Columbia River Project Water Use Plan

Kinbasket Reservoir Fish and Wildlife Information Plan

Kinbasket Reservoir Fish Stranding Assessment

Implementation Year 2

Reference: CLBMON-4

Kinbasket Reservoir Fish Stranding Assessment

Study Period: February 2017 to May 2018

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KINBASKET RESERVOIR

Monitoring Program No. CLBMON-4
Kinbasket Reservoir Fish Stranding Assessment




Implementation Year 2 – 2018
Final Report

Prepared for

BC Hydro Generation
Water Licence Requirements
6911 Southpoint Drive
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Cover photos:

From left to right: adult Peamouth (*Mylocheilus caurinus*); high elevation (751 mASL) isolated pool with grass riparian; dead sculpin sp. (*Cottus* sp.*)* in a dry low elevation isolated pool; low elevation (730 mASL) isolated pool. Photos © Elmar Plate, LGL Limited.

EXECUTIVE SUMMARY

This year marked the first year (one of two years) of field-level sampling as part of CLBMON-4, which is part of a three-year fish stranding monitoring study in the drawdown zone (DDZ) of Kinbasket Reservoir. Seven management questions were investigated in this study. The primary objective of this monitoring program was to qualitatively evaluate the extent of fish stranding caused by the annual drawdown, and whether changes to the reservoir's operating regime or non-operating mitigations can reduce fish stranding. CLBMON-4 was initiated in 2010 by identifying isolated pools formed on slopes less than 6% under current reservoir operations (elevation 754-725 mASL) through a GIS desktop analysis using a digital elevational model. Based on the digital model output, a fish stranding risk ranking model was developed, which was completed prior to the implementation of field studies (years 2 and 3). The validation of results from Year 1 (2010) was part of the field surveys carried out in 2017-2018.

In Year 2 (2017-2018), fifty-eight pools (n=14 in fall 2017, n=50 in spring 2018) were sampled in the drawdown zone of Kinbasket Reservoir ranging in elevation from 724 to 753 mASL and across the three main arms (Bush Arm – including Bear Island, Canoe Reach and Columbia Reach). All sampled pools were deemed as candidates for high risk of stranding due to their position in the low gradient part of the DDZ which contains a high proportion of the isolated pools. Sampling effort was greatest (50% of sampled pools) in Bush Arm due to high heterogeneity (i.e., distribution of pools across elevation, size of pools) and greater access from shore to low elevation pools (67% below 735 mASL). Seventy-five percent of all pools sampled in 2018 were not previously identified by the DEM (based on 2002 aerial photography) in Year 1 (2010) of CLBMON-4. Forty-three percent of the sampled stranding pools were hydrologically connected (i.e., channel) to the reservoir.

Fishes were present in 78% (n=45) of sampled pools and distributed across the entire DDZ (within a range of 29 m in elevation). Fish presence and abundance did not vary between study area, fish stranding risk, or whether stranded pools had a channel connecting to the reservoir. Fish abundance was positively correlated with pool area and depth, indicating that larger and deeper pools contained more fishes. The average fish density for all pools sampled was 0.08 fish/m^2 +/- 0.03.

Most fishes (83%) were encountered in their juvenile life stage in all sampled pools containing fish. Adults and juveniles were observed in equal proportions for Peamouth Chub and Prickly Sculpin. The few salmonids observed (Bull Trout, Kokanee Salmon, Pygmy Whitefish) were juvenile.

The following thirteen fish taxa were identified of which nine were identified to species:

- Redside Shiner (*Richardsonius balteatus*)
- Lake Chub (*Couesius plumbeus*)
- Peamouth Chub (*Cottus asper*)
- Longnose Dace (*Rhinichthys cataractae*)
- Longnose Sucker (*Catostomus Catostomus*)
- Prickly Sculpin (*Cottus asper*)
- Bull Trout (*Salvelinus confluentus*)
- Kokanee Salmon (*Oncorhynchus nerka*)

- Pygmy Whitefish (*Prosopium coulterii*)

Dead fish were present in 15 (26%) of the 45 isolated pools containing fish, and three of these pools also contained live fish. The abundance of dead fishes observed was negatively correlated with days of pool isolation, suggesting that as pools are isolated longer, they contain fewer dead fish. Seventy-six percent of dead fish could not be identified in the field due to deterioration but were likely sculpins, based on the fact that 99% of identifiable dead fish were sculpins. Most dead fish were observed in low elevation pools (below 735 mASL). Cause of mortality may be the result of pool freezing, since nine of the 10 stranded pools surveyed in February 2017 (first data logger trip for CLBMON-4) were completely frozen leaving no water in liquid form. Taxonomic diversity did not vary between reach, fish stranding risk or by elevation. The number of taxa observed per sampled pool ranged from 0 to 5, with most pools (58%) containing 1-2 taxa.

Cyprinids (mostly Redside Shiner and Lake Chub) were the most encountered and abundant fishes observed in sampled pools, followed by suckers and sculpins. Of the four species of concern (Bull Trout, Rainbow Trout [*Oncorhynchus mykiss*], Kokanee Salmon, and Burbot [*Lota lota*]) identified by BC Hydro, only one juvenile Bull Trout and two juvenile Kokanee Salmon were observed. The Bull Trout was observed in a connected high elevation pool (752 mASL) adjacent to the Bush River Causeway in the fall, while the two Kokanee Salmon were observed in a connected low elevation pool (735 mASL) in the Columbia Reach.

Six high elevation pools (between 748 and 753 mASL) sampled in fall of 2017 containing live fish were re-sampled in spring 2018. Live fish were present in four pools, while dead fish were present in one pool after repeat sampling in the spring, indicating that fishes do survive through the winter season in high elevation pools. Live and dead fish were not observed in the same pools during this re-peat sampling. There was no trend in daily dissolved oxygen (DO) levels and the presence of live or dead fishes in these high elevation stranded pools (from the six data loggers deployed between October 2017 and May 2018).

Since fishes were observed in isolated pools across the entire drawdown zone (elevation 724-753 mASL) in spring 2018, an operational recommendation for Kinbasket Reservoir to reduce fish stranding is to keep low pool as high as possible, which would reduce the number of isolated pools. Fifty percent of pools identified in Year 1 (2010) occurred below 733 mASL, which is 25.29 m above the licenced minimum elevation (707.41 mASL).

Non-operational recommendations will be provided in Year 3 after results of the May 2018 aerial overflight survey become available since 75% of pools sampled in Year 2 (2018) were not previously identified in Year 1 (2010). Data from this survey will determine which high-risk areas (Bush Arm, Canoe Reach, Columbia Reach) have remained relatively unchanged since the aerial survey conducted in 2002 (used in DEM 2010 Year 1 analysis). Physical works, including slope re-contouring (increase slope to reduce pool formation) and pool channelization (providing fish egress) may be suggested if stranding pools are static over time to ensure that these suggested mitigations remain effective.

The current status of CLBMON-4 after Year 2 (2018) with respect to the management questions is summarized below.

Management question (MQ)	Able to address MQ?	Scope		Sources of uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ1: What is the extent of fish stranding as a result of annual drawdown of the reservoir?	Mostly	Data collected in Oct 2017 and May 2018 identified the presence of fish in pools across all elevations	• Re-construct the stranding risk ranking model based on field collected data and for all species combined • Inventory pools down to minimum licenced elevation (707.41 mASL) • Additional sampling years to provide an indication of whether the stranding rate is typical or anomalous.	• Annual stranding variation • Long term pool stability • Variable reservoir operations
MQ2: Which areas of the reservoir have the greatest risk of fish stranding, and why?	Mostly	DEM analysis in Year 1. Data collected in 2017/2018 confirmed the presence of fish stranded in pools located in Bush Arm, Canoe Reach and Columbia Reach	• Identify pools down to the minimum licenced elevation to determine if other areas of the reservoir contain large numbers of pools = greater fish stranding	• Annual stranding variation • Long term pool stability • Variable reservoir operations
MQ3: What is the area covered by isolated pools in the dewatered zone during maximum drawdown, relative to the total surface area of the drawdown zone?	Partially	DEM analysis in Year 1. Aerial overflight survey conducted in May 2018 (results available in Year 3)	• Repeat DEM analysis using more current LiDAR imagery and hydroacoustic bathymetry mapping • Inventory pools down to minimum licenced elevation (707.41 mASL)	• Pool permeability (i.e., dewatering) • Long term pool stability • Variable reservoir operations

Management question (MQ)	Able to address MQ?	Scope		Sources of uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ4: What percentage of isolated pools contains stranded fish?	Partially	One year of field data collected in Oct 2017 and May 2018 on 58 pools	• Additional years of sampling will provide an indication of whether the stranding rate is typical or anomalous and to better understand the mechanisms behind stranding.	• Annual stranding variation • Variable reservoir operations
MQ5: At what time of year and/or reservoir elevations is stranding risk highest (e.g., at maximum drawdown)?	Mostly	One year of field data collected in Oct 2017 and May 2018 on 58 pools. Risk model developed in Year 1	• Additional years of sampling • Re-construct the stranding risk ranking model based on field collected data and for all species combined	• Natural annual population variation • Variable reservoir operations
MQ6: What fish species and life history stages are potentially most affected by stranding as the reservoir is drawn down?	Mostly	One year of field data collected in Oct 2017 and May 2018 on 58 pools	• Additional years of sampling to capture additional species • Use of gill nets in larger and deeper pools to investigate the presence of larger fishes listed under the four species of concern identified by BC Hydro.	• Natural annual population variation • Variable reservoir operations
MQ7: Are operational or non-operational changes recommended to mitigate or to reduce the risk of fish stranding?	Partially	DEM analysis in Year 1. One year of field data collected in Oct 2017 and May 2018 on 58 pools. Aerial overflight survey conducted in May 2018 (results available in Year 3)	• Re-construct the stranding risk ranking model based on field collected data and for all species combined • Repeat DEM analysis using more current LiDAR imagery	• Pool permeability (i.e., dewatering) • Long term pool stability • Long-term persistence of mitigations

Key Words: CLBMON-4, Fish, life history, Kinbasket Reservoir, isolated pools, drawdown zone, stranding risk, reservoir elevation

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1.0 INTRODUCTION

Dams regulate the flow regime in most of the world's large river systems, and the flooding resulting from dam construction and water storage creates a complex disturbance that can modify entire ecosystems (Nilsson and Berggren 2004; Eskew et al. 2012). These impacts are not restricted to the direct flooding and loss of fish and wildlife habitat upstream of dams, but also extend downstream of dams through disturbance of annual flooding regimes needed to maintain the health of floodplain environments (MacKenzie and Shaw 2000; Nilsson and Berggren 2004; Kupferberg et al. 2011; Eskew et al. 2012, Nagrodski et al. 2012). To date, most fish studies on the effects of impoundment have focused primarily on the instream effects on fish stranding downstream of dams and irrigation projects (Nagrodski et al. 2012). The need to understand the operational aspects of reservoir effects upstream of dams on fish stranding remains high, and that is the focus of this study.

1.1 Project Background

There are 14 dams on the Columbia River, three of which are in B.C. (Mica, Revelstoke, and Hugh Keenleyside); the remainder are in the U.S. Kinbasket Reservoir is one of British Columbia's largest reservoirs and was created when the Columbia River was impounded by Mica Dam in 1973. Mica Dam was built under the Columbia River Treaty to provide water storage for power generation and flood control. The creation of Kinbasket Reservoir flooded ~42,650 ha resulting in the loss or alteration of eight broad habitat types (lakes: 2,343 ha; rivers: 4,897 ha; streams: 192 ha; shallow ponds: 555 ha; gravel bars: 236 ha; wetlands: 5,863 ha; floodplain [riparian]: 15,527 ha; and upland forest: 13,036 ha; Utzig and Schmidt 2011).

During the Columbia River Water Use Planning Process (WUP), the WUP Consultative Committee (WUP CC) expressed concerns about the potential impacts of the operations of Kinbasket Reservoir on fish, wildlife, and associated habitat. (BC Hydro 2005, 2007a). A lack of qualitative information on the relative abundance, distribution, life history, and habitat use of these animals made it difficult to assess the impact of current operations and operating alternatives. These uncertainties led to the BC Hydro and Power Authority (BC Hydro) initiating a series of long-term monitoring programs, which included a 3-year study to qualitatively evaluate the extent of fish stranding caused by the annual drawdown of Kinbasket Reservoir (BC Hydro 2007a, CLBMON-4). Prior to this study, only anecdotal observations of fish being stranded in isolated pools have been reported (Table 2, RSMI 1994, V. Hawkes, LGL Limited, pers. comm.).

This report summarizes the findings of Year 2 (2017/2018) for BC Hydro's monitoring program CLBMON-4 Kinbasket Reservoir Fish Stranding Assessment, focusing on field investigations on isolated pools identified in Year 1 (Hanson and Nadeau 2010) of the drawdown zone of the Kinbasket Reservoir.

2.0 STUDY OBJECTIVES

2.1 Study Design

The key objective of this monitoring program (CLBMON-4) was to qualitatively evaluate the extent of fish stranding caused by the annual drawdown of Kinbasket

Reservoir under current reservoir operations in a 3-year time frame. Year 1 of this program was implemented by conducting a GIS desktop analysis using a digital elevation model (DEM) and following the methodology developed by Korman and Buszowski (2000), to identify the number, size and location of isolated pools formed in the drawdown zone (DDZ) of Kinbasket Reservoir (Hanson and Nadeau 2010, Appendix 1). Year 1 report is appended to this report and all references to that report will from here on be referred to as Appendix 1. Pools were identified on slopes less than six percent. This slope threshold value was based on the results of a study by Bell et al. (2008) that indicated that most fish stranding occurred on slopes of < 6% gradient. As part of the Year 1 report, a fish stranding risk ranking model was developed using a series of criteria:

- Pool Area
- Pool Depth
- Number of Days Pools is Isolated
- Time of Year Pool is Isolated

A risk category (low, medium, high) was then assigned to each identified pool to suggest the likelihood/potential risk of the pool to strand fish (Table 2-1 in Appendix 1). A total of 6,548 pools were identified from the DEM analysis and summarized by risk Table 3-1 in Appendix 1). Eighty-eight percent of identified pools were located in three broad geographical regions of Kinbasket Reservoir due to their lower gradient slopes. Canoe Reach contained 13.5%, while 74.5% were located between Bush Arm and Columbia Reach. These regions became the focus of field work for Year 2. Field surveys in Year 2 and 3 were to verify the presence of the pools identified in Year 1 via ground-level sampling and aerial overflight surveys, and investigate the presence of stranded fish in these pools.

Field planning for Year 2 of CLBMON-4 was focused on opportunistic sampling during optimal weather and operational conditions. Under BC Hydro's CLBMON-4 Terms of Reference (BC Hydro 2007a), surveys are to coincide with: drafting of the reservoir prior to snow accumulation and ice cover to obtain counts of newly stranded fish; low minimum pool; and early refill of the reservoir after snow ice melt and before the majority of high risk areas are re-inundated. Meeting these criteria has proven challenging over the last few years due to extreme weather patterns and variation in reservoir operational activities (e.g., increase in average minimum water reservoir level in the past 10 years, (Figure 1). As such, field surveys have been revised in an effort to best respond to the CLBMON-4 management questions (see METHODS).

2.2 Management Questions

In 2007, the Columbia River WUP (BC Hydro 2007a) developed seven management questions (MQs) to determine the effects of reservoir drawdown on pool formation and potential fish stranding:

MQ1: What is the extent of fish stranding as a result of annual drawdown of the reservoir?

MQ2: Which areas of the reservoir have the greatest risk of fish stranding, and why?

MQ3: What is the area covered by isolated pools in the dewatered zone during maximum drawdown, relative to the total surface area of the drawdown zone?

MQ4: What percentage of isolated pools contains stranded fish?

MQ5: At what time of year and/or reservoir elevations is stranding risk highest (e.g., at maximum drawdown)?

MQ6: What fish species and life history stages are potentially most affected by stranding as the reservoir is drawn down?

MQ7: Are operational or non-operational changes recommended to mitigate or to reduce the risk of fish stranding?

Management questions 1, 2, 3, and 5 were partially addressed in Year 1 through a DEM desk top analysis that predicted the level of fish stranding risk largely as a function of reservoir water surface elevation (Appendix 1). Field surveys in Year 2 were planned to provide input into and verify the results from Year 1, and obtain the necessary information to address management questions 4 and 6. MQ 7 will be further addressed in detail in Year 3.

3.0 STUDY AREA

3.1 Kinbasket Reservoir

Located in southeastern B.C., Kinbasket Reservoir is surrounded by the Rocky and Monashee Mountain ranges, and is approximately 216 km long (Map 1). The Mica hydroelectric dam, located 135 km north of Revelstoke, B.C., spans the Columbia River and impounds Kinbasket Reservoir. The original Mica powerhouse, completed in 1973, has a generating capacity of 1,805 MW, and Kinbasket Reservoir has a licensed storage volume of 12 million acre feet (MAF; BC Hydro 2007b). The addition of two new turbines at Mica Dam completed in 2016 increased the generating capacity of Kinbasket Reservoir by roughly 1,000 megawatts (BC Hydro 2007b).

Kinbasket Reservoir has been in operation since 1976, and has a licenced operating elevation range between 707.41 and 754.68 mASL resulting in a maximum drawdown zone elevation change of 46 m. In recent years, the reservoir has been typically operated between 725 and 754 mASL, creating an operating range of 29 m. Analyses conducted in Year 1 focused on pool identification within this current operating range. While the average minimum reservoir level has been increasing (six meters) in the past 15 years (Figure 1), the reservoir level has been drawn down below 725 mASL four times in the past ten years, down to a minimum elevation of 718 and 719 mASL in 2008 and 2018, respectively (Figure 2).

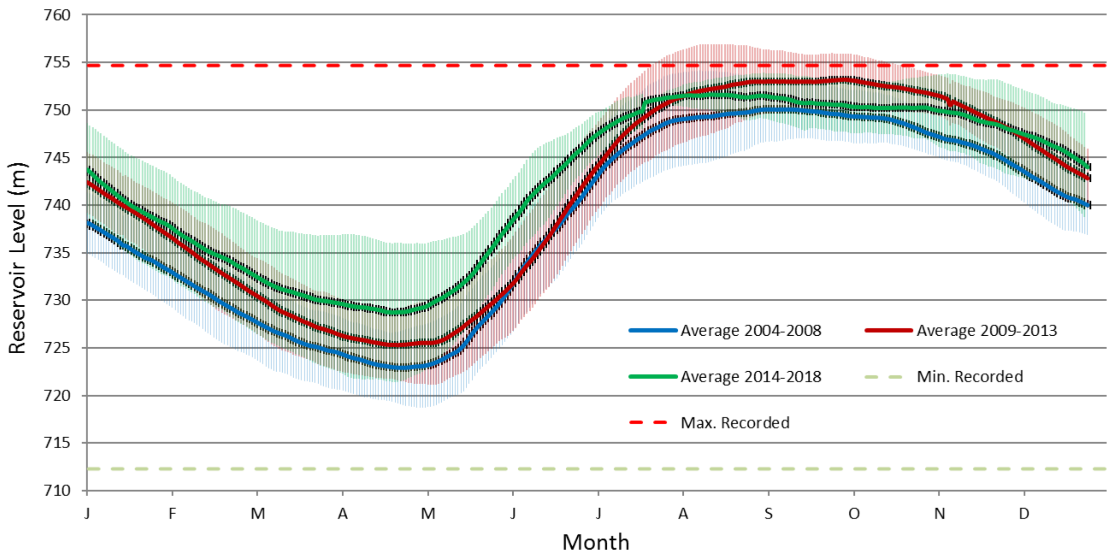


Figure 1. **Kinbasket Reservoir average low elevation between 2004 and 2018.** Averages show for periods 2004-2008 (blue, low average=723 m), 2009-2013 (red, low average=725 m) and 2014-2018 (green, low average=729 m). Range is shown in the grey-shaded area for the same time frame (2004-2018). Data obtained from BC Hydro. Maximum recorded high pool (754.68 mASL) occurred on August 28, 2012 and minimum recorded low pool (712.29 mASL) occurred on April 12, 2002.

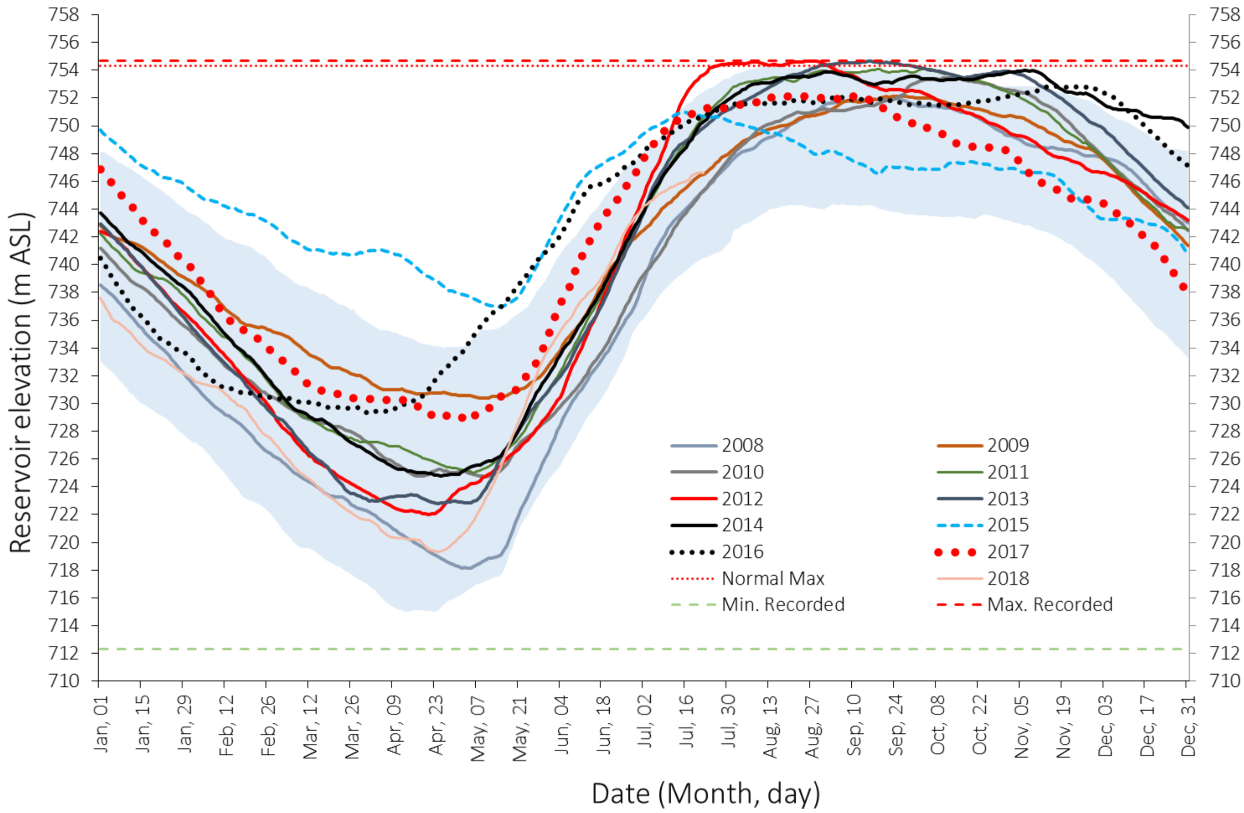
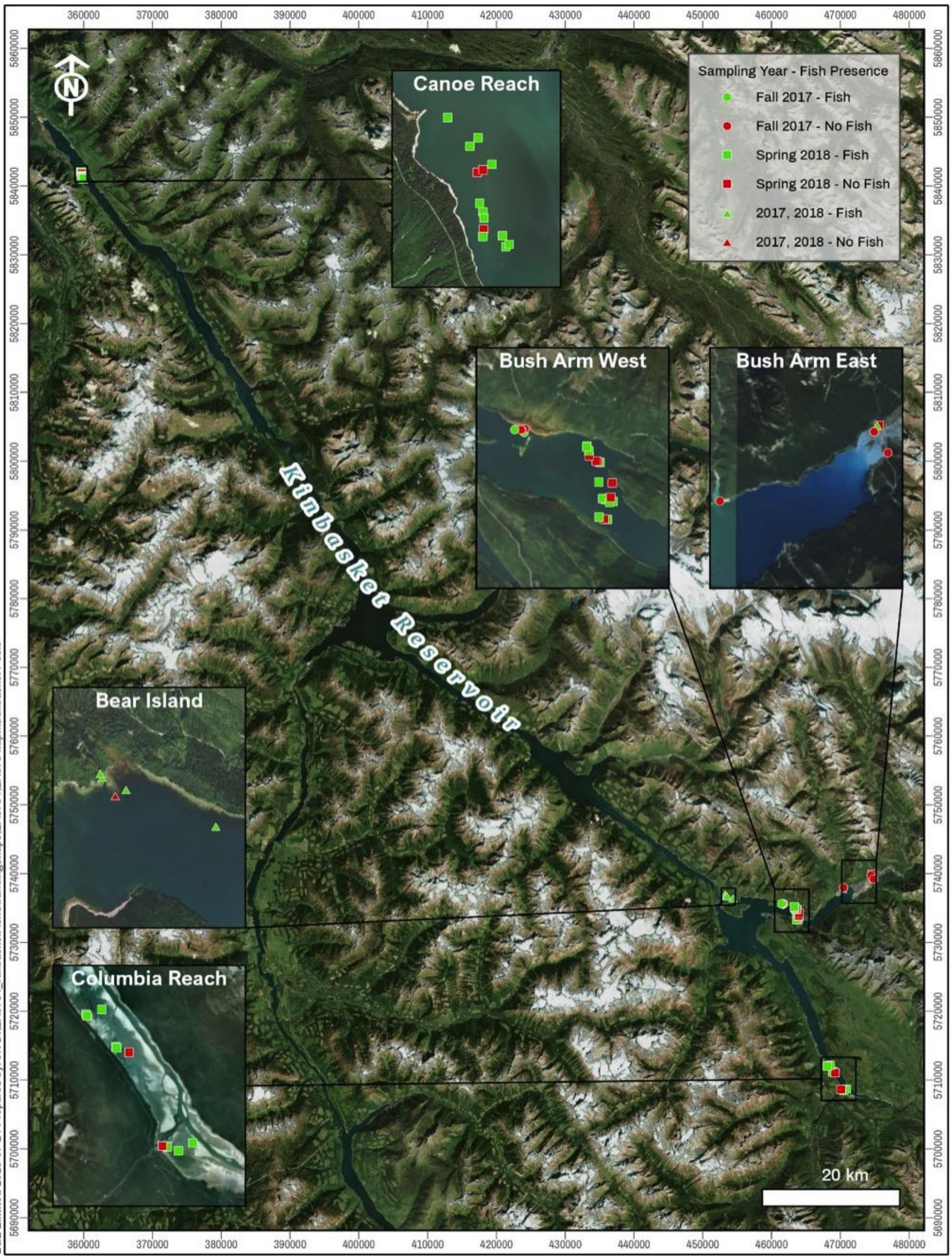


Figure 2. **Kinbasket Reservoir hydrograph for the period 2008 through 2018.** The shaded area represents the 10th and 90th percentile for the period 1976 to 2018; the dashed red line is the normal operating maximum. Data obtained from BC Hydro. Maximum recorded high pool (754.68 mASL) occurred on August 28, 2012 and minimum recorded low pool (712.29 mASL) occurred on April 12, 2002.

3.2 Study Locations

Canoe Reach, Bush Arm, and Columbia Reach were the primary focus for field sampling in Year 2 due to the large numbers of potential isolated pools identified in Year 1 (Map 1, Appendix 1).



Map 1. **Kinbasket Reservoir.** Inset images denote Year 2 study sites for CLBMON-4, the location of pools sampled along the drawdown zone (DDZ) and the presence of fish during both the fall 2017 and spring 2018 sampling periods.

4.0 METHODS

4.1 Field Schedule

A list of field surveys for Year 2 is summarized in Table 1. Field surveys for Year 2 was initiated on February 28, 2017, to deploy dissolved oxygen (DO) loggers in approximately eleven high risk isolated pools below 740 mASL (most high risk pools occurred below 740 mASL) along Bush Arm and Columbia Reach to determine fish survival through winter conditions (Appendix 2). These pools were accessed via helicopter. Reservoir water level during the field trip was estimated to be between 731 and 732 mASL. Ten pools with minimum depth of 0.5 m (identified from Year 1 desktop analysis) were drilled (with an ice auger) for data logger installment, of which nine pools were completely frozen (Photo 1). The tenth pool only contained 10 cm of water which was not deep enough for the data logger. While winter air temperatures in 2017 were below normal, freezing of isolated pools is likely common and to occur between November and March for any given year (Figure 3).

Table 1. Field surveys and associated tasks conducted in 2017 and 2018 for Year 2 of CLBMON-4. Reservoir elevation was obtained from BC Hydro.

Survey Date	Elevation (mASL)	Main Tasks
2017		
February 28	731	DO Logger Deployment in low elevation pools (below 740 mASL) in Bush Arm and Columbia Reach. No loggers deployed. Nine pools frozen. Tenth pool only contained 10 cm of water.
October 24-26	748.4	Deployed six DO loggers and surveyed 14 isolated pools at high elevation (between 747 and 753 mASL) in Bush Arm
2018		
May 5	721.2	LGL wildlife crew retrieved three DO loggers from Bush Arm.
May 10	723.2	Surveyed 10 isolated pools (elevation between 730-739 mASL) in Columbia Reach
May 11	723.6	Final three DO loggers retrieved from Bush Arm/Bear Island.
May 11-13	723.6-724.4	Surveyed 26 isolated pools (elevation between 724-753 mASL) in Bush Arm and Bear Island
May 15-16	725.4-726	Surveyed 14 isolated pools (elevation between 726-737 mASL) in Canoe Reach

In 2017, from October 24 to 26, ground-level sampling and data logger deployment was conducted by a crew of two biologists in high elevation pools (between 747 and 753 mASL) along the drawdown zone (DDZ) of Bush Arm and Bear Island to coincide with maximum drafting prior to winter freezing (Photo 2). Kinbasket Reservoir elevation in October was at 748.4 mASL (Government of Canada 2017) during the field survey, slightly reduced from the full pool elevation of 752.19 m on August 19, 2017. Predicted reservoir levels obtained from BC Hydro were incorporated into field scheduling to determine how much of the DDZ would be available for sampling. Transportation to Bush Arm and Bear Island occurred by pick-up truck (with 4X4 capability) traveling along forestry service roads from Golden BC. The objective of this field survey was to obtain counts of newly stranded fish caused by reservoir drawdown prior to winter freezing, then re-sample pools (containing fish) in the spring (after snow melt) to determine if fish survive in pools over the winter season. DO and temperature loggers were deployed in the pools before freezing to assess water quality parameters for fish survival.

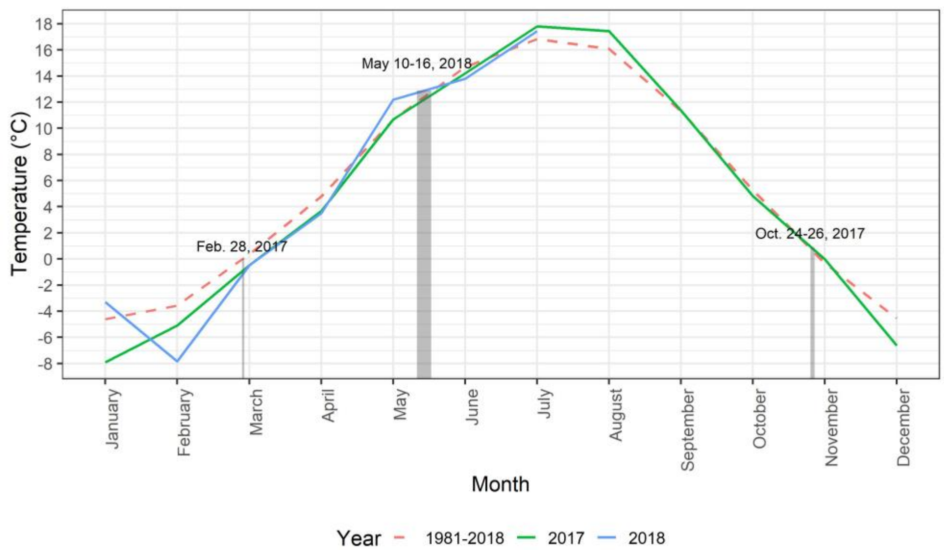


Figure 3. Average monthly air temperatures recorded for Mica Dam. Data obtained online from www.climate.weather.gc.ca. Grey vertical bars illustrate when field sampling occurred for Year 2 of CLBMON-4.

Similar scheduling logistics used in fall 2017 were adopted in 2018. Ground-level sampling and data logger retrieval was conducted from May 10 to 16 by a crew of three. Ground level surveys occurred within a 29 m elevational range from 724 to 753 mASL shortly after low pool (April 23 – 719 mASL, Figure 4, Photo 3). The Kinbasket Reservoir elevation was between 723 and 726 mASL during the seven-day field trip and rising rapidly at 0.4 m a day during the survey period. All surveys were conducted in pools along the DDZ of Bush Arm, Bear Island (northwest shore of Bush Arm), Canoe Reach, and Columbia Reach. Canoe Reach was accessed via forestry service roads from Valemount, B.C., while Bush Arm, Bear Island, and Columbia Reach were accessed via forestry service roads from Golden, B.C. Data collected from Year 2 (spring 2018) provided the following information:

- Verified the presence of pools identified in Year 1 and evaluate the criteria used to build the fish stranding risk ranking model (Appendix 1).
- Assesses fish survival in pools isolated over the winter period by re-sampling pools with fish observed as part of the fall 2017 survey.
- Determined the presence of fishes (species, relative numbers and life stages) in pools over a greater elevational gradient (29 m in spring 2018 vs. 5 m in fall 2017) and pool size range to encompass the three fish stranding risk categories (Appendix 1).

- Determined if fish stranding varied by geographical location (Bush Arm, Canoe Reach, Columbia Reach identified as being areas of greatest risk to fish stranding).
- In combination with Year 3 answered management questions 4, 6, and 7 and validated the responses to management questions 1, 2, 3, and 5 in Year 1 (Appendix 1).

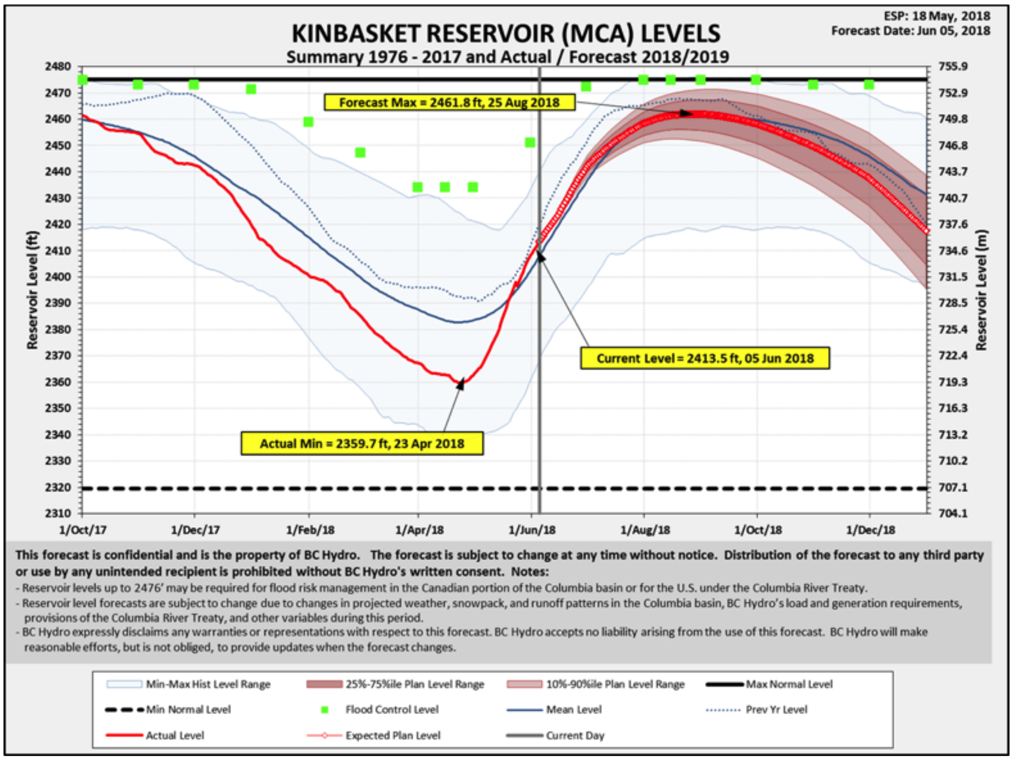


Figure 4. Kinbasket Reservoir elevation levels for Year 2018, updated on June 05, 2018. Provided by BC Hydro. Minimum pool was reached on April 23, 2018 (719.24 m).

4.2 Pool Sampling

Prior to field work, pools identified in Year 1 were organized by fish stranding risk and uploaded onto a field iPad. The software program 'Collector' was used on the iPad to help navigate field staff to the pools once on-site. Other pool attributes, such as pool depth, area, and elevation were also uploaded on the iPad, and were used to help select which pools to sample. A wide variety of pools across the DDZ elevational range was sampled. Due to challenges and unsafe conditions such as very soft and sticky substrate, and road access limitations pools were often sampled opportunistically based on site access. At each visited pool, the maximum wetted length and width was measured using a handheld Tasco 600 range finder to calculate an approximate wetted surface area. A maximum wetted depth was measured with a cm-graded measuring pole for all pools one metre deep or less. For deeper pools (and out of safety concern), a maximum depth was estimated visually based on a number of reference points such as local topography, water clarity and standing objects such as tree stumps. Elevation for pools that were not identified in Year 1 was obtained using a handheld Garmin GPS with elevational measurement capability. Due to a large proportion of sampled pools not previously identified in Year 1, fish stranding risk was re-calculated (using the same stranding risk ranking model developed in Year 1 for CLBMON-4) for all pools sampled. The following criteria used in the stranding risk ranking model were approximated (retain consistency) to assign a stranding risk to each sampled pool:

- Pool area – maximum wetted length and width measured at time of field survey.
- Pool depth – maximum wetted depth measured at time of field survey.
- Number of days pool was isolated – based on a 27-year daily average pool elevation from 1990 to 2017 (Year 1 used a 20-year time frame from 1990 to 2010).
- Time of year pool is isolated – two factors were listed in Year 1 report (Hanson and Nadeau 2010), of which "Life History" was adopted with no adjustment, and "Reservoir Levels" were based on a 27-year daily average pool elevation from 1990 to 2017 (Year 1 used a 20-year time frame from 1990 to 2010).

Each pool was photo-documented with a digital camera and its position recorded with a handheld Garmin GPS.

The presence of surficial hydrologic connectivity was assessed for each pool sampled. This refers to the occurrence of a wetted surface channel connecting a pool to the reservoir, which in turn may provide fish access to and from the reservoir despite the pool's exposure in the DDZ. The wetted depth, width and flow rate of channels were not measured during field investigations. Pool connectivity was not identified or evaluated during the GIS analysis in Year 1 (Appendix 1) or in the methodology developed by Korman and Buszowski (2000).

4.3 Fish Survey Data

All fish sampling was conducted under the Ministry of Forests, Lands and Natural Resource Operations Fish Collection Permit: CB17-282309.

For each pool sampled, fish presence was determined from a combination of sampling techniques used opportunistically based on the complexity of the pool (e.g., size and depth of pool, amount of pool cover) (Photo 4):

- Minnow traps – 0.6 cm mesh, three per pool, each trap baited with a 3 oz. can of Great Choice wet cat food (seafood flavour). Cans were hole punched for slow release of scent. Traps were soaked overnight and retrieved the following day. Minnow traps were deployed in pools with thick in-pool cover and in deep pools with a wetted depth greater than 0.5 m (with preference in pools deeper than 1.2 m, which would otherwise prevent beach seining).
- Beach seine – 15 m long by 1.5 m height with 0.5 cm mesh. This method was used on pools with a wetted depth up to 1.2 m and little to no in-pool cover (most common in mid to low elevation pools).
- Dip netting – 40 cm net frame on a 1.8 m monorail pole, and 0.5 cm mesh. This method was effective in shallow pools or in pools with in-pool cover (except no large woody debris that could snag nets) along the shoreline where juvenile fishes often rear. Also effective in open shallow pools where fishes were visible from the surface.

- ARIS 1200 sonar – effective in deep and turbid pools, however due to the large amount of accessory gear (field laptop, cords and cables) and heavy weight of the sonar unit and accompanying gas-powered generator (Honda 1000), this method was only used in fall 2017 on a single pool (BA29) situated along the forestry service road adjacent to Prattle Creek (Bush Arm).
- Visual survey – very effective in clear shallow pools with limited in-pool cover. Juvenile cyprinids and salmonids often occupy the upper water column and nearshore littoral zone, making them easy to detect. Species identification can be challenging in mixed cyprinid schools, and very difficult to nearly impossible to distinguish sculpins and suckers. Since physical handling of fish does not occur with visual surveys, no length measurements were obtained.

All fishes were identified to the lowest taxonomic level (with preference to species), enumerated, and a fork length measurement (total length for sculpins due to rounded caudal fin) obtained from a set of approximately 30 fish of each taxa per sampling method, per pool. Fish lengths were used to estimate life history stage, particularly for cyprinids, suckers, and sculpins where juvenile features are not conspicuous. All captured fish were released back in their respective pools. The presence of dead fishes was also documented, this included identification (if possible) and enumeration.

4.4 Data Loggers

An initial winter (February 28, 2017) trip failed to deploy DO data loggers below ice cover in high fish stranding risk pools (with minimum 50 cm depth water) identified from Year 1 due to the finding that nine of the ten pools sampled were frozen from top to bottom(Appendix 2, Photo 1). The remaining pool only had 10 cm depth of ice-free water overlain by 50 cm of ice. To determine temperature and Dissolved Oxygen (DO) and related fish survival in isolated pools during winter, a second data logger deployment trip was carried out in fall 2017 before ice formation.

On October 24 to 25, 2017, six PME miniDOT (dissolved oxygen and temperature) loggers were deployed opportunistically in six high elevation (between 747 and 753 mASL) pools along the DDZ of Bush Arm (Appendix 3, Photo 3, Photo 4). These pools were identified either based on CLBMON-4 Year 1 reporting, or based on anecdotal information provided by LGL Limited field staff working on CLBMON-58 (Table 2). The data loggers were deployed in pools that were observed to contain fish during the fall field survey for CLBMON-4, or in pools reported anecdotally to contain fish during summer 2017 field surveys for CLBMON-58. Data loggers were mounted horizontally on 2 m length rebar, placed fully submerged under water and the sensor raised a minimum of 5 cm off the pool floor to approximately mid-water column height (20 to 55 cm depth). The horizontal positioning of the loggers prevented buildup of bubbles on the sensor. DO concentration (mg/L), temperature (°C) and time (24 hr) were programmed to record data every 10 minutes and data were downloaded using the manufacture's software (PME miniDOT software). Three data loggers were retrieved on May 05, 2018, from LGL staff working on CLBMON-58, while the remaining three loggers were retrieved on May 11, 2018, by crew working on CLBMON-4.

Table 2. **Pools in the DDZ of Bush Arm, Kinbasket Reservoir with fish observed during summer 2017 by LGL Limited while conducting field surveys for CLBMON-58 (V. Hawkes, LGL Limited, pers. comm.).** Fishes observed were not identified to species or processed (measured or enumerated) but some photos were obtained.

Location	Pool ID*	UTM (11 U) E	UTM (11 U) N	Elevation	Sampled in fall 2017 (CLBMON-4)
Bush Arm	N/A	474536	5740067	753.4	No
Bush Arm	N/A	474624	5739965	753.1	No
Bush Arm	N/A	474542	5739992	753.0	No
Bush Arm	N/A	474739	5739188	751.4	No
Bush Arm	N/A	474771	5739160	752.5	No
Bush Arm	N/A	474460	5739970	752.6	No
Bush Arm	BA22	461687	5735550	749.3	Yes
Bush Arm	BA23	461701	5735647	751.5	Yes
Bush Arm	BA24	461635	5735609	750.8	Yes
Bush Arm	BA25	461604	5735624	750.9	Yes
Bush Arm	BA26	461438	5735621	748.2	Yes
Bush Arm	BA28	474832	5739249	751.1	Yes
Bear Island	BI1	453221	5736975	751.0	Yes
Bear Island	BI2	453202	5737017	752.5	Yes
Bear Island	BI4	453471	5736839	749.4	Yes
Bear Island	BI5	454425	5736473	747.9	Yes

*Pool ID was created for CLBMON-4.

4.5 Helicopter Overflight Survey

Aerial digital photographs of targeted areas in the Kinbasket Reservoir DDZ were taken on May 08, 2018, by a Yucwmenlúcwu biologist to validate the presence of pools identified by Hansen and Nadeau in the Year 1 CLBMON-4 study (2010, Appendix 1). Pools within the drawdown zone were targeted in the Canoe Reach, Bush Arm, Bush Harbour, Bear Island, Columbia Reach, and the outlet of Gold River. Information from the twin engine helicopter aerial survey was also used to inform the ground survey team of potential suitable sampling sites. Flight survey elevation was at 1,000 mASL at a speed of 60 knots.

A geospatially referenced track of the flight path was recorded by the helicopter pilot with a Garmin GPS unit. The flight path travelled along the reservoir, facing the DDZ beginning along a north–south direction looking westward, and then pivoting 180° and going south–north looking eastwards. Geospatially referenced digital photographs were taken using a Nikon D810 with AF-S Nikkor 24-70mm f/2.8G lens. Photos were taken from the rear left position of the helicopter at a frequency of 5-9 seconds per frame in order to capture overlap of pool and shoreline features. Time between frames varied as the autofocus of the camera established focus. Camera position was offset by approximately 60° from the direction of the flight path and at a downward angle (approximately 15-20°) to capture the entire extent of the DDZ.

Imagery from the survey can be combined using the location data as well as overlapping shoreline and pool features in order to identify individual and relative pool information (e.g., qualitative size classes and number of pools).

4.6 Environmental Data

The following environmental data were collected at each sampled pool to assess fish habitat quality and potential signs of predation from wildlife:

- Turbidity via a Triton Turbidity Wedge© in fall 2017 survey and a LaMotte 2020 we/wi turbidity meter in spring 2018 survey.
- Physicochemistry – DO (mg/L), temperature (°C) from a YSI Pro2030 handheld dissolved oxygen meter, and pH from a Hanna HI 98129 combo pen.
- Visual assessment of pool riparian and in-pool vegetation cover and large woody debris using the Reconnaissance Fish and Fish Habitat Inventory methods (RIC 2001).
- Incidental wildlife or wildlife sign observations (potential fish predators).

4.7 Statistical Analyses

While this study was primarily qualitative in nature, statistical analyses were performed on qualitative data to assess the relationship between fish community (fish presence – fish health status, and species composition) and the criteria used to develop fish stranding risk ranking model from Year 1 (Appendix 1**)** as well as important physicochemical properties (e.g., DO, temperature, and pH) for fish survival.

All statistical analyses were conducted using the statistical program PRIMER with the PERMANOVA (Permutational Multivariate Analysis of Variance) add-on (Anderson et al. 2008; Clarke and Gorley 2015). Two separate analyses were conducted, first for the presence of fish (dead or alive) and species composition found in pools, and then just for dead fish. A PERMANCOVA, a permutational multivariate analysis of covariance (Gerwing et al. 2016), was used to determine how stranded fish varied spatially, as well as which of our covariates (pool elevation, pool depth, pool area, days of pool isolation, water temperature, dissolved oxygen (DO), pH, and reservoir reach) were associated with this variation. The response variable of this analysis was a resemblance matrix constructed for observed fish (live and dead for all species) in pools. The resemblance matrix was calculated using Bray-Curtis coefficients, and a dummy variable of 1 was added to each pool to deal with pools with no observed fish (Clarke et al. 2006). Fish data were fourth root transformed to improve assessment of rare and common observations on community structure (Clarke et al. 2006; Clarke and Gorley 2015).

Prior to analysis, all possible correlations between all pairs of covariates were assessed by calculating univariate Pearson's correlation coefficients. We used a threshold of 0.95 (Anderson et al. 2008; Gerwing et al. 2016) to determine if variables were too correlated to be considered independent. As the highest correlation coefficient observed was 0.4, all variables were included in our models. All covariates were normalized prior to analysis to handle measurements with different units and scales (e.g., pH and DO) (Clarke and Ainsworth 1993). Pool area and DO content were log transformed, while pool depth and days of pool isolation were square root transformed prior to normalization to correct for skewed distributions (Clarke and Gorley 2015). Beyond the covariates, Reach (fixed factor; four levels – Bear Island, Bush Arm, Canoe Reach, and Columbia Reach) and Pool (pool ID), nested within Reach (random factor), were also included in the PERMANCOVA. For all analyses we used $\alpha=0.05$ (Beninger et al. 2012). As part of the PERMANCOVA, we quantified variance components, and the proportion of the multivariate variation accounted for by each variable (Searle et al. 1992; Clarke and Gorley 2015; Gerwing et al. 2016). Variance components estimate the proportion of the observed variation in fish observations each covariate and factor in the PERMANCOVA accounted for. To determine the nature of the relationship between covariates identified as of importance ($p < 0.05$) in the PREMANOCVA and total fish numbers, Parson's univariate correlation coefficient was calculated.

Finally, an analysis of similarity (ANOVSIM) was used to determine if fish (live or dead) stranded in hydrologically connected versus isolated pools varied (Clarke et al. 2006; Clarke and Gorley 2015).

5.0 RESULTS

5.1 Pools Sampled

A total of 58 pools were sampled in the DDZ of Kinbasket Reservoir, of which 14 were sampled in October 2017 (Bush Arm only), 50 in May 2018 (all locations), and six were sampled at both times, fall and spring (five at Bear Island and one near the Bush river causeway of Bush Arm) to assess fish survival in isolated pools over the winter season (Table 3). Sampling occurred in all three fish stranding risk categories, with 52% (n=30) of sampled pools assigned to the high-risk category. Half of the pools (50%) were sampled in Bush Arm due to greater heterogeneity of isolated pools (e.g., area, depth, elevational range, and fish stranding risk) and ease of site access. Seventy-four percent of pools sampled were not identified as part of the pool risk stranding model carried out in Year 1 (DEM based on 2002 aerial photography), but located in close by geographical locations and elevations, suggesting a high degree of pool shifting across the DDZ in the 16-year period (Map 1, Appendix 4). Hydrologic connectivity was present in 27 (47%) of the 58 pools (Appendix 4). Connectivity occurred across all elevational ranges (from 725 to 753 mASL) and stranding risk categories. All four pools with hydrologic connectivity sampled at Bear Island in fall 2017 continued to have a flowing channel in spring 2018. A single pool (BA14) that had an out-flowing channel surveyed in fall of 2017 was disconnected in spring 2018.

Table 3. Number of isolated pools sampled by geographical location and by fish stranding risk in the drawdown zone (between elevation 753 to 724 mASL) of Kinbasket Reservoir, and the number of isolated pools fish were observed.

Location/Risk	Number of pools sampled	Pools sampled with fish	Pools sampled Oct 2017	Sampled pools with fish 2017	Pools sampled May 2018	Sampled pools with fish 2018
Location						
Bear Island	5	5	5	5	5	4
Bush Arm	29	22	9	3	21	20
Canoe Reach	14	12	0	0	14	12
Columbia Reach	10	6	0	0	10	6
Risk						
Low	8	4	8	4	3	3
Moderate	20	16	5	3	18	15
High	30	25	1	1	29	24
Total	**58**	**45**	**14**	**8**	**50**	**42**

5.2 Fish Sampling

5.2.1 Fish Presence

Fish were observed in 45 pools (78%) and were present in all study locations and throughout all risk criteria categories used to develop the fish stranding risk ranking model in Year 1(Table 3, Appendix 5). Fish presence in isolated or connected pools did not vary between reaches or by criteria used to develop the fish stranding risk ranking model (Appendix 4, Appendix 5). With respect to pool connectivity, the ANOSIM did not identify a statistically significant relationship between fish presence and pool connectivity (n=44, R=-0.08, and p=0.97).

Pool depth, area, and temperature were significantly associated with observed fish, and each of these variables accounted for a small proportion of the variation (3-8%; Table 4). Each of these variables were positively correlated with observed fish numbers, suggesting that larger and deeper pools contained more fish, while warmer waters also contained more fish (Table 5).

Table 4. PERMANCOVA (permutational multivariate analysis of covariance) on fish community (total fish numbers observed in pools and species composition) observed within pools sampled in October 2017 and May 2018 combined along the DDZ of Kinbasket Reservoir. df=degrees of freedom; MS= mean square; Pseudo-F=test statistic; *p*=probability value. Significant and interpretable *p* values are denoted in bold.

Variable	df	MS	Pseudo-F	Unique permutations	*p*	Variance components (%)
Elevation	1	1,363.80	0.89	9,958	0.51	0.00
Pool depth	**1**	**6,416.20**	**4.17**	**9,943**	**0.001**	**5.43**
Days isolated	1	2,074.40	1.35	9,942	0.26	6.01
Pool area	**1**	**6,171.90**	**4.01**	**9,940**	**0.002**	**7.73**

Variable	df	MS	Pseudo-F	Unique permutations	*p*	Variance components (%)
Temperature	**1**	**3,592.30**	**2.33**	**9,950**	**0.04**	**3.06**
DO	1	1,641.40	1.07	9,949	0.41	0.13
pH	1	2,056.00	1.33	9,940	0.26	0.93
Reach	3	1,910.20	1.24	9,920	0.24	3.49
Residual (pool)	33	1,540.40				73.22
Total	43					

Table 5. Pearson's univariate correlation coefficient between variables identified as of interest in the PERMANOCVA (Table 4) and total fish numbers observed in pools.

Variable	Correlation coefficient
Pool depth	0.15
Pool area	0.26
Temperature	0.12

Dead fish were present in 15 pools, of which five pools were dried up (Appendix 6). The five dried up pools occurred at low elevation (between 724 and 728 mASL) and had not been identified in Year 1. Dead fish were also observed in pools up to 1500 m^2 in size and pools with live fish (n=3). The presence of dead fish did not vary between reach or by any variable except for days of pool isolation (a reflection of elevation), which accounted for 36% of the observed variation (Table 6). A negative correlation (Pearson's Correlation Coefficient=-0.13) was observed between the number of dead fish and days since isolation, suggesting that as pools are isolated longer, they contain fewer dead fish. Pools observed with dead fish were isolated less than 200 days and were located in an elevation below 740 mASL. With respect to pool connectivity, the ANOSIM did not identify a statistically significant relationship between the presence of dead fish and pool connectivity (n=44, R=-0.06, and *p*=0.96). Physicochemistry (DO, temperature, turbidity and pH) measured at each of these pools fell within the tolerance levels for fish survival (see Environmental Data section in Methods) at the time of sampling. It was unknown if fish found dead were killed from winter freezing, or if physicochemical conditions fluctuated into lethal ranges prior to field surveys. These low elevation pools also lacked riparian and in-pool cover which are known to regulate DO and water temperature (Kalny et al. 2017).

Table 6. **PERMANCOVA (permutational multivariate analysis of covariance) on dead fish observed within pools sampled along the DDZ of Kinbasket Reservoir in May 2018.** df=degrees of freedom; MS=enter definition here; Pseudo-F=enter definition here; *p*=enter definition here. Significant and interpretable *p* values are denoted in bold.

Variable	df	MS	Pseudo-F	Unique permutations	*p*	Variance components (%)
Elevation	1	388.57	0.82	9,950	0.45	0
Pool depth	1	1,421.80	2.99	9,953	0.06	2.81
Days isolated	**1**	**1,674.40**	**3.52**	**9,949**	**0.04**	**35.99**
Pool area	1	294.10	0.62	9,954	0.54	0
Temperature	1	694.91	1.46	9,948	0.23	0.87
DO	1	168.36	0.35	9,937	0.58	0
pH	1	230.92	0.49	9,963	0.62	0
Reach	3	119.12	0.25	9,934	0.96	0
Residual (pool)	33	475.59				60.32
Total	43					

5.2.2 Taxonomic Richness

Most observed fishes were identified. Fish identification could not be completed due to the following factors:

- The absence of key features from the decomposition of dead fish.
- Identifiable characteristics of juvenile cyprinids (minnows) and suckers were obscure and difficult to distinguish and a decision was made to release fish alive before positive and stressful identification to species level could be made.

As a result, we adopted the term “taxonomic richness” to describe the number of taxa (e.g., species, genus, family) observed in pools (Gerwing et al. 2015; Gerwing et al. 2016; Gerwing et al. 2017).

Thirteen fish taxa were observed in pools containing fish in the DDZ of Kinbasket Reservoir during the fall 2017 and spring 2018 combined (n=45), including an unknown fish category for dead fishes that were severely deteriorated (Figure 5, Photo 5). Of these taxa nine were identified to species. Redside Shiner was the most common species encountered, occurring in 22 pools, followed by Lake Chub (n=15) and Prickly Sculpin (n=11). Two of the four species of concern (Bull Trout and Kokanee Salmon) identified by BC Hydro (2007a) were observed in a single isolated pool each.

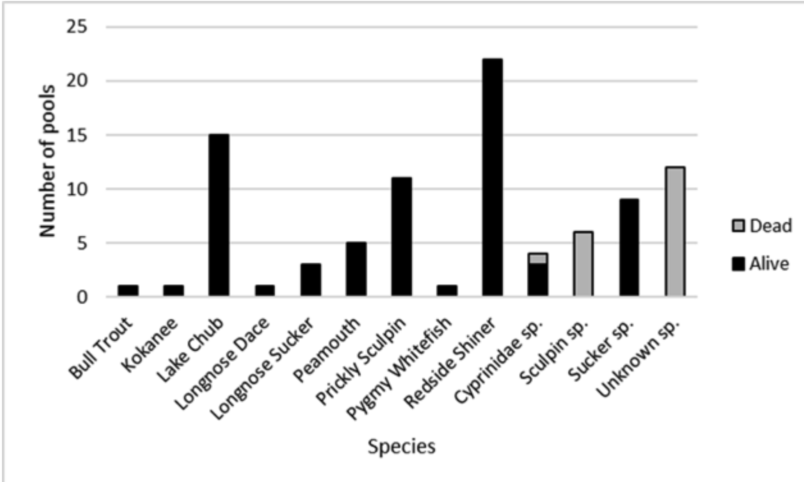


Figure 5. Fish species occurrence in isolated pools (n=58) sampled in the DDZ of Kinbasket Reservoir; fall 2017 and spring 2018 field surveys combined. All sculpin sp. and unknown sp. were dead.

The number of taxa observed per pool ranged between zero to five (Figure 6). Fish were not observed in thirteen pools while most pools with fish presence contained one or two taxa. A single pool each in Bush Arm (BA21) and Columbia Reach (CO5) contained five taxa.

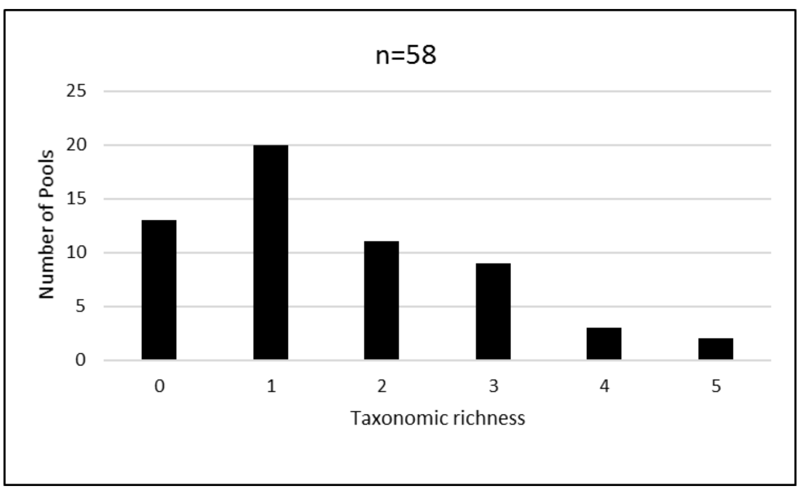


Figure 6. Taxonomic richness in the 58 isolated pools sampled in the drawdown zone of Kinbasket Reservoir in fall 2017 and spring 2018 surveys combined.

5.2.3 Fish Abundance and Density

Dead fishes (primarily sculpin sp. and unknown sp.) comprised 33% of all fishes observed (Appendix 7, Photo 6). Redside Shiner and Lake Chub were the most abundant live species and together they comprised 53% of all fishes observed (Figure 6).

Dead fishes were common in isolated pools containing fish and often found in relatively large numbers. This trend was also true for Redside Shiner and Lake Chub. While Prickly Sculpin occurred in 26% of isolated pools containing fish, their relative abundance per pool was low. Since dead sculpins were not identified to species and no other sculpin species were detected, it is likely that these dead sculpins were Prickly Sculpin, which would increase their presence in isolated pools by 18%, making Prickly Sculpin one of the more abundant species stranded in isolated pools.

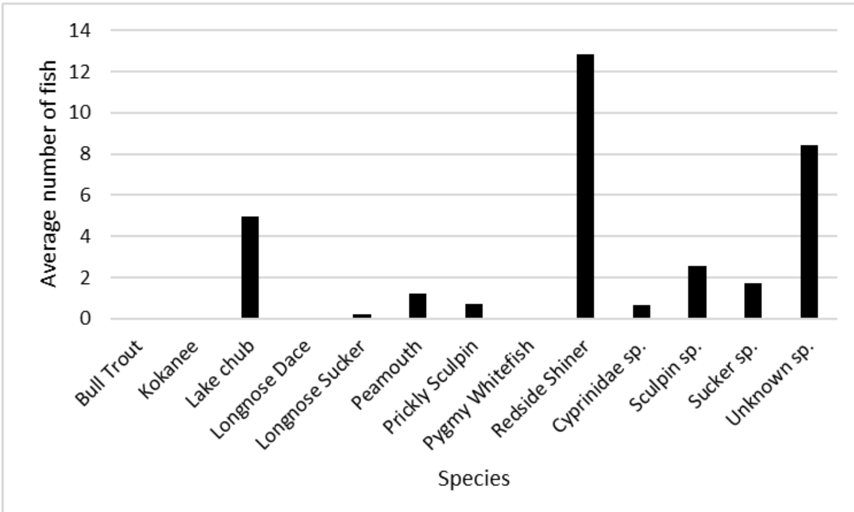


Figure 7. Average number of fish by taxa observed in isolated pools sampled (n=45) along the drawdown zone (between elevation 724-753 mASL) of Kinbasket Reservoir. All sculpin sp. and unknown sp. were dead.

The mean fish density per sampled pool (n=58) was 0.08 fish/m^2 +/- 0.03 (Figure 8). Bear Island and low fish stranding risk pools had the highest average density compared to other study locations and risk levels, however the small pool sample size (n=5 and n=8, respectively) likely accounted for the large amount in variation. The overlap in variation indicates that fish density does not differ between geographical location and between fish stranding risk.

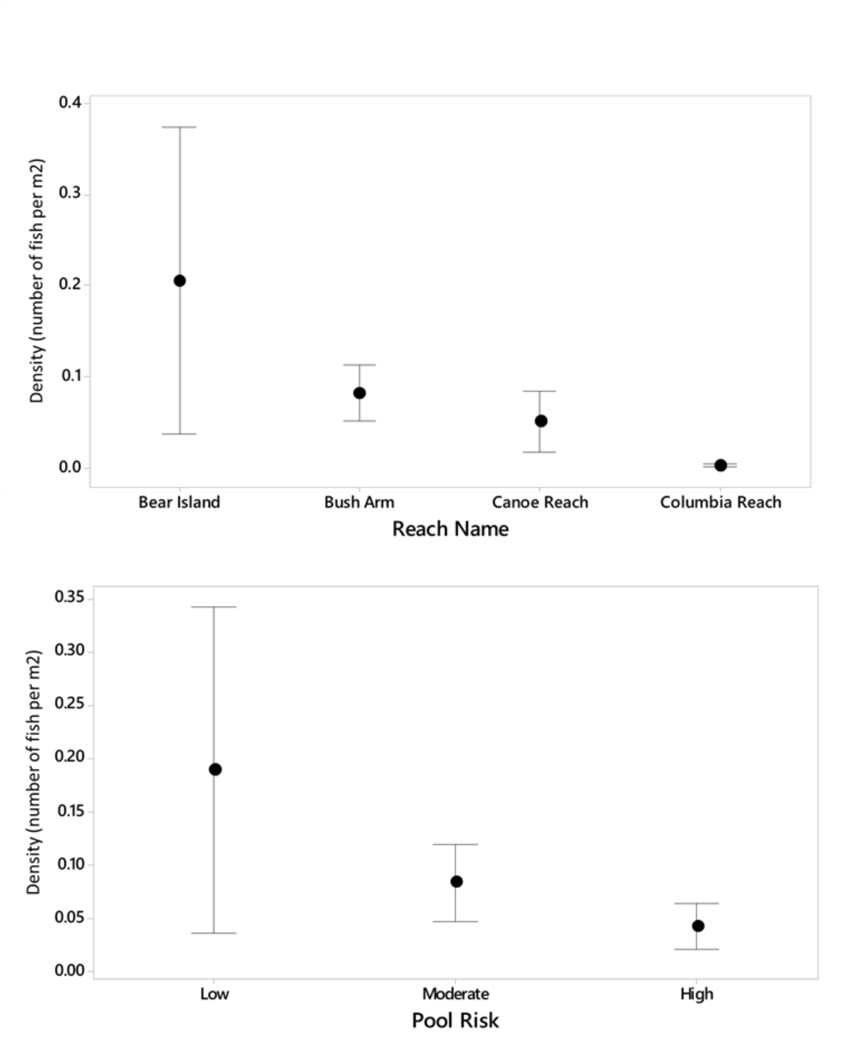


Figure 8. **Average fish density (number of fish per m^2) per isolated pool sampled, derived from all pools sampled (n=58) by Reach and Pool Risk.** Bars are one standard error from the mean.

5.2.4 Elevational Distribution

Sixty-seven percent (n=39) of sampled pools occurred below 735 mASL of which 34 pools contained fishes. Suckers (including Longnose Sucker) and Redside Shiner had the greatest elevational distribution and were the only species consistently stranded at elevations greater than 735 mASL. There was no relationship between species presence and elevation (Figure 9). Dead fish (unknown and sculpin sp.) were primarily observed below ~733 mASL.

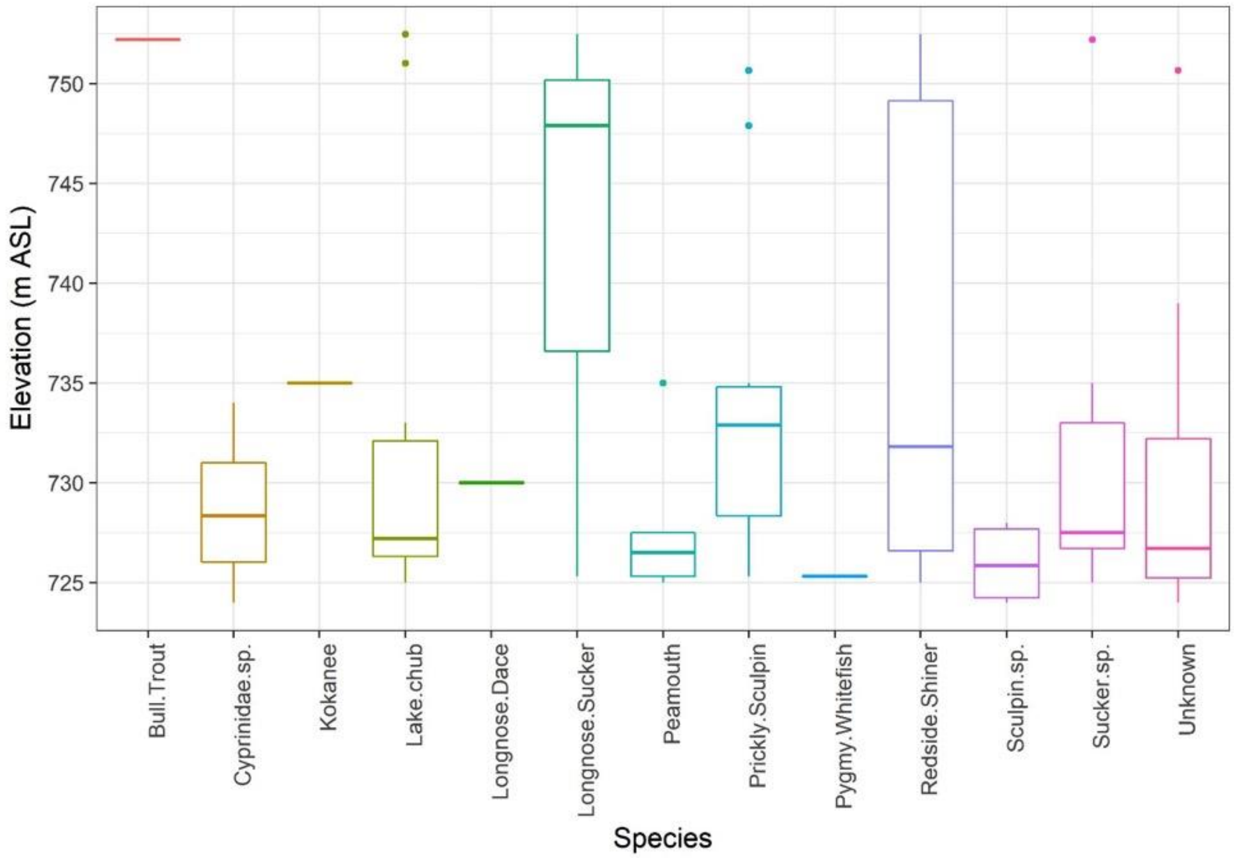


Figure 9. Elevational distribution of fish taxa collected in pools sampled along the DDZ of Kinbasket Reservoir. Only 19 of the 58 pools sampled were above 735 mASL. Reservoir water level reached low pool on April 23, 2018, at an elevation of 719 mASL. Pools were sampled between 724 and 753 mASL.

5.2.5 Life Stage

Fork lengths were used to approximate life history stage (juvenile/adult) for all cyprinids, suckers and sculpins, while superficial features such as the presence of parr marks were used in addition to length to approximate life history stage (juvenile/adult) of salmonids and whitefishes. The following juvenile-to-adult length thresholds were applied to all species measured in our study (McPhail 2007; Scott and Crossman 1973; Kang and Warnock 2017; Sebastian and Weir 2013):

- Kokanee Salmon (*Oncorhynchus nerka*) – 200 mm
- Bull Trout (*Salvelinus confluentus*) – 400 mm
- Pygmy Whitefish (*Prosopium coulterii*) – 150 mm
- Suckers (Catostomus sp.) – 200 mm
- Peamouth (*Mylocheilus caurinus*) – 150 mm
- Lake Chub (*Couesius plumbeus*) – 70 mm
- Redside Shiner (*Richardsonius balteatus*) – 70 mm
- Longnose Dace (*Rhinichthys cataractae*) – 70 mm
- Sculpins (Cottus sp.) – 70 mm

Fork length measurements (total length for sculpins) were performed on 467 fishes across 10 taxa (Appendix 8). The length measurements obtained indicates that fishes stranded in pools in the DDZ were primarily juvenile (83%) across all taxa (Figure 10). The single Bull Trout, Pygmy Whitefish, Longnose Dace, and two Kokanee Salmon were all juvenile. Adults were less commonly stranded but did occur in cypriniformes and sculpins, and were mostly stranded in isolated pools.

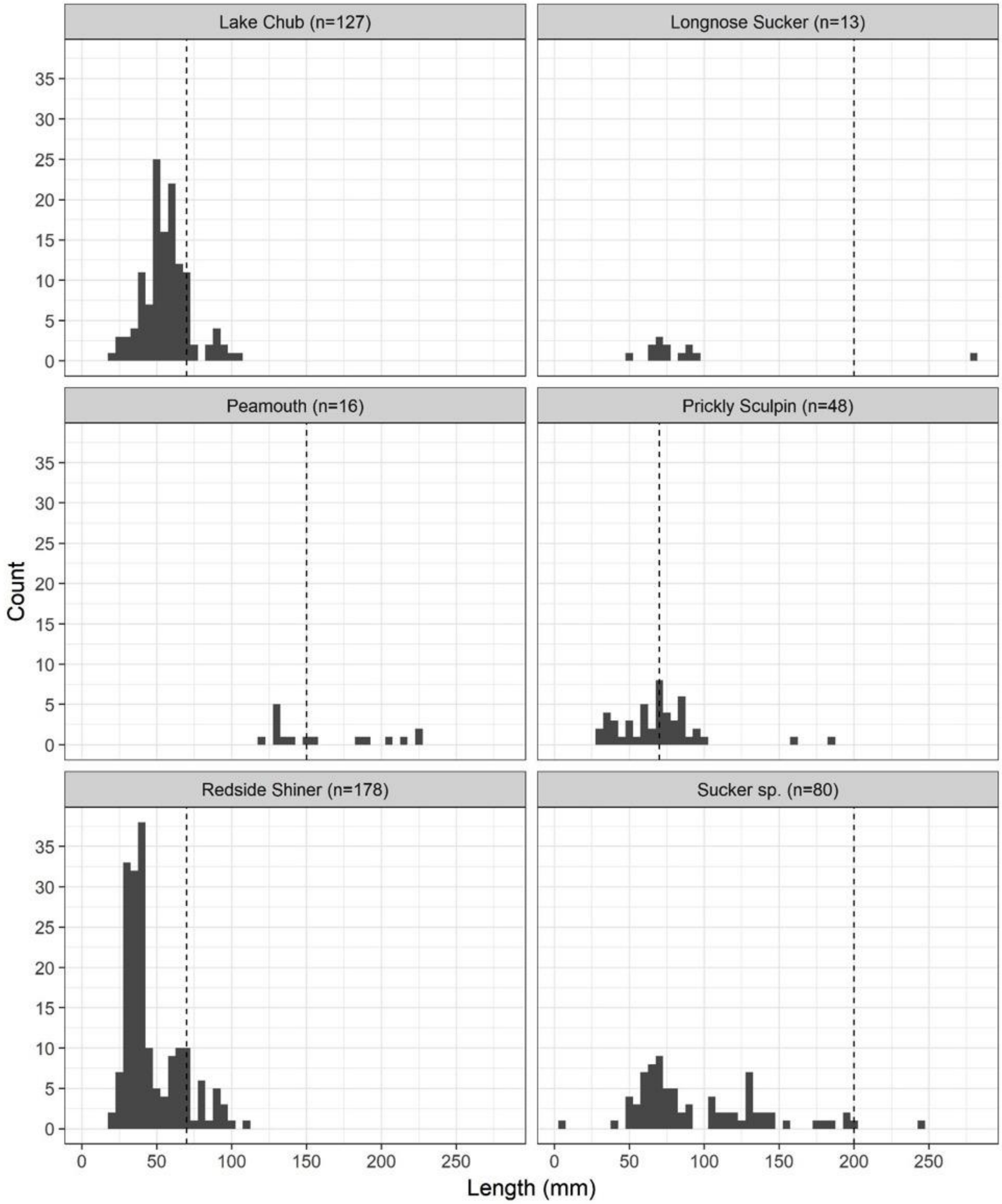


Figure 10. Length (mm) frequencies of fishes (n >10 measured fish) sampled in isolated pools along the DDZ of Kinbasket Reservoir between elevation 724 and 753 mASL. The dotted vertical line in each graph represents the approximate juvenile-to-adult length

thresholds. Measurements above (to the right) the dotted line represents adult life history stage.

5.2.6 Overwinter Survival

Six pools sampled in fall 2017 containing fish were re-sampled in spring 2018 during reservoir filling (Table 7). Live fishes were present in four pools (including three pools with connectivity) after repeat sampling in the spring, indicating that fishes survive through winter conditions in high elevation pools. Species composition did however change between sampling periods. The difference in species occurrence between surveys may be due to detection failure, or migration access via a channel connecting to the reservoir or another pool.

Table 7. High elevation Pools in the DDZ of Kinbasket Reservoir with fish observed in fall 2017 and re-sampled in spring 2018. Provincial freshwater fish codes used from Appendix 9 A. of the Fisheries Information Summary System (FISS): BT – Bull Trout, CAS – Prickly Sculpin, LKC – Lake Chub, LSU – Longnose Sucker, RSC – Redside Shiner, SU – Sucker sp., UNK – unknown fish.

Location	Pool label	Elevation (mASL)	Hydrologic connectivity	Fish fall 2017	Fish spring 2018
Bush Arm	BA14	752.20	Yes 2017, No 2018	BT	RSC, SU
Bear Island	BI1	751.01	Yes	RSC	LKC
Bear Island	BI2	752.47	Yes	LKC, LSU	LKC, RSC
Bear Island	BI3	750.66	No	CAS	UNK (dead)
Bear Island	BI4	749.35	Yes	RSC	RSC
Bear Island[a]	BI5	747.89	Yes 2017, No 2018	LSU, CAS, RSC	None

[a] Reservoir water elevation was standing at 748.45 mASL during the fall data logger deployment (24-25 October). Pool BI5 was still inundated until 04 November (water levels provided by BC Hydro) when the reservoir water level declined to 747.61 mASL.

Dissolved oxygen (DO) levels varied substantially between isolated pools (from the data loggers deployed in the six pools from October 2017 to May 2018), (Figure 11). A relationship was not observed between this variation in DO levels and the presence of live or dead fishes (Appendix 3). This suggests that DO levels is not likely related to fish survival in isolated pools. The instantaneous minimum threshold of dissolved oxygen for fish survival is 5 mg/L (BC MOE 2018) for which a single pool (BI1) containing live fish before and after data logger deployment had a steady DO reading above this value (Figure 11). . While pool BI5 showed a similar trend in DO levels (except for a few days of hypoxia in April), no fishes were observed in the spring. This pool was still inundated during the fall survey and it is possible that fishes emigrated before the pool became exposed and isolated. Pool BI3 was the only pool to contain dead fish in the spring. DO levels in this pool fell below 5 mg/L before the pool started to freeze, suggesting that reduced DO levels may have resulted in fish death. This pool was also isolated from channels connecting to the reservoir which otherwise may have allowed fishes to emigrate to better suited environments. In the case of BI2 where DO levels declined to hypoxic levels immediately after installation, live fishes were still observed in the spring. This pool had a channel connecting to the reservoir. Although DO levels reached hypoxic levels in most pools, data loggers only detected environmental conditions in immediate proximity to the sensor, therefore it is possible that DO levels in these pools exhibited stratification across the water column and fishes distributed themselves accordingly. It is also likely that DO levels were sometimes measured when the loggers were frozen in ice, leading to possible erroneous readings.

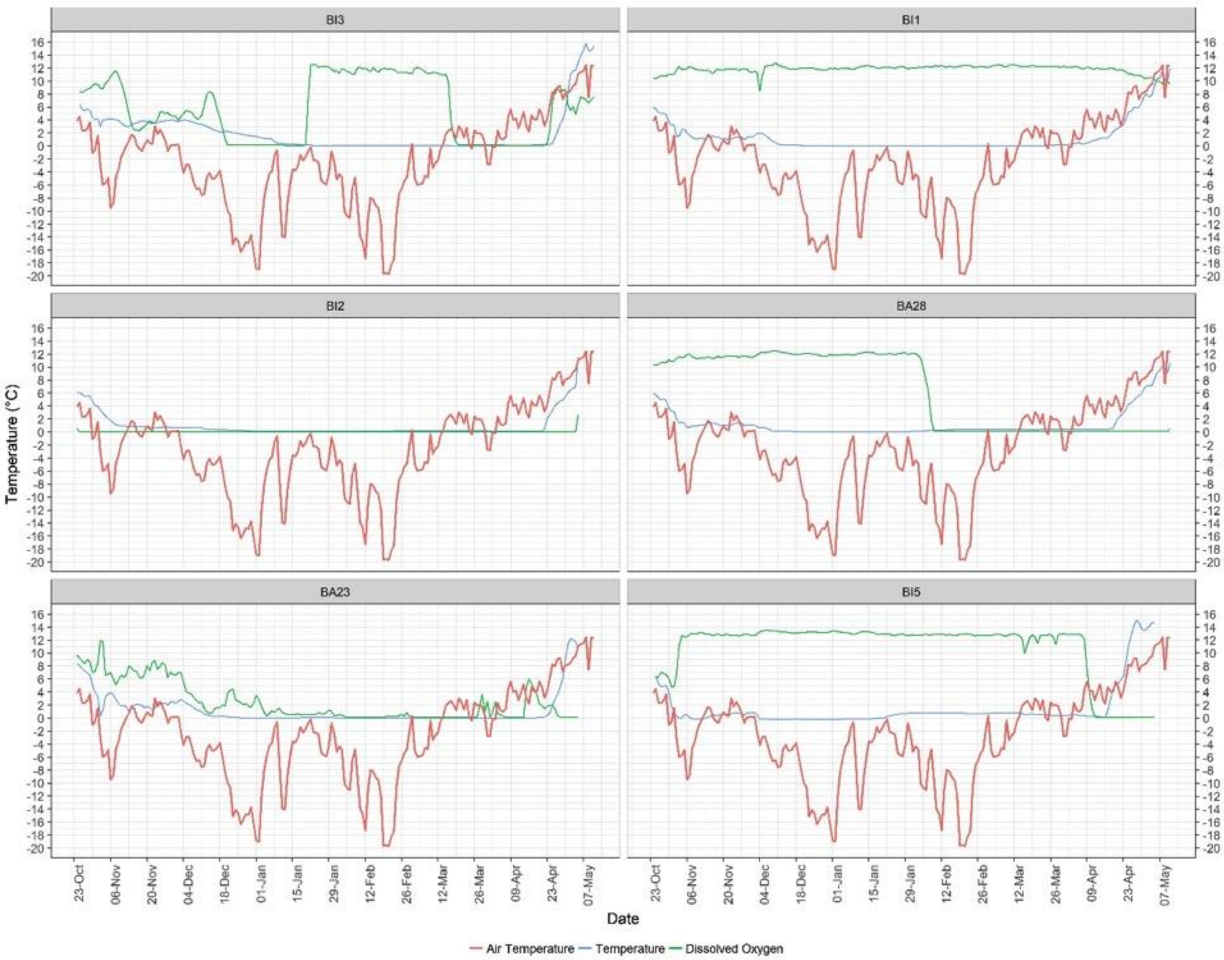


Figure 11. **Daily variation in dissolved oxygen (DO; mg/L) (green line) and water temperature (°C) (blue line) relative to air temperature (°C)** (measured at Mica Dam – https://pacificclimate.org/data/bc-station-data) at six high elevation pools (between 753 and 747 mASL) located along the DDZ of Bush Arm (BA) and Bear Island (BI) of Kinbasket Reservoir. Data loggers were set at a depth between 25 and 55 cm below the surface when first installed. Data loggers were deployed in October 2017 and retrieved in May 2018.

5.3 Environmental Data

Physicochemical conditions were measured at 12 of the 14 pools sampled in fall 2017 and 45 of the 50 pools sampled in spring 2018 (Table **8**). One pool in the fall was too shallow (less than 10 cm) for water quality measurements while another pool was still partially inundated by the reservoir. Five pools in the spring were dry.

Table 8. Physicochemical variables collected at 12 isolated pools in the fall and 45 pools in the spring sampled along the DDZ of Kinbasket Reservoir during the spring 2018 survey. Definitions and justifications for the measured parameters were compiled from the Canadian Aquatic Biomonitoring Network (CABIN 2012), Guidelines for Interpreting Water Quality Data (RISC 1998), and Key Ecological Temperature Metrics for Canadian Freshwater Fishes (Hasnain et al. 2010).

Parameter	Mean ± SD	Typical limits and discussion
Dissolved oxygen (mg/L) Fall 2017 Spring 2018	 8.44 ± 2.86 8.89 ± 8.12	Maximum solubility of oxygen is ~15 mg/L at 0˚C. Fishes require an instantaneous minimum DO of 5 mg/L for all life stages other than buried embryos and alevins. All DO values were above the minimum level for fish survival. DO ranged between 5.1 and 60 mg/L for all pools measured.
pH Fall 2017 Spring 2018	 7.50 ± 0.32 8.52 ± 0.47	Natural fresh waters have a pH ranging from 4.0 to 10.0. Most lakes in BC have pH of 7.0 or greater. Lethal effects of aquatic life occur below pH 4.5 and above pH 9.5, with optimal levels being between pH 6.5 and 9.0. All recorded values except for one pool sampled in the spring fell within the range that aquatic life can tolerate. All pH measurements ranged 7.1 to 9.67. The single One isolated pool (CA2) sampled with a pH greater than 9.5 (pH = 9.67) did not have fish.
Water Temperature (˚C) Fall 2017 Spring 2018	 6.74 ±. 1.36 19.98 ± 4.21	Temperature naturally varies in a waterbodies from 0˚ to 40˚ (hot springs). The maximum weekly average for adult and juvenile salmonids is 18-19°C. The mean critical thermal maxima for Catostomidae (suckers), Cyprinidae (minnows) in Canada are 32.7°C and 32.6°C, respectively. Long term maximum temperature should be maintained below 25°C for all freshwater fishes. All temperature measurements fell between 3.7 and 28.4˚C. Air temperature from the 2018 spring survey (10-16 May) measured between 12 and 23°C. Three isolated pools in Bush Arm and four connected pools in Canoe Reach during the spring survey had temperatures greater than 25°C. Fish were not detected in the pool (CA2) with the warmest recorded temperature (28.4°C). Live and dead fishes were observed in pools with temperatures recorded above 25°C. Suckers, Redside Shiner, Lake Chub, and Peamouth were the predominant fishes in these warm pools, followed by a couple of dead sculpins. Temperature did not appear to be correlated with the presence of live or dead fish (See Fish Presence section).

Parameter	Mean ± SD	Typical limits and discussion
Turbidity (NTU) Fall 2017 Spring 2018	 <50 all pools 11.56 ± 9.18	Pure distilled water has a turbidity of 0 Nephelometric Turbidity Units (NTU). High levels of turbidity reduce light penetration and therefore plant growth and can thereby suppress fish productivity. Turbid waters become warmer as suspended particles absorb heat from sunlight, causing oxygen levels to fall. Suspended solids in turbid water can clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. Drinking water has a turbidity limit of 1 NTU for health, and 5 NTU for aesthetics. The recommended turbidity limit for aquatic life is 50 NTU. All turbidity measurements fell below 50 NTU and ranged between 0.34 and 42.9 NTU for all pools measured.

Pool habitat was assessed for all 58 pools sampled. Most pools were homogenous and provided little to no vegetation cover (Table 9). Vegetation cover only occurred in isolated pools above elevation 747 mASL. Large woody debris occurred in 84% (n=48) of pools but most often in very small quantities.

Table 9. Presence of habitat cover from pools (n=58) sampled along the DDZ of Kinbasket Reservoir during the spring 2018 survey. Habitat data collection followed the Reconnaissance Fish and Fish Habitat Inventory methods (RIC 2001).

Habitat	Number of pools
Riparian vegetation	
Grass	13
None	45
In-pool vegetation	
Algae	7
Vascular plants	14
None	37
Large woody debris	
Present	49
None	9
Dominant bed material	
Fines	57
Organic	1

5.4 Incidental Wildlife Observations

Presence (any form of evidence such as tracks, droppings, sighting) of potential wildlife predators was documented during the spring 2018 field survey (Table 10). No signs of wildlife were observed during the fall 2017 survey. Signs of wildlife were observed on 48% (n=28) of pools, comprising of eight mammal and six bird taxa. Tracks (86%) were the dominant form of evidence belonging primarily to bears, mustelids (weasel family), corvids (crows and ravens), and small passerines (Photo 7). Two old beaver ponds located at Bear Island were well known from previous studies (e.g., CLBMON-58) and are not currently maintained by any beavers. No direct evidence of fish predation or signs of physical damage to fish were observed; however, an Osprey was hovering over pool CO8 along the DDZ of Columbia Reach.

Table 10. **Number of pools along the DDZ of Kinbasket Reservoir with incidental wildlife observations from the spring 2018 survey for CLBMON-4.** No signs of wildlife were detected during the fall 2017 survey. Evidence of wildlife were observed at 28 pools surveyed in spring 2018.

Wildlife Taxa	Evidence		
	Sighting	**Tracks**	**Dam**
Mammals			
Bear sp. (*Ursus* sp.)		5	
Black Bear (*Ursus americanus*)		1	
Grey Wolf (*Canis lupus*)		2	
Coyote (*Canis latrans*)		1	
Red Fox (*Vulpes vulpes*)		1	
Wild Cat (Felidae)		1	
Mustelid sp. (Mustelidae)		7	
North American Beaver (*Castor canadensis*)			2
Birds			
Goose (Anserinae)		1	
Gulls (Laridae)	1	2	
Osprey (*Pandion haliaetus*)	1		
Bird of Prey (Owls, Hawks, and Falcons)		1	
Corvid (Corvidae)		5	
Small Passerine (Passeriformes)		8	
Total number of pools	**2**	**24**	**2**

6.0 DISCUSSION and RECOMMENDATIONS

6.1 Management Questions

MQ1: What is the extent of fish stranding as a result of annual drawdown of the reservoir?

The response to this question was initially addressed in Year 1 (Appendix 1) and to be validated by field data collected in Years 2 and 3. Based on the surveys conducted in Year 2, fishes were present in pools across all elevational ranges (724-753 mASL) in the DDZ of Kinbasket Reservoir (Appendix 5). Species composition and the presence of fish stranded in pools did not vary statistically with elevation, geographical location, or by stranding risk (Table 4). Therefore, the extent and risk of fish stranding appears to be similar for all isolated pools formed at slopes less than six percent. The average fish density stranded in the 58 isolated pools sampled in Year 2 between elevations 753-724 mASL was 0.08 fish/m^2 +/- 0.03. Results from the May 2018 aerial survey to document the number and size of isolated pools formed in 2018 will be available in Year 3 and will provide a rough estimate of the number of fishes stranded in the DDZ. MQ1 will thus be addressed once the data from Year 3 are available.

Recommendations:

Identify all pools down to the minimum licensed operating elevation of 707.41 mASL to encompass the potential extent of fish stranding along the entire licenced DDZ of Kinbasket Reservoir. This analysis can follow the same methodology as in Year 1 based on Korman and Buszowski (2000). As suggested by Hanson and Nadeau (2010), orthographic and aerial photographs from past years can be obtained from BC Hydro and UBC to assist in the identification of historic pools, wetlands, or lakes that could be isolated if reservoir levels were drawn down to the minimum licensed level. Hydroacoustic bathymetry mapping would also provide a detailed slope and bottom topography of the reservoir which in turn can be used to identify isolated pools.

Additional years of sampling is recommended to further document any fish species stranded in pools that were not previously observed in Year 2. Some populations of fish such as Kokanee (a species of concern) are known to fluctuate in their abundance from year to year. Therefore, additional years of sampling would further determine the stranding risk of the four species of concern identified by BC Hydro. Should the stranding occurrence of these species remain low/absent, this will add confidence to the data collected in Year 2 that currently suggests that these species of concern are at low risk of stranding.

The 78% stranding rate is high and could be a concern as a potential source of mortality if this high level of stranding is persistent across years. Additional sampling years will provide an indication of whether the stranding rate is typical or anomalous. In natural experiments, such as the current stranding study, we rely on nature to provide a randomization of environmental factors that may be of interest. As such, additional years of sampling should provide exposure to differing environmental factors that may impact stranding rates, which can be used to better understand the mechanism behind stranding and develop a risk stranding model specific to Kinbasket Reservoir.

Some of the objectives of additional sampling are:

- Does the proportion of pools with stranded fish stay constant from year-to-year or is it variable between years?

- If the proportion of stranding is variable between years, was the current year typical (i.e., close to the between year average) or was it anomalous. In case of the latter, did XXX represent an usually high proportion of stranding?

- Are there other environmental factors associated with the yearly stranding rates?

MQ2: Which areas of the reservoir have the greatest risk of fish stranding, and why?

Results from a study by Bell et al. (2008) indicated that most fish were stranded in habitats with a slope of less than six percent. This slope was used as a threshold for identifying isolated pools in Kinbasket Reservoir down to elevation 725 mASL, using a digital elevation model (DEM) based on 2002 aerial photography. A total of 6,548 pools were identified in Year 1, of which 4,989 (76%) pools were concentrated in Canoe Reach, Bush Arm, and Columbia Reach (Hanson and Nadeau 2010). Since fish presence and species composition did not vary between geographical location, elevation or by stranding risk, (according to data collected from the field surveys in Year 2 Table 4), these reaches were deemed at greatest risk of fish stranding due to the high proportion of isolated pools present.

Recommendations:

Isolated pools should be identified down to the minimum licenced operating elevation (707.41 mASL) to determine if other areas of the reservoir contain large concentrations of isolated pools should the reservoir be drawn to lower elevations.

MQ3: What is the area covered by isolated pools in the dewatered zone during maximum drawdown, relative to the total surface area of the drawdown zone?

This question will be addressed in Year 3 as results of the spring (May) 2018 aerial overflight survey become available. The results from this aerial survey will validate the presence, number, and approximate size of pools identified in Year 1 (Appendix 1). Seventy-four percent of pools sampled in Year 2 were not previously identified in Year 1 in their exact current (2018) locations and elevations, but occurred in the same general areas as those identified in Year 1 (Appendix 4).

Recommendations:

To date isolated pools formed in the DDZ of Kinbasket Reservoir have been surveyed between elevation 724-753 mASL. Although the reservoir has typically been operated down to 725 mASL in recent years, it has reached below this level four times in the past decade (2008-2018). In 2008 and 2009, the reservoirs was drawn down to elevations of 718 mASL and 719 mASL, respectively (Figure 2). Reservoir bottom topography and pool locations down to Kinbasket Reservoir's minimum licenced elevation (707.41 mASL) can be assessed through hydroacoustic surveys using a Biosonics MX Echosounder. These hydroacoustic surveys can be carried out any time of the year, thus avoiding winter conditions and ice cover. Hydroacoustic bathymetry mapping has a topographic delineation accuracy of 1.7 cm to a maximum depth of 100 m below the water's surface.

MQ4: What percentage of isolated pools contains stranded fish?

Seventy-eight percent (n=45) of isolated pools sampled in Year 2 contained fish. Thirty-three (57%) sampled pools contained live fish, 15 pools (26%) contained dead fish and three pools (5%) contained both live and dead fish. There was no statistical relationship between the presence of fish in isolated pools and geographical location, elevation, fish stranding risk (model Year 1), or the presence/absence of channels connecting to the reservoir. However, there was a positive correlation between fish abundance and pool depth/area, suggesting that deeper and larger pools contain more fish. The presence of dead fish did appear to be negatively correlated with days of pool isolation – a product of elevation, which seems counter-intuitive. It is possible that more dead fish may have been present in isolated pools, but that they decayed or were consumed by predators prior to these surveys.

Winter kill is likely a significant factor in isolated pool fish mortality. As part of the data logger trip in February 2017, it was discovered that nine of the ten low elevation (below 740 mASL) high risk pools (depths greater than 0.5 m) were frozen from surface to bottom and any fishes stranded in these pools would have died.

Another likely factor in fish mortality is dewatering of pools. All five dried pools surveyed contained dead fishes, which comprised 72% of all dead fishes observed. Pool dewatering is likely common, as observed during the February 2017 data logger survey by observing the depth of clear ice (presence of liquid water prior to freezing) present in the drilled holes. The proportion of clear ice to snow ice indicated that pools contained less than 60% depth (average=25%) of liquid water prior to freezing.

Recommendations:

Additional years of field sampling to determine if more species are being stranded that were not detected in Year 2, and to assess any annual variation in fish stranding. The data collected in Year 2 suggested that the four species of concern identified by BC Hydro were at low risk of stranding due to their absence in stranding pools. Additional years of sampling will provide an indication of whether the stranding risk of these species observed in Year 2 is typical or anomalous. To this end, gillnetting in deeper locations of large pools as a fish capture method in addition to beach seining, may reveal whether larger fish that can escape beach seining are in those pools.

Sampling under different ramping rates to determine if the rate of drawdown has any influence on fish stranding. Multiple years of sampling/monitoring will better assist in developing a fish stranding risk ranking model specific to Kinbasket Reservoir using criteria supported by baseline field data.

MQ5: At what time of year and/or reservoir elevations is stranding risk highest (e.g. at maximum drawdown)?

This question was partially addressed in Year 1 (Appendix 1) and will be further addressed in Year 3.

Hanson and Nadeau (2010) speculated that stranding risk should increase for the four species of concern (Bull Trout, Rainbow Trout, Burbot and Kokanee) when reservoir levels drop rapidly which occurs between January and May. Fishes were observed in isolated pools during both field surveys (October 2017 and May 2018) and across all elevations from 753 to 724 mASL, suggesting no relationship between fish stranding and drawdown rate or time of year of pool isolation (Table 4, Appendix 5). The presence of fish stranded in isolated pools did not vary across elevation (Table 4). According to the analyses conducted in Year 1 (Hanson and Nadeau 2010), pool formation increases with decreasing elevation (Figure 12), therefore, fish stranding risk increases with lower elevation as more pools become exposed. The data collected in Year 2 did not find a relationship between pool elevation and risk of stranding, but rather that fishes were equally stranded at all elevations. Therefore, it is suggested that fish stranding risk increases as more pools become exposed. This occurs in spring when low pool is observed. Furthermore, data from the spring 2018 aerial overflight will validate the presence and abundance of pools identified in Year 1 (Hanson and Nadeau 2010) which will become available in Year 3.

Recommendations:

Additional years of field-level monitoring will better identify any apparent patterns in fish stranding and based on additional data, a fish stranding risk-ranking model specific to the current Kinbasket Reservoir operations can be developed. Such a model should be developed for all fish species, not just salmonids and Burbot. The current model (developed in Year 1) has been customized only for the four species of concern identified by BC Hydro.

MQ6: What fish species and life history stages are potentially most affected by stranding as the reservoir is drawn down?

Based on the field surveys conducted in fall 2017 and spring 2018, cypriniformes (minnows and suckers) and sculpins were the dominant fishes stranded in isolated pools comprising 74.6% of all stranded fish observed. While 83% of fishes were juvenile, adult suckers and cyprinids were present. Twenty five percent of observed fish were not identifiable due to their state of decomposition; however, it is believed that most (if not all) of these unidentifiable dead fish were sculpins, based on the fact that nearly all dead and identifiable fish observed (except for a single unidentified cyprinid) were sculpins. BC Hydro identified four fish species of concern (Bull Trout, Rainbow Trout, Kokanee Salmon, and Burbot) for which monitoring programs have been developed by the Columbia River WUP CC. Only two Kokanee Salmon fry and one Bull Trout parr were observed in stranded pools suggesting that these species are not at high risk of stranding in Kinbasket Reservoir. After spring emergence, Kokanee Salmon fry migrate to the pelagic zone of lakes, avoiding shallow areas where stranding pools are forming (McPhail 2007; Sebastian and Weir 2013). Habitat assessments conducted for CLBMON-6 indicated that juvenile Bull Trout in Kinbasket Reservoir occupy nearshore areas with abundant cover (e.g., cobble, large woody debris, and vegetation) (Kang and Warnock 2017). The single Bull Trout parr observed during the fall survey occurred in a high elevation pool (752.2 mASL) adjacent to the Bush River causeway that contained cobble, large woody debris, and aquatic vegetation. Vegetation cover was restricted to isolated pools above elevation 747 mASL. Studies conducted for CLBMON-5, suggested that Burbot are at risk of stranding due to their spawn timing (January to April) in shallow littoral waters that coincides with the reservoir's highest drawdown rate (Kang et al. 2017). Despite this risk, no Burbot were observed in the 58 isolated pools surveyed for CLBMON-4.

Recommendations:

Additional years of sampling to identify any new fish species that were not previously observed in Year 2. The use of gill nets in large/deep pools to capture larger fishes (ex. adult Rainbow Trout, Kokanee, Bull Trout etc.).

MQ7: Are operational or non-operational changes recommended to mitigate or to reduce the risk of fish stranding?

This question will be addressed in detail in Year 3.

Operational Changes

Fish stranding was observed at all elevations along the DDZ of Kinbasket Reservoir, and did not appear to have a correlation with geographical area, or with the stranding risk ranking model developed in Year 1 (Figure 9, Table 4, Appendix 1). As a result, fish stranding risk in isolated pools appears to be similar across the DDZ. Based on the DEM analysis conducted in Year 1, the number of isolated pools increases with decreasing elevation, and 50% of pools are located below 733 mASL (Figure 12). Therefore, to reduce fish stranding, it is recommended to maintain a higher minimum low pool elevation, which would reduce the number of isolated pools exposed.

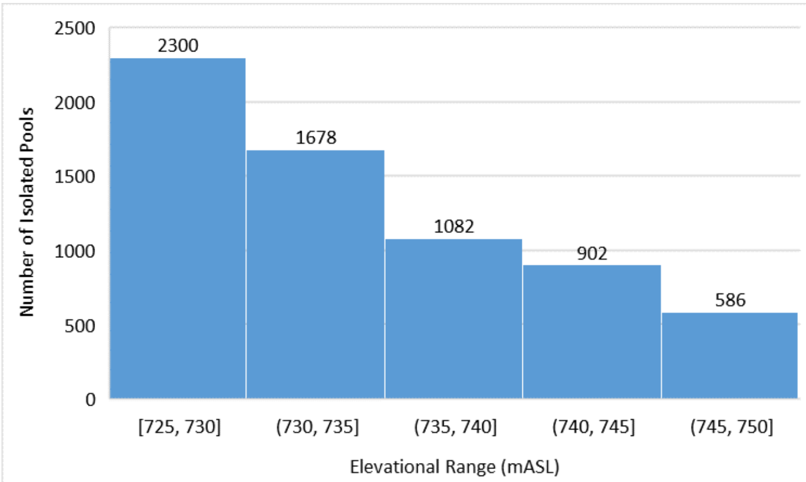


Figure 12. Number of isolated pools by elevational range located in the DDZ of Kinbasket Reservoir as identified from DEM in Year 1 (Appendix 1). DEM was based on 2002 aerial photography, flown at an elevation of 714 mASL. A total of 6,548 pools were identified between elevation 754 and 725 mASL along slopes less than six percent.

Non-operational Changes

Since 74% of isolated pools sampled in Year 2 (October 2017 and May 2018) were not previously identified in Year 1 (GIS analysis), it is currently unknown how many pools of the ones used for the DEM Analysis in Year 1 are still present (Appendix 1). Results from the May 08, 2018, aerial survey (available in Year 3) will determine the proportion of pools identified in Year 1 (2002) that still exist and where they are most concentrated. This will provide a sense of which areas are more stable (i.e., where pools persist longer overtime). Non-operational changes should occur in the most static locales with high pool formation, in order for these mitigations to remain effective in the long term. Physical works should focus on eliminating the number of isolated pools by increasing slope, providing egress channels, or both (Bell et al. 2008; Nagrodski et al. 2012).

6.2 Management Questions – Summary

Our preliminary answer to each of the management questions is summarized below (Table 11). The methods used are appropriate for collecting data that can be used to answer certain questions. For others, a different approach is required. Continued monitoring of fish stranding and pool formation in the drawdown zone should provide the necessary information to answer most management questions. To be sure we can answer some of the questions, recommended modifications to CLBMON-4 are provided below.

Table 11. Relationships between management questions (MQs), methods and results, sources of uncertainty, and the future of project CLBMON-4.

Management question (MQ)	Able to address MQ?	Scope		Sources of uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ1: What is the extent of fish stranding as a result of annual drawdown of the reservoir?	Mostly	Data collected in Oct 2017 and May 2018 identified the presence of fish in pools across all elevations	• Re-construct the stranding risk ranking model based on field collected data and for all species combined • Inventory pools down to minimum licenced elevation (707.41 mASL) • Additional sampling years to provide an indication of whether the stranding rate is typical or anomalous.	• Annual stranding variation • Long term pool stability • Variable reservoir operations
MQ2: Which areas of the reservoir have the greatest risk of fish stranding, and why?	Mostly	DEM analysis in Year 1. Data collected in 2017/2018 confirmed the presence of fish stranded in pools located in Bush Arm, Canoe Reach and Columbia Reach	• Identify pools down to the minimum licenced elevation to determine if other areas of the reservoir contain large numbers of pools = greater fish stranding	• Annual stranding variation • Long term pool stability • Variable reservoir operations
MQ3: What is the area covered by isolated pools in the dewatered zone during maximum drawdown, relative to the total surface area of the drawdown zone?	Partially	DEM analysis in Year 1. Aerial overflight survey conducted in May 2018 (results available in Year 3)	• Repeat DEM analysis using more current LiDAR imagery and hydroacoustic bathymetry mapping • Inventory pools down to minimum licenced elevation (707.41 mASL)	• Pool permeability (i.e., dewatering) • Long term pool stability • Variable reservoir operations

Management question (MQ)	Able to address MQ?	Scope		Sources of uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ4: What percentage of isolated pools contains stranded fish?	Partially	One year of field data collected in Oct 2017 and May 2018 on 58 pools	• Additional years of sampling will provide an indication of whether the stranding rate is typical or anomalous and to better understand the mechanisms behind stranding. •	• Annual stranding variation • Variable reservoir operations
MQ5: At what time of year and/or reservoir elevations is stranding risk highest (e.g., at maximum drawdown)?	Mostly	One year of field data collected in Oct 2017 and May 2018 on 58 pools. Risk model developed in Year 1	• Additional years of sampling • Re-construct the stranding risk ranking model based on field collected data and for all species combined	• Natural annual population variation • Variable reservoir operations
MQ6: What fish species and life history stages are potentially most affected by stranding as the reservoir is drawn down?	Mostly	One year of field data collected in Oct 2017 and May 2018 on 58 pools	• Additional years of sampling to capture additional species • Use of gill nets in larger and deeper pools to investigate the presence of larger fishes listed under the four species of concern identified by BC Hydro.	• Natural annual population variation • Variable reservoir operations
MQ7: Are operational or non-operational changes recommended to mitigate or to reduce the risk of fish stranding?	Partially	DEM analysis in Year 1. One year of field data collected in Oct 2017 and May 2018 on 58 pools. Aerial overflight survey conducted in May 2018 (results available in Year 3)	• Re-construct the stranding risk ranking model based on field collected data and for all species combined • Repeat DEM analysis using more current LiDAR imagery	• Pool permeability (i.e., dewatering) • Long term pool stability • Long-term persistence of mitigations

6.3 Summary of Recommendations

1. **Re-visit the fish stranding risk ranking model** to incorporate all fish species documented in Kinbasket Reservoir. The current risk model only includes the four species of concern identified by BC Hydro. Only three individual fish, one Bull Trout, and two Kokanee Salmon out of a total 2,133 fish captured in Year 2 belonged to the current four focal species. Nearly all fish sampled in stranded pools were cyprinids, suckers, and sculpins. A risk stranding model specific to Kinbasket Reservoir should be developed based on field-collected data and include multiple years of sampling to better understand the mechanism behind stranding and better identify the criteria used to develop such a model.
2. **Additional years of ground-level sampling to document additional fish species and life histories and provide an indication of whether the current stranding rate is typical or anomalous.** Field-level data from Year 2 determined no relationship between fish presence/abundance and elevation or fish stranding risk (based on model developed in Year 1) but indicated a positive relationship with fish abundance and size of pool (increased depth and area). Additional years of field data should provide exposure to differing environmental factors that may impact stranding rates, which can be used to better understand the mechanism behind stranding and develop a risk stranding model specific to Kinbasket Reservoir. Long term monitoring will better assess which areas of the reservoir have the greatest risk of stranding. Should additional field sampling be carried out, one day of helicopter transportation should be considered based on the conditions found in the spring of 2018. The deep mud only allowed for safe ground travel by foot and excluded transportation by ARGO, ATV, or boat (all boat ramps are stranded far above the reservoir level) which limits surveys to areas close to road access points. Helicopter access would allow the sampling of additional areas between road access points with high densities of stranding pools. Also, the use of gill nets in larger and deeper pools should be considered to better determine the presence of larger adult fishes that are listed as focal species by BC Hydro.
3. **Identify pools to minimum licenced elevation and for all slopes**. DEM analysis in Year 1 identified 6,548 pools in the DDZ of Kinbasket Reservoir along slopes less than 6% between elevation 754 and 725 mASL. Although the average minimum reservoir level has been increasing, the reservoir has been lowered below 725 mASL four times in the past 10 years (2008-2018) and down to 712 mASL in 2002. In order to capture the extent of fish stranding for all potential elevations, it is recommended to identify all potential isolated pools down to the reservoir's minimum licenced elevation of 707.42 mASL (or at least 718 mASL) and to identify other areas of the reservoir that may contain large numbers of isolated pools below 725 mASL.
4. **Analysis of aerial overflight surveys to validate Year 1 responses to management questions 1, 2, and 3, and to determine DDZ stability to develop non-operational mitigations to reduce fish stranding risk**. We conducted aerial surveys in May 2018 but have not yet completed data processing and analysis due to our preliminary findings that pool position and size have changed considerably (74% of pools sampled) since the aerial photography-based analysis was carried out in 2010 (Year 1). We are therefore suggesting to carry out this analysis in Year 3 to validate the responses (from Year 1) to management questions 1, 2, and 3. Imagery obtained from the 2018 helicopter overflight survey can approximate the number of pools isolated and categorize these pools (by area) into the same three area categories used for the "pool area" criterion used in the fish stranding risk ranking model developed in Year 1. These data combined with the average

fish density calculated from Year 2 can further address management question 1. In addition, results from the aerial survey will assess the presence of pools (e.g., number, size and location) located in areas (e.g., Canoe Reach, Bush Arm, and Columbia Reach) that contain large numbers of isolated pools as identified in Year 1. These data in turn can be used to evaluate the stability (i.e., areas where pools persist longer overtime) of these locations and identify areas that are relatively static for potential long-term non-operational mitigations such as slope re-contouring and pool channelization (fish egress).

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8.0 PHOTOS

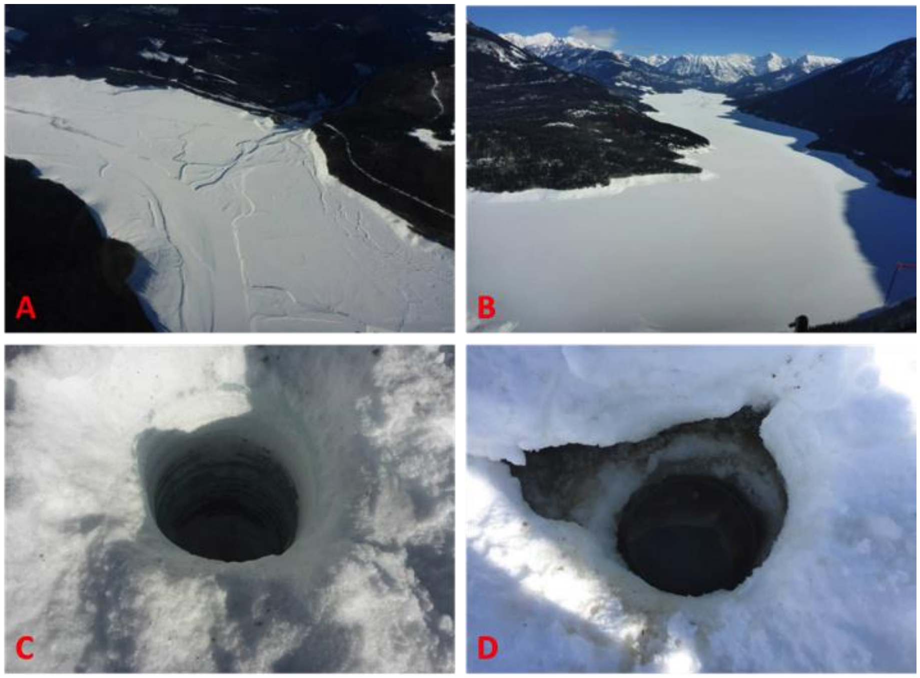

Photo 1. Winter conditions during the February 28, 2017, data logger survey. A. Looking upstream at Columbia Reach at the confluence with Beaver River. B. Looking upstream in Bush Arm. C. Drilled hole of a completely frozen isolated pool. D. Drilled hole of an isolated pool with presence of liquid water (only 10 cm deep).

Photo 2. **A. High elevation pool (752.47 mASL) with hydrologic connectivity via beaver dam in fall 2017, and B. spring 2018. C. High elevation (750.66 mASL) isolated pool in fall 2017, and D. spring 2018.** Both pools were located across Bear Island.

Photo 3. **A. Small, and B. large isolated pools located at low elevation (below 735 mASL).** All isolated pools below 747 mASL were bare of vegetation. Fifty percent of pools identified in Year 1 were located below 733 mASL.

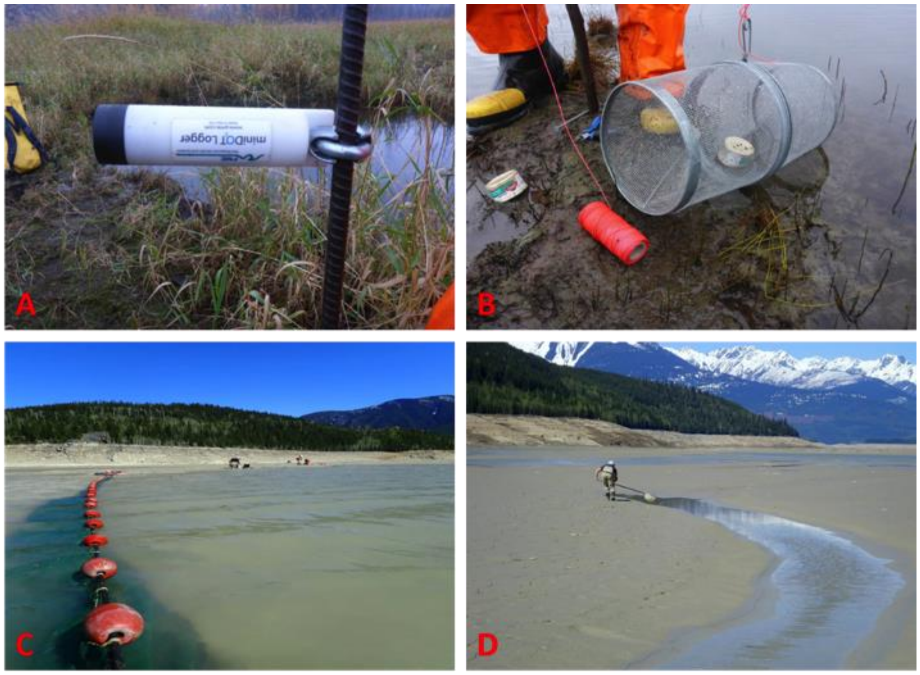

Photo 4. **A. MiniDOT data logger deployed in a high elevation pool in fall 2017. B. Minnow trap baited with canned cat food. C. Beach seine net deployed in a large low elevation isolated pool. D. Dip netting was an effective method for catching fish in shallow isolated pools.**

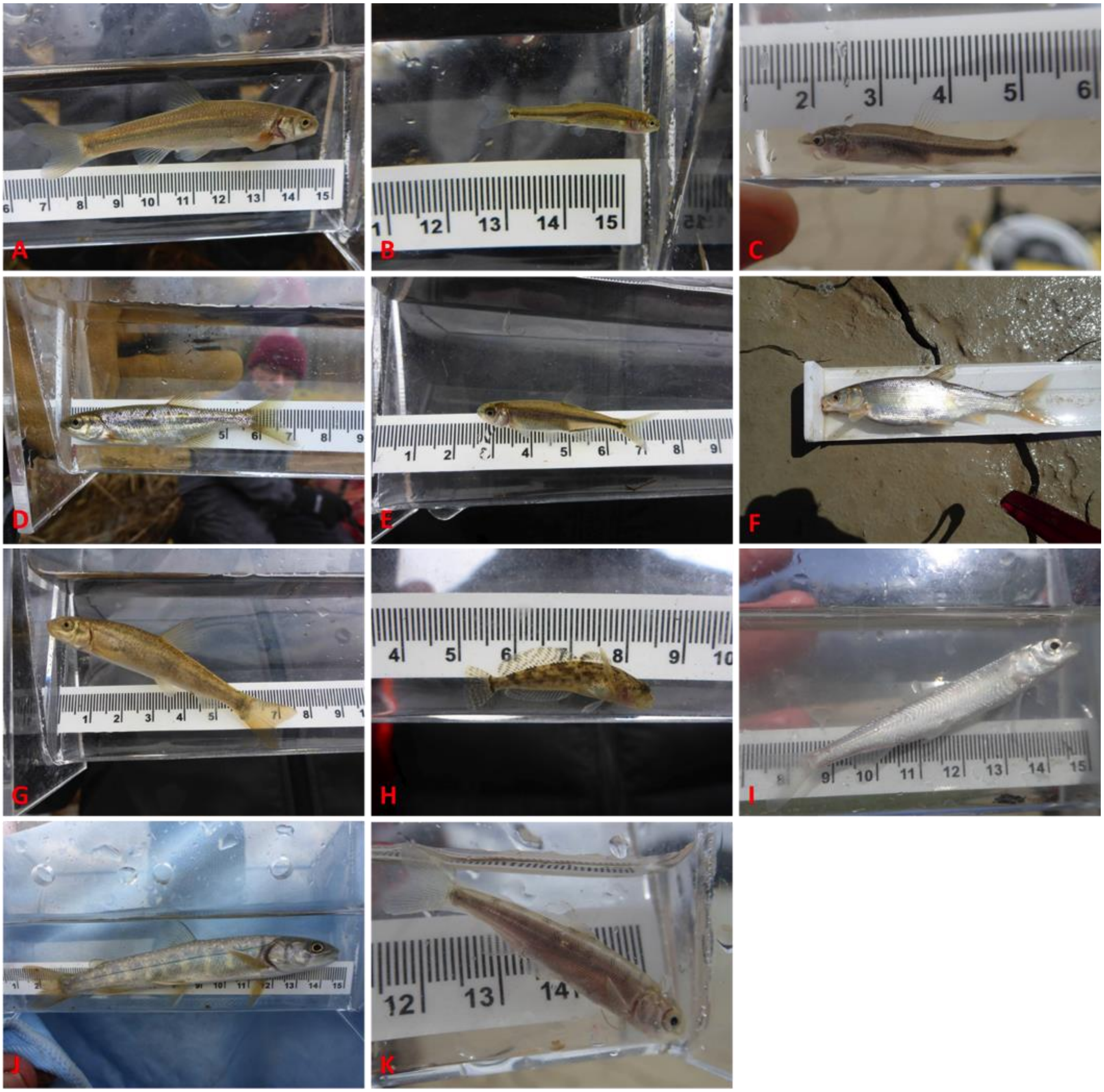

Photo 5. **Nine fishes captured in isolated pools were identified to species.** A. Lake Chub adult. B. Lake Chub juvenile. C. Longnose Dace juvenile. D. Redside Shiner adult. E. Redside Shiner juvenile. F. Peamouth adult. G. Longnose Sucker juvenile. H. Prickly Sculpin juvenile. I. Pygmy Whitefish. J. Bull Trout parr. K. Kokanee Salmon fry.

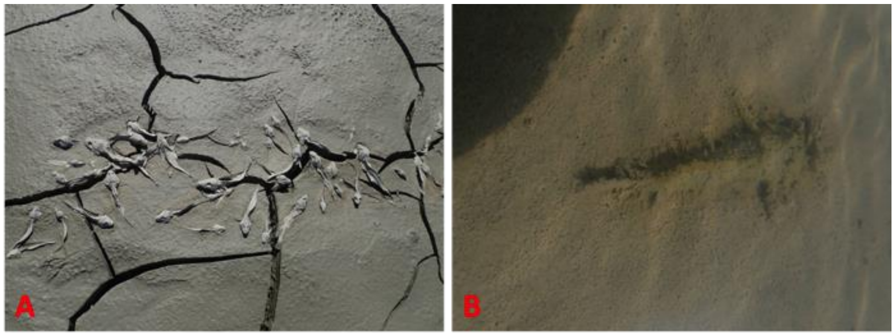

Photo 6. **Dead fish comprised 33% of all fishes observed and were present in 15 isolated pools sampled.** Dead sculpins were abundant in A. dried pools, and B. wetted pools.

Photo 7. **Tracks were the most common sign of wildlife observed at isolated pools, occurring at 24 (41%) sampled pools.** A. Gull tracks. B. Wolf tracks.

9.0 APPENDICES

Appendix A

Appendix 1. Year 1 CLBMON-4 report by Hanson and Nadeau (2010): Kinbasket Reservoir Fish Stranding Assessment.

Appendix 2. Summary data of the 11 stranded pools drilled in Kinbasket Reservoir on February 28. Only one stranded pool had water but not deep enough (10 cm) to deploy a data logger. The 11th pool drilled was not stranded but rather sampled for estimating reservoir elevation of ice-free water.

Location	Pond	UTM E	UTM N	Elevation (m)	Water present	Water depth (cm)	Total ice thickness (cm)	Clear ice thickness (cm)	Predicted pool depth[a] (cm)	Measured depth[b] (cm)	Pool fullness[c] (%)	Substrate
Columbia Reach	1	5708624	470084	739	No	0	55	20	177	20	11	Fines/mud
Columbia Reach	1	5708621	470082	739	No	0	59	20	177	20	11	Fines/mud
Columbia Reach	2	5709299	470932	735	No	0	48	0	70	20	0	Fines/mud
Bush Arm	3	5737911	471083	740	No	0	20	0	59	20	0	Fines/mud
Bush Harbour	4	5733683	459833	735	No	0	52	20	81	20	25	Fines/mud
Bush Harbour	5	5733776	459726	736	Yes	10	50	20	103	30	29	Fines/mud
Columbia Reach	6	5708693	471451	735	No	0	65	29	80	20	37	Fines/mud
Columbia Reach	7	5708788	471376	735	No	0	65	29	80	20	37	Fines/mud
Columbia Reach	8	5711550	469353	733	No	0	75	60	140	20	43	Fines/mud
Columbia Reach	9	5707686	473204	739	No	0	66	60	100	20	60	Fines/mud
Columbia Reach	10	5711814	469083	732	No	0	49	18	60	20	30	Fines/mud
Columbia Reach	11	5712066	468259	731	Yes	93	71	55	76	N/A	N/A	Fines/mud

[a] Predicted pool depth – Based from Year 1 CLBMON-4 report by Hanson and Nadeau (2010) – Appendix III High Risk Pools.
[b] Measured depth – Watered depth of the pool (sampled in February 2017) based on the sum of clear ice thickness and depth of liquid water (if present).
[c] Pool fullness – Percent of predicted pool depth holding water/clear ice prior to snow precipitation.
N/A – This pool was not stranded therefore pool water depth and fullness could not be determined.

Appendix 3. Six dissolved oxygen (DO) and temperature data loggers were deployed in fall 2017 in high elevation pools (between 752 and 747 mASL) in the drawdown zone of Bush Arm and shoreline north of Bear Island (west of Bush Arm) of Kinbasket Reservoir. Provincial freshwater fish codes used from Appendix 9 A. of the Fisheries Information Summary System (FISS): CAS – Prickly Sculpin, LKC – Lake Chub, LSU – Longnose Sucker, RSC – Redside Shiner.

Location	Pool label	Deployment date	Retrieval date	Elevation (mASL)	Hydrologic connectivity	Pool depth (cm)	Sensor depth (cm)	Fish in 2017	Fish in 2018
Bush Arm	BA23	24-Oct-17	05-May	751.51	Yes	30	25	None	N/A
Bush Arm	BA28	25-Oct-17	05-May	751.1	Yes	50	20	None	N/A
Bear Island	BI1	24-Oct-17	11-May	751.01	Yes	100	35	RSC	LKC
Bear Island	BI2	24-Oct-17	11-May	752.47	Yes	100	30	LKC, LSU	LKC, RSC
Bear Island	BI3	25-Oct-17	11-May	750.66	No	60	36	CAS	UNK (dead)
Bear Island[a]	BI5	24-Oct-17	05-May	747.89	No	100	55	LSU, CAS, RSC	None

[a] Reservoir water elevation was standing at 748.45 mASL during the fall data logger deployment (24-25 October). Pool BI5 was still inundated until 04 November (water levels provided by BC Hydro) when the reservoir water level declined to 747.61 mASL.

Appendix 4. Pools sampled in the DDZ of Kinbasket Reservoir in fall 2017 and spring 2018.

Location	Pool label	UTM(11U) Easting	UTM(11U) Northing	Date	Elevation (mASL)	Risk	Depth[a] (m)	Area[a] (m^2)	Identified in Year 1	Hydrologic connectivity[b]	Fish presence
Fall 2017											
Bush Arm	BA14	474554	5739956	25-Oct	752.20	Low	0.30	525	No	Yes	Yes
Bush Arm	BA22	461687	5735550	24-Oct	749.29	High	0.20	209	No	Yes	Yes
Bush Arm	BA23	461701	5735647	24-Oct	751.51	Low	0.30	504	No	Yes	No
Bush Arm	BA24	461635	5735609	24-Oct	750.76	Low	0.15	162	No	Yes	No
Bush Arm	BA25	461604	5735624	24-Oct	750.85	Low	0.10	1,100	No	Yes	No
Bush Arm	BA26	461438	5735621	24-Oct	748.18	Low	0.25	768	No	Yes	Yes
Bush Arm	BA27	474476	5739774	25-Oct	748.18	Low	0.23	720	No	Yes	No
Bush Arm	BA28	474831	5739230	25-Oct	751.10	Moderate	0.50	19,240	No	Yes	No
Bush Arm	BA29	470472	5737976	26-Oct	747.80	Moderate	2.13	19,266	Yes	Yes	No
Bear Island	BI1	453221	5736975	24-Oct	751.01	Moderate	1	450	No	Yes	Yes
Bear Island	BI2	453202	5737017	24-Oct	752.47	Moderate	1	600	No	Yes	Yes
Bear Island	BI3	453358	5736787	24-Oct	750.66	Low	0.60	30	No	No	Yes
Bear Island	BI4	453470	5736850	24-Oct	749.35	Low	0.20	60	No	Yes	Yes
Bear Island	BI5	454402	5736469	24-Oct	747.89	Moderate	1	2,349	No	Yes	Yes
Spring 2018											
Bush Arm	BA1	463847	5733295	13-May	727.50	Moderate	0	0	No	No	Yes
Bush Arm	BA2	463844	5733842	13-May	726.40	Moderate	0.30	160	Yes	No	No
Bush Arm	BA3	463825	5733825	13-May	726.70	Moderate	0.10	60	Yes	No	Yes
Bush Arm	BA4	463795	5733812	13-May	726.70	Moderate	0.15	90	No	No	Yes
Bush Arm	BA5	463723	5733838	13-May	726.40	High	0.50	60,000	Yes	No	Yes
Bush Arm	BA6	463762	5733303	13-May	726.50	Moderate	0	0	No	No	Yes
Bush Arm	BA7	463628	5733356	13-May	726.50	High	1	1,000,000	No	Yes	Yes
Bush Arm	BA8	463996	5733761	13-May	726.70	High	0.40	200	No	Yes	Yes
Bush Arm	BA9	463619	5734263	12-May	725	High	0.80	100,000	No	No	Yes
Bush Arm	BA10	474603	5739934	12-May	749	Moderate	0.50	240	No	No	Yes
Bush Arm	BA11	463902	5733736	13-May	726.70	Moderate	0.20	60	Yes	No	Yes
Bush Arm	BA12	463934	5733868	13-May	726.70	High	0.50	490	No	No	Yes
Bush Arm	BA13	463314	5735197	12-May	725.30	Moderate	0.20	30	No	Yes	Yes

Location	Pool label	UTM(11U) Easting	UTM(11U) Northing	Date	Elevation (mASL)	Risk	Depth[a] (m)	Area[a] (m^2)	Identified in Year 1	Hydrologic connectivity[b]	Fish presence
Bush Arm	BA14	474554	5739956	11-May	752.20	Low	0.30	525	No	No	Yes
Bush Arm	BA15	463976	5734245	12-May	725	Moderate	0	0	No	No	Yes
Bush Arm	BA16	463657	5734774	12-May	724	Moderate	0.20	200	No	No	Yes
Bush Arm	BA17	463598	5734792	12-May	724	Moderate	0	0	No	No	Yes
Bush Arm	BA18	463557	5734812	12-May	724	Moderate	0.10	20	No	No	Yes
Bush Arm	BA19	463374	5734941	12-May	725.30	Moderate	0.10	200	No	No	Yes
Bush Arm	BA20	463366	5735076	12-May	725.30	High	1	567	No	Yes	Yes
Bush Arm	BA21	463311	5735177	12-May	725.30	High	2	90,000	No	No	Yes
Bear Island	BI1	453221	5736975	11-May	751.01	Moderate	1	450	No	Yes	Yes
Bear Island	BI2	453202	5737017	11-May	752.47	Moderate	1	600	No	Yes	Yes
Bear Island	BI3	453358	5736787	11-May	750.66	Low	0.60	30	No	No	Yes
Bear Island	BI4	453470	5736850	11-May	749.35	Low	0.20	60	No	Yes	Yes
Bear Island	BI5	454402	5736469	11-May	747.89	Moderate	1	2,349	No	No	Yes
Canoe Reach	CA1	359645	5841826	16-May	728	Moderate	0	0	No	No	Yes
Canoe Reach	CA2	359336	5842396	15-May	728	High	0.30	600	No	Yes	No
Canoe Reach	CA3	359567	5842098	15-May	727.70	High	0.60	1,600	Yes	Yes	Yes
Canoe Reach	CA4	359653	5842186	15-May	727.50	High	0.60	2,000	No	Yes	Yes
Canoe Reach	CA5	359796	5841910	15-May	726	High	0.30	300	No	Yes	Yes
Canoe Reach	CA6	359705	5841853	15-May	728	High	0.30	240	No	Yes	Yes
Canoe Reach	CA7	359669	5841505	15-May	737	High	2	1,500	No	No	Yes
Canoe Reach	CA8	359704	5841416	15-May	737.10	High	0.30	400	No	No	No
Canoe Reach	CA9	359714	5841351	15-May	734	High	0.30	800	Yes	Yes	Yes
Canoe Reach	CA10	359709	5841237	15-May	733.40	High	0.60	300	No	No	Yes
Canoe Reach	CA11	359703	5841160	15-May	732.90	High	2	20,000	Yes	Yes	Yes
Canoe Reach	CA12	359941	5841056	15-May	733	High	2	5,000	Yes	No	Yes
Canoe Reach	CA13	359906	5841169	15-May	733	High	1	300	Yes	No	Yes
Canoe Reach	CA14	359977	5841079	15-May	734.60	High	2	3,000	No	No	Yes
Columbia Reach	CO1	468864	5711208	10-May	731	High	0.20	336	No	No	No
Columbia Reach	CO2	468893	5711174	10-May	731.80	High	0.20	10,000	No	Yes	Yes
Columbia Reach	CO3	469212	5711055	10-May	731.80	High	0.20	10,000	Yes	Yes	Yes
Columbia Reach	CO4	468502	5712169	10-May	730	High	0.50	900	Yes	No	Yes

Location	Pool label	UTM(11U) Easting	UTM(11U) Northing	Date	Elevation (mASL)	Risk	Depth[a] (m)	Area[a] (m^2)	Identified in Year 1	Hydrologic connectivity[b]	Fish presence
Columbia Reach	CO5	468093	5712047	10-May	730	High	0.50	240,000	No	No	Yes
Columbia Reach	CO6	468119	5712006	10-May	731	High	0.41	800	Yes	No	No
Columbia Reach	CO7	470866	5708709	10-May	735	High	0.20	140	Yes	No	No
Columbia Reach	CO8	470498	5708501	10-May	735	High	0.80	166,000	No	Yes	Yes
Columbia Reach	CO9	470206	5708603	10-May	736	Moderate	0.60	800	No	No	No
Columbia Reach	CO10	470080	5708623	10-May	739	High	0.52	1,500	Yes	No	Yes

[a] Depth and area values denoted by a “0” indicate a dry pool.

Appendix 5. Number of isolated pools sampled and the number of pools containing fish (live and dead) sampled by risk criteria used in the fish stranding risk ranking model developed in Year 1 (Hanson and Nadeau 2010, Appendix 1).

Risk criteria	# Pools available[a]	# Pools sampled	# Pools with live fish	# Pools with dead fish
Wetted pool depth				
<0.1 m	1,168	7	1	5
≥0.1 m ≤0.3 m	4,186	25	11	6
>0.3 m	1,194	26	21	4
Wetted pool area				
<20 m^2	1,990	5	0	5
≥20 m ≤200 m^2	3,085	13	6	6
>200 m^2	1,473	40	27	4
Days of isolation				
>300 days	184	10	7	1
≤200 ≥300 days	1,111	5	2	0
<200 days	5,253	43	24	14
Time of year pool is isolated				
Jun through Sep	145	10	7	1
Oct through Dec	1,619	5	2	0
Jan through May	4,784	43	24	14
Risk category				
Low	1,601	8	4	1
Moderate	801	20	7	10
High	4,146	30	22	4
Total	**6,548**	**58**	**33**	**15**

[a] Number of pools available was informed from Year 1 for CLBMON-4 using a digital elevation model (DEM) based on 2002 aerial photography flown at an elevation of 714 mASL.

Appendix 6. Presence and composition of live and dead fishes sampled in pools in the fall 2017 and spring 2018 surveys. Refer to Appendix 4 for location and sampling dates.

Location	Pool label	Elevation (mASL)	Hydrologic connectivity	Sampling method[a]	Live fishes[b]	Live fish count	Dead fishes[b]	Dead fish count
Bush Arm	BA14	752.20	No	DN	BT	1		
Bush Arm	BA22	749.29	Yes	DN	RSC	106		
Bush Arm	BA23	751.51	Yes	DN				
Bush Arm	BA24	750.76	Yes	None				
Bush Arm	BA25	750.85	Yes	None				
Bush Arm	BA26	748.18	Yes	DN	RSC	55		
Bush Arm	BA27	748.18	Yes	None				
Bush Arm	BA28	751.10	Yes	DN, MT				
Bush Arm	BA29	747.80	Yes	ARIS				
Bear Island	BI1	751.01	Yes	DN, MT	RSC	9		
Bear Island	BI2	752.47	Yes	MT	LKC, LSU	9		
Bear Island	BI3	750.66	No	DN	CAS	4		
Bear Island	BI4	749.35	Yes	DN	RSC	103		
Bear Island	BI5	747.89	No	DP, MT	LSU, CAS, RSC	15		
Fall Total						**302**		**0**
Bush Arm	BA1	727.50	DRY	V			UNK	148
Bush Arm	BA2	726.40	No	V				
Bush Arm	BA3	726.70	No	V			UNK	7
Bush Arm	BA4	726.70	No	V			C, CC	5
Bush Arm	BA5	726.40	No	BS	LKC, RSC	3		
Bush Arm	BA6	726.50	DRY	V			UNK	80
Bush Arm	BA7	726.50	Yes	BS	PCC, RSC, SU	101		
Bush Arm	BA8	726.70	Yes	BS	LKC, CAS, SU	4		
Bush Arm	BA9	725	No	BS	LKC, PCC, RSC, SU	390		
Bush Arm	BA10	749	No	DN	RSC	2		
Bush Arm	BA11	726.70	No	DN	LKC, SU	16		
Bush Arm	BA12	726.70	No	BS, V	LKC, RSC	8	UNK	12
Bush Arm	BA13	725.30	Yes	DN	LKC, RSC	3		
Bush Arm	BA14	752.20	No	MT	RSC, SU	12		
Bush Arm	BA15	725	DRY	V			CC, UNK	96
Bush Arm	BA16	724	No	V	C	30	UNK	90
Bush Arm	BA17	724	DRY	V			CC	25
Bush Arm	BA18	724	No	V			CC, UNK	5
Bush Arm	BA19	725.30	No	V			UNK	9
Bush Arm	BA20	725.30	Yes	BS	PCC, CAS, RSC	7		

Location	Pool label	Elevation (mASL)	Hydrologic connectivity	Sampling method[a]	Live fishes[b]	Live fish count	Dead fishes[b]	Dead fish count
Bush Arm	BA21	725.30	No	BS	LKC, LSU, CAS, PW, RSC	179		
Bear Island	BI1	751.01	Yes	DN	LKC	1		
Bear Island	BI2	752.47	Yes	DN	LKC, RSC	13		
Bear Island	BI3	750.66	No	DN			UNK	1
Bear Island	BI4	749.35	Yes	DN	RSC	6		
Bear Island	BI5	747.89	No	None				
Canoe Reach	CA1	728	DRY	V			CC	86
Canoe Reach	CA2	728	Yes	None				
Canoe Reach	CA3	727.70	Yes	BS	LKC, RSC	11		
Canoe Reach	CA4	727.50	Yes	BS	PCC, SU	27		
Canoe Reach	CA5	726	Yes	BS	LKC	16		
Canoe Reach	CA6	728	Yes	V			CC	1
Canoe Reach	CA7	737	No	MT	RSC	9		
Canoe Reach	CA8	737.10	No	MT				
Canoe Reach	CA9	734	Yes	V	C	10		
Canoe Reach	CA10	733.40	No	V			UNK	130
Canoe Reach	CA11	732.90	Yes	MT	CAS	4		
Canoe Reach	CA12	733	No	MT	CAS	21		
Canoe Reach	CA13	733	No	MT	LKC, CAS, RSC, SU	33		
Canoe Reach	CA14	734.60	No	MT	CAS	7		
Columbia Reach	CO1	731	No	None				
Columbia Reach	CO2	731.80	Yes	V	RSC,	100		
Columbia Reach	CO3	731.80	Yes	BS	LKC, RSC	29	UNK	6
Columbia Reach	CO4	730	No	BS	C, LKC, CAS, RSC	6		
Columbia Reach	CO5	730	No	BS	LKC, LNC, CAS, RSC, SU	68		
Columbia Reach	CO6	731	No	None				
Columbia Reach	CO7	735	No	None				
Columbia Reach	CO8	735	Yes	BS	KO, PCC, CAS, SU	11		
Columbia Reach	CO9	736	No	BS				
Columbia Reach	CO10	739	No	BS			UNK	3
Spring Total						**1,127**		**704**
Year 2 Total						**1,429**		**704**

[a] Sampling method: ARIS – sonar, BS – beach seine, DN – dip net, MT – minnow trap, V – visual.
[b] Provincial freshwater fish codes from Appendix 9 A. of the Fisheries Information Summary System (FISS): BT – Bull Trout (*Salvelinus confluentus*), KO – Kokanee Salmon (*Oncorhynchus nerka*), LKC – Lake Chub (*Couesius plumbeus*), LNC – Longnose Dace (*Rhinichthys cataractae*), LSU – Longnose Sucker (*Catostomus Catostomus*), PCC – Peamouth (*Mylocheilus caurinus*), Prickly Sculpin (*Cottus asper*) – CAS, PW – Pygmy Whitefish (*Prosopium coulterii*), RSC – Redside Shiner (*Richardsonius balteatus*), C – Minnow sp. (Cyprinidae), CC – Sculpin sp. (*Cottus* sp.), SU – Sucker sp. (*Catostomus* sp.), UNK – Unknown fish.

Appendix 7. Fish counts (live and dead) in sampled pools along the DDZ of Kinbasket Reservoir for CLBMON-4. Bull Trout is provincially blue-listed and ranked a Species of Special Concern in Canada (COSEWIC 2012). Bull Trout and Kokanee Salmon were identified by BC Hydro (2007) as species of concern.

Species	Total count	Live count	Dead count
Bull Trout (*Salvelinus confluentus*)	1	1	
Kokanee Salmon (*Oncorhynchus nerka*)	2	2	
Lake Chub (*Couesius plumbeus*)	316	316	
Longnose Dace (*Rhinichthys cataractae*)	1	1	
Longnose Sucker (*Catostomus catostomus*)	13	13	
Peamouth (*Mylocheilus caurinus*)	77	77	
Prickly Sculpin (*Cottus asper*)	45	45	
Pygmy Whitefish (*Prosopium coulterii*)	1	1	
Redside Shiner (*Richardsonius balteatus*)	822	822	
Sculpin sp. (*Cottus* sp.)	165		165
Sucker sp. (*Catostomus* sp.)	109	109	
Cyprinidae sp.	43	42	1
Unidentifiable fish	538	0	538
Total count	**2,133**	**1,429**	**704**

Appendix 8. Length measurement statistics for all fish taxa observed in pools sampled along the DDZ of Kinbasket Reservoir.

Species	Number of fish measured	Average length (mm)	Minimum length (mm)	Maximum length (mm)
Bull Trout (*Salvelinus confluentus*)	1	125	125	125
Kokanee Salmon (*Oncorhynchus nerka*)	2	40	40	40
Lake Chub (*Couesius plumbeus*)	127	56	22	105
Longnose Dace (*Rhinichthys cataractae*)	1	35	35	35
Longnose Sucker (*Catostomus catostomus*)	13	90	50	280
Peamouth (*Mylocheilus caurinus*)	16	162	120	226
Prickly Sculpin (*Cottus asper*)	48	69	30	184
Pygmy Whitefish (*Prosopium coulterii*)	1	71	71	71
Redside Shiner (*Richardsonius balteatus*)	178	46	22	108
Sucker sp. (Catostomus sp.)	80	96	7	245
Total	**467**			