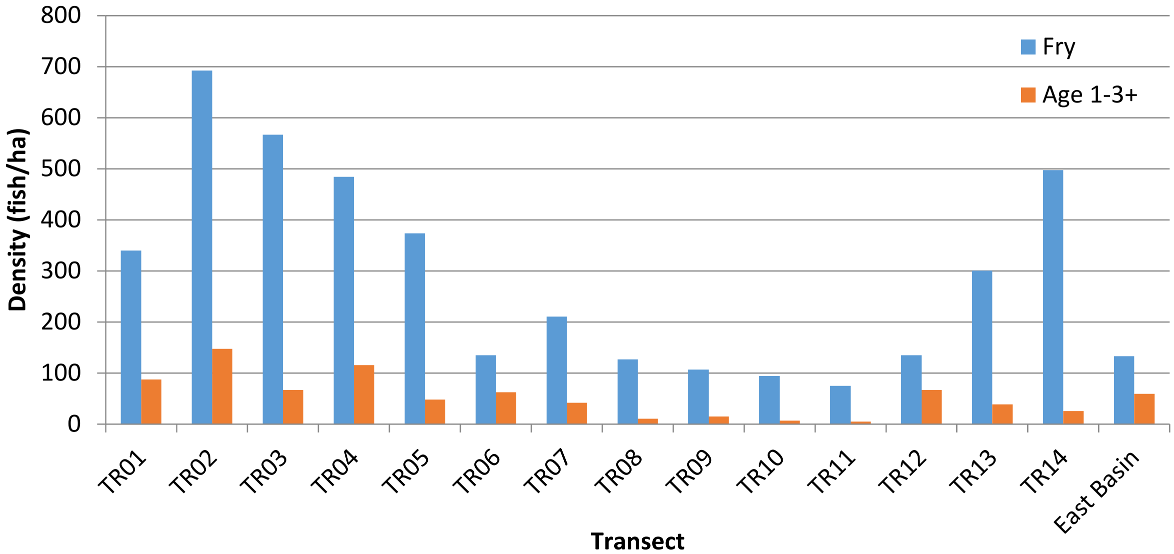

Figure 9. Kokanee fry and age 1-3+ density distribution (fish/ha) by hydroacoustic transect in Duncan Reservoir in late August, 2016.

Summary

The August 2016 field surveys met the primary objective of acquiring the first year of baseline information on the biological characteristics, distribution and abundance of in-lake kokanee populations in Duncan Reservoir. The proposed survey design included a hydroacoustic survey and mid-water trawling in conjunction with a limited limnological survey of water quality parameters and zooplankton sampling. The survey methodology was adjusted in the field to include mid-water gillnet sampling after evaluation of the acoustic data suggested high densities of fish targets located near bottom in relatively shallow water, primarily in the northern arm of the lake. As this habitat was incompatible with trawl sampling, we deployed gillnets which proved effective at sampling this habitat and provided a significant number of fish for biological data and species composition.

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. Kokanee densities were skewed with higher densities towards either end of the reservoir but towards the north end in particular. It is possible that the mature fish were beginning to move north towards spawning areas in the Duncan River by late August, which would partially explain the uneven distribution; however the same pattern occurred for the kokanee fry, suggesting that other factors such as food availability or predation pressure may have influenced their distribution at the time of the survey.

Spawner size data is an important biological parameter collected from mature fish at terminal spawning locations. Spawner sampling was not a component of this study, however the trawl and gillnet sampling in late August provided size data from a significant number of fish showing clear evidence of advanced sexual maturity. Size data collected from these fish are likely very comparable to biological data collected from terminal spawning areas given that very little somatic growth would be expected at this stage as energy is diverted towards gonad development. 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. Regardless, we still expect maturing fish captured in-lake in late August to be generally representative of actual spawner size.

Estimation of kokanee biomass is useful as it incorporates both size (weight) and abundance; and converting to biomass density allows for more meaningful comparisons across basins than size and/or density independently. The BC provincial standard for estimating biomass requires a reliable estimate of age structure and size at age which can then be applied to the acoustic age 1-3+ population. In other data rich systems such as Kootenay and Arrow Lakes, located near Duncan Lake, these data are collected through comprehensive standardized trawl sampling. Unfortunately, the kokanee densities and distribution observed in Duncan Reservoir in 2016 was not conducive to equivalent trawl sampling, and comparability of age structure derived via gillnetting with that of trawl sampling is undetermined. However, the province of BC is developing methodology to estimate biomass using acoustic data in conjunction with size data from gillnetting and trawling which does not require an estimate of trawl-based age structure. This approach will allow for estimation of biomass for Duncan Reservoir in future reporting, and importantly will also allow for the generation of estimates in a comparable fashion across systems regardless of the quality of trawl data.

Zooplankton sampling was conducted at three stations in late August to support interpretation of the kokanee data, in accordance with the DDMMON-17 terms of reference. We acknowledge that a single sampling period per season is not sufficient to provide in-depth insight into zooplankton dynamics in the reservoir. However, over the course of the study period, these data collected concurrently with the acoustic and fish sampling data may provide insight should any highly abnormal conditions be observed with respect to kokanee growth and survival.

Recommendations

- Refine habitat areas using 1 meter intervals to account for changes in annual reservoir elevations for refinement of abundance estimates.
- 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.

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Appendix

Appendix 1. Gillnet set data from 2016 Duncan Reservoir sampling.

Attribute	GN1	GN2
Set date	30-Aug-16	30-Aug-16
Retrieval date	31-Aug-16	31-Aug-16
General location	TR05	TR04
Net depth(s) in meters	25,25	20,15,15
Lake depth (m) start/end	37/67	27/27
Start Latitude	50 25.538	50 26.304
Start Longitude	116 57.255	116 55.719
Set time (24:00hr)	20:00	20:30
Retrieval time (24:00hr)	11:30	12:30
Total time (hrs)	15.5	16

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)	-26.7 dB (2016 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[2]	40 log r density based on SED
	Fish size distributions	From *in situ* single echo detections

[1] Lower Threshold for fish in 2016 survey was -62dB.
[2] Note: echo counting used for determining fish densities in 2016.

Appendix 3. Gillnet catch data from August 30, 2016 set in Duncan Reservoir.

Set	depth	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
1	25	1	BT	411	649.8	M	Imm			
1	25	2	MWF	295	275.7	unk				
1	25	3	KO	223	132.1	F	Mat		3	3
1	25	4	KO	215	127.8	F	Mat		4	4
1	25	5	KO	208	105.3	F	Mat		5	5
1	25	6	KO	229	145.4	F	Mat		6	6
1	25	7	KO	203	112.3	M	mat		7	7
1	25	8	KO	229	129.8	F	Mat		8	8
1	25	9	KO	217	116.9	F	Mat		9	9
1	25	10	KO	225	140	M	mat		10	10
1	25	11	KO	230	130.8	F	Mat		11	11
1	25	12	KO	202	85.4	M	Imm	12		12
1	25	13	KO	175	63.1	unk	Imm	13		13
1	25	14	KO	186	81.3	F	Imm	14		14
1	25	15	KO	156	48.8	F	Imm	15		15
1	25	16	KO	157	43.1	F	Imm	16		16
1	25	17	KO	163	49.8	unk	Imm	17		17
1	25	18	KO	153	45.3	unk	Imm	18		18
1	25	19	KO	167	52.8	M	Imm	19		19
1	25	20	KO	172	62.0	unk	Imm	20		20
1	25	21	KO	152	38.8	F	Imm	21		21
1	25	22	KO	298	317.7	M	Mat			22
1	25	23	KO	240	175.7	M	Mat		23	
1	25	24	KO	223	128.9	M	Mat		24	
1	25	25	KO	218	119.4	M	Mat		25	
1	25	26	KO	164	53.3	M	Imm	26		
1	25	27	KO	168	56.2	M	Imm	27		
1	25	28	KO	157	50.2	F	Imm	28		
1	25	29	KO	168	54.2	F	Imm	29		
1	25	30	KO	155	38.9	unk	Imm	30		
1	25	31	KO	176	69.4	M	Imm	31		
1	25	32	KO	196	82.7	F	Imm	32		
2	20	33	KO	233	136.1	M	Mat		33	
2	20	34	KO	210	113.7	F	Mat			
2	20	35	KO	230	152.3	M	Mat		35	
2	20	36	KO	229	114.9	F	Mat		36	
2	20	37	KO	227	144.7	M	Mat		37	

Appendix 3. Continued

Set	depth	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	20	38	KO	221	128.9	F	Mat		38	
2	20	39	KO	215	127.3	M	Mat		39	
2	20	40	KO	193	86.5	F	Imm	40		
2	20	41	KO	236	160.9	M	Mat		41	
2	20	42	KO	212	127.6	M	Mat		42	
2	20	43	KO	217	137	M	Mat		43	
2	20	44	KO	164	50.5	F	Imm	44		
2	20	45	KO	238	157.2	F	Mat		45	
2	20	46	KO	231	157.1	M	Mat		46	
2	20	47	KO	222	145.1	M	Mat		47	
2	20	48	KO	216	116.5	F	Mat		48	
2	20	49	KO	229	152.5	M	Mat		49	
2	20	50	KO	225	142.1	M	Mat		50	
2	20	51	KO	186	78.1	F	Imm	51		
2	20	52	KO	166	53.2	unk	Imm	52		
2	20	53	KO	239	161.1	F	Mat		53	
2	20	54	KO	218	133.4	M	Mat		54	
2	20	55	KO	207	104	M	Mat		55	
2	20	56	KO	189	75.3	unk	Imm	56		
2	20	57	KO	214	124.5	M	mat		57	
2	20	58	KO	224	125.5	F	Mat		58	
2	20	59	KO	233	142.2	M	Mat		59	
2	20	60	KO	174	56.2	unk	Imm	60		
2	20	61	KO	242	163.4	M	Mat		61	
2	20	62	KO	229	147.2	M	Mat		62	
2	20	63	KO	228	130.4	F	Mat		63	
2	20	64	KO	213	117.5	F	Mat		64	
2	20	65	BT	454	816.5	F	Imm			
2	20	66	KO	220	134.7	F	Mat			
2	20	67	KO	229	148.9	M	Mat			
2	20	68	KO	219	137.1	M	Mat			
2	20	69	KO	210	113.9	F	Mat			
2	20	70	KO	161	52.1	F	Imm	70		
2	20	71	KO	251	176	M	Mat			
2	20	72	KO	179	61.4	unk	Imm	72		

Appendix 3. Continued

Set	depth	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	20	73	KO	200	110.9	M	Mat			
2	20	74	KO	164	55.3	F	Imm	74		
2	20	75	KO	209	123.4	M	Mat			
2	20	76	KO	214	114.9	F	Mat			
2	20	77	KO	167	56.1	unk	Imm	77		
2	20	78	KO	225	137.1	F	Mat			
2	20	79	KO	161			Imm			
2	20	80	KO	205	120.6	M	Mat			
2	20	81	KO	231	147.2	F	Mat			
2	20	82	KO	201	107.4	M	Mat			
2	20	83	KO	223	141.4	M	Mat			
2	20	84	KO	220	135	F	Mat			
2	20	85	KO	200	95.1	F	Imm	85		
2	20	86	KO	221	134.9	F	Mat			
2	20	87	KO	162	58.1	unk	Imm	87		
2	20	88	KO	163	50.7	unk	Imm	88		
2	20	89	KO	168	55.4	unk	Imm	89		
2	20	90	KO	218	121.5	F	Mat			
2	20	91	KO	165	51	F	Imm	91		
2	20	92	KO	176	64.3	F	Imm	92		
2	20	93	KO	164	47.8	F	Imm	93		
2	20	94	KO	158	50.5	F	Imm			
2	20	95	KO	210	118.5	M	Mat			
2	20	96	KO	216	119.7	F	Mat			
2	20	97	KO	209	122.3	F	Mat			
2	20	98	KO	224	111.6		Mat			
2	20	99	KO	207	124.5		Mat			
2	20	100	KO	174	55.6	F	Imm	100		
2	20	101	KO	155	42.9	unk	Imm			
2	20	102	KO	162	45.4	unk	Imm			
2	15	103	KO	219	136.7		Mat			
2	15	104	KO	218	128.7		Mat			
2	15	105	KO	232	139.3		Mat			
2	15	106	KO	205	112.1		Mat			
2	15	107	KO	223	138.5		Mat			

Appendix 3. Continued

Set	depth	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	15	108	KO	195	84.2	M	Imm	108		
2	15	109	KO	193	83	F	Imm	109		
2	15	110	KO	204	99.4	F	Mat			
2	15	111	KO	242	160.9		Mat			
2	15	112	KO	212	116.3		Mat			
2	15	113	KO	236	162		Mat			
2	15	114	KO	116	18.1		Imm			
2	15	115	KO	180	67.3		Imm	115		
2	15	116	KO	196	81.2	F	Imm	116		
2	15	117	KO	238	150.9		Mat			
2	15	118	KO	238	151.6		Mat			
2	15	119	KO	223	127.8		Mat			
2	15	120	KO	223	130.8		Mat			
2	15	121	KO	225	118.9		Mat			
2	15	122	KO	193	85.6		Mat			
2	15	123	KO	232	151.6		Mat			
2	15	124	KO	201	101.8		Mat			
2	15	125	KO	227	145.9		Mat			
2	15	126	KO	222	134.9		Mat			
2	15	127	KO	171	64.3	F	Imm	127		
2	15	128	KO	172	61.8	unk	Imm	128		
2	15	129	KO	213	106.5		Mat			
2	15	130	KO	209	111.4		Mat			
2	15	131	KO	226	144.3		Mat			
2	15	132	KO	215	119.1		Mat			
2	15	133	KO	208	112.9		Mat			
2	15	134	KO	220	134.9		Mat			
2	15	135	KO	221	120.4		Mat			
2	15	136	KO	232	152.8		Mat			
2	15	137	KO	169	57.5	unk	Imm	137		
2	15	138	KO	170	60.2	unk	Imm	138		
2	15	139	KO	180	70.5	unk	Imm	139		
2	15	140	KO	154	47.2	unk	Imm	140		
2	15	141	KO	218	113.8		Mat			
2	15	142	KO	221	127.9		Mat			
2	15	143	KO	209	110.7		Mat			

Appendix 3. Continued

Set	depth	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	15	144	KO	211	127.4		Mat			
2	15	145	KO	223	134.4		Mat			
2	15	146	KO	205	114.9		Mat			
2	15	147	KO	219	133.6		Mat			
2	15	148	KO	156	47.1		Imm			
2	15	149	KO	204	113.7		Mat			
2	15	150	KO	218	134.8		Mat			
2	15	151	KO	216	133.7		Mat			
2	15	152	KO	212	118.5		Mat			
2	15	153	KO	217	132.4		Mat			
2	15	154	KO	192	82.2	unk	Imm	154		
2	15	155	KO	177	66.4	unk	Imm	155		
2	15	156	KO	194	86.4	unk	Imm	156		
2	15	157	KO	160	48.1	unk	Imm	157		
2	15	158	KO	174	59.3	unk	Imm	158		
2	15	159	KO	171	56.2	F	Imm	159		
2	15	160	KO	166	56.6		Imm	160		
2	15	161	KO	115	18.2		Imm			
2	15	162	KO	184	48.4	F	Imm	162		
2	15	163	KO	170	67.2	F	Imm	163		
2	15	164	KO	205	104.3	unk	Imm			
2	15	165	KO	187	81.4		Imm			
2	15	166	KO	207	111.6		Mat			
2	15	167	KO	233	170.2		Mat			
2	15	168	KO	227	134.2		Mat			
2	15	169	KO	217	144.8		Mat			
2	15	170	KO	243	165.2		Mat			
2	15	171	KO	218	140.3		Mat			
2	15	172	KO	229	143.7		Mat			
2	15	173	KO	236	156.5		Mat			
2	15	174	KO	227	139.3		Mat			
2	15	175	KO	177	66.9		Imm			
2	15	176	KO	194	82		Imm			
2	15	177	KO	224	133.7		Mat			
2	15	178	KO	233	155.3		Mat			
2	15	179	KO	218	128.3		Mat			

Appendix 3. Continued

Set	depth	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	15	180	KO	175	62.4	F	Imm			
2	15	181	KO	225	151		Mat			
2	15	182	KO	171	61.7		Imm			
2	15	183	KO	167	62.3		Imm			
2	15	184	KO	215	126.6		Mat			
2	15	185	KO	249	197.6		Mat			
2	15	186	KO	178	69.6		Imm			
2	15	187	KO	240	170		Mat			
2	15	188	KO	213	120.2		Mat			
2	15	189	KO	226	135.8	F	Mat			
2	15	190	KO	215	127		Mat			
2	15	191	KO	216	119.2		Mat			
2	15	192	KO	236	143.7		Mat			
2	15	193	KO	210	112.7		Mat			
2	15	194	KO	238	145.6		Mat			
2	15	195	KO	168	53		Imm			
2	15	196	KO	160	46.3		Imm			
2	15	197	KO	225	138.5		Mat			
2	15	198	KO	229	148.1		Mat			
2	15	199	KO	153	43.3		Imm			
2	15	200	KO	200	99.9		Mat			
2	15	201	KO	214	113.9		Mat			
2	15	202	KO	212	119.7		Mat			
2	15	203	KO	233	143.3		Mat			
2	15	204	KO	221	132.2		Mat			
2	15	205	KO	194	86.9		Imm			
2	15	206	KO	221	118.4		Mat			
2	15	207	KO	221	123.3		Mat			
2	15	208	KO	166	53		Imm			
2	15	209	KO	212	118.8		Mat			
2	15	210	KO	229	154.6		Mat			
2	15	211	KO	216	119.9		Mat			
2	15	212	KO	216	117.7		Mat			
2	15	213	KO	220	133.3		Mat			

Appendix 3. Continued

Set	depth	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Scale Sample No	Otolith Sample No	DNA Sample No
2	15	214	KO	211	120		Mat			
2	15	215	KO	223	137.9		Mat			
2	15	216	KO	168	55		Imm			
2	15	217	KO	162	47.9		Imm			
2	15	218	KO	155	43.2		Imm			
2	15	219	KO	167	43.2		Imm			
2	15	220	KO	208	112.5		Mat			
2	15	221	KO	182	68.3		Imm			
2	15	222	KO	188	88.5		Imm			
2	15	223	KO	154	42.9		Imm			
2	15	224	KO	167	53.1		Imm			
2	15	225	KO	147	33.6		Imm			
			KO (released)				Mat			
			KO (released)				Mat			
			KO (released)				Mat			
			KO (released)				Mat			
			KO (released)				Mat			
			BT (released; estimated FL = 450mm)							

Appendix 4. Trawl data from August 30th, 2016 on Duncan Reservoir.

Trawl Duration – 45 minutes **Location – ~acoustic transect TR05**

Trawl Depth – 19.5m to 26.5m **Start 50˚ 25'.573 / 116˚57'.303** **End 50˚ 24'.490 / 116˚58'.137**

Trawl No	Sample No	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Condition Factor
1	1	KO	170	60.4		Immature	1.23
1	2	KO	185	77.9		Immature	1.23
1	3	KO	191	80.3		Immature	1.15
1	4	KO	212	122.0		Mature	1.28
1	5	KO	200	110.2		Mature	1.38
1	6	KO	186	77.7		Immature	1.21
1	7	KO	74	3.7		Immature	0.91
1	8	KO	105	12.3		Immature	1.06
1	9	KO	233	160.3		Mature	1.27
1	10	KO	215	119.1		Mature	1.20
1	11	KO	162	51.5		Immature	1.21
1	12	KO	110	13.5		Immature	1.01
1	13	KO	46	1.1		Immature	1.13
1	14	KO	47	1.1		Immature	1.06
1	15	KO	168	59.6		Immature	1.26
1	16	KO	204	103.0		Mature	1.21
1	17	KO	216	129.7		Mature	1.29
1	18	KO	235	170.0		Mature	1.31
1	19	KO	36	0.5		Immature	1.07

Appendix 5. Fish density data* based on two size groups of acoustic targets. Shaded cells indicated bottom depth

a) Fry targets -62 dB to -47 dB (equates to 13-76 mm based on Love 1977).

Fry

Depth	TR01	TR02	TR03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TR11	TR12	TR13	TR14	East Basin
3	74	23	16	44	-	-	44	18	-	-	-	18	-	22	26
5	10	30	34	23	28	-	16	-	-	14	7	-	36	34	27
10	24	39	26	14	26	18	17	-	4	-	-	-	7	11	7
15	233	259	96	44	38	7	26	47	30	25	18	6	5	193	1
20		341	306	260	179	29	36	28	43	23	31	15	49	190	6
25			89	97	103	33	46	17	13	14	7	24	61	47	11
30						44	20	13	14	14	12	39	62		27
35						2	2	2	2	2	-	21	18		20
40						1	3	1	-	2	-	8	21		7
45						1	1	-	1	1	-	5	40		0
Sum	**340**	**692**	**567**	**484**	**373**	**135**	**211**	**126**	**107**	**94**	**75**	**135**	**300**	**497**	**133**

*data subject to change once habitat areas are finalized

b) Age 1-3 Kokanee targets >-47 dB (>76 mm based on Love 1977).

Big Fish

Depth	TR01	TR02	TR03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TR11	TR12	TR13	TR14	East Basin
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	11	-	-	-	-	-	-	-	-	-	-	-
10	16	17	-	-	-	-	-	-	-	-	-	-	-	-	-
15	72	91	25	53	18	-	4	-	-	-	-	-	-	13	1
20		39	42	51	27	6	5	3	7	-	-	14	2	4	4
25			-	2	3	34	16	2	5	1	2	14	8	8	16
30						17	15	5	4	3	2	21	7		20
35						4	2	2	-	3	1	8	4		13
40						1	-	0	-	-	-	8	8		4
45						-	-	-	-	-	-	2	11		0
Sum	**88**	**147**	**67**	**118**	**48**	**62**	**42**	**11**	**15**	**7**	**5**	**67**	**39**	**25**	**59**

*data subject to change once habitat areas are finalized