Columbia River Project Water Use Plan

Mica Tailrace Fish Indexing Study

Reference: CLBMON 60

Columbia River Headpond Drawdown Impacts (Fish Stranding and Water Quality) Monitoring –Interim Report (Year 2)

Study Period: March 2013 to May 2014

Canadian Columbia River Inter-tribal Fisheries Commission (CCRIFC)

Poisson Consulting Ltd.

Applied Aquatic Research Ltd.

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Executive Summary

BC Hydro recently completed the Water Use Plan (WUP) for the Columbia River Mica Dam Hydroelectric Project (BC Hydro, March 2006) and an Environmental Impact Assessment (EIA). for the installation of two new turbines (Mica 5 and 6). The EIA was completed in response the Order (then Ministry of Environment – MOE), dated August 12, 2010 section 1-b. Two key concerns were identified:

1. Changes in distribution of ichthyofauna downstream of the tailrace; and
2. The effects of addition of Mica 5 & 6 turbines on water temperatures downstream of the Mica Dam Tailrace (BC Hydro 2011).

Given the proposed time line of monitoring, BC Hydro determined that hypothesis testing to address the management questions was neither practical nor feasible. The primary objectives of the program are to monitor the ichthyofauna and thermal regime in the Mica Dam tailrace during the two summers before and the two summers after the service date for full operations of Mica 5 and 6 (cf. Schedule, section 2.5) (BC Hydro 2011a). Based on discussions with the project team, the ichthyofauna surveys were and will be conducted in the fall (October) while the temperature study will be conducted year round with 3-5 visits per year.

To address the key concerns two field surveys were initiated: 1) an ichthyofauna survey of the section of Columbia River between the Mica Dam tailrace to the Blue Bridge ~2.5 km downstream, 2) a temperature study which deployed temperature loggers at six to eight locations (opposite banks) between the tailrace and the Blue Bridge. The temperature logger deployment was initiated in September 2012, and will continue until the end of the study in spring 2017. The fish surveys (using electrofishing) were done in October 2012 and 2013 and are tentatively targeted for fall 2016 and 2017. The study years were chosen to meet the Water Use Planning requirements for two years pre- and post- monitoring, as outlined in the CLBMON 60 project Terms of Reference (BC Hydro 2011a), and refined through consultation with BC Hydro project staff.

Boat electrofishing was used to enumerate and characterize the ichthyofauna within the five sites in the study area after stable discharge from the dam had been achieved for a minimum period of 4-6 hours. The 2013 sampling events all occurred at a constant minimum discharge value of ~530m^3/s with two turbines in operation. In 2013 a total of 231 fishes of three species were captured, including nine Bull Trout (366-820mm and 466g – 6kg) 125 Kokanee (67 – 388mm and 1g – 674g) and 96 Mountain Whitefish (75 –367mm and 3 – 438g). Over all sites a total of 1006 fishes were observed, which included two Rainbow Trout, 515 Mountain Whitefish, 440 Kokanee and 23 Bull Trout.

Four backpack electrofishing sites were used to define the sampling for capture of small bodied fish fauna (Ford and Hildebrand 2008). Due to the consistent, moderate flow levels in 2013, all four of the backpack sites were sampled, whereas only two sites could be sampled in 2012. In 2013, a total of 2324electroseconds was used over four sites to capture 16 fishes of three (3) species (and several unidentified Sculpins). A Smith-Root LR24 backpack electrofisher set at 300 volts, 60 Hertz, and a pulse width of 25% was used by a three person crew. At site EF01,

no fish were captured. At site EF02, one (1) Prickly Sculpin and six (6) unidentified Sculpins species were captured, and ranged in length from 17 to 28 mm. At site EF03, a total of 19 fishes, including one (1) Kokanee (89mm length), eight (8) Slimy Sculpin, four (4) Prickly Sculpin and six (6) unidentified Sculpins which ranged in size from 21mm to 82mm were captured. At site EF04, four (4) Slimy Sculpin, two (2) Prickly Sculpin and three (3) unidentified sculpin species were captured. Fishes ranged in size from 25 to 87mm.

The condition of adult Mountain Whitefish, fry Kokanee and adult Sculpins (all species aggregated) decreased since 2008, while the condition of juvenile Mountain Whitefish and adult Bull Trout increased since 2008. The largest decrease in average condition was for Kokanee fry and the greatest increase in average condition since 2008 was for adult Bull Trout.

The body condition of the four salmonid species was assessed with respect to their percent change in weight for a typical fish within a size class and compared to 2012 condition values. Bull Trout have increased in weight, though not significantly, since 2012 for both small and large fish and had the lowest condition in the 2008 sampling year. Kokanee adults were significantly heavier in 2013 than in 2012 and the effect size estimate for fry was quite variable and did not show a significant increase or decrease since 2012. Mountain Whitefish fry had a significant decrease in body condition since 2012 and adults had a significant increase in comparison to 2012. The body condition of Mountain Whitefish in 2008 was lower, though not significantly, for the fry and higher for the adults. Sculpin body condition was higher in 2013 but not statistically significant due to high variability in the data.

In 2012 temperature loggers were deployed downstream of Mica Dam on both banks in paired arrays to assess temperature effects of operations and were downloaded on April 3, June 11, and October 3, 2013 and May 2014. From November 2013 until May 2014, there is no discernable difference between the reference logger and the other loggers, indicating that the same winter conditions and isothermal flow through the dam are affecting all tailrace sites in an equivalent way. There were issues associated with data collection intervals for TidbiTs in the headpond as well as in several of the downstream loggers, particularly the pairs deployed on the left and right upstream banks near the blue bridge. We are currently working to address the deployment issues and QA/QC the data. It has not been included in the analysis for this report and may be included as part of the analysis in future reports once the data deficiencies have been fully addressed. All loggers were recently downloaded at the end of the 2014 summer season. Based on preliminary review it appears that the downstream temperature data is complete. This would give us two (2) full summers of pre-operation temperature and ichthyofauna data for analysis, which meets the requirements of the Environmental Assessment and allows us to address the key management questions. Once we have completed collection of two years post-operation data, we will be able to analyse the pre- and post- data, to see what the effects of Mica 5 and Mica 6 are. The temperature data collected to date shows no consistent difference between left and right banks in the tailrace section. We will discuss the proposed alterations to the headpond area with project and BC Hydro staff. We recommend that the existing temperature monitoring remain continuous throughout the project to completion, to allow more interpretation and analysis of temperature trends.

Suggested citation:

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CCRIFC/KNC staff - JoAnne Fisher, Jim Clarricoates (CCRIFC field technicians), Bill Green (Director) Will Warnock, Aquatic Biologist and Jose Galdamez (KNC GIS, mapping specialist).

Table of Contents

List of Tables

List of Figures

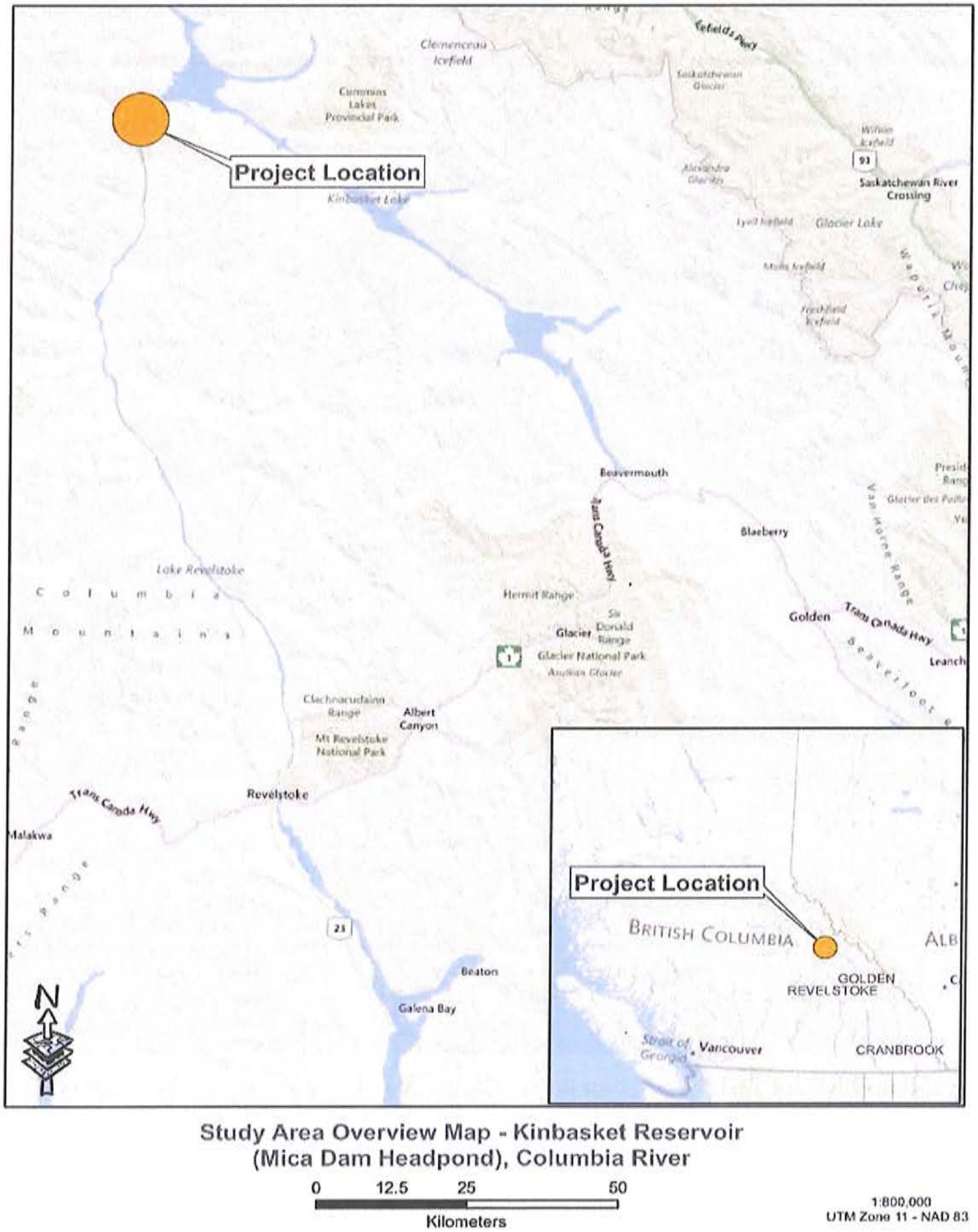

Figure 1-1. General Project Location and Columbia River Study Area for the Mica Tailrace Fish Population Indexing Study, relative to the town of Revelstoke and Kinbasket Reservoir.

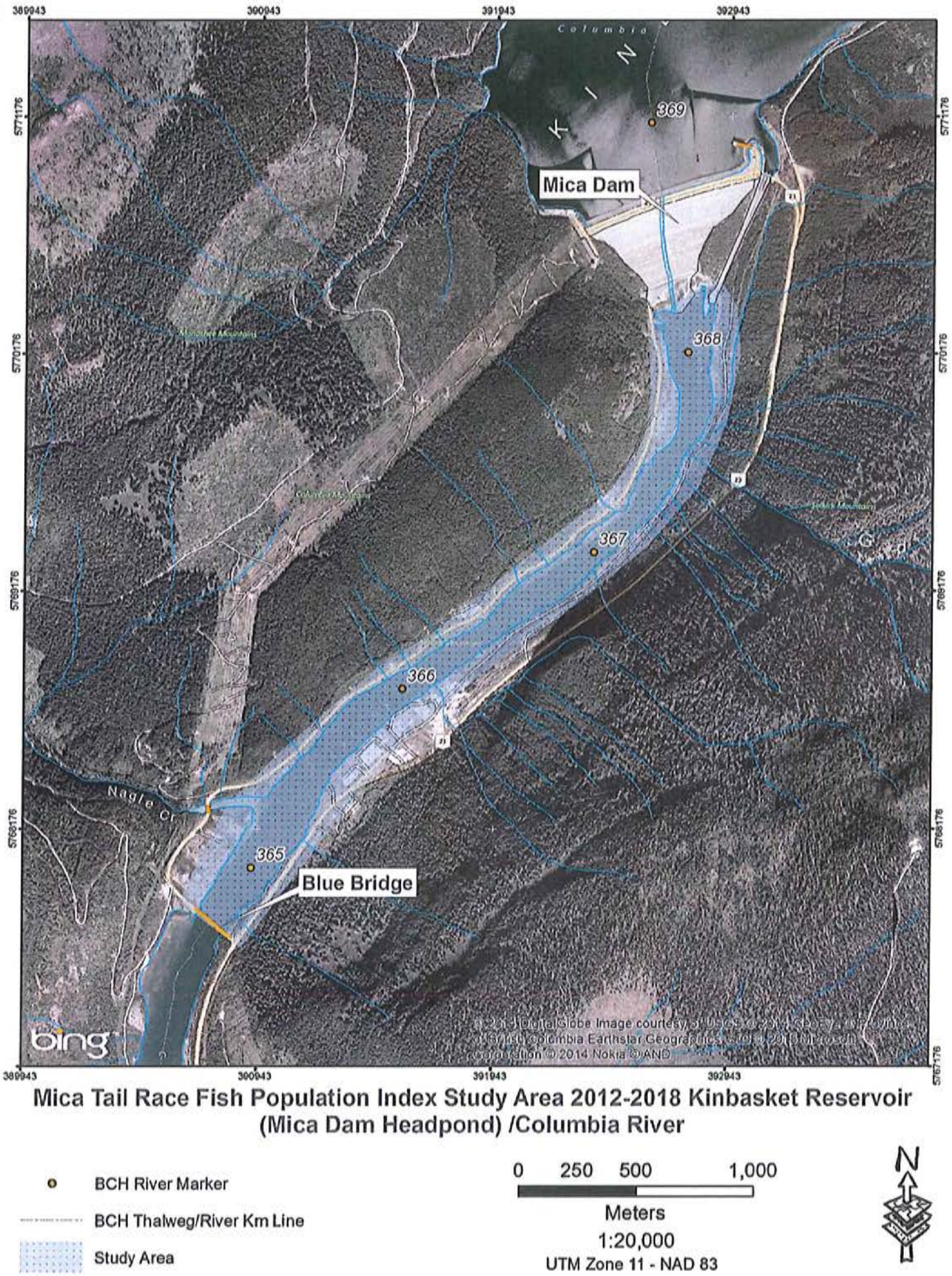

Figure 1-2. **Mica Tailrace Fish Population Index Study Area 2013.Locations of Mica Dam, Nagle Creek and the Blue Bridge shown for reference.**

List of Appendices

1 Introduction

BC Hydro recently completed a Water Use Plan (WUP) for the Columbia River, along with the Kinbasket Reservoir Fish and Wildlife Information Plan, which outlined the Terms of Reference (TOR) for monitoring programs required through the WUP process (RL&L 2001; BC Hydro 2007; Kinbasket Reservoir Fish and Wildlife Monitoring Program TOR August 2011).

The WUP seeks to balance power generation with other water uses that provide social, environmental and economic benefits to British Columbians. The WUP process for the Columbia River was initiated in 2004 and completed in 2007 based on recommendations from the Consultative Committee (BC Hydro 2004, BC Hydro, 2007). Subsequently, Monitoring Program TOR (BC Hydro 2011a, 2011b) were developed to implement and assess recommendations from the WUP and the subsequent Environmental Impact assessment, which was triggered by the proposed addition of two turbines (Mica 5/6). This particular study was designed to assess the impacts to fish and fish habitat in the Mica Dam Tailrace (CLBMON 60) as a result of the proposed expansion.

In 2009, in accordance with the BC Environmental Assessment Act, BC Hydro submitted two Environmental Assessment Certificate Applications (EACAs), one for each of the proposed Mica Unit 5 and Mica Unit 6 projects (BC Hydro 2011a). The potential effects of the operation of the proposed project on the downstream fish community in the Columbia River are unknown. One of the commitments of the project Environmental Assessment (EA) mitigation measures was the fish indexing and thermal regime monitoring program outlined in the TOR (KCP 2009 p. 4/5).

As stated in the Mica Tailrace Fish Indexing Study TOR (CLBMON 60) Request for Proposals (RFP) and monitoring program requirements (BC Hydro 2011b), "There are no management hypotheses associated with this program, as hypotheses are unlikely to be falsified within the time frame allocated for the project.". "The primary objectives of the monitoring program are to monitor the ichthyofauna and thermal regime in the Mica Dam tailrace during the two summers before and the two summers after the service date for full operations of Mica 5 and 6" (cf. Schedule, section 2.5), as described in the RFP (BC Hydro 2011). The Year 1 interim report (Irvine et. al. 2013) summarized the field sampling program and results from September 2012 to February 2013. The general project location is shown in Figure 1-1. The proposed study area, as described in the TOR (BC Hydro 2011a) is shown in Figure 1-2.

This report which represents the second interim report, outlines the study design and results for Year Two (2) (2013-14) of the ichthyofauna and water temperature monitoring program and how the key management questions and key water use decisions affected by the operation of the proposed projects are addressed. This report summarises the field program and results from March 2013 to May 2014. Year 2 activities included continued temperature (March 2013 to May 2014) and ichthyofauna monitoring (October 2013). Subsequent reports will synthesize the pre-assessment results and post-construction monitoring results.

The proposed completion date for construction and operation of the two additional turbines is tentatively 2015. To fulfill the requirements for two years of study prior to and after turbine installation, studies are required in 2013, 2014 and in 2016 and 2017. The Year One (1) Study and report were completed and submitted in October 2013 (Irvine et. al. 2013); this report completes the second year (2014) requirement. The post-installation studies are required to assess the potential impacts of operation of turbines five (5) and six (6) on water temperatures and fish distribution within the zone of effect downstream of the Mica Dam, particularly in the ~2.5 km section between the tailrace and the Blue Bridge (Figure 1-1). Other studies have been or are currently being completed with respect to flows, temperature, fish habitat and fish distribution in the Kinbasket Reservoir and Columbia River downstream of the dam, including CLBMON-1 (Total Gas Pressure Monitoring), CLBMON-2 (Kokanee population monitoring), CLBMON-4 (Fish stranding assessment), and many others (BC Hydro 2013).

The second year of study was completed in 2013 and the study program will now have a hiatus until the installation of the two additional turbines for Mica 5 and Mica 6 has been completed. It is predicted that Mica 6 will be operational by 2015 so the project is slated to recommence in 2016.

1.1 Background and Scope

Seasonal flow patterns in the Columbia River are typical of mountain streams in the area. As a result, a single snowmelt runoff dominates the hydrograph peak, while secondary rainfall events in the summer and fall also increase seasonal flow variation (KCB 2009). There are 2 currently operating Water Survey of Canada (WSC) gauging stations (WSC 08NE049, 08NB005) and several historic stations that provide baseline hydrology information. Poisson Consulting Ltd. (Poisson) have developed and maintain a database to consolidate flow, elevation and temperature data for WLR projects. There is also a continuous gauge above the Mica Dam at Donald operated by BC Hydro which characterises flow patterns and precipitation within the Columbia River. The WSC data showed that Columbia River is a snowmelt dominated system, with peak runoff/freshet conditions typically observed in late May through to early July and winter low flows from October to April. Low flow periods are typically observed in the late winter, when the dominant precipitation form occurs as snowfall. The annual peak monthly inflow for the period from 1940 to 1999 at Mica averaged 574.25 m^3s^{-1}, with winter low flows ranging from mean monthly inflows of 103 to 132 m^3s^{-1} (BC Hydro 2007).

This background data was used to develop hydrographs for Columbia River and inform hydrology studies. The hydrologic studies were then used to identify constraints and determine operational requirements for the facility, identify periods of low (i.e., critical) flows relative to fish habitat use and develop minimum flow requirements.

Previous fish studies suggest that the Columbia River below Mica Dam supports populations of Rainbow Trout (RBT), *Oncorhynchus mykiss*, Kokanee (*O. nerka*), Bull Trout (*Salvelinus confluentus*) and Mountain Whitefish (*Prosopium williamsoni*), all of which are salmonids, in addition to Slimy (*Cottus cognatus)*, Torrent (*C. rhotheus*) and Prickly Sculpins (*C. asper*) as outlined in Table 1-1.

Table 1-1. Fish species documented in the Columbia River which may be observed downstream of the Mica Tailrace (Sources: RL & L 2001,; Ford and Hildebrand 2008; BC Hydro 2007; BC Hydro 2011b)

Common Name	Scientific Name
Rainbow Trout	*Oncorhynchus mykiss*
Bull Trout	*Salvelinus confluentus*
Kokanee	*O. nerka*
Mountain Whitefish	*Prosopium williamsoni*
Slimy Sculpin	*Cottus cognatus*
Torrent Sculpin	*C. rhotheus*
Prickly Sculpin	*C. asper*
Burbot	*Lota lota*
Lake Whitefish	*Coregonus clupeaformis*
Yellow Perch	*Perca flavescens*
White Sturgeon	*Acipenser transmontanus*
Pygmy Whitefish	*P. coulteri*
Cutthroat Trout	*O. clarkii*
Lake Chub	*Couesius plumbeus*
Bridgelip Sucker	*Catostomus columbianus*

1.2 Objectives

BC Hydro implemented the CLBMON-60 study, as it relates to the order dated August 12, 2010, as a four-year monitoring program. The goal of the program is to evaluate potential impacts of the addition of two generating units to the Mica Dam Project (Mica 5 and 6) on the ichthyofauna and the thermal regime immediately below Mica Dam. The management questions are to detect whether the operations of Mica 5 and Mica 6 change the aquatic thermal regime and/or ichthyofauna in the tailrace. No management hypotheses were provided in the TOR as it was thought to be unlikely that the hypotheses could be falsified during the time span of the study. An additional stated objective was to collect opportunistic information about rare or invasive species.

The monitoring program goals are described in detail in the BC Hydro Columbia River Project Water Use Plan Monitoring Program Terms of Reference – Mica Units 5 and 6 Project Commitments -CLBMON-60 Mica Tailrace Fish Indexing Study (BC Hydro 2011a, 2011b). The methods section below describes how the CCRIFC/Poisson/Westslope/AAR project team implemented and will implement the monitoring program, including field activities and monitoring, data analysis, interpretation and reporting for the period from start-up (summer 2012) to completion (April 2018).

1.3 Study Area

The Columbia River Mica Dam hydroelectric project is part of BC Hydro's integrated generation system, and is located approximately 137 km north of Revelstoke on Highway 23 (Figure 1-1). The Mica Dam impounds the Columbia River and forms Kinbasket Lake. Mica Dam was completed in 1973 as part of the Columbia River Treaty (1964) and is the furthest upstream dam on the Columbia River. It reached a maximum full pool elevation of 754.71 m in August 2012, and 754.31 m in 2007. While the generating station contains four single-jet impulse turbines with a total capability of generating 1,805 megawatts (MW) of power, maximum generation capacity is limited by available flow (KCB 2009, BC Hydro 2007). The proposed expansion will take the facility from four to six turbines at completion for a total generating capacity of 2,805 MW.

The study area is the approximately 2.5 km of river from about 1 km downstream of the face of the dam to the Blue Bridge. The five boat electrofishing sites used for observation and capture and the four backpack electrofishing sites used for capture of small-bodied fish are those laid out for a 2008 study (Ford and Hildebrand 2008; Figure 1-3). The thermal monitoring sites include eight stations located throughout the ~2.5 km of the study reach evenly distributed along both banks.

2 Methods

Temperature studies and ichthyofauna surveys were initiated in September 2012 and October 2012 respectively. Temperature studies have continued since that time. A second round of ichthyofauna surveys was completed in October 2013. With downloading scheduled for fall (September-October 2014), the second season of summer temperature studies will be completed.

Initially, the temperature study and ichthyofauna survey was scheduled to start in July-August 2012. Record high water levels and freshet conditions precluded installation of HOBO TidbiT data loggers until September 2012 and did not allow operations to provide flows suitable for fish sampling until early October.

Consultation between the CCRIFC/Poisson project team and BC Hydro staff between June and September 2012 resulted in changes to the fish sampling schedule. Ultimately, the October period was selected and agreed to as representing the most diverse fish communities, and the period where the stable target flows required for fish sampling could be consistently achieved over the four years of the study program.

The workplan for 2013 was developed and finalized in August and September 2012 through discussions with the project team and BC Hydro staff (Irvine et. al. 2013). The workplan for the remainder of 2013 and 2014 followed similar timelines and flow targets for sampling. A more detailed description of activities is provided below.

2.1 Discharge

It was considered critical to have stable discharge from the dam for at least four hours prior to sampling to allow any re-distribution of fish in response to flow changes to occur before the onset of sampling. It was also important to ensure provision of flow levels that were low enough for efficient sampling and likely repeatable over all four years of field work. In 2012, this goal was met by dropping flows at 22:00h, waiting for 4-6 hours after the drop and then sampling at that flow level from 03:00h until 07:00h in late October. In 2013, a full plant outage began on October 16th so sampling at the same time of year as 2012 sampling was not possible. The sampling occurred in the first week of October when two turbines were online and Mica Dam was running at a constant minimum discharge value of ~530m^3/s. The discharge ranged between 527 and 531 m^3/s in the week from September 30-October 7. In order to assess the range of discharge values over which sampling was conducted, hourly discharge values were averaged for the 3 hours prior to sampling and 1 hour following sampling to obtain the approximate mean discharge at which fish were counted or captured. Discharge values were then separated out by site, year and type of sampling occurring (count or capture).

2.2 Fish Observation and Capture

Boat electrofishing was used to enumerate and characterize the ichthyofauna within the study area. Twenty-four hours prior to the fish capture phase of the field work began, an initial pass with the boat electrofisher was completed to observe and record the species, size (to the nearest 10 mm) and georeferenced location of fish within the study reach with data grouped by sampling site. The same range of settings on the boat electrofisher were used as for the capture session.

The observers were stationed in standard netting positions and each observer was paired with a recorder who had a watch synchronized to the GPS time and the standardized data sheets on a clipboard. Each recorder noted the fish data as well as the exact time of the observation. Two GPS units (Garmin 62S) ran track logs during the sampling session to provide a backup data source. One was on the console of the electrofishing vessel (the distance from the console GPS to the midpoint of the anode and boom when extended was 6.2 m) and the other was in a backpack with an external antenna and was carried by one of the observers on the bow of the boat. A detailed description of electrofishing locations is provided in Figure 2-1.

Following the observation sampling, standard boat electrofishing capture was completed in each of the five sites. Fish of all targeted indexing species were captured, transferred to the live well and at the end of each site, were assessed for length, weight, species, and sex (if possible). Comments were noted about exceptional characteristics for individual fish and crews were aware of the study program's stated objective to collect opportunistic information about rare or invasive species.

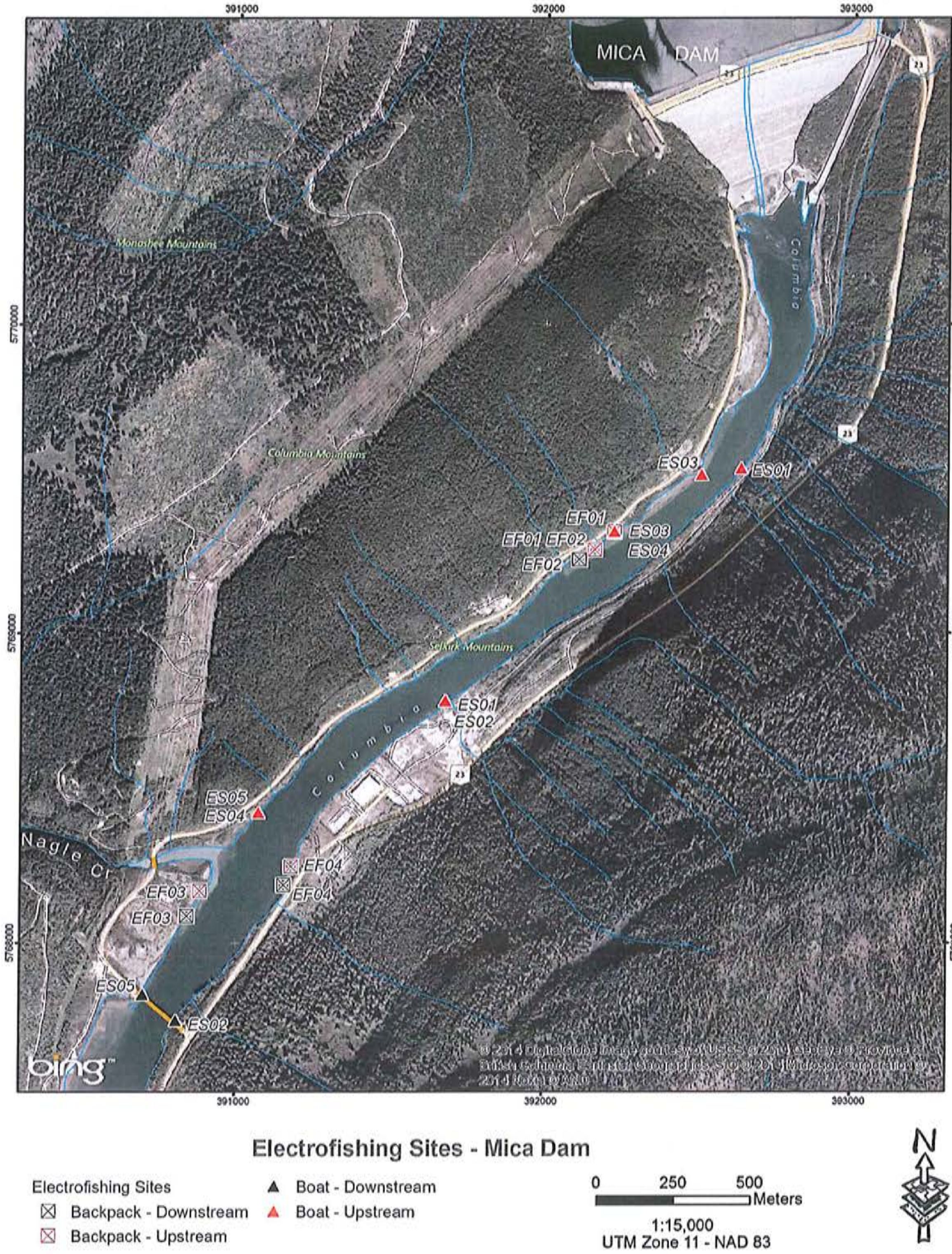

Figure 2-1. Electrofishing Locations for the Mica Tailrace Fish Index Study 2012 and 2013.

Small-bodied fish were captured using a Smith-Root LR 24 backpack electrofisher during daylight hours. The four sites demarcated for backpack electrofishing work by Golder within the study reach were sampled for small bodied fish fauna (Ford and Hildebrand 2008). Due to the consistent, moderate flow levels in 2013, all four of the backpack sites were sampled; only two sites could be sampled in 2012.

2.3 Habitat

Habitat information was not collected at the fish sampling locations in 2012. The sites were classed by mesohabitat variables by Ford and Hildebrand (2008) and it was proposed that in 2013, additional habitat variables would be assessed as appropriate to answer the management questions using photo interpretation of the study site. A photogrammetry flight was conducted on November 4, 2013 during the plant shutdown and the photos were obtained from BC Hydro for photo interpretation. However, the cloud cover in the photos was extensive, not allowing for habitat type and availability interpretation to occur. It is recommended that if this deliverable is still a desired outcome of this project that a flight in better visibility conditions at low flow conditions be completed and photos provided to the study team to carry out habitat interpretation.

2.4 Water Temperature

There are currently 16 loggers downstream of the dam in the study reach (Figure 2-2). There are 4 arrays on each bank of the river downstream from the dam located approximately across from each other and dispersed along the length of the study reach. Each array has duplicate loggers. The initial deployment included 12 loggers downstream (3 pairs on opposite banks) of the dam and 16 in the headpond, to address the management question. An additional set of loggers was deployed downstream of the confluence with Nagel Creek, to identify potential influences of Nagel Creek on mainstem Columbia water temperatures. Unfortunately the stations at the blue bridge downstream of Nagel Creek had inconsistent depths (likely as a result of gravel bars and water level fluctuations). The loggers were initially deployed to record at one (1) minute intervals and as a result do not have a complete data set. As a result the data from these loggers was not used in the analysis for this report. The deficiencies in water depth and logging interval are currently being addressed, and it is anticipated that we will present an analysis of this additional data in subsequent reports. In May, 2014 the most upstream array on the right bank had to be moved to make room for the deployment of a safety boom by BC Hydro. It was moved ~50 m downstream and redeployed. In the current study year, the loggers were downloaded on April 3, June 11 and October 3, 2013 and on May 10, 2014. Data from the original 6 paired loggers is analyzed in this report.

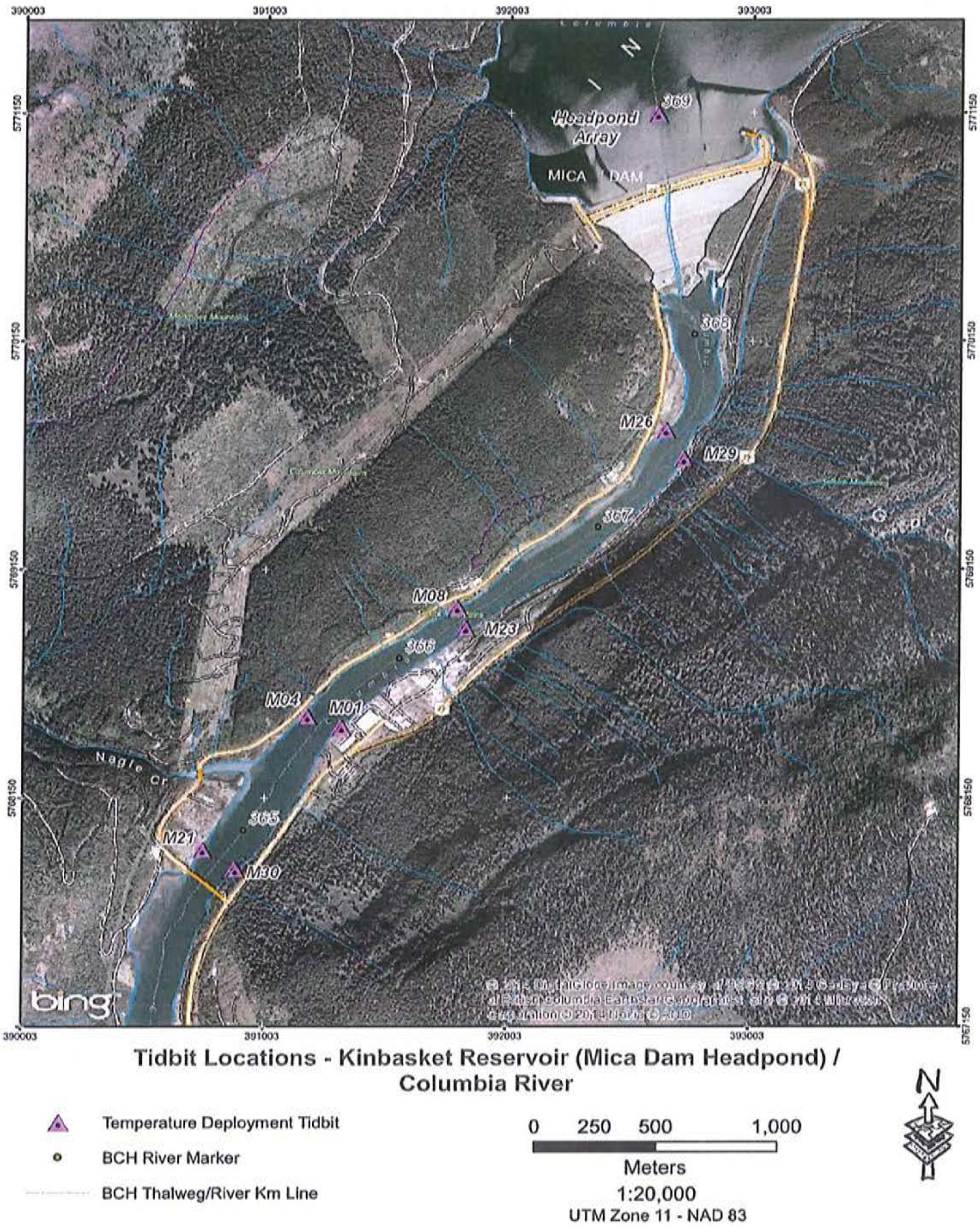

Figure 2-2 TidbiT deployment locations in the Kinbasket Reservoir (Mica Dam Headpond) and Columbia River from October 2012 to May 2014.

2.5 Historical Water Temperature Data

Historical water temperature data were available for the forebay and two downstream sites within the study area. A vertical array of temperature loggers deployed by DFO was in place in the Mica Dam forebay and the historical data from May, 2011 until March, 2012 was provided and imported into the temperature database (G. Martel, Pers. Comm.). Downstream of the dam, water temperature data were obtained from Golder Associates Ltd. for the March – November 2008 time period from a temperature logger that was installed mid-channel on the Blue Bridge at the downstream end of the study area. These data were not plotted in the current report. Data were also obtained from a water temperature logger installed just below the tailrace of the dam on the right downstream bank from a study running from 2001 - 2004 conducted by Karen Bray, BC Hydro. All historical water temperature data are in the CLBMON-60 water temperature database.

2.6 Data

Temperature data were downloaded as .hobo files and were exported to Excel spreadsheets for QA/QC and formatting for inclusion into the customized Access database. Fish faunal data were entered into Excel spreadsheets by CCRIFC technicians and underwent QA/QC procedures as outlined in the study plan for this project then imported into the customized Access database. The historical indexing information was obtained from the database for the 2008 study in the Mica Dam tailrace (Ford and Hildebrand 2008). The current program's (CLBMON-60) fish sampling and biological information were placed into a separate database since the methods used and the structure of the data were substantially different from the previous work.

The information about temperature loggers' deployment, individual logger's identification and locations as well as all downloaded temperature data from historical studies in the area and the current program were imported into a customized Access database. The discharge and elevation information for Kinbasket and Revelstoke Reservoirs were extracted from the Poisson Consulting Ltd. maintained database containing Power Records data for the Columbia River system.

Spatial data from the Garmin 62S GPS units were downloaded after each night's survey into Garmin BaseCamp software and were saved as .gpx files for import into other GIS software. A shape file provided by Karen Bray of BC Hydro provided a center line down the thalweg of the river and river kilometer references that will be common to all Water License Requirement projects on the Columbia River (K. Bray, Pers. Comm.). The observations of individual fish were spatially located by taking the exact time of the recorded observation from the data sheet and matching that to the spatial point on the time referenced .gpx file to give a UTM coordinate in the river for that fish. The specific locations were then assigned a river kilometer by drawing a perpendicular line from the fish's location to the provided thalweg line and assessing where on the line it was located. Each river km and bank is associated with a particular habitat type as defined in Ford and Hildebrand (2008) so assigning each fish's location to a river km allowed each fish to also be affiliated with a habitat type as well as providing the distribution of the fish.

Should more detailed habitat data be obtained in future, this georeferencing will allow an assessment of habitat use throughout the study reach for all years of the study.

2.7 Analysis

As per the terms of reference (BC Hydro 2011), the following variables were assessed from the fish observation and capture data: relative abundance, condition, and spatial distribution throughout the study area. Species evenness was also assessed for the study area by site.

The annual variation in fish condition (body weight when accounting for body length) was estimated from the boat and backpack electrofishing captures using a mass-length model (He et al. 2008). Preliminary analyses indicated that site and day of the year were not informative predictors of condition so they were not included in the final model.

Key assumptions of the condition model include:

- Weight varies with body length as an allometric relationship, i.e., $W=\alpha L^{\beta}$.
- α varies with year.
- β varies with year.
- The residual variation in weight is log-normally distributed.

The annual variation in relative abundance was estimated from the boat count and catch data using an over-dispersed Poisson model (Kéry 2010, Kéry and Schaub 2011). Lineal densities are calculated by kilometre of river as extracted from the BC Hydro thalweg line.

Key assumptions of the relative abundance model include:

- Lineal density varies with year.
- Lineal catch density is a fixed proportion of lineal count density.
- Expected counts (and catches) are the product of the count (catch) density and the length of river (half the length of bank) sampled.
- Observed counts (and catches) are described by a Poisson-gamma distribution.
- Preliminary analyses indicated that site was not an informative predictor of lineal density.

The model estimates the count of fish, which is the product of estimated abundance and observer efficiency, and therefore does not distinguish between abundance and observer efficiency. Consequently, it is necessary to assume that changes in observer efficiency by year are negligible in order to interpret the estimates as relative abundance.

The Shannon index of species evenness (E), or diversity scaled by the number of species, was calculated from the relative abundance analyses for the adult salmonids using the following formula where S is the number of species (in this case four) and p_i is the proportion of the sum of the relative abundances belonging to the i^{th} species.

$$E = \frac{-\sum pi * \log(pi)}{\ln(s)}$$

A hierarchical Bayesian approach was used to model the data using R Version 3.0.2 (R Core Team 2013). Libraries used included the Poisson Consulting Ltd. library Jaggernaut (Thorley 2013) and the JAGS library V 3.3.0 (Plummer 2003).

Unless specified, the models assumed vague (low information) prior distributions (Kéry and Schaub, 2011). The posterior distributions were estimated from a minimum of 1,000 Markov Chain Monte Carlo (MCMC) samples thinned from the second halves of three chains (Kéry and Schaub 2011). Model convergence was confirmed by ensuring that Rhat (Kéry and Schaub 2011) was less than 1.1 for each of the parameters in the model (Kéry and Schaub 2011). When possible model adequacy was confirmed by examination of residual plots.

The posterior distributions of the fixed (Kéry and Schaub 2011) parameters are summarised below in terms of a point estimate (mean), lower and upper 95% credible limits (2.5th and 97.5th percentiles), the standard deviation (SD), percent relative error (half the 95% credible interval as a percent of the point estimate) and significance (Kéry and Schaub, 2011).

The results are displayed graphically by plotting the modeled relationships between particular variables and the response with 95% credible intervals (CRIs) with the remaining variables held constant. In general, continuous and discrete fixed variables are held constant at their mean and first level values respectively while random variables are held constant at their typical values (expected values of the underlying hyperdistributions) (Kéry and Schaub, 2011). Where informative the influence of particular variables is expressed in terms of the effect size (i.e., percent change in the response variable) with 95% credible intervals (Bradford et al. 2005). Through the report Bull Trout data and estimates are plotted in black while Rainbow Trout are plotted in red. Plots were produced with the ggplot2 library (Wickham 2009).

Temperature data for the six tailrace monitoring stations were plotted as absolute temperatures as well as with respect to the station with the most continuous data stream so that differences between each station are plotted.

The full descriptions and code for all fish indexing modeling efforts are provided online at: http://www.poissonconsulting.ca/temporary-hidden-link/-186605684/mica-indexing-13/index.html. The temperature plots and information can be found online at: http://www.poissonconsulting.ca/temporary-hidden-link/1456262863/mica-temperature-13/index.html.

3 Results

3.1 Discharge

The discharge throughout the year from Mica Dam for the past four years including the two years during which fish sampling occurred is summarized in Figure 3-1. In 2013, there was spill from August 29th until September 20th and a brief spill from the 21st to the 22nd of September and the plant shutdown is evident in the late October period (Figure 3-1).

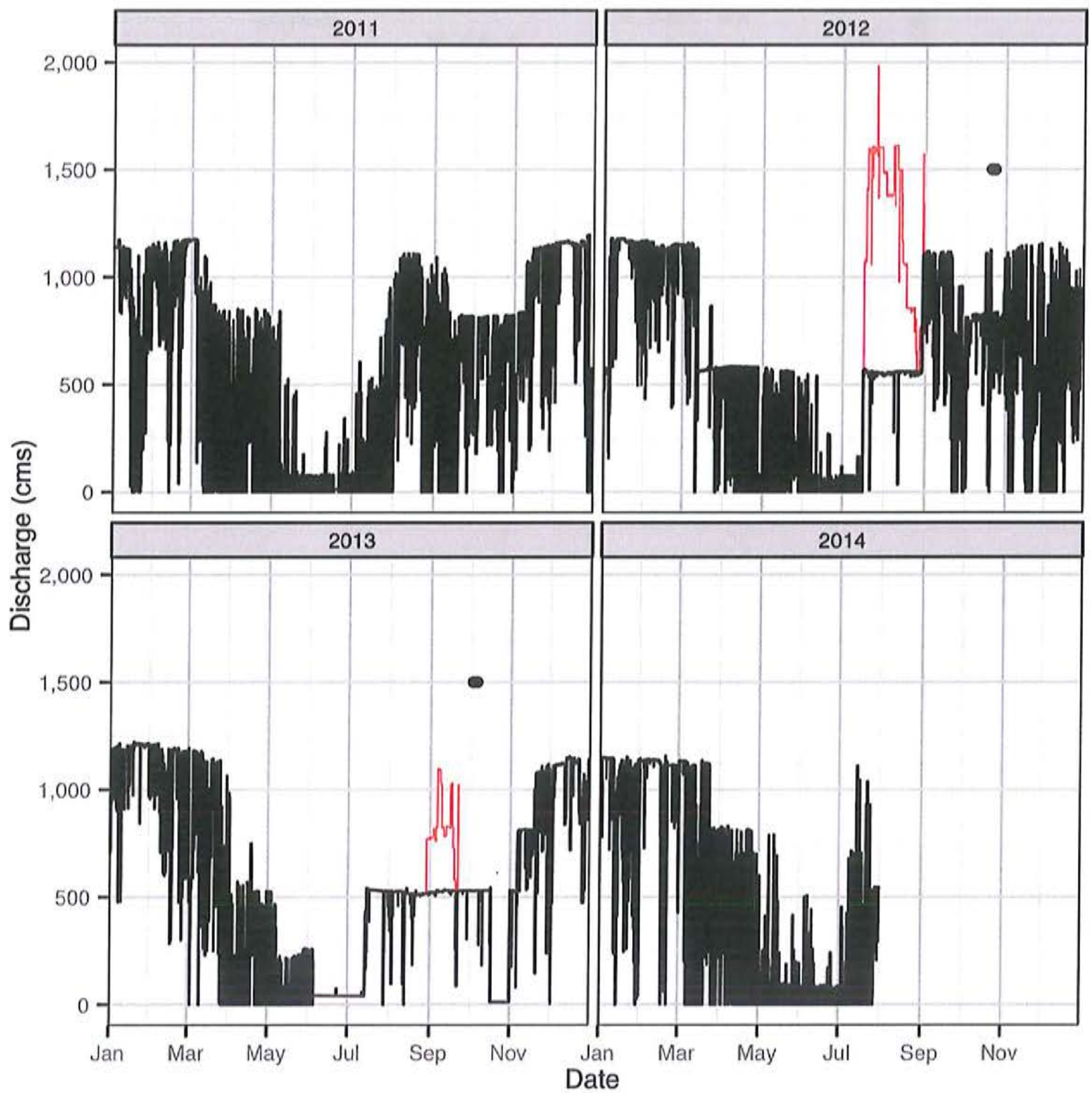

Figure 3-1. Hourly discharge (cms) from Mica Dam for 2011-2014 with spill shown in red and turbine flow in black.

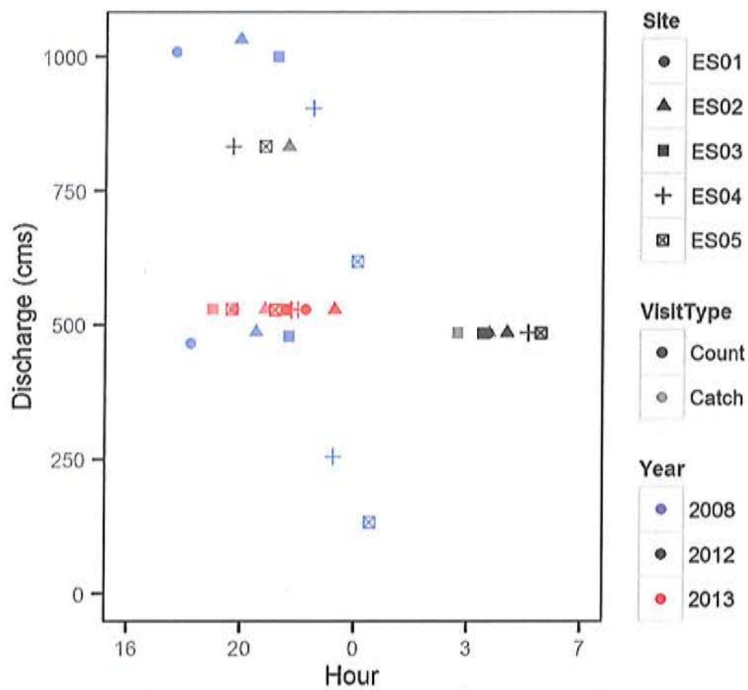

Figure 3-2. Discharge (cms) from Mica Dam by site (symbol type), visit type (shading level) and year (colour). Discharge was averaged for 3h before and 1 h after the start time for all sampling bouts.

Sampling occurred at a moderately low, continuous flow of ~530 m^3/s during early October with two turbines operating (Figure 3-1). The discharge levels experienced over all fish sampling bouts for this program and the historical 2008 program are summarized in Figure 3-2. The range of discharges experienced during counting sessions in 2013 was from 484-528 m^3/s (Figure 3-2).

3.2 Boat Electroshocking Fish Observation and Capture

The five boat electroshocking sites were sampled for counts on October 2, 2013 using the observation methods. Sampling began at 21:11h and continued until 23:34h. Over all five sites, 1006 fish were observed. The most common fish observed was Mountain Whitefish with 515 individuals enumerated. Kokanee were also numerous with 440 individuals counted. Only two Rainbow Trout were observed and 23 Bull Trout. On October 4th and 5th, 2013, boat electrofishing capture was done with 231 fish captured for assessing biometric data and verifying the observers' estimated sizes. Nine Bull Trout were captured ranging from 366-820mm in length and 466g- 6kg in weight; 125 KO were captured ranged from 67-388mm and 1g-674g in weight; 96 MW were captured ranging from 75-367mm in length and 3-438g in weight.

The length frequency data for the four salmonid species counted by observers and caught by netters in both pre-Mica 5 and 6 study years are plotted with juvenile and adult length cut-off values plotted with vertical lines (Figure 3-3). The observers were generally good at size estimation as shown by the overlap of the observation vs. catch curves though demonstrated slight overestimation of the size of KO, and slight over and underestimation of the size of larger MW (Figure 3-3). No Rainbow Trout were captured to compare to the estimated lengths of the observed individuals. Individuals were classified as fry (age-0), juvenile (age-1 and older subadults) or adult (sexually mature) based on the length cut-offs by species outlined in Table 3-1.

Table 3-1. Size cut-offs for life stages of four salmonid species observed and captured in Mica Indexing Program.

Species	Fry	Juvenile	Adult
Bull Trout	<120	<400	>400
Mountain Whitefish	<120	<175	>175
Rainbow Trout	<120	<250	>250
Kokanee	<100	<250	>250

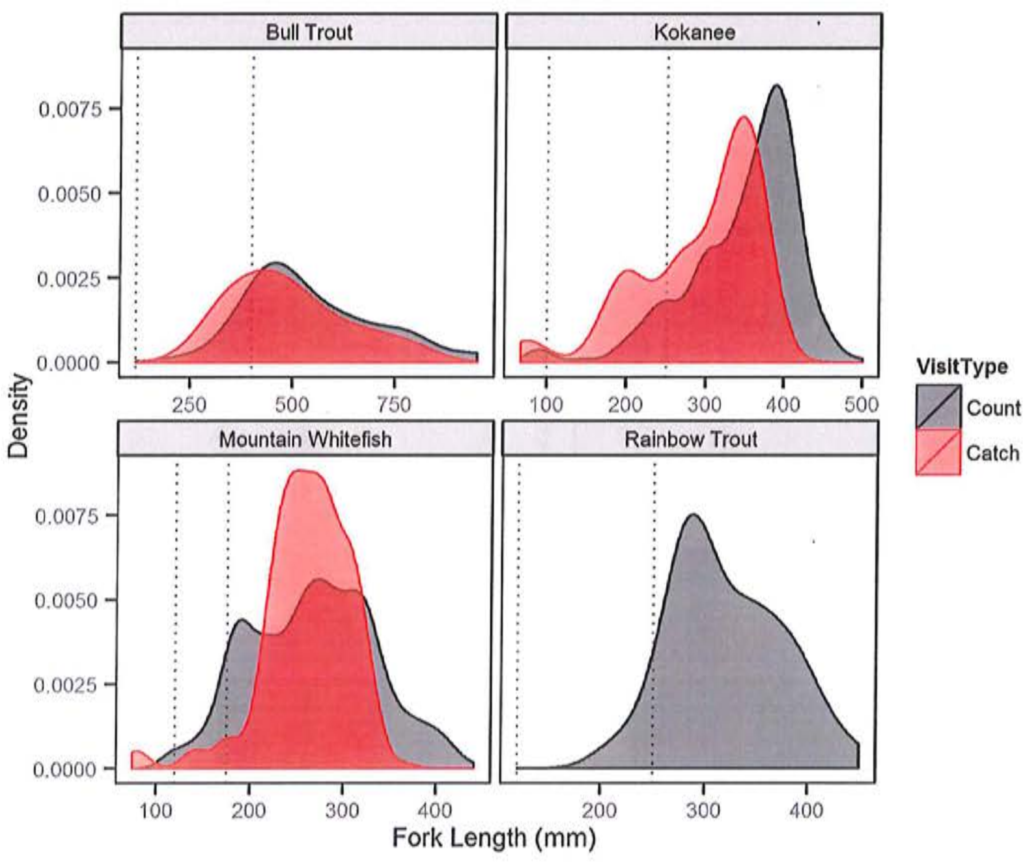

Figure 3-3. Length-density plot for boat count versus boat catch with fry and juvenile length cut-offs (dotted vertical lines).

Mountain Whitefish were the most dominant fish species observed by proportion in the study reach, with Kokanee the second most predominant (Figure 3-4). Bull Trout were the third most prevalent with Rainbow Trout as the least observed fish (Figure 3-4).

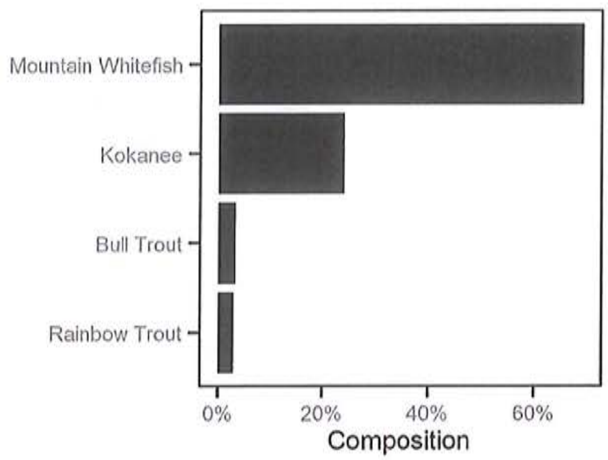

Figure 3-4. Predicted percent composition of the four salmonid species.

The lineal density decreased, though not significantly for Bull Trout and Mountain Whitefish, and increased significantly, for Kokanee in the Mica reach between 2008 and 2013 (Figure 3-5). Rainbow Trout lineal density is highly variable and based on very low numbers of fish and shows a decrease in the last year (Figure 3-5).

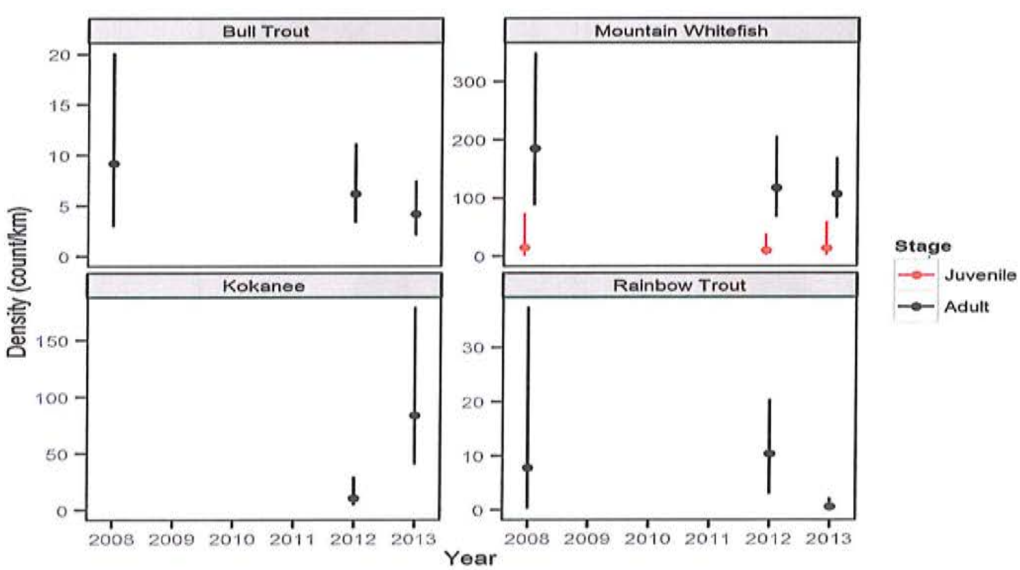

Figure 3-5. Predicted lineal count density (with 95% CRIs).

The body condition of the four salmonid species was assessed with respect to their percent change in weight for a typical fish within a size class as compared to 2012 condition values. A typical fish for the small size class was 300mm for Bull Trout, 80mm for Mountain Whitefish, 80mm for Kokanee and 30mm for Sculpin. A typical fish for the large size class was 600mm for Bull Trout, 250mm for Mountain Whitefish, 250mm for Kokanee and 75mm for Sculpin. Bull Trout have increased in weight, though not significantly, since 2012 for both small and large fish and had the lowest condition in the 2008 sampling year (Figure 3-6). Kokanee adults are significantly heavier in 2013 than in 2012 and the effect size estimate for fry was quite variable and did not show a significant increase or decrease since 2012. Mountain Whitefish fry had a significant decrease in body condition since 2012 and adults had a significant increase in comparison to 2012. The body condition of MW in 2008 was lower, though not significantly, for the fry and higher for the adults (Figure 3-6). Sculpin body condition was higher in 2013 but not statistically significant due to high variability in the data (Figure 3-6).

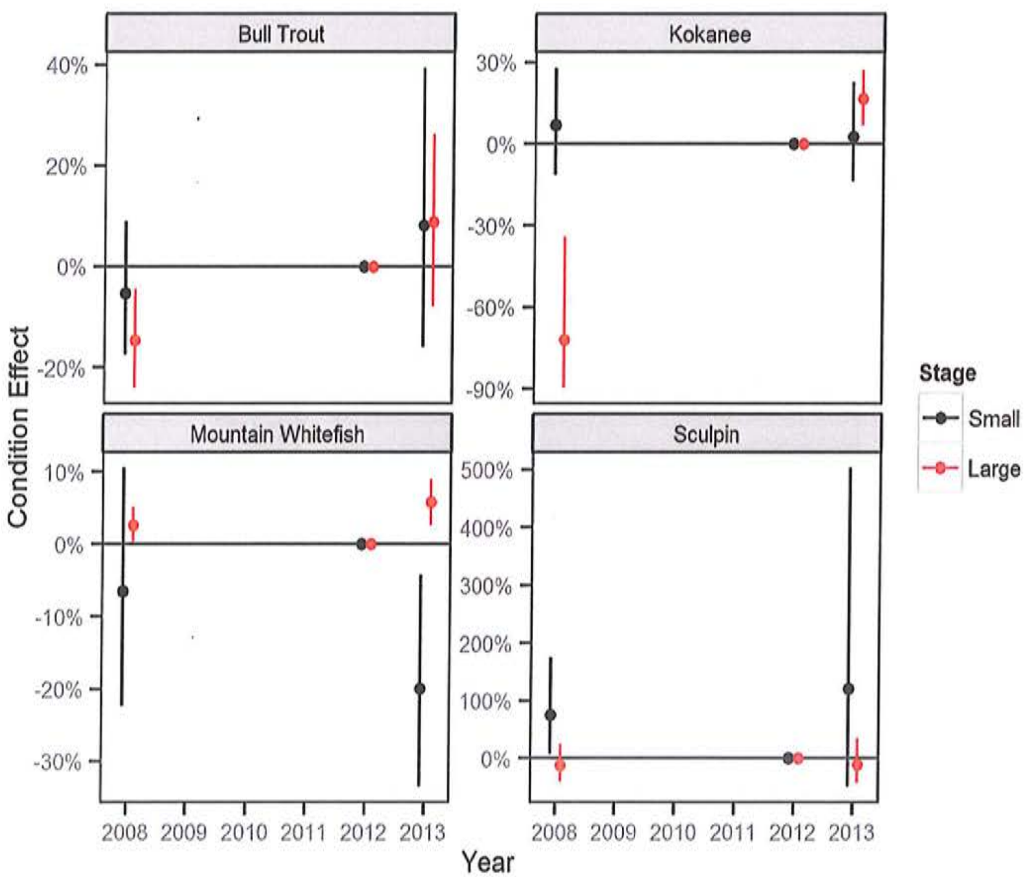

Figure 3-6. Expected percent change in body condition with respect to 2012 (with 95% CRIs).

The modeled density of fish by site and river km was estimated for each species and life stage with sufficient data; these results are plotted in Figures 3-7 to 3-14. The frequency histograms for each fish species and life stage are also shown in Figures 3-8 to 3-14. The general trend is for more fish along the left downstream bank though Mountain Whitefish and Kokanee show clumped distributions at locations on the right bank (3-9, 10 and 3-11, 12) and juvenile Mountain Whitefish were predominantly found on the right bank in 2013 (Figure 3-13, 14). Rainbow Trout are so few in number that no density plot could be generated for 2013 and in 2012, those RB observed were on both banks (Figure 3-15); it can be seen that only 2 fish were observed in the frequency histogram (Figure 3-16). Kokanee were far more numerous in 2013 than in 2012 (Figure 3-9, 10), likely due to the sampling being completed 3 weeks earlier.

These distribution data are also shown on maps with each fish's georeferenced location marked spatially (Appendix 1).

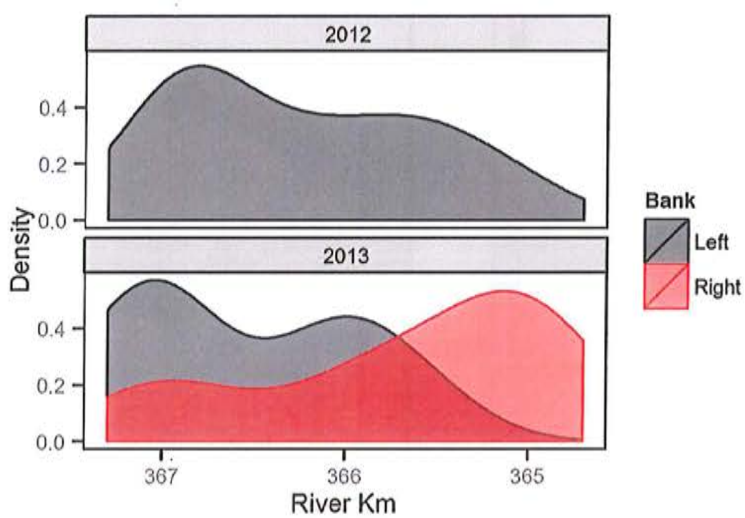

Figure 3-7. Density plot of observed adult Bull Trout by river kilometre.

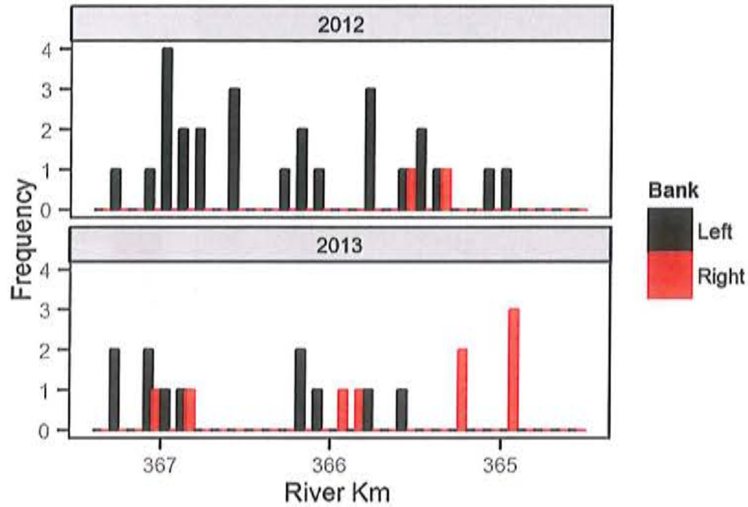

Figure 3-8. Frequency plot of observed adult Bull Trout by river kilometre.

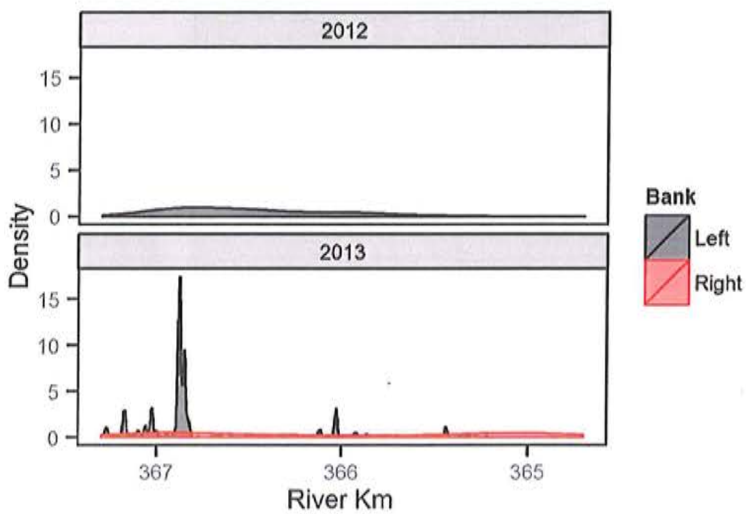

Figure 3-9. Density plot of observed adult Kokanee by river kilometre.

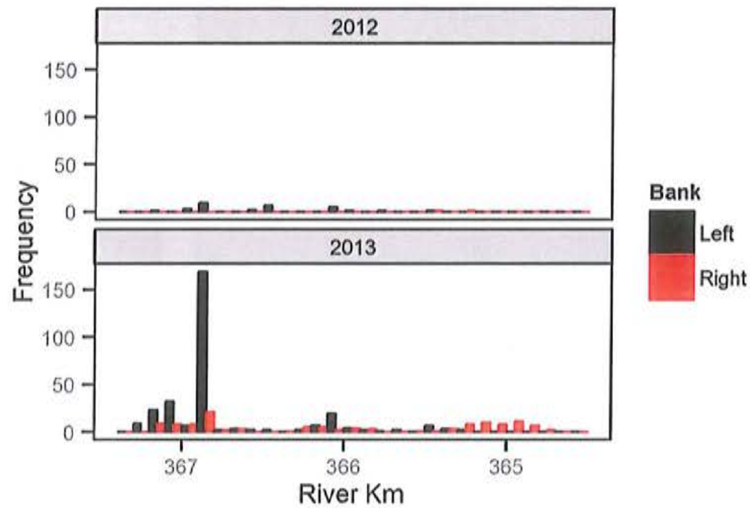

Figure 3-10. Frequency plot of observed adult Kokanee by river kilometre.

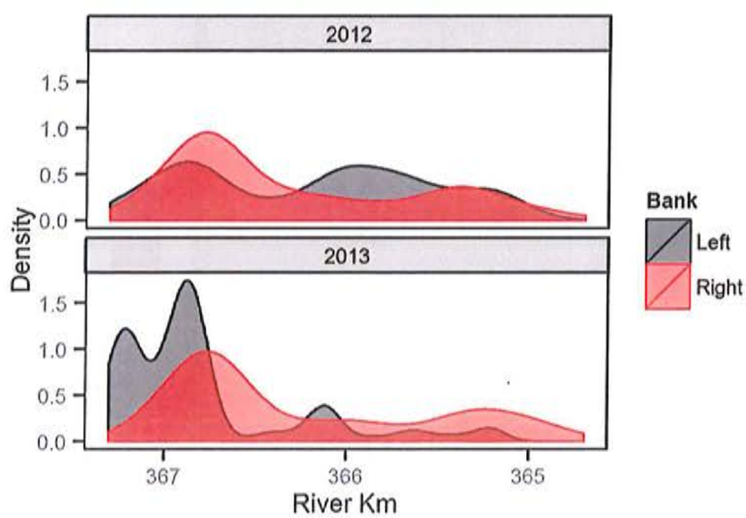

Figure 3-11. Density plot of observed adult Mountain Whitefish by river kilometre.

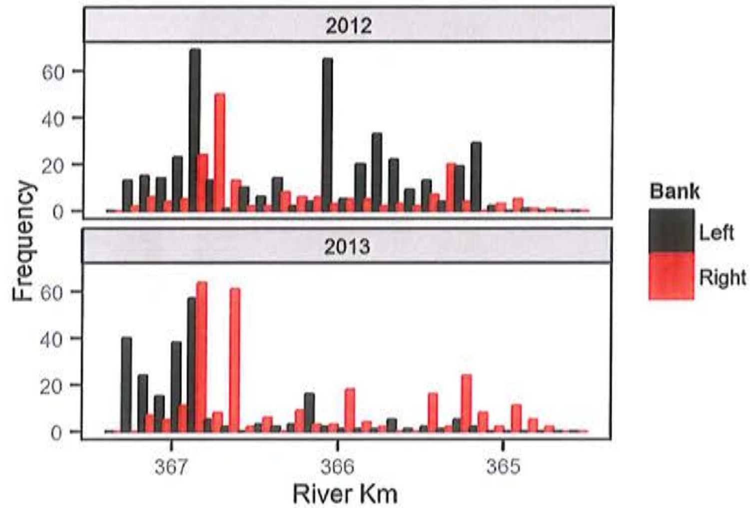

Figure 3-12. Frequency plot of observed adult Mountain Whitefish by river kilometre.

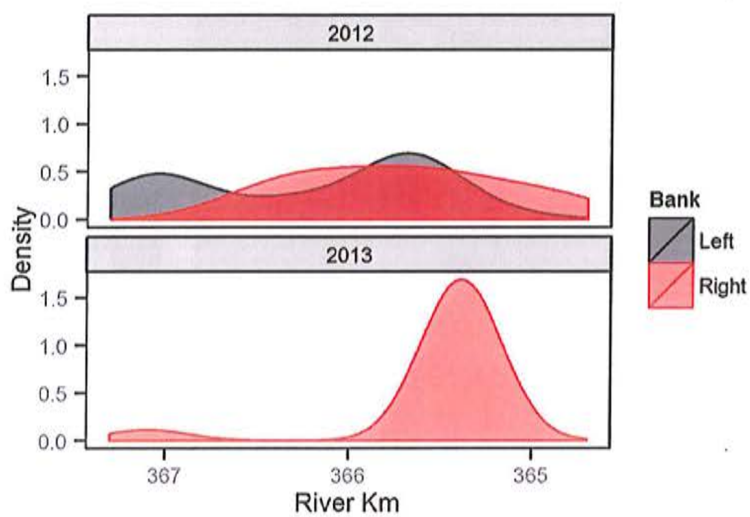

Figure 3-13. Density plot of observed juvenile Mountain Whitefish by river kilometre.

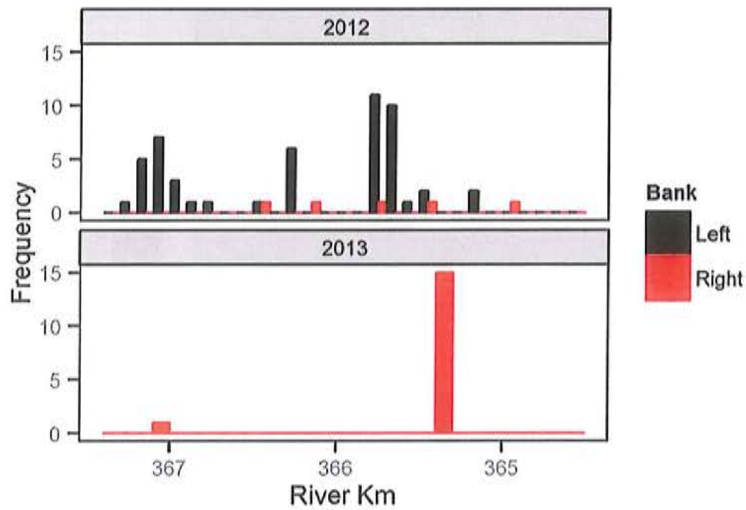

Figure 3-14. Frequency plot of observed juvenile Mountain Whitefish by river kilometre.

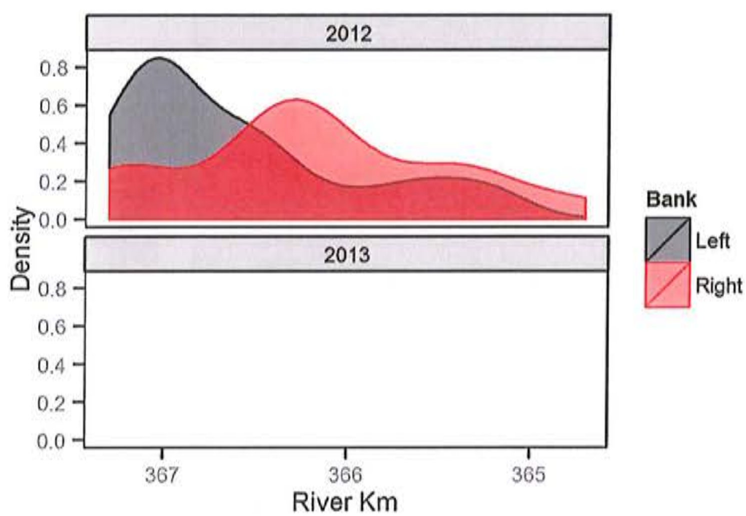

Figure 3-15. Density plot of observed adult Rainbow Trout by river kilometre.

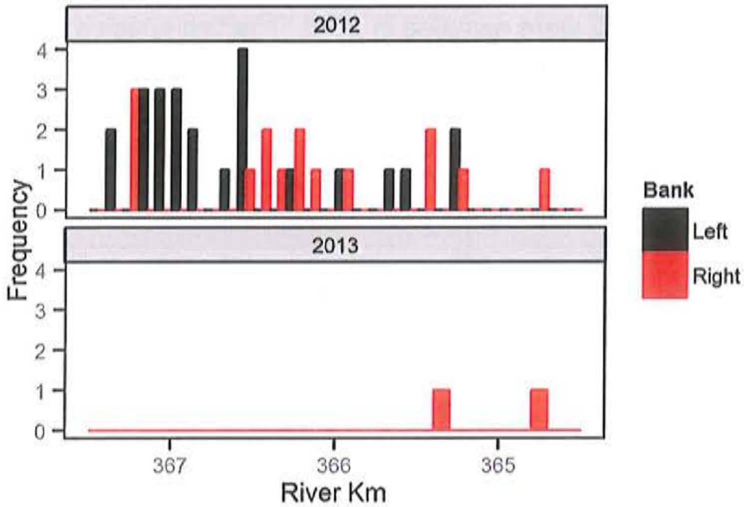

Figure 3-16. Frequency plot of observed adult Rainbow Trout by river kilometre.

The data from observed fish and captured (netted) fish were used to calculate a ratio and test the assumption that the observation method was more efficient (Figure 3-17). The data show of the observed Bull Trout, the netter catch 47% of the observed number, 23% of the observed adult Mountain Whitefish are netted, 12% of the juvenile Mountain Whitefish are netted, and 48% of the observed Kokanee are captured. Very few Rainbow Trout are observed, but of those, 3% were captured (Figure 3-17).

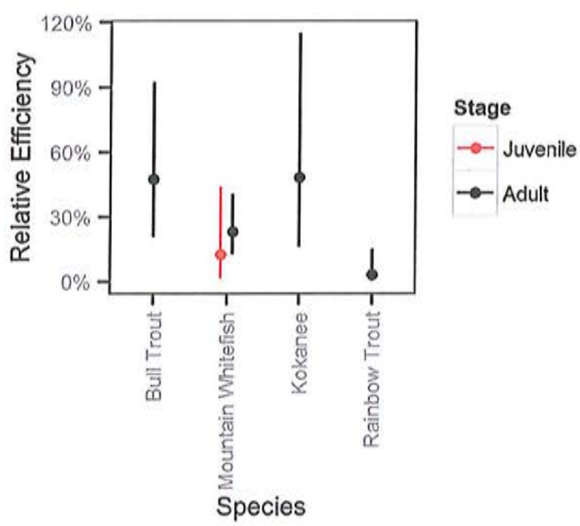

Figure 3-17. Predicted catch to count relative efficiency (with 95% CRI).

The four backpack sites demarcated by Golder in 2008 had suitable habitat for sampling in 2013. Only sites ES01 and ES02 were sampled in 2012. The fish species and lengths captured in all three years of study are shown in Figure 3-18.

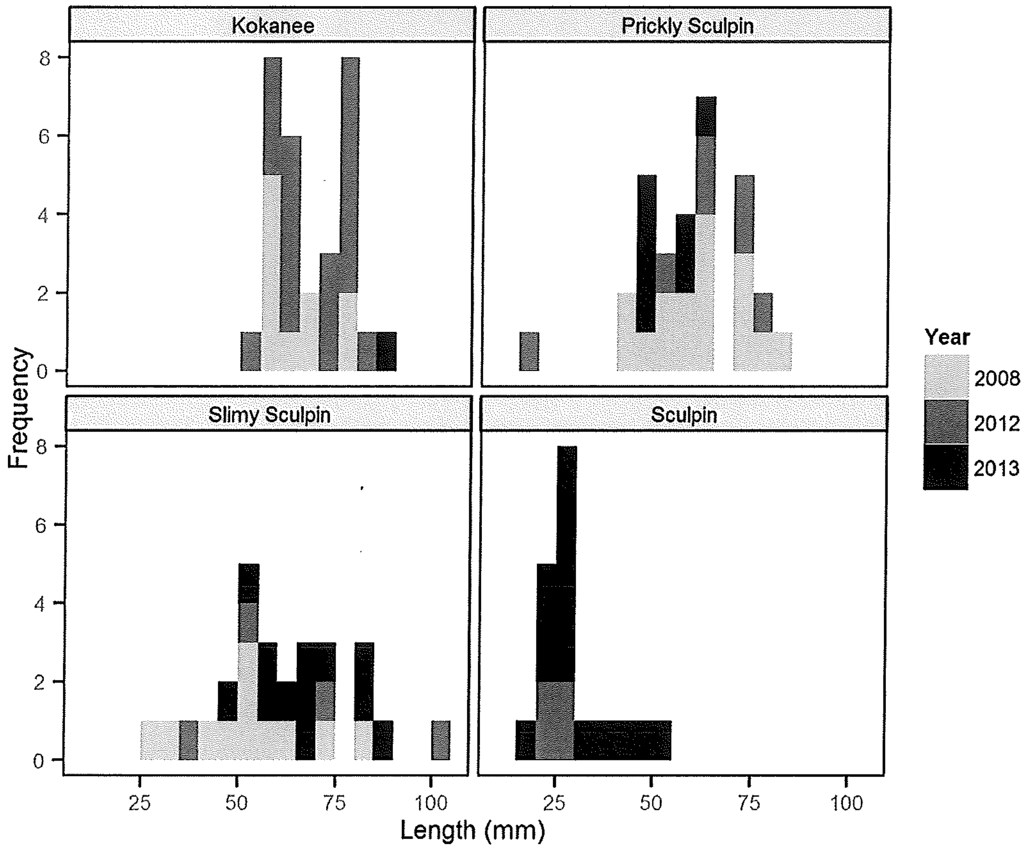

Figure 3-18. Length frequency plots by species for fish captured with backpack electrofishing in 2008, 2012, 2013.

The species evenness biodiversity index was calculated from the model results for apparent fish densities from the boat electroshocking observer data by year for the adults of all four observed salmonids. The evenness increased from 2012-2013 from 46% to 55%, though the increase was not significantly different (Figure 3-19).

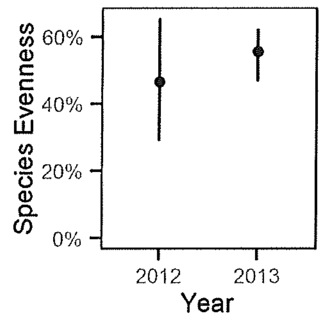

Figure 3-19. Predicted species evenness for adult salmonids (with 95% CRIs).

3.3 Temperature

All the tailrace loggers installed in October 2012 or April 2013 (for replicate loggers) were downloaded on May 10, 2014 and cumulative data over the course of the program are presented here.

Tailrace water temperature loggers show typical seasonal patterns with the exception of three distinct and sudden increases in water temperature during the winter period of 2013 (early Jan, mid-Feb, early March) that are echoed in all loggers so cannot be put down to logger error (Figure 3-20). There are no sudden changes in discharge that were captured by the summary data provided by BCH (grouped by all discharge gates or spill gates) that would explain the increase either (Figure 3-1).

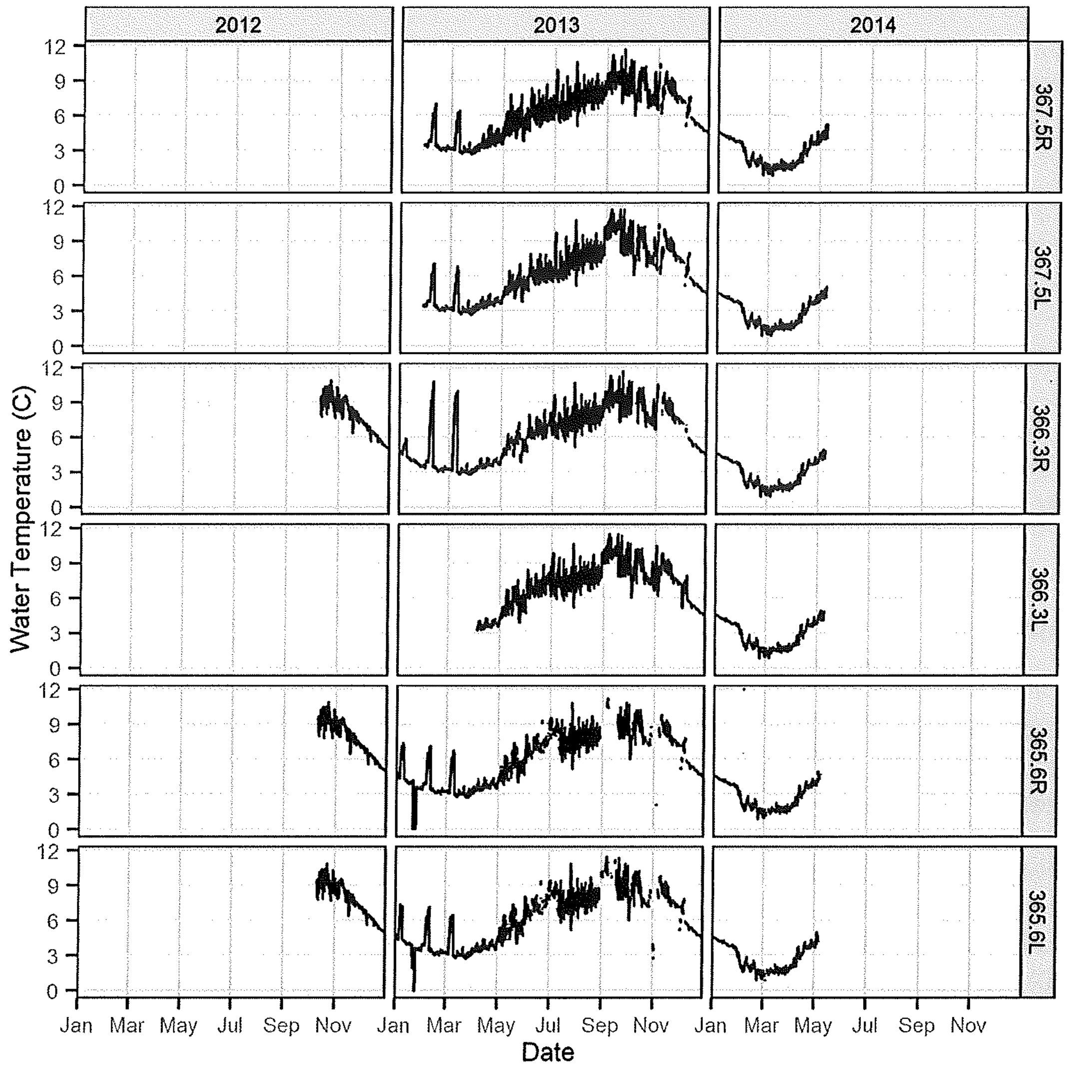

Figure 3-20. Water temperature through time plotted by river km and site for the six loggers downstream of Mica Dam. The dam is located approximately at river km 369 and the blue bridge at 364.7.

The differences between the left and right bank most upstream loggers at river km 366.3 indicate no obvious differences between the left and right bank water temperatures (Figure 3-21). From November 2013 until the last downloaded data in May 2014, there is no discernable difference between the reference logger and the other loggers indicating the same winter conditions and isothermal flow through the dam are affecting all tailrace sites in an equivalent way (Figure 3-21).

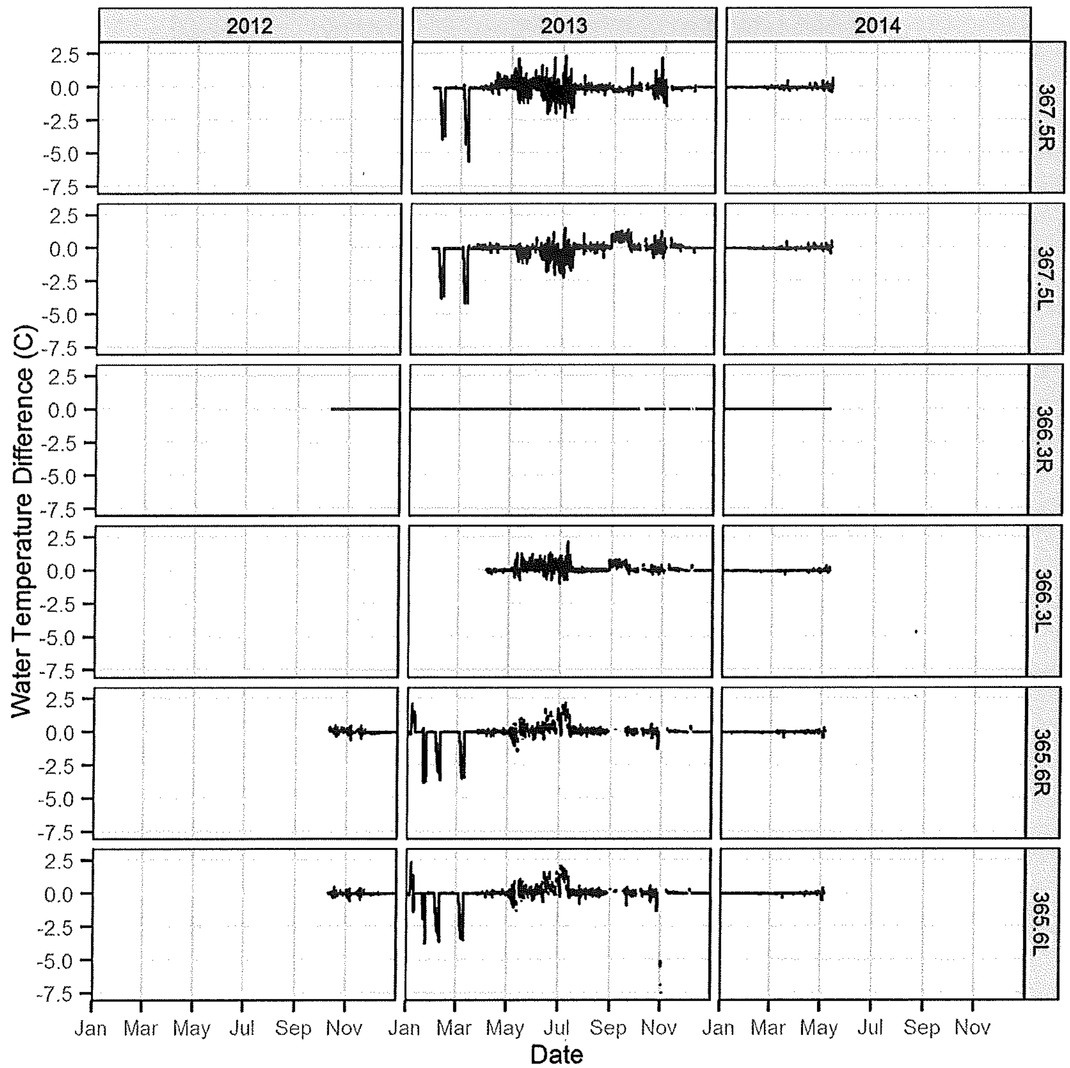

Figure 3-21. Water temperature through time plotted as the difference between each logger and the water temperature measured by the logger on the right bank at the location of river km 366.3 R.

The reservoir elevation fluctuates throughout the year following predictable operational patterns as well as being affected by within year fluctuations due to extreme water events. In 2012, the lowest elevation occurred in late April with an elevation of 721.9m and the highest elevation occurred in early September with an elevation of 753.6m for an annual change of 31.7m (Figure 3-22). In 2013, the minimum elevation occurred on April 24 with a value of 722.8 m and the maximum elevation was 754.6 m on September 16 for an annual change of 31.8 m.

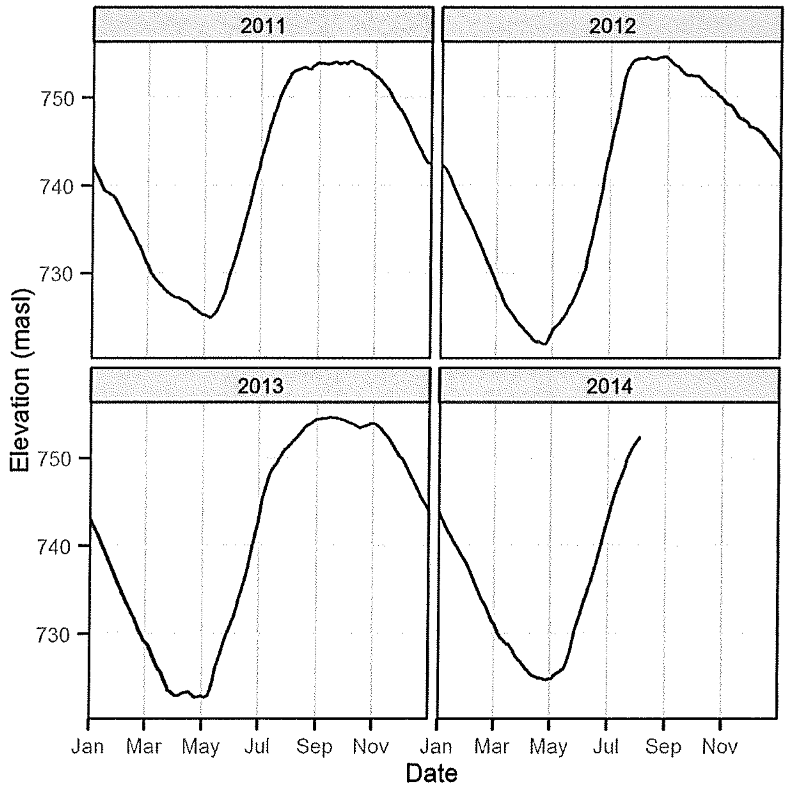

Figure 3-22. Kinbasket Reservoir hourly elevation in metres at the Mica Dam Forebay recording station for the 2011-2014 period.

4 Discussion

The addition of Mica 5& 6 is predicted to result in average monthly changes in reservoir elevations of -0.1 to 0.2m (BC Hydro 2011 TOR). Water velocities in the Mica tailrace are expected to increase to maximal levels of 1.5-2.4 m/s during peak demand periods and these daily flows could alter the water temperature (BC Hydro 2011). However, changes in water temperature resulting from the operational changes from the two additional units are predicted to be small and not distinguishable from the existing variability (BC Hydro 2011). The effect the velocity changes may have on the fish community is unclear and part of the reason for the implementation of CLBMON-60.The management questions to be addressed by this project as described in the Terms of Reference are:

"to detect whether changes in the operation of the additional two units (Mica 5 and Mica 6) generates changes in the aquatic thermal regime ('thermal regime') and ichthyofauna in the Mica Dam tailrace." (BC Hydro 2011). To determine the effects, a study design that required two years of pre-operation data and two years of post-operation data (at a minimum) was proposed.

Similar to Year one, the second year field season focused on electrofishing to collect ichthyofauna distribution data between the tailrace and the blue bridge. The second component involved assessing the aquatic thermal regime with a series of HOBO TidbiT™ data loggers deployed in the headpond of Mica Dam and the Columbia River below the dam from the tailrace to the blue bridge.

In the second field season of CLBMON-60, the boat electroshocking observation method with georeferenced fish data was used again with good success and higher efficiency than netting for obtaining information on fish distribution in the study reach. The fish capture program that was also conducted allowed the assessment of condition for three of the four salmonid species observed in the study area. In future, the fish condition can be related to changes in the flow and temperature by looking at the percent change in condition from year to year. The species evenness was estimated using the Shannon evenness biodiversity index and was 46% in 2012 and 55% in 2013, though the fact that the operational shutdown required sampling to occur 3 weeks earlier in 2013 is a confounding factor when comparing the two years of pre-upgrade data for all assessed metrics.

The second component of the study program is the monitoring of the changes in temperature in relation to alterations in operations at Mica Dam resulting from the addition of two turbine units. 2014 represents the second complete summer period to meet the management question requirements for characterizing changes to the aquatic thermal regime. High flows prevented installation of TidbiTs until fall 2012. Following installation in October 2012, TidbiTs have collected data continuously, providing a complete set of data at three locations on each of the left and right banks downstream of the Mica Tailrace, between the dam and the blue bridge. The minimum requirements as specified in the TOR and our proposal have been achieved for 2013; initial indications from recent downloads suggest that we also have a complete set of temperature data downstream of the tailrace for 2014, which meet the pre-operation requirement for two continuous years of summertime temperature data. Following collection of two years post-implementation data, we will analyse the results to assess whether there are statistical differences.

The headpond water temperature data are not presented in this year's report. Although headpond data have been downloaded since the initial array deployment in October 2012, the array set-up and metadata are being evaluated and clarified prior to analysis and presentation to ensure accurate representation of the data and to better enable comparison with previous temperature data collected in Mica headpond.

Once the two years of post-assessment data are collected, the fish data will be analyzed to estimate the percent changes in relative abundance, condition (weight relative to length), growth (size at age), and distribution to estimate any effect due to change in operations resulting from the installation of Mica 5/6. The temperature analysis will look at: 1) the rate of change in water temperature and the water temperatures associated with different operational strategies and turbine configurations and how that changes with season, and 2) the spatial structure and variability in temperature changes throughout the study reach (i.e., when does it fully mix, do different banks have different regimes, etc.).

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Appendix 1. Fish Distribution Maps – Mica Tailrace Fish Indexing Study

Figure 5-1. Observed Juvenile and Adult Bull Trout Distribution – Mica Dam Tailrace October 2012, October 2013.

Figure 5-2. Observed Juvenile and Adult Rainbow Trout Distribution – Mica Dam Tailrace October 2013.

Figure 5-3. Observed Juvenile and Adult Kokanee Distribution – Mica Dam Tailrace October 2012 and October 2013.

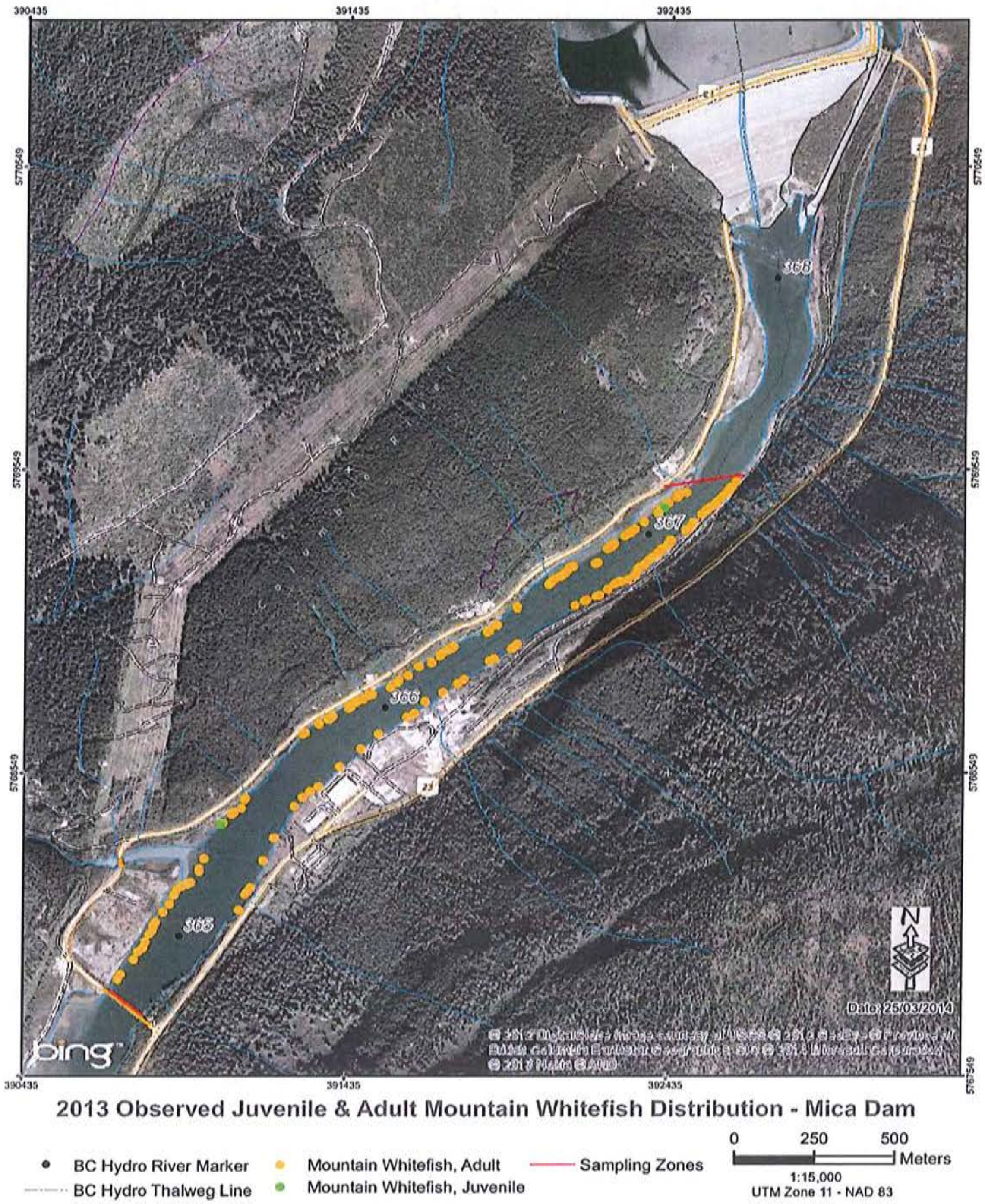

Figure 5-4. Observed Juvenile Mountain Whitefish Distribution – Mica Dam Tailrace October 2012 and October 2013.

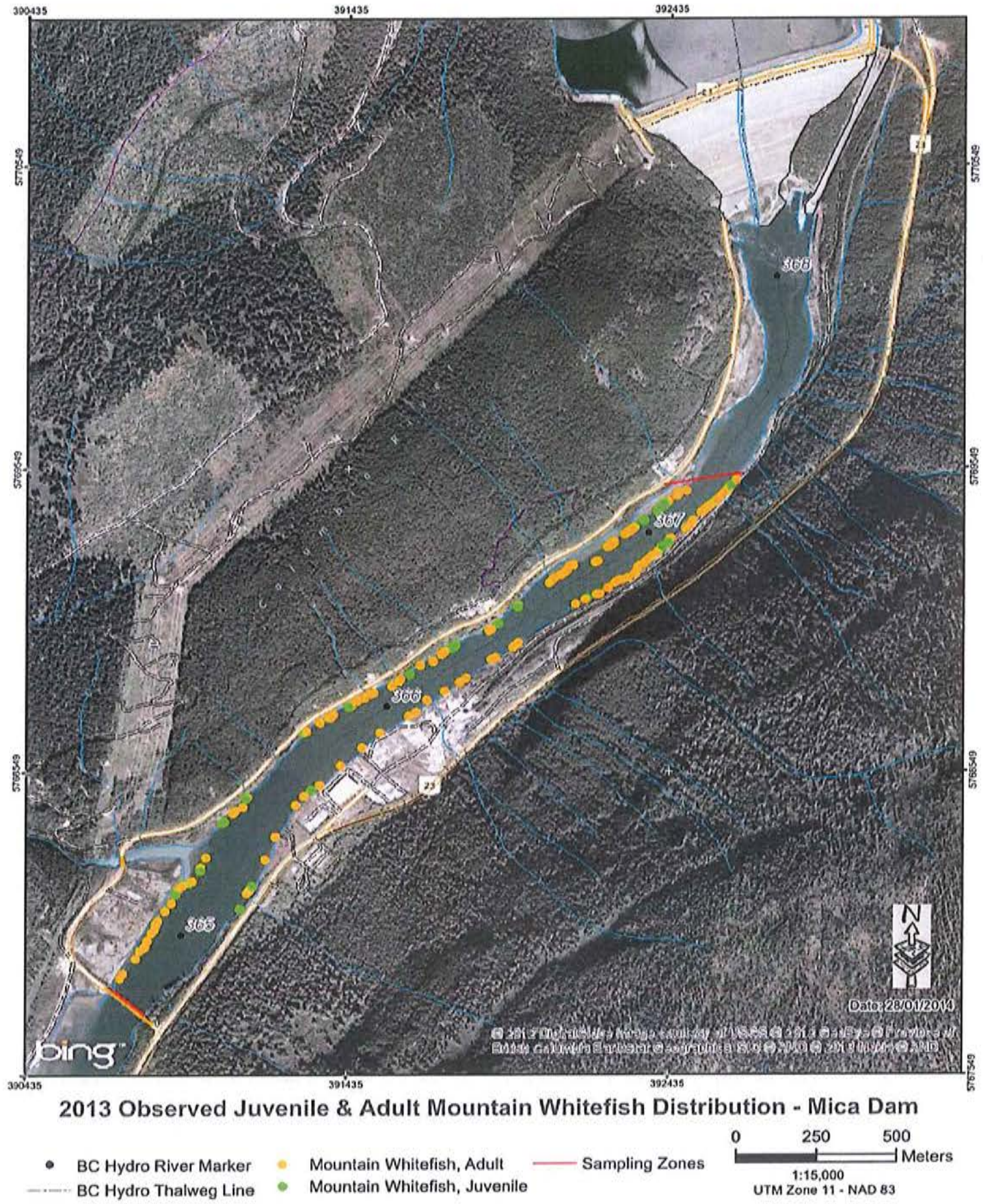

Figure 5-5. Observed Adult Mountain Whitefish Distribution – Mica Dam Tailrace October 2012 and October 2013.

Figure 5-6. Observed Juvenile and Adult Sculpin Distribution – Mica Dam Tailrace October 2013.

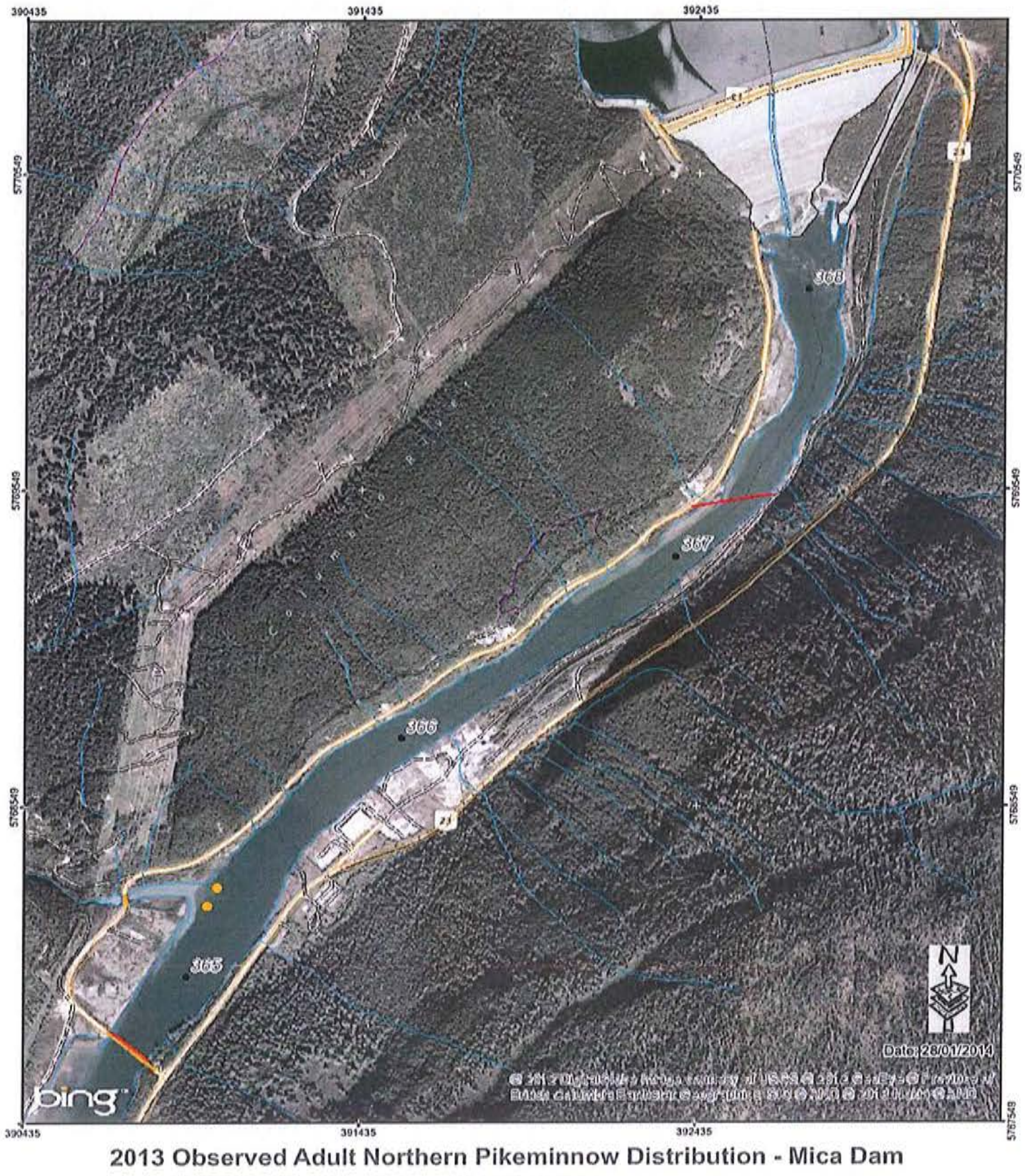

Figure 5-7. Observed Adult Northern Pikeminnow Distribution – Mica Dam Tailrace October 2013.

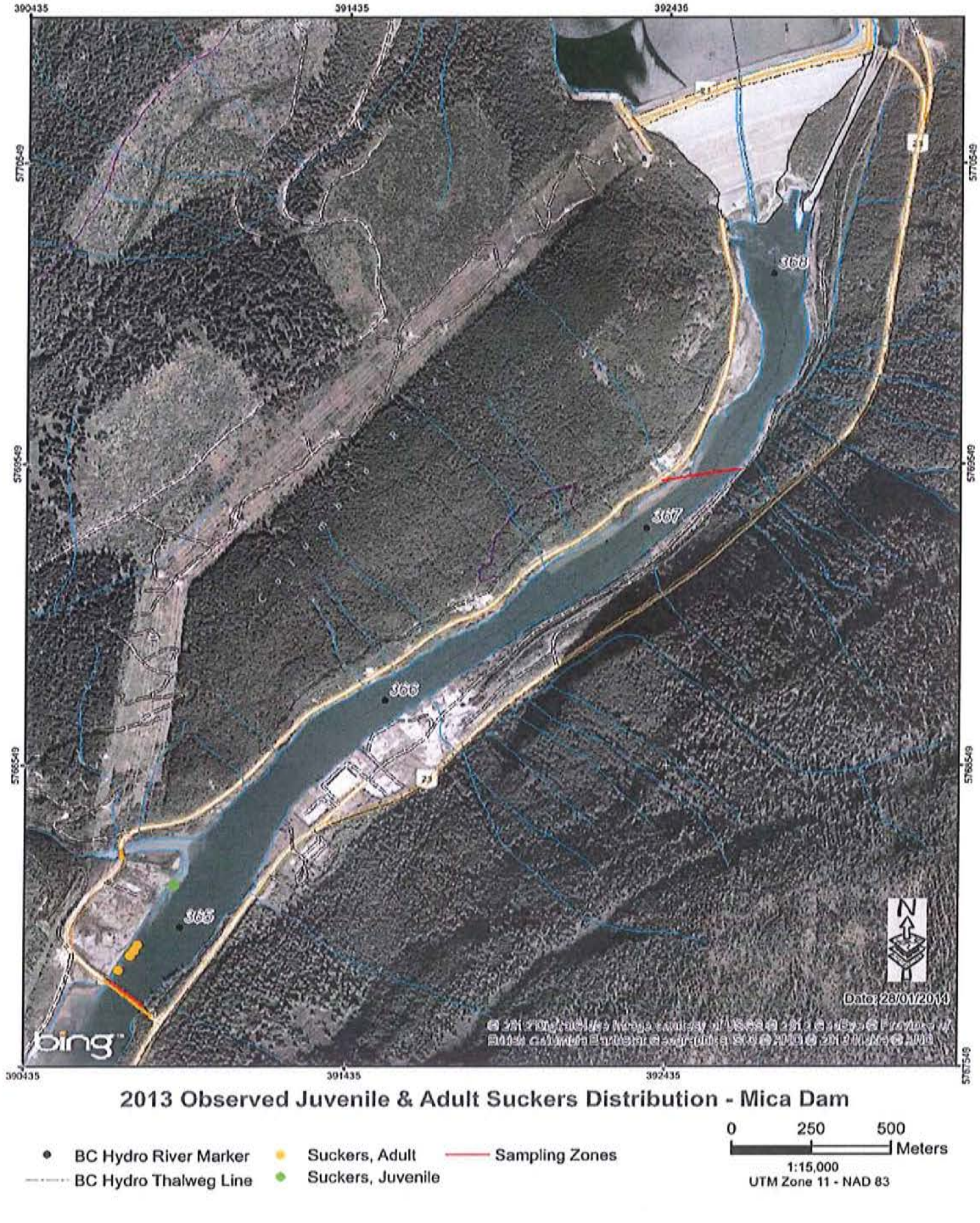

Figure 5-8. Observed Juvenile and Adult Suckers Distribution – Mica Dam Tailrace Fish Study October 2013.

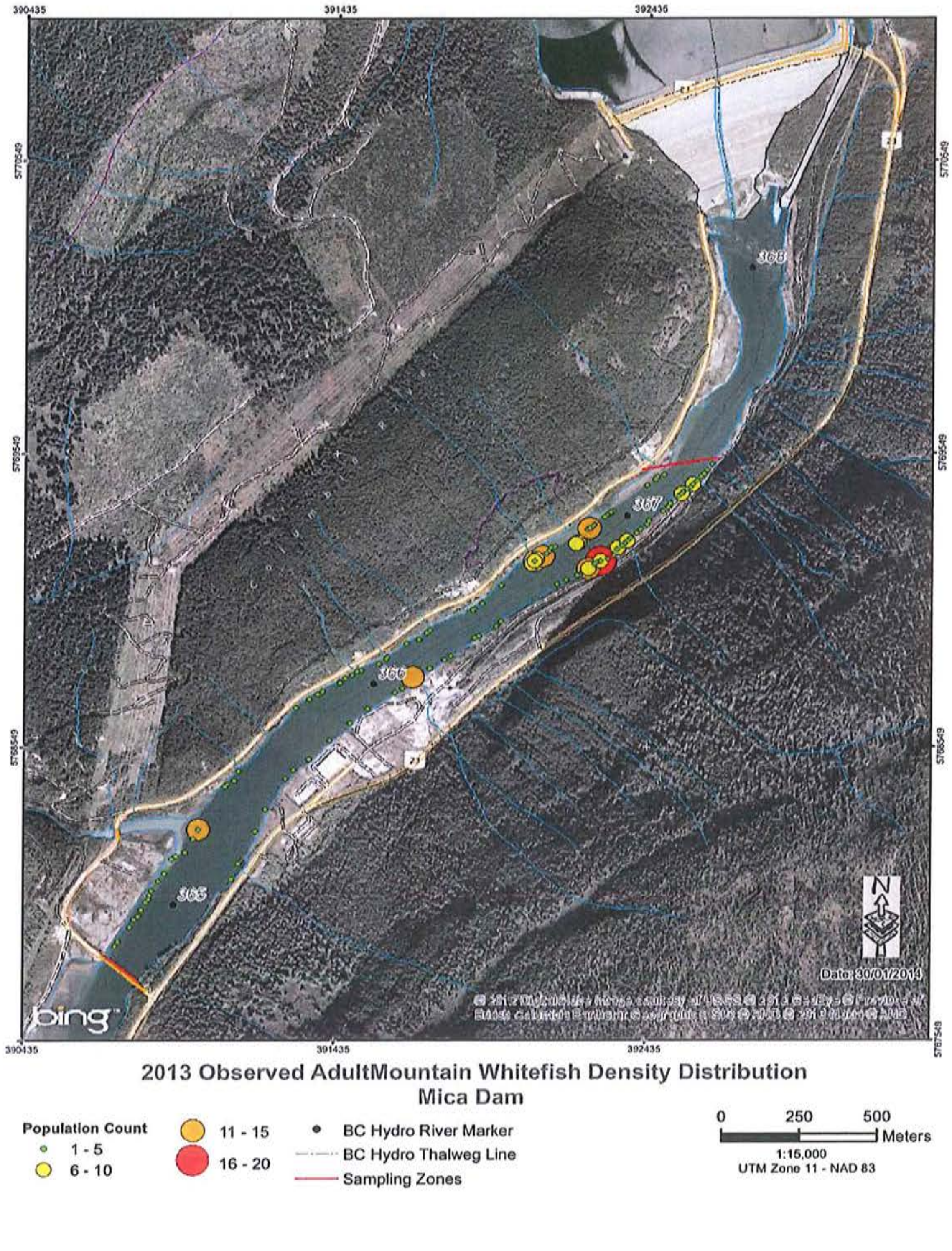

Figure 5-9. Observed Adult Mountain Whitefish Density Distribution – Mica Tailrace Fish Index Study, October 2013.

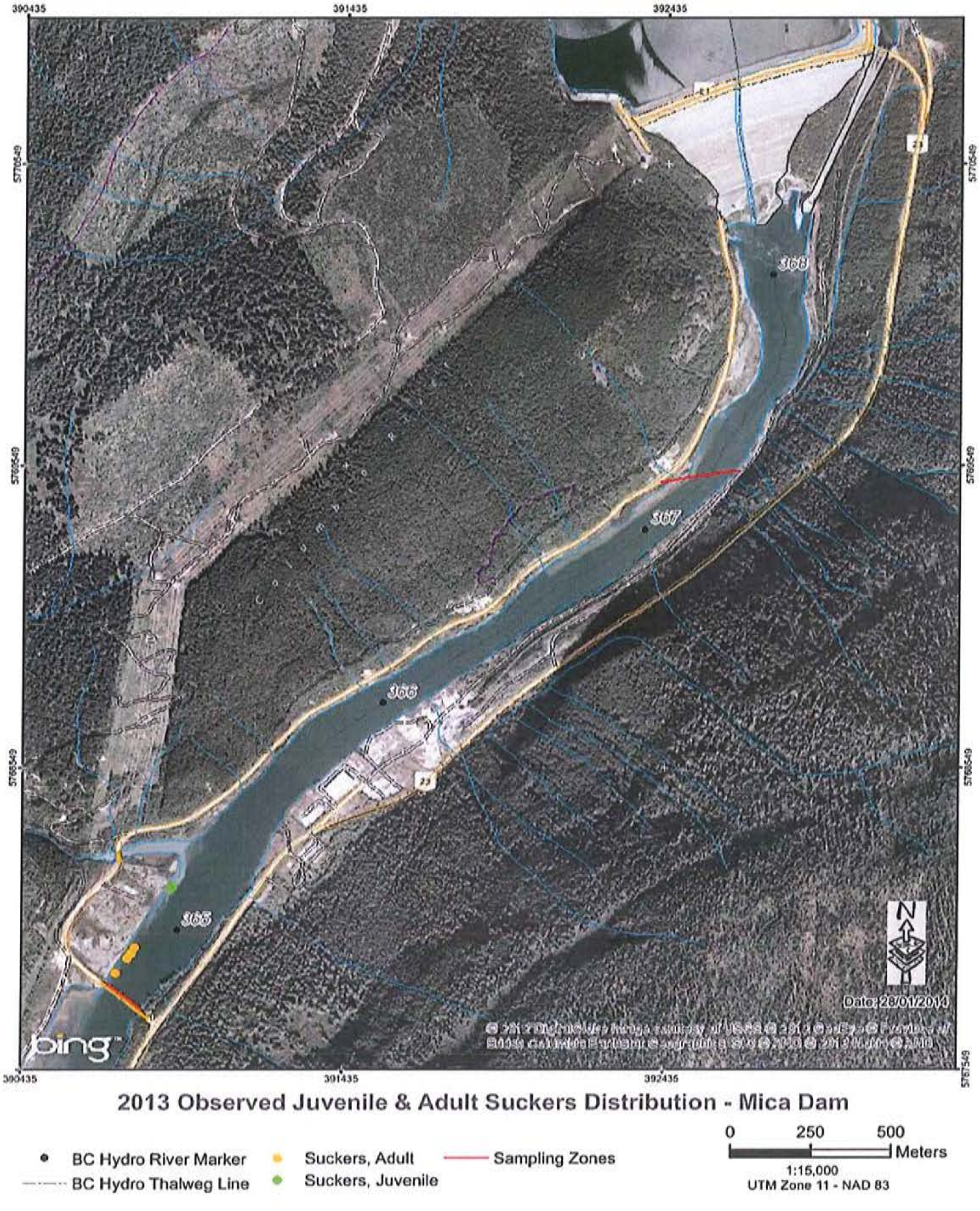

Figure 5-8. Observed Juvenile and Adult Suckers Distribution – Mica Dam Tailrace Fish Study October 2013.

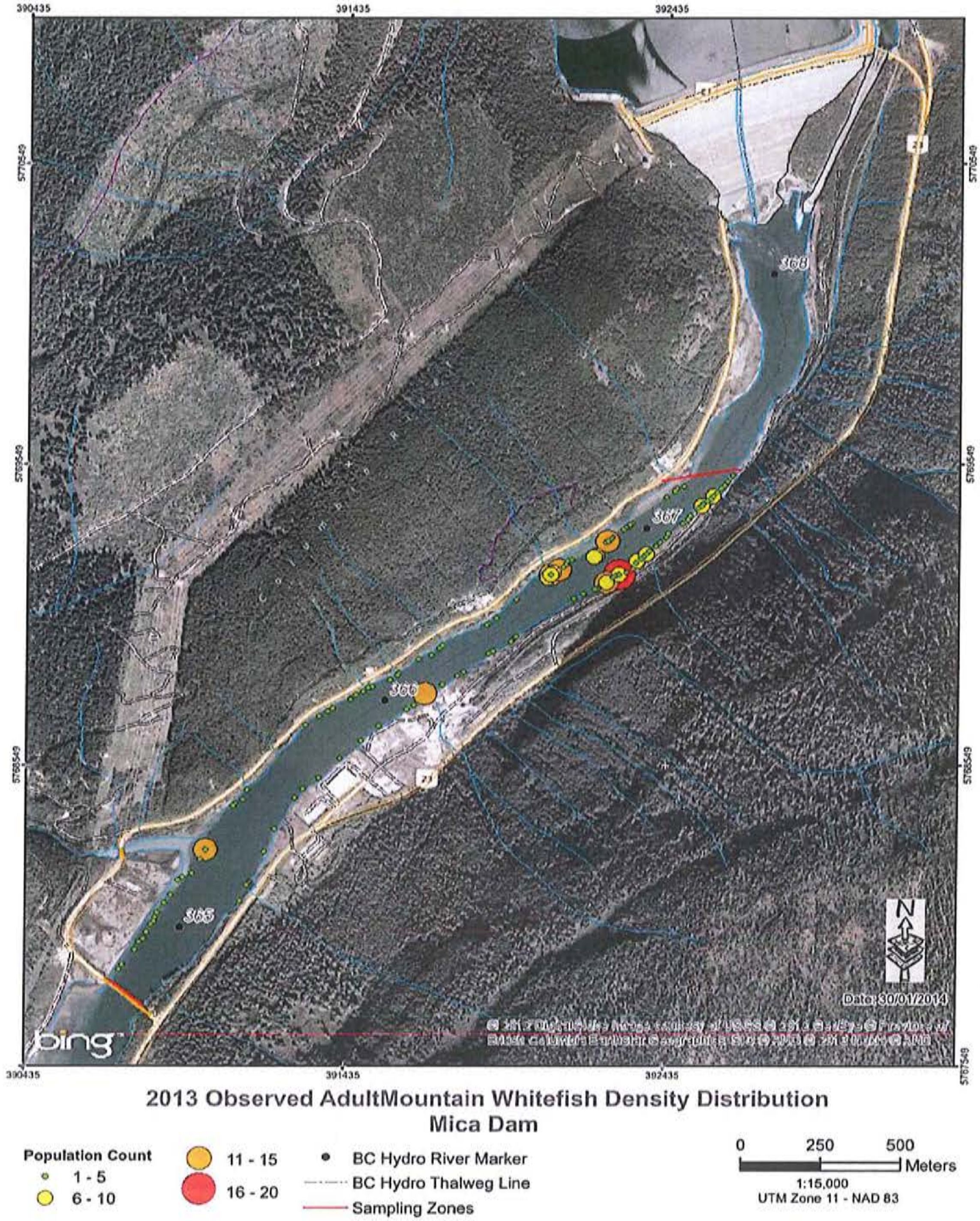

Figure 5-9. Observed Adult Mountain Whitefish Density Distribution – Mica Tailrace Fish Index Study, October 2013.

Appendix 2. Field Notes – Temperature Study

Temperature Study Field Notes are provided on DVD submitted to BC Hydro project manager

Appendix 3. Field Notes – Electrofishing Data

Electrofishing Data Field Notes are provided on DVD submitted to BC Hydro project manager

Appendix 4. Digital Data – Electrofishing, Temperature Data

Digital Data (Temperature, Electrofishing) are provided on DVD submitted to BC Hydro project manager

Appendix 5. Analytic Appendix.

Hierarchical Bayesian Analysis

Joe Thorley Ph.D., R.P.Bio.
Poisson Consulting Ltd.

5 March 2013

1 General Approach

Hierarchical Bayesian models were fitted to the fish indexing data below Mica Dam using the software packages R 2.15.2[8] and JAGS 3.3.0[6] which interfaced with each other via the jaggernaut R package. The models assumed low information uniform or normal prior distributions. The posterior distributions were estimated from a minimum of 1,000 samples thinned from the second halves of three Gibbs sampling chains. Model convergence was confirmed by ensuring that R-hat (the Gelman-Rubin-Brooks potential scale reduction factor) was less than 1.1 for each of the parameters in the model[2, 4, 3].

Following Bradford et al. (2005)[1], the influence of particular variables was, where informative, expressed in terms of the effect size (i.e., percent change in the response variable) with 95% credibility intervals. When the variable was considered a random effect, the percent change in the response was quantified with respect to the typical value, i.e., the expected value of the underlying distribution from which the observed values represent random draws. Plots were produced using the ggplot2 R package [9].

2 JAGS Distributions, Functions and Operators

JAGS distributions, functions and operators are defined in the following two tables. For additional information on the JAGS language, which is a dialect of the BUGS language, see the JAGS User Manual[7].

JAGS Distribution	Description
dlnorm(mu, sd^-2)	Log-normal distribution
dnorm(mu, sd^-2)	Normal distribution
dpois(lambda)	Poisson distribution
dunif(a, b)	Uniform distribution

JAGS Function or Operator	Description
<-	Deterministic relationship
~	Stochastic relationship
1:n	Vector of integers from 1 to n
a[1:n]	Subset of first n values in a
for (i in 1:n) {...}	Repeat ... for 1 to n times incrementing i each time
log(x)	Log of x
x^y	Power where x is raised to the power of y

3 JAGS Models

The following section provides the variable and parameter definitions and JAGS model code for the analyses.

3.1 Condition

Condition was estimated via an analysis of body weight conditional on body length [5].

3.1.1 Condition Model - Variables and Parameters

Variable/Parameter	Description
bLength	Effect of log length on log weight
bYear[yr]	Effect of yrth year on log weight
eLogWeight[i]	Expected log weight of ith fish
LogLength[i]	Log length of ith fish
bIntercept	Log weight intercept
sWeight	SD of residual variation in log weight
Weight[i]	Weight of ith fish
Year[i]	Year the ith fish was encountered

3.1.2 Condition Model - JAGS Code

```
model {
  sWeight ~ dunif(0, 5)

  bIntercept ~ dnorm(5, 5^-2)
  bLength ~ dnorm(0, 5^-2)

  bYear[1] <- 0
  for(yr in 2:nYear) {
    bYear[yr] ~ dnorm(0, 2^-2)
  }

  for(i in 1:nrow) {
    eLogWeight[i] <- bIntercept + bLength * LogLength[i] + bYear[Year[i]]
    Weight[i] ~ dlnorm(eLogWeight[i], sWeight^-2)
  }
}
```

3.2 Relative Abundance

Apparent lineal density was estimated via an analysis of the observer counts.

3.2.1 Relative Abundance - Variables and Parameters

Variable/Parameter	Description
Count[i]	Count for ith visit
bIntercept	Count intercept
bSite[st]	Effect of stth site on count
eFish[i]	Expected apparent abundance for ith visit
eDensity[i]	Expected apparent lineal density for ith visit
LengthSite[i]	Length of site for ith visit
sSite	SD of effect of site on count
Site[i]	Site for ith visit

3.2.2 Relative Abundance - JAGS Code

```
model {

  sSite~dunif(0, 5)

  bIntercept~dnorm(0,5^-2)

  for(st in 1:nSite) {
    bSite[st]~dnorm(0, sSite^-2)
  }

  for (i in 1:nrow) {
    log(eDensity[i]) <- bIntercept + bSite[Site[i]]
    eFish[i] <- eDensity[i] * LengthSite[i]
    Count[i] ~ dpois(eFish[i])
  }
}
```

References

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[4] A. Gelman and D. Rubin. Inference from iterative simulation using multiple sequences. *Statistical Science*, 7:457–511, 1992.

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[7] M. Plummer. *JAGS Version 3.1.0 User Manual*, 2011.

[8] R Development Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria, 2012. ISBN 3-900051-07-0.

[9] H. Wickham. *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag, New York, 2009.

Appendix 6. Columbia River Database

The Columbia River Database is available upon request from the BC Hydro project manager