Bridge River Power Development Water Use Plan

Carpenter Reservoir and Middle Bridge River Fish Habitat and Population Monitoring Terms of Reference

Implementation Year 2

Reference: BRGMON-4

Study Period: 2013-2014

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INSTREAM FISHERIES RESEARCH INC.

Bridge-Seton Water Use Plan

Implementation Year 2 (2013-2014):

Carpenter Reservoir and Middle Bridge River Fish Habitat and Population Monitoring

Reference: BRGMON-04

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Executive Summary

The Carpenter Reservoir and Middle Bridge River fish habitat and population monitoring program was developed during the Bridge River Valley water use planning (WUP) process to address uncertainties relating to fish and fish habitat in Carpenter Reservoir and the Middle Bridge River. Primary objectives of the monitor are to collect information on the biological characteristics and abundance of fish in Carpenter Reservoir and the Middle Bridge River, and to determine how operation of BC Hydro facilities affects fish productivity. Tisdale Environmental Consultants Inc. (TEC) began monitoring in 2012 and 2013 (Year 1) using Mountain Whitefish surveys in the Middle Bridge River, general population indexing via shoreline electroshocking, spawner surveys in reservoir tributaries, and PIT tagging of Bull Trout and Rainbow Trout for growth, distribution, and abundance estimation. TEC ceased monitoring following Year 1, and in Year 2 the monitoring program was transferred to InStream Fisheries Research Inc. (IFR). Initial data analyses suggested that the original monitoring program would not adequately answer management questions as outlined in the terms of reference (TOR), and BC Hydro initiated a review and redevelopment of the TOR based on results of Years 1 and 2. The Year 2 field season was used to continue field activities from Year 1 (i.e., tributary spawner surveys and mark-recapture activities) and to test alternative survey and data capture methods including closed mark-recapture modeling, short set gill netting, the use of a sonar camera in the Middle Bridge River, and Bull Trout radio telemetry.

Results from preliminary field work in Carpenter Reservoir and the Middle Bridge River suggest the fish community is dominated by Bull Trout and Mountain Whitefish and that Rainbow Trout and kokanee are present in lower densities. Although general population indexing featured prominently in the initial monitoring plan, this method did not produce reliable data due to high and variable turbidity in Carpenter Reservoir, unknown electrofishing capture efficiency, and high costs relative to data value. IFR recommends shifting the monitoring program away from general population indexing to focus on an open mark-recapture model for Bull Trout in the reservoir; identifying preferred habitat use for different species in the reservoir; and quantifying the risk of egg and redd dewatering for Mountain Whitefish and kokanee in the Middle Bridge River. Making adjustments to the current TOR hypotheses and survey methods based on lessons learned in the first two years will allow for a targeted monitoring program that can produce data more likely to adequately answer management questions. Carpenter Reservoir is a large and complex system, and the BRGMON-04 monitoring program will continue to adapt as our knowledge and understanding of the system grows.

BRGMON-04 status of objectives and management questions after Year 2[1].

Study Objectives	Management Questions	Year 2 (2013-2014) Status
1: Collect comprehensive information on the life history, biological characteristics, distribution, abundance, and composition of the fish community in Carpenter Reservoir and Middle Bridge River.	1: What are the basic biological characteristics of parameters of fish populations in Carpenter Reservoir and Middle Bridge River?	Biological information was collected in both Years 1 and 2 and a basic understanding of fish populations in Carpenter Reservoir and the Middle Bridge River is being developed. This was the primary focus of Year 2 of BRGMON-04 and methods and results in this report relate primarily to this management question.
2: Provide information required to link the effects of reservoir operation on fish populations.	2: Will the selected alternative result in positive, negative, or neutral impact on abundance and diversity of fish populations?	No specific method targets this management question. This question will be answered using a weight of evidence approach using biological data and regression analysis with operating conditions.
	3: Which are the key operating parameters that contribute to reduced or improved productivity of fish populations in Carpenter Reservoir and Middle Bridge River?	No specific method targets this management question. This question will be answered using a weight of evidence approach using biological data and regression analysis with operating conditions.
	4: Is there a relationship between specific characteristics of the in stream flow in Middle Bridge River that contribute to reduced or improved productivity of fish populations in Carpenter Reservoir and Middle Bridge River?	In Year 1 Tisdale Environmental Consultants performed Mountain Whitefish sampling in the Middle Bridge River and found that Middle Bridge River water levels are not likely affecting Mountain Whitefish productivity (see section 4.5). In Year 2 IFR tested the ability of a sonar camera to quantify kokanee migration into the river (see section 4.6).

[1] Management hypotheses are not included in this summary because they are not directly relatable to individual management questions. In addition, a review of the BRGMON-04 TOR was completed in March of 2015 and the management questions were revised.

	5: Can refinements be made to the operation of Carpenter Reservoir and management of in stream flow releases from Lajoie Generating Station into the Middle Bridge River to improve protection or enhance fish populations in both of these areas, or can existing constraints be relaxed?	No specific method targets this management question. This question will be answered using a weight of evidence approach using biological data and regression analysis with operating conditions.

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1 Introduction

1.1 Background

The Bridge River power project, located in the Bridge River Valley of southwestern British Columbia (Figure 1-1), was initiated in the 1920s and completed in 1960 with the construction of Terzaghi Dam (BC Hydro 2014). Following its construction, the Bridge River generating system (consisting of three dams and four generating facilities) was the largest generator of power in British Columbia and today contributes 6-8% of BC Hydro's total generating capacity. Construction of the Bridge River power complex significantly altered flow of the Bridge River and substantially impacted aquatic ecosystems throughout the valley. Following the construction of Terzaghi Dam, flow in the Bridge River ceased completely below the dam (with the exception of periodic spill releases), and a four-kilometer section of channel remained dewatered before being fed by groundwater and tributary inflows further downstream. As a result of concerns from multiple user groups, an agreement was reached in 1998 and implemented in 2000 that resulted in a minimum 3.0 m^3s^{-1} water release from Terzaghi Dam to the Lower Bridge River and continuous watering of the Lower Bridge River channel.

The Bridge River valley is an important cultural and sustaining resource for the St'át'imc First Nation, and the development of hydro facilities in the valley has greatly altered use of the watershed. In response to concerns regarding the environmental and social impacts of power generation in the Bridge River Valley, a Water Use Planning (WUP) process was initiated in 1999. Recommendations were put forward in 2003 by a multi-stakeholder consultative committee (Bridge River Consultative Committee, BRCC) to implement an alternative operating strategy (N2-2P) aimed to balance fish and wildlife health, recreation opportunities, flood management, water security, and power generation. A draft WUP was developed in 2003 following recommendations from the BRCC, and a final WUP was accepted in 2011 (BC Hydro 2011).

Throughout the WUP process, uncertainties were identified that hindered the development of explicit fish population level performance measures for decision making purposes. Qualitative performance measures were developed during the WUP process that aided in the development of the current operating strategy; however, a lack of quantitative data resulted in significant uncertainties. As a result, the WUP recommended comprehensive environmental monitoring in the Bridge River Valley to address uncertainties and to monitor impacts of the alternative operating strategy (BC Hydro 2011). These recommendations include monitoring of fish and fish habitat in Carpenter Reservoir and the Middle Bridge River, and led to the development of BRGMON-04.

1.2 Previous Research in Carpenter Reservoir and the Middle Bridge River

Few historic data are available for Carpenter Reservoir and the Middle Bridge River; however, a number of preliminary investigations into fish populations and reservoir productivity have been undertaken. In 1995 and 1996 R.P. Griffith & Associates and Limnotek Research and Development Inc. performed an assessment of fish and fish habitat and limnological conditions in the reservoir (Griffith 1999). The fish and fish habitat assessment included a) the identification and assessment of stream spawning habitat using closed-site electroshocking, and b) fish index surveys via gill netting in the lower (pelagic) portion of the reservoir. Total counts of Rainbow Trout and Bull Trout were low in Carpenter Reservoir tributaries, and habitat investigations suggested limited stream-lengths accessible to fish (due to steep gradients and barriers to passage), limited spawning substrate in streams, and lack of cover in streams heavily affected by reservoir drawdown. Despite these habitat limitations, Griffith (1999) hypothesized that the large number of tributaries in the Carpenter Reservoir system could allow the reservoir to support large populations of Bull Trout, Rainbow Trout, and kokanee. Gill netting conducted in the vicinity of the Bridge 1 and Bridge 2 diversion tunnels (in the lower portion of the reservoir) yielded high numbers of both Rainbow Trout and Bull Trout, and low numbers of kokanee. Gill netting during high and low reservoir elevations suggested that Bull Trout and Rainbow Trout may be less reliant on pelagic habitat than kokanee, with the former able to occupy intermediate and upper portions of the reservoir during low pool conditions. Limnological surveys found low numbers of zooplankton and phytoplankton in Carpenter Reservoir, possibly due to a short water retention time in the reservoir. Griffith (1999) hypothesized that production, rather than spawning and recruitment, may limit fish production in Carpenter Reservoir and the Middle Bridge River.

A preliminary study into the impacts of hydro operations on Bull Trout and kokanee migrations, life histories, and critical life history stages was completed in 1999 and 2000 (Chamberlain et al. 2001). Two years of radio tracking were performed on adult Bull Trout, and tributary spawner surveys were undertaken to determine relative spawning counts of kokanee in a number of Carpenter Reservoir tributaries. Radio tracking indicated that Bull Trout generally migrate upstream into the top end of the reservoir as it fills in the spring and summer, and occupy the lower portion of the reservoir during the winter (Chamberlain et al. 2001). Stream surveys failed to identify spawning kokanee in any of the eleven streams surveyed, and only 2 kokanee carcasses were observed (both in Gun Creek). Also in 2000, a preliminary study of primary production resulted in the development of a light-based productivity model suggesting that Carpenter Reservoir productivity increases in an upstream direction (unpublished, referenced in Chamberlain et al. 2001).

The results of the preliminary fish and productivity studies were used during the WUP process, and data and methods were used to inform the development of reservoir monitoring programs in the Bridge River Valley. The Carpenter Reservoir and Middle Bridge River Fish Habitat and Population Monitoring program (BRGMON-04) was designed to build on information compiled during the WUP process to inform management of the Bridge River power generating system.

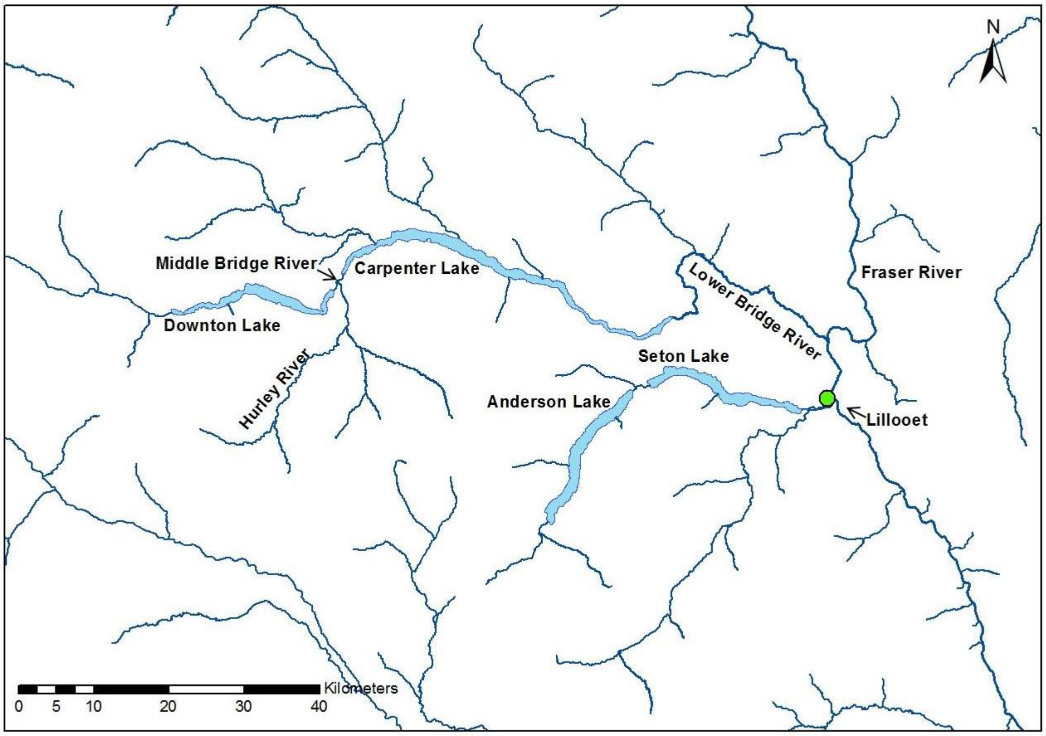


Figure 1-1 Bridge River system showing locations of BC Hydro reservoirs and dams.

1.3 Management Questions

BRGMON-04 addresses five primary management questions identified during the WUP process (BC Hydro 2012)[2]:

1. What are the basic biological characteristics of parameters of fish populations in Carpenter Reservoir and its tributaries?
2. Will the selected alternative (N2-2P) operation result in positive, negative, or neutral impact on abundance and diversity of fish populations?
3. Which are the key operating parameters that contribute to reduced or improved productivity of fish populations in Carpenter Reservoir and Middle Bridge River?
4. Is there a relationship between specific characteristics of the in-stream flow in the Middle Bridge River that contribute to reduced or improved productivity of fish populations in Carpenter Reservoir and Middle Bridge River?
5. Can refinements be made to the operation of Carpenter Reservoir and management of in-stream flow releases from Lajoie Generating Station into the Middle Bridge River to improve protection or enhance fish populations in both of these areas, or can existing constraints be relaxed?

1.4 Detailed Hypotheses

The primary hypotheses (and sub-hypotheses) associated with the management questions are as follows:

[2] An amendment to the TOR was completed in 2015, during which the monitor hypotheses were modified. The management questions (presented here) were not modified during the TOR amendment.

H1. The abundance and diversity of Carpenter Reservoir fish populations is limited by habitat impacts directly related to the operation of the reservoir.

H1a. Operation of the reservoir at low elevations reduces fish productivity due to stranding of fish or fish eggs.

H1b. Operation of the reservoir at low elevations (typically during later-winter to early-spring) reduces productivity of fish populations due to fish entrainment from the reservoir.

H1c. Operation of the reservoir at low elevations reduces littoral productivity and this results in reduced abundance and diversity of Carpenter Reservoir fish populations.

H1d. Operation of the reservoir at low elevations reduces pelagic productivity and this results in reduced abundance and diversity of Carpenter Reservoir fish populations.

H2. The abundance and diversity of Carpenter Reservoir fish populations is limited by habitat impacts directly related to operation of the Lajoie Generating Station.

H2a.Operation of the reservoir of Lajoie Generating Station restricts the amount of available effective spawning habitat (through egg dewatering) in Middle Bridge River and this limits the productivity of Carpenter Reservoir fish populations.

1.5 Key Water Use Decision Affected

Key water use decisions affected by the BRGMON-04 monitor relate to the development of minimum and maximum elevations for Carpenter Reservoir, minimum elevations for Downton Reservoir, and management of releases from Lajoie Generating Station. During the WUP process, a higher priority was placed on reducing spills in the Lower Bridge River and protecting anadromous fish species than protecting species resident to the reservoir (BC Hydro 2011). Whitefish egg dewatering in Middle Bridge River was identified as an issue of concern during the WUP process, and a deeper drawdown of Downton Reservoir was adopted to reduce egg dewatering in the Middle Bridge River during winter months (BC Hydro 2011). BRGMON-04 aims to determine whether operating parameters for Carpenter and Downton Reservoirs and in-stream flow releases from Lajoie Generating Station have a negative effect on fish and fish habitat, and whether current management practices can be refined to reduce negative impacts or enhance reservoir fish populations.

2 Monitoring Program Methods

2.1 Objectives and Scope

BRGMON-04 has two primary objectives, with the scope of monitoring being limited to fish populations in Carpenter Reservoir, Middle Bridge River, and fish-bearing tributaries of both systems.

1) Collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Carpenter Reservoir and Middle Bridge River.
2) Provide information required to link the effects of reservoir operation on fish populations to
    a. document impacts of the N2-2P alternative on existing reservoir fish populations, and
    b. allow more informed decision-making in the future regarding the operation of Carpenter Reservoir.

2.2 Monitoring Approach

The goal of this monitoring program is to collect a comprehensive long-term dataset of fish populations and habitat conditions (in Carpenter Reservoir and the Middle Bridge River) to resolve current gaps in data and scientific understanding. This information will be used to identify changes in population structure, and any changes over time can be used to develop and test hypotheses linking habitat conditions and population responses.

The first year of BRGMON-04 monitoring (completed by Tisdale Environmental Consultants [TEC]) highlighted deficiencies in some of the original hypotheses and methodological approaches outlined in the terms of reference. Carpenter Reservoir is a very large and remote reservoir, and there are significant logistical challenges to collecting comprehensive information for all species and life stages in both the reservoir and the Middle Bridge River. Techniques used in other large reservoirs and river systems (e.g., boat electrofishing, fly-over spawner surveys, hydroacoustic transects; Sebastian and Weir 2014, Zwart et al. 2013, Sebastian et al. 2003) proved to be challenging or not cost-effective in Carpenter Reservoir and the Middle Bridge River due to the large size of the system, remote access, high turbidities, and large reservoir fluctuations. Monitoring in Year 2 of was used to evaluate the effectiveness of alternative sampling methods for their ability to answer the BRGMON-04 management questions.

The monitoring program outlined in this report is adaptive in nature and uses a variety of methods to explore different aspects of the Carpenter Reservoir and Middle Bridge River system. The Carpenter Reservoir system is large and complex and the results of Years 1 and 2 demonstrated that one single method will not be successful in answering the management questions. A number of different methods were used in Years 1 and 2 to develop an understanding of the system and identify methods that can target specific management hypotheses. The results of these initial monitoring years were used to evaluate and revise the management hypotheses to reflect the quantity and type of data that can be obtained within the constraints of BRGMON-04. This adaptive process will continue into future monitoring years, with some methods being repeated each year, and new methods being tested and modified yearly based on their ability to answer specific management hypotheses.

3 Methods

3.1.1 Carpenter Reservoir Population Indexing

General population indexing was proposed in the BRGMON-04 TOR to determine habitat preferences and changes in relative abundance over time of fish species in Carpenter Reservoir. General population indexing is a relative measure that allows researchers to make assumptions about an entire community based on data obtained from a subsample of the population. It is often difficult or impossible to perform a complete population census in large systems, and indexing uses less effort and resources while still providing meaningful population data. However, population indexing can be misleading if the relationship between the population and the subsample is poorly understood, and care must be taken to obtain consistent, reliable indexing data. Shoreline electroshocking was used as a population indexing method in Year 1 in four different habitat types: creek mouths (with a 25 m buffer zone on either side), fluvial fans, shoreline of slope <15%, and shoreline of slope >15% (see Blackman, Murphey and Cowie 2004 for greater detail). Two periods of single-pass shoreline electroshocking (900 s per site) occurred in the spring (low pool) and fall (maximum pool) in a random sample of each of the four habitat types. Bridgelip Suckers (*Catostomids* *columbianus*) and Redside Shiners (*Richardsonius balteatus*) were enumerated by the boat operator, while Mountain Whitefish, Rainbow Trout (*Oncorhynchus mykiss*), Bull Trout (*Salvelinus confluentus*), and kokanee (*Oncorhynchus nerka*) were brought into a live tank on board the boat and processed to obtain biological measurements. All captured fish were anaesthetized with a diluted solution of clove oil (dissolved 1:10 in ethanol) and weighed and measured, while Bull Trout and Rainbow Trout were also tagged with Passive Integrated Transponder (PIT) tags. Aging structures (i.e., scales, fin sections, and/or otoliths) were recovered from a subset of Bull Trout, Rainbow Trout, Mountain Whitefish, and kokanee.

In Year 2, two periods of population indexing were performed in Carpenter Reservoir; however, the focus of the shoreline electroshocking was modified to determine the efficiency of boat electroshocking. The electroshocking program in Year 1 provided strictly index data; no measure of abundance could be calculated because the efficiency of electroshocking was unknown. Another issue with the index program was that varying physical conditions (i.e., changes in reservoir elevation and turbidity) confounded changes in fish abundance and distribution. For example, high turbidities in the fall of Year 1 resulted in no fish being observed or captured in the upper portion of the reservoir despite fish being angled in the same areas during the fall time period. Issues such as varying turbidity may be resolved if electrofishing efficiency is known at different physical conditions, and in Year 2 we attempted to determine spring and fall electrofishing efficiency in Carpenter Reservoir using closed population mark-recapture modelling. Closed population mark-recapture methods have been used in large reservoirs and rivers to obtain estimates of electroshocking capture efficiency and to estimate population abundance (Ford and Thorley 2012; Mainstream Aquatics Ltd. and Gazey Research 2007). To determine electroshocking efficiency in Carpenter Reservoir, all fish caught during an electrofishing pass were tagged and re-released within the site. Each site was left for a 24-hour period to allow fish to redistribute, then sites were electroshocked a second time and the number of marked and unmarked fish was recorded. Although this simple method allows for the calculation of electrofishing efficiency, the assumptions of a closed model must be met in order for the efficiency to be reliable (i.e., there must be no immigration or emigration to or from the sample area between the marking and recapture periods).

Electroshocking sites were originally selected for the closed mark-recapture experiment based on general population indexing site locations and habitat categories (created by TEC in Year 1); however, shoreline of slope <15% and shoreline of slope >15% were removed from the experiment as only creek mouths and alluvial fans had high enough fish capture rates to be used for mark-recapture modelling. In the spring survey, where electrofishing was used as both a marking and a recapture tool, recaptures of all species of fish were virtually zero in all habitat types during recapture passes. There was also a general decline of total catch numbers in consecutive electrofishing sites, suggesting that electrofishing may have been causing fish to emigrate permanently from the sites over the one-week period. Because a closed mark-recapture model assumes that sites are closed, any emigration violates the assumptions of the model and a measure of efficiency cannot be obtained. In an effort to reduce or eliminate emigration between marking and recapture events, a similar mark-recapture experiment was performed in the fall where angling was used as a marking method and electrofishing was used only as a recapture method. Creek mouths and fluvial fans were heavily angled for two days prior to one night of electrofishing recapture. A mark-recapture model can be performed using different techniques for marking and recapture, but if the different methods target different species or size classes the results of the model are limited to the targeted size/age class. When using angling as a marking tool at Carpenter Reservoir creek mouths, any resulting efficiency estimate could only be applied to fish vulnerable to angling (i.e., adult Bull Trout); however, any measure of efficiency would aid in interpreting and extrapolating population indexing results.

In addition to marking of Bull Trout and Rainbow Trout during spring and fall population indexing, additional PIT tagging of both species (and some kokanee and Mountain Whitefish) occurred throughout the summer and fall of Years 1 and 2. This opportunistic angling was used to obtain biological data for all fish species in Carpenter Reservoir and to increase the number of marked fish for future distribution and growth rate calculations. Fish were angled at tributary confluences (primarily using roe-baited hooks), anaesthetized with clove oil, weighed, measured, and PIT tagged. Aging structures were also collected from Bull Trout, Rainbow Trout, kokanee, and Mountain Whitefish. Throughout the duration of the monitor, data from PIT tagged fish will provide information on biological characteristics including spatial distribution and movement, growth rates, and population age structures.

3.1.2 Tributary Spawner Surveys (Rainbow Trout, Bull Trout, and kokanee)

Visual stream bank counts of spawning Rainbow Trout, Bull Trout, and kokanee were conducted in Years 1 and 2 in Carpenter Reservoir tributaries. Counts occurred in Big Horn Creek, Girl Creek, Gun Creek, Jones Creek, McDonald Creek, Marshall Creek, Sucker Creek, and Truax Creek (Figure 3-1). With the exception of Gun Creek, all tributaries measured less than 5m across, and crews were able to see the entire channel by walking on one bank. For Gun Creek, observers were only able to survey the East side of the creek due to time constraints. Two observers walked in a downstream direction on the streambank looking for evidence of fish or redds. Observers recorded the number of spawners, weather conditions (temperature and percent cloud cover), water clarity (good, moderate, or poor), and the presence of additional species in each tributary. Surveys began prior to the estimated start of spawning for each species, and continued weekly until fish were no longer observed in monitored tributaries. For both Rainbow Trout and kokanee, spawners were already present in some tributaries during the first survey (i.e., spawning migrations had already commenced), and surveys will begin earlier in future years to attempt to determine the timing of the start of migration.

The Middle Bridge River has very high turbidity and cannot be surveyed using visual surveys. Because kokanee spawners tend to roll at the surface during spawning migration, the presence of kokanee spawners was noted in the Middle Bridge River directly underneath the Hurley River Bridge and the Goldbridge Bridge (but no counts could be made). These data cannot be used to quantify kokanee spawning in the Middle Bridge River, but provide information regarding kokanee presence and migration timing in the Middle Bridge River. Mountain Whitefish also spawn in the Middle Bridge River and therefore cannot be evaluated using visual surveys. Mountain Whitefish were monitored by TEC in Year 1 using egg mats and angling surveys during the spawning period (see Tisdale 2010 for methods). Egg mat surveys and Mountain Whitefish angling will be repeated by IFR during Years 5, 7, and 9 to answer BRGMON-04 management questions.

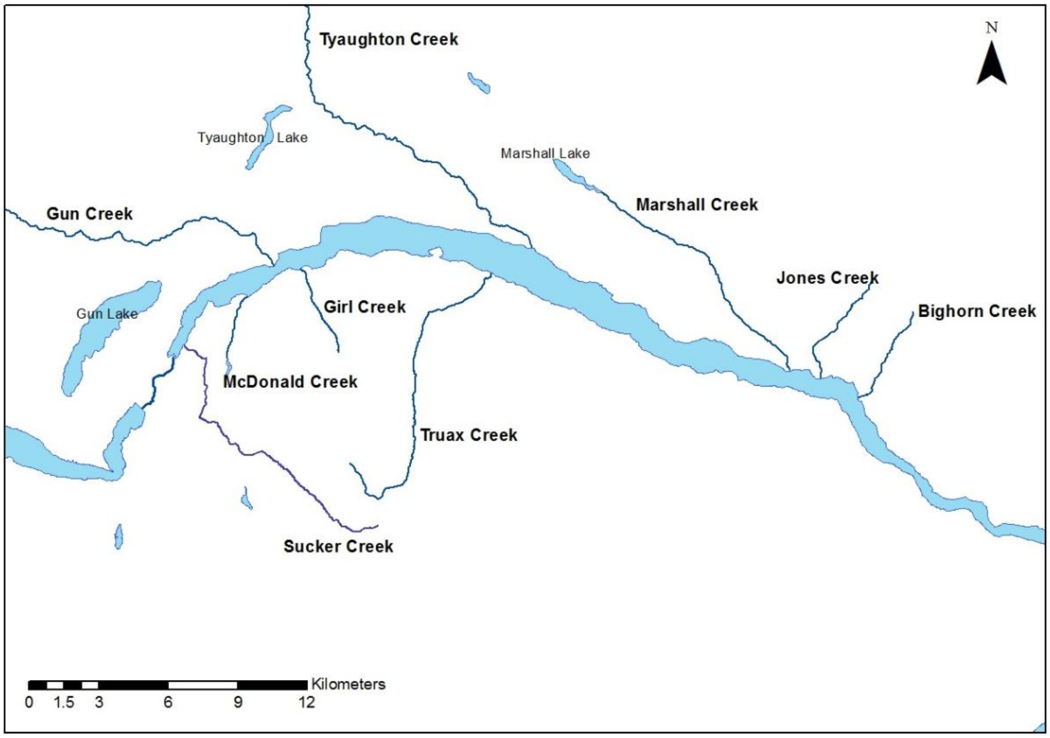


Figure 3-1. Locations of Carpenter Reservoir tributaries assessed for spawning activity.

3.1.3 Bull Trout Radio Telemetry

Radio telemetry tags (Lotek Wireless, NTC-6-2, 9 mm x 30 mm) were surgically implanted into 30 Carpenter Reservoir Bull Trout in August of 2014 to assess Bull Trout behaviour and identify potential spawning locations in Carpenter Reservoir and its tributaries. Bull Trout were angled at two locations (Truax Creek, and Gun Creek), anaesthetized using clove oil, surgically implanted with a gastric radio tag, and recovered and released at the tagging location (see methods in Wagner et al 2011). Weekly manual tracking (hand-held Lotek W31 radio receiver) occurred on foot and from a vehicle throughout the Carpenter Reservoir valley from August 19, 2014 to October 7, 2014. The time of detection, relative signal strength, and a GPS coordinate was recorded for each fish detected during manual tracking surveys. The radio tags have an expected battery life of two years, and manual tracking will continue during the Year 3 field season.

3.1.4 Short-set Gill Netting in Carpenter Reservoir

One day of short-set gill netting took place in Carpenter Reservoir on October 16, 2014 to evaluate the use of gill nets as a mark-recapture tool. Short-set gill netting has been used successfully by other programs as a non-lethal capture method for mark-recapture modelling (e.g., Mills, Chalanchuk and Allan 2002), and gill netting can be used to target mid-lake habitats that cannot be assessed using electroshocking, seining, or angling. Overnight gill netting as an indexing tool was not considered for BRGMON-04 as it is a lethal method that should not be combined with a live tagging program such as mark-recapture.

Resource Inventory Committee (RIC) standard sinking gill nets (91.2 m long, 2.4 m deep) consisting of six panels of variable mesh sizes (25 mm to 76 mm) were set in the littoral zone, perpendicular to the Carpenter Reservoir shoreline at a maximum depth of 15 m. Nets were set between 10 am to 3 pm for a maximum duration of 30 minutes to reduce mortality. Bridgelip Suckers, Mountain Whitefish, and Redside Shiners were enumerated, while Bull Trout and Rainbow Trout were weighed, measured, and PIT tagged to obtain data on biological characteristics.

3.1.5 Mountain Whitefish Spawning Survey in Middle Bridge River (TEC)

Mountain Whitefish spawning timing and distribution was previously assessed by TEC in the Middle Bridge River in 2005 and 2009 through the use of aging analysis and submerged egg screens in suspected spawning areas (Tisdale 2010). Mountain Whitefish were angled throughout the Middle Bridge River using commercially cured single salmon eggs and weighed, measured, and assessed for spawning condition. Spawning mats were deployed in five areas of suspected Mountain Whitefish spawning, and whitefish eggs were counted during weekly mat retrievals. In November and December of 2012 and 2013 (Year 1 of the current monitor; no report published) TEC repeated Mountain Whitefish angling surveys completed in the Middle Bridge River in 2005 and 2009. Mountain whitefish were assessed for spawning condition and tagged with PIT tags for open mark-recapture purposes. No surveys of Mountain Whitefish spawning occurred during the current monitor year (Year 2); however, the use of egg mats will be repeated in future monitoring years to further assess risks to Mountain Whitefish spawning in the Middle Bridge River.

3.1.6 Kokanee Enumeration in Middle Bridge River

In Year 1, TEC observed kokanee spawning in the Middle Bridge River directly beneath both the Hurley River Bridge and the Goldbridge Bridge; however, high turbidity in the river prevented the possibility of enumeration for abundance estimation or population indexing. To enumerate spawning kokanee migrating from Carpenter Reservoir into the Middle Bridge River, IFR assessed the use of a sonar camera (Blue View Technologies) in the Middle Bridge River. A sonar camera allows visualization of fish and other aquatic organisms in poor visibility conditions through the use of multi-beam echo-sounding technology. The camera was tested in two locations: directly below the Goldbridge Bridge and in a portion of the Middle Bridge River slightly upstream of the top end of Carpenter Reservoir (Figure 3-2).

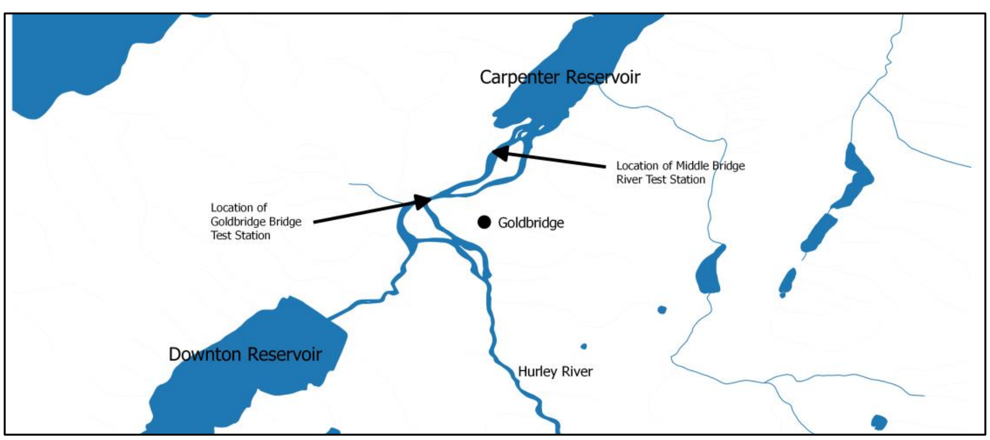


Figure 3-2. Location of sonar camera testing sites in the Middle Bridge River.

4 Results

4.1 Carpenter Reservoir Population Indexing

General population indexing (900 sec/site) of the Carpenter Reservoir littoral zone occurred in 2013 at 80 sites in June and October (Table 4-1). During the June session a total of 8 Rainbow Trout, 6 Bull Trout, 170 Mountain Whitefish, and 326 Bridgelip Suckers were enumerated in Carpenter Reservoir. Catch per unit effort (CPUE; represented here as catch per seconds electrofishing) across all habitat types was 0.0003 fish/s for Rainbow Trout, 0.0003 fish/s for Bull Trout, 0.0071 fish/s for Mountain Whitefish, and 0.0136 fish/s for Bridgelip Suckers. During the fall session, total catches were 7 Rainbow Trout (0.0003 fish/s), 23 Bull Trout (0.0010 fish/s), 146 Mountain Whitefish (0.0061 fish/s) and 499 Bridgelip Suckers (0.0108 fish/s). Physical conditions (e.g., water temperature and turbidity) were not recorded during electrofishing surveys, and no measure of capture efficiency has been quantitatively determined for this method in Carpenter Reservoir.

Closed mark-recapture model testing in Carpenter Reservoir was unsuccessful both with electrofishing as a marking and recapture method and with angling as a marking method and electrofishing as a recapture method. Few recaptures of any species occurred during spring and fall closed mark-recapture experiments at marking sites throughout the reservoir (Table 4-2), suggesting that (a) movement of fish in and out of sites occurred between marking and recapture periods and/or (b) capture efficiency was extremely low. In addition, even when targeting tributary confluences with high fish densities (i.e., high densities relative to non-creek mouth sites) it was very difficult to mark a large number of fish with the available level of effort. Based on these results, the closed method should not be used in Carpenter Reservoir to obtain abundance estimates or to estimate electrofishing capture efficiency because of presumed low fish densities and violations to the closed mark recapture assumptions (i.e., fish moved in and out of sites between marking and recapture periods).

Additional Bull Trout and Rainbow Trout were PIT tagged in Carpenter Reservoir and Middle Bridge River throughout the Year 1 and Year 2 field seasons during general population indexing, gill net testing, and angling (Table 4-3). An open mark-recapture model has not yet been run for Carpenter Reservoir due to sparse data; however, very low rates of recapture for Rainbow Trout and Mountain Whitefish suggest that mark-recapture models are not suitable for enumerating these populations in Carpenter Reservoir. Bull Trout recapture percentages in the fall of Year 2 (during angling, gill netting, and electrofishing surveys) ranged from 0% to 20% of all available marks, indicating that an open mark-recapture study of Bull Trout might be successful in Carpenter Reservoir with sufficient effort. Approximate CPUE calculations from population indexing in Year 1 and fieldwork in Year 2 (Table 4-4) suggest that targeted electrofishing at tributary confluences and short set gill netting may be the most efficient methods of Bull Trout capture for an open mark-recapture study. Although CPUE for angling is lower than for electrofishing and gill netting, angling is a very efficient and cost-effective capture method (particularly with a skilled crew) and is an important capture method that will be used for BRGMON-04.

Table 4-1. Counts and effort (fish/second shocking) for June and October electrofishing general population indexing in Carpenter Reservoir (BT: Bull Trout, RB: Rainbow Trout, MW: Mountain Whitefish, BSU: Bridgelip Sucker).

Index Session	Habitat Type	# of Sites	Count (fish/second in parentheses)			
			RB	BT	MW	BSU
June	Creek Mouth	1	1 (0.0033)	8 (0.0267)	31 (0.1033)	16 (0.0533)
	Fluvial Fan	21	0 (0)	7 (0.0011)	42 (0.0067)	230 (0.0365)
	Shallow Slope	18	3 (0.0006)	4 (0.0007)	33 (0.0061)	131 (0.0243)
	Steep Slope	40	3 (0.0003)	4 (0.0003)	40 (0.0033)	122 (0.0102)
October	Creek Mouth	1	0 (0)	0 (0)	1 (0.0033)	2 (0.0067)
	Fluvial Fan	13	6 (0.0015)	5 (0.0013)	33 (0.0085)	87 (0.0223)
	Shallow Slope	23	1 (0.0001)	1 (0.0001)	76 (0.0110)	118 (0.0171)
	Steep Slope	43	1 (0)	0 (0)	60 (0.0047)	119 (0.0092)

Table 4-2. Summary of closed mark-recapture data for spring and fall electrofishing periods, 2014.

EF Period and Site	# Mark Events	# Marks			# Recap Events	# Recaptures		
		BT	RB	MW		BT	RB	MW
SPRING								
Shallow slope adjacent Bighorn Creek	1	0	0	5	1	0	0	0
Jones Creek Confluence	1	4	1	1	1	0	0	0
Keary Creek Confluence	1	5	3	29	1	0	0	1
Marshall Creek Confluence	2	3	21	10	2	0	1	0
Nosebag Creek Confluence	1	3	1	14	1	0	0	0
FALL								
Girl Creek Confluence	2	10			1	0		
Truax Creek Confluence	2	15			1	0		
Tyaughton Creek Confluence	1	2			1	0		
Gun Creek Confluence	2	10			1	0		

Table 4-3. Total marks (PIT tags) applied by project year and species in Carpenter Reservoir and the Middle Bridge River.

Species	Year 1	Year 2	Total
BT	375	146	521
RB	86	55	141
MW	123	89	212
KO	0	2	2

Table 4-4. Approximate catch per unit effort (CPUE) for Bull Trout and Rainbow Trout according to capture method in Carpenter Reservoir. CPUE could not be calculated for Rainbow Trout angling surveys in Year 2 due to insufficient data.

Method	Targeted Habitat Type	CPUE (fish/second)	
		BT	RB
Year 1 General Population Indexing (electrofishing)	Shoreline (tributary confluences, fluvial fans, steep and shallow slopes)	0.40 e-03	0.21 e-03
Year 2 Closed Mark-Recapture (electrofishing)	Tributary confluences	5.10 e-03	3.50 e-03
Angling (Year 2 only)	Tributary confluences	0.36 e-03	-
Year 2 Gill Netting	Maximum depth 15 m	2.67 e-03	0

4.1.1 Biological Characteristics of Fish Populations in Carpenter Reservoir

4.1.1.1 <u>Bull Trout</u>

A total of 644 Bull Trout (mean fork length 363.9 mm) were captured and sampled for length and weight in Carpenter Reservoir and the Middle Bridge River in the Year 1 and Year 2 field seasons. Aging structures (fin rays) were taken from a subsample of Bull Trout, and will be analyzed in future monitoring years to obtain length at age data for Carpenter Reservoir (scales and/or otoliths were also retained from Rainbow Trout and kokanee for aging purposes). In Year 1, 432 Bull Trout were captured (mean fork length 363.9 mm), and in Year 2, 212 Bull Trout were captured (mean fork length 385.0 mm) (Figure 4-1). Sampling effort, methods, and sampler experience were not consistent between Years 1 and 2, and overall capture numbers are not meant to be used as an index of abundance in the reservoir.

A two sample t-test indicated that average fork lengths of Bull Trout differ significantly between Year 1 and Year 2 (p = 1.0 E-04, df = 495), and general linear modeling of fork length, year, and gear type (electrofishing, angling, variable mesh-gill netting) suggested that year (but not gear type) is a significant predictor of Bull Trout fork length (p = 3.0 E-04). Length-weight relationships were developed for Bull Trout in both Year 1 and Year 2 (Figure 4-2). Linear modeling of Bull Trout weight as a function of length and year indicated that the length-weight relationships are statistically different between the two monitor years: the p-value of the interaction between year and length is 2.2 E-04. The reasons for differences in distributions between Years 1 and 2 may be related to biological differences, but it is more likely that they are related to differences in sampling effort, timing, and the distribution of fish at different sites. Although we do not have high enough resolution in these parameters to include them in simple regression models, the effect of year may become more clear as more years of data are added to the monitor time series.

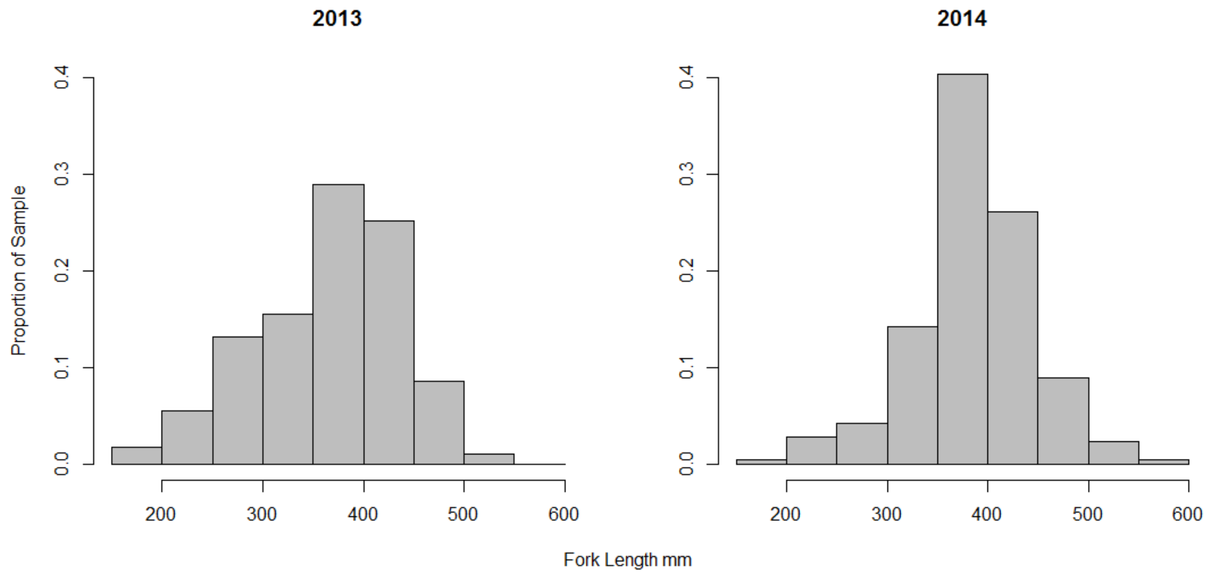


Figure 4-1. Histograms of fork length for Bull Trout captured in Carpenter Lake in 2013 (Year 1) and 2014 (Year 2).

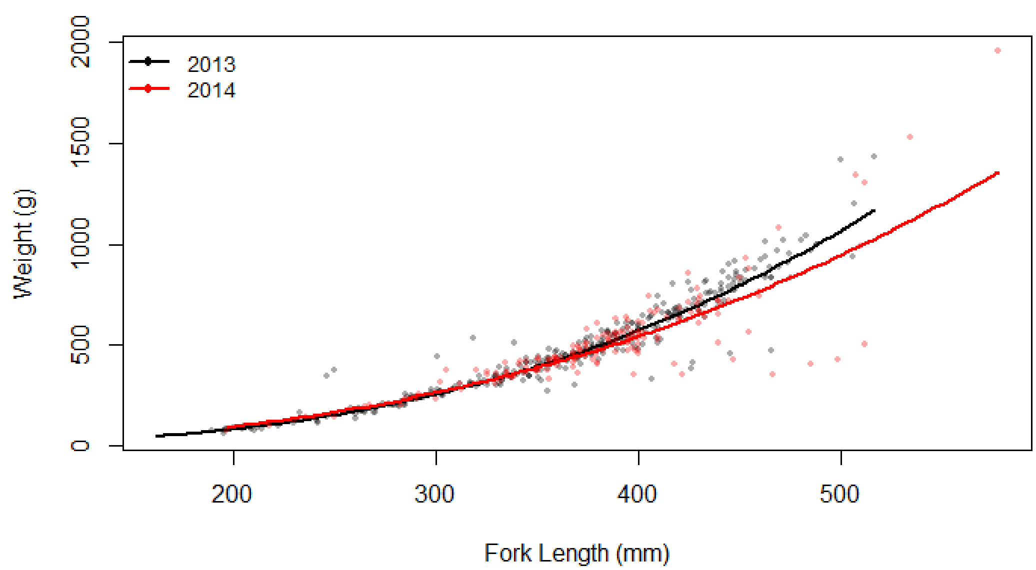


Figure 4-2. Length-weight relationships for Bull Trout captured in Carpenter Lake in 2013 (Year 1) and 2014 (Year 2).

4.1.1.2 Mountain Whitefish

A total of 560 Mountain Whitefish were captured in Carpenter Reservoir in Year 1 and Year 2, and the mean fork length of all Mountain Whitefish was 226.2 mm. In Year 1, 311 Mountain Whitefish were captured (mean fork length 224.3 mm) and in Year 2, 249 Mountain Whitefish were captured (mean fork length 228.5 mm) (Figure 4-3). Mean fork lengths between the two years are not statistically different (two sample $p = 0.46$, $df = 539$), and gear type and year are not significant predictors of fork length according to general linear model fitting. Length-weight relationships for Mountain Whitefish were developed for Year 1 and Year 2 (Figure 4-4), and an ANOVA of the linear model with length and year as predictor variables indicates that length-weight relationships for Mountain Whitefish are not statistically different between the two years (p-value of the interaction between year and length = 0.82).

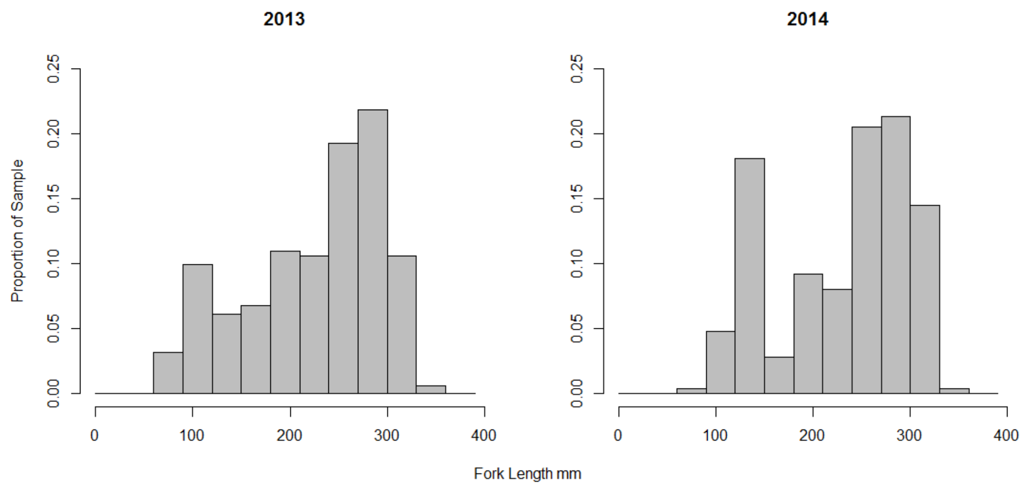


Figure 4-3. Histograms of fork length for Mountain Whitefish captured in Carpenter Lake in 2013 (Year 1) and 2014 (Year 2).

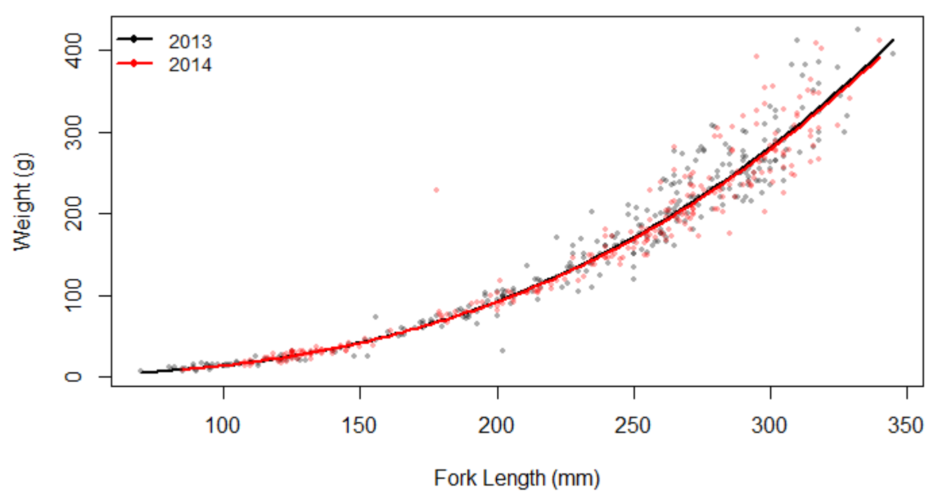


Figure 4-4. Length-weight relationships for Mountain Whitefish captured in Carpenter Lake in 2013 (Year 1) and 2014 (Year 2).

*4.1.1.3 **Rainbow Trout***

In Year 1 and Year 2, a total of 158 Rainbow Trout were captured in Carpenter Reservoir. The mean fork length of Carpenter Reservoir Rainbow Trout is 335.8 mm across both years, 336.0 mm in Year 1 ($n = 92$), and 335.6 mm ($n = 66$) in Year 2 (Figure 4-5). Mean fork lengths between the two years are not statistically different (two sample T-test $p = 0.95$, $df = 155$), and gear type and year are not significant predictors of fork length according to general linear model fitting. Length-weight relationships developed for Carpenter Reservoir Rainbow Trout (Figure 4-6) are statistically different between the two years according to linear modeling of length and year as predictors of weight (p-value of the interaction between year and length: 5 E-05).

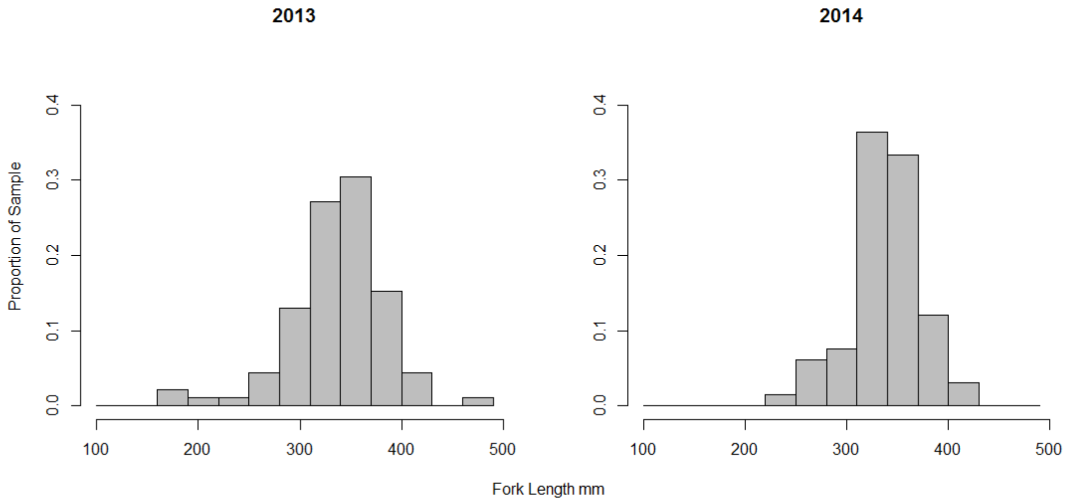


Figure 4-5. Histograms of fork length for Rainbow Trout captured in Carpenter Lake in 2013 (Year 1) and 2014 (Year 2).

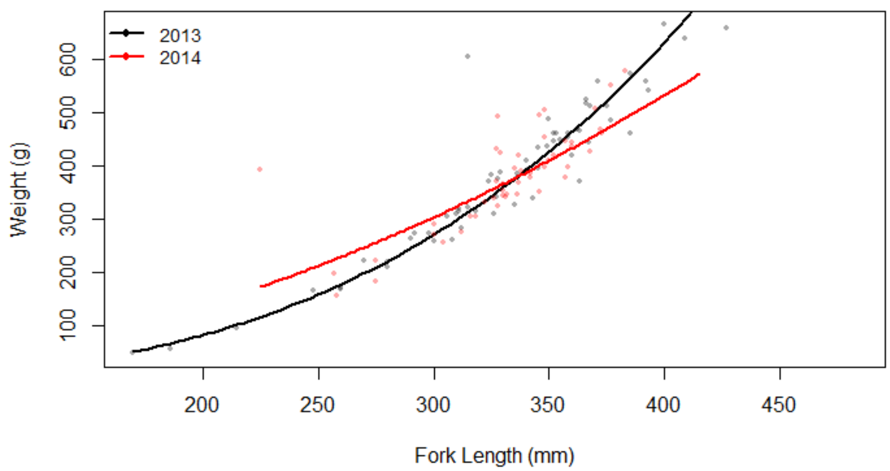


Figure 4-6. Length to weight relationships for Rainbow Trout captured in Carpenter Lake in 2013 (Year 1) and 2014 (Year 2).

4.2 Tributary Spawner Surveys (Rainbow Trout, Bull Trout, kokanee)

Visual counts in Carpenter Reservoir tributaries were performed by TEC from May 29, 2013 to September 6, 2013 (at approximately weekly intervals), and weekly by IFR from May 14, 2014 to June 20, 2014 and August 19, 2014 to October 1, 2014. The first date of spawner observation and peak counts for Rainbow Trout and kokanee are presented in Table 4-5 and the distributions of kokanee and Rainbow Trout counts are shown in Figure 4-7 and Figure 4-8. For both Rainbow Trout and kokanee, fish were observed on the first day of visual surveys in many of the tributaries, suggesting that the spawning migration had already commenced. Surveys will begin earlier in future years to determine the beginning of the spawning migration for both species.

A relatively small number of Rainbow Trout were observed in Carpenter Reservoir tributaries in Year 1 and Year 2, and kokanee counts were substantially higher in Year 2 than in Year 1. Due to data shortages, it is not known whether Rainbow Trout were present in fewer numbers and in fewer tributaries in Year 1, or whether visual counts did not take place as frequently or as extensively as in Year 2. Bull Trout spawners were rarely observed during visual counts. One Bull Trout was observed in Marshall Creek on August 26, 2014, possibly during a spawning migration, while two other Bull Trout sightings (in Marshall Creek and in Girl Creek) occurred during the spring and were not related to spawning behaviour. The absence of Bull Trout spawners could be explained by a number of hypotheses: (a) Bull Trout were present but observers were not able to locate them due to inexperience, high flows, high turbidities, etc, (b) Bull Trout spawn in areas further upstream than were covered during visual surveys, or (c) Bull Trout spawn primarily in the Middle Bridge or Hurley Rivers, which are not included in visual surveys due to high flows, high turbidity, and challenging access conditions. In future monitoring years, acoustic telemetry will be used in the Middle Bridge River to determine if Bull Trout spawn in Carpenter Reservoir tributaries or in the Middle Bridge and Hurley Rivers.

Visibility was a notable issue during visual tributary counts throughout the year. Tributaries were originally selected for visual counts due to their accessibility and suitability for spawning; however, a number of tributaries proved too turbid to assess visually. Visual counts were not possible in the Middle Bridge River, Gun Creek and Tyaughton Creek at any time of the year, and Girl Creek, Macdonald Creek, and Sucker Creek had very low visibility during spring counts of Rainbow Trout.

Table 4-5. Dates of arrival, date last observed, and peak counts of Rainbow Trout and kokanee in Carpenter Reservoir tributaries.

Species	Date of Arrival	Date Last Observed	Date of Peak Count	Peak Count (all streams)	Tributaries Observed In:
2013					
RB	Jun 11, 2013	Jun 11, 2013	Jun 11, 2013	4	Jones, Marshall
KO	Sep 6, 2013	Sep 6, 2013	Sep 6, 2013	14	Macdonald, Sucker
2014					
RB	May 14, 2014	Jun 20, 2014	Jun 20, 2014	14	Marshall, Girl, Macdonald, Truax
KO	Aug 19, 2014	Sep 16, 2014	Aug 26, 2014	257	Macdonald, Sucker, Girl, Truax, Marshall,

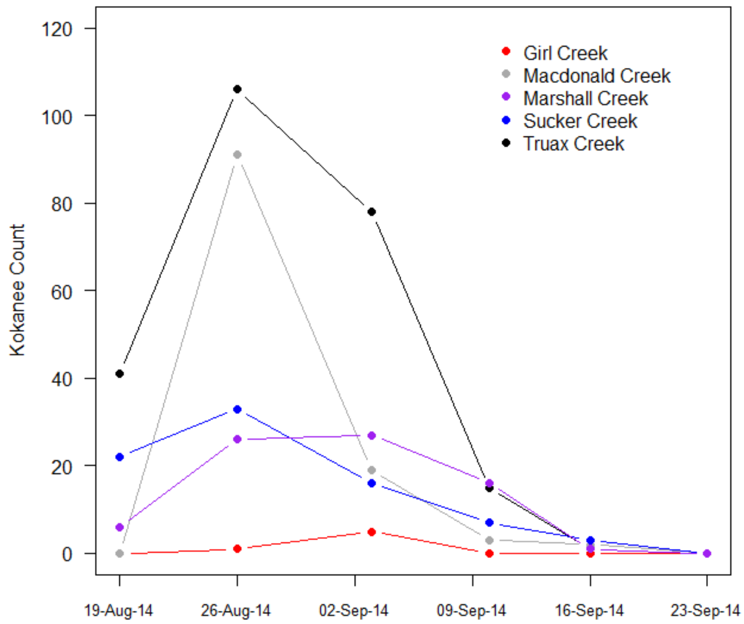


Figure 4-7. Counts of kokanee in Carpenter Reservoir tributaries, fall Year 2.

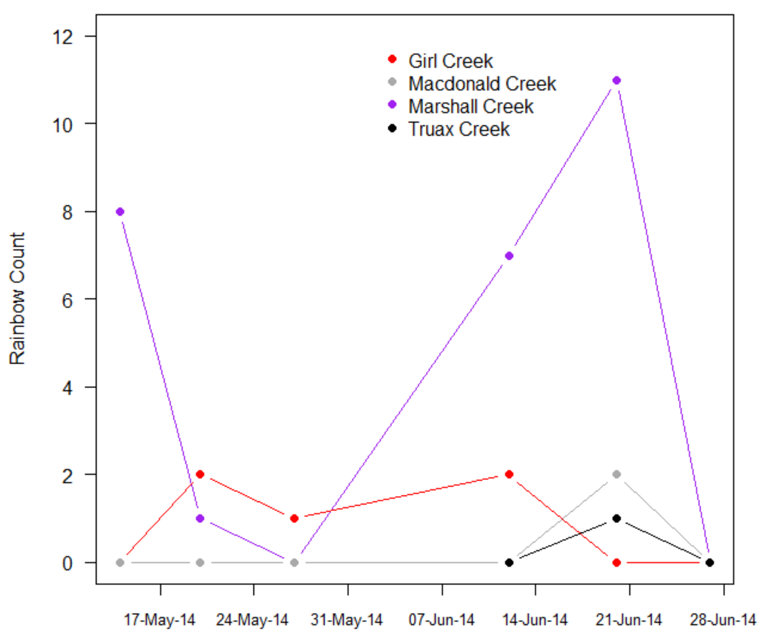


Figure 4-8. Counts of Rainbow Trout in Carpenter Reservoir tributaries, spring Year 2.

4.3 Bull Trout Radio Telemetry

A total of 30 Bull Trout were radio tagged in Carpenter Reservoir in August of 2014; however, one tag was recovered onshore on August 21 thus total tags in the reservoir was reduced to 29. The mean fork length of radio tagged Bull Trout was 415 mm (range 375 mm to 490 mm). All tagged Bull Trout successfully recovered and were released at their tagging location. Mobile/manual tracking surveys (on foot and by vehicle) occurred weekly from August 19 to October 7, 2014. It was difficult to pinpoint precise locations of tagged fish due to high signal interference in the Bridge River Valley and because tracking took place on land; however, manual tracking provided a rough idea of fish location and movement throughout the summer and early fall.

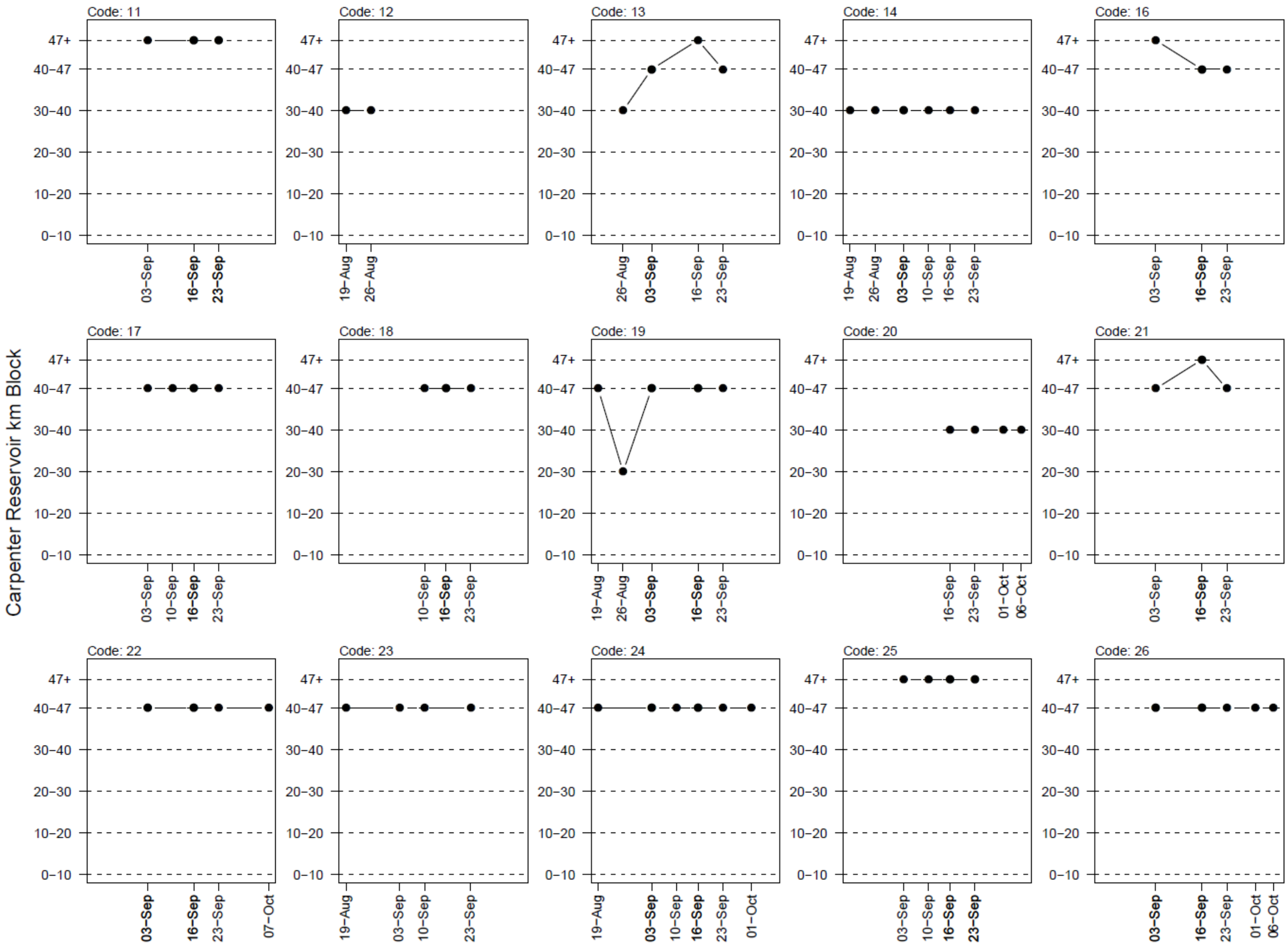
Of the 29 tags present in Carpenter Reservoir, 28 fish were manually tracked following their release (one tag was not located following the original tagging event; Table 4-6). Although a number of Bull Trout traveled large distances within the reservoir and Middle Bridge River, a large portion of tagged fish remained at their tagging location. It is not possible to determine if these fish were alive but stayed at their original location, or if they did not survive tagging. Of the 14 fish tagged at Truax Creek, 3 were detected only at Truax Creek, and of the 16 fished tagged at Gun Creek, 8 fish remained in the vicinity of Gun Creek and Girl Creek. Gun Creek and Girl Creek are approximately 1.2 km apart and detections at Girl Creek may have been of fish located at Gun Creek. Of the 19 Bull Trout that left their original tagging location, 7 were detected in the Middle Bridge River and 6 were detected upstream of creek confluences (Truax, Tyaughton, and Gun Creeks).

To visualize the detections of radio tagged Bull Trout in Carpenter Reservoir and the Middle Bridge River, the reservoir was split into six sections based on distance from Terzaghi Dam: 0-10 km, 10-20 km, 20-30 km, 30-40 km, 40-47 km, and 47+ km (i.e., the Middle Bridge River). Figure 4-9 shows manual detections of individual Bull Trout tag codes through time in 2014, separated into the six reservoir/river sections. The plots suggest that most of the tagged Bull Trout remained at or within 10 km of their original tagging location throughout the tracking period. Previous research by Chamberlain et al (2001) suggested that Bull Trout move upstream (towards the LaJoie Dam) as reservoir elevation increases in the spring and downstream (towards the Terzaghi Dam) during fall reservoir drafting. Radio telemetry results from Year 2 do not support this hypothesis because Bull Trout appeared to move upstream and downstream of their tagging location at different times of the year, and movement patterns were not consistent within the radio tagged subsample. Both telemetry studies (BRGMON-04 and Chamberlain et al) were limited by small subsamples, unknown detection probabilities, and short tracking durations, making it difficult to draw conclusions regarding Bull Trout movement and distribution. In addition, no kokanee were observed during visual surveys by Chamberlain et al. (2001), whereas kokanee were frequently observed during Year 2 of BRGMON-04. The presence of kokanee may have had a substantial effect on Bull Trout behaviour during kokanee spawning periods because Bull Trout likely alter their behaviour to predate on spawning kokanee and kokanee eggs.

Tracking results cannot determine whether fish detected in the Middle Bridge River and tributaries of Carpenter Reservoir were undergoing spawning migrations, although their presence corresponds with known life history timing for Bull Trout spawning (McPhail 2007). The timing also corresponds with kokanee spawning, and Bull Trout may have been travelling up tributaries to predate on kokanee eggs. Bull trout spawning likely occurs further upstream in areas inaccessible to radio tracking and tributary spawner surveys or, more likely, in the Middle Bridge and Hurley Rivers. In future monitoring years, acoustic telemetry (with known detection probability) will be used to explore Bull Trout movement in Carpenter Reservoir and the Middle Bridge River.

Table 4-6. Bull trout tagging location and detection information in Carpenter Reservoir, fall 2014 (Year 2).

Tag #	Tagging Location	# of Detections	Max Dist from Tagging Loc (km)	Movement Notes
11	Gun Creek	5	5.5	Gun Creek to Middle Bridge River
12	Truax Creek	2	0	Remained at Truax Creek
13	Truax Creek	5	13	Truax Creek to Middle Bridge River
14	Truax Creek	7	0.3	Detected up Truax Creek
15	Truax Creek	0	0	Not detected following release
16	Gun Creek	4	5.5	Gun Creek to Middle Bridge River
17	Gun Creek	5	1.5	Gun Creek to Macdonald Creek
18	Gun Creek	4	1.2	Remained in Gun Creek vicinity
19	Gun Creek	7	1.2	Remained in Gun Creek vicinity
20	Truax Creek	4	2	Detected up Tyaughton Creek
21	Gun Creek	4	5	Gun Creek to Middle Bridge River
22	Gun Creek	6	1.2	Remained in Gun Creek vicinity
23	Gun Creek	4	1.2	Remained in Gun Creek vicinity
24	Gun Creek	8	1.2	Remained in Gun Creek vicinity
25	Truax Creek	6	8	Truax Creek to Middle Bridge River
26	Gun Creek	7	1.2	Remained in Gun Creek vicinity
27	Gun Creek	3	4	Gun Creek to Middle Bridge River
28	Gun Creek	4	1.6	Gun Creek to Macdonald Creek
29	Truax Creek	4	0	Remained at Truax Creek
30	Truax Creek	9	0.5	Detected up Truax Creek
31	Gun Creek	4	1.2	Remained in Gun Creek vicinity
32	Gun Creek	4	1.8	Gun Creek to Girl Creek
33	Gun Creek	1	0	Remained in Gun Creek vicinity
34	Truax Creek	8	9	Truax Creek to Gun Creek
35	Truax Creek	4	20	Truax Creek to Nosebag Creek
36	Gun Creek	7	8	Gun Creek to Middle Bridge River
37	Truax Creek	4	10	Detected up Tyaughton Creek
38	Truax Creek	3	0.2	Detected up Truax Creek
39	Truax Creek	8	0	Remained at Truax Creek
40	Truax Creek	8	10	Detected up both Gun Creek and Truax Creek


Carpenter Reservoir km Block
Code: 11
Code: 12
Code: 13
Code: 14
Code: 16
Code: 17
Code: 18
Code: 19
Code: 20
Code: 21
Code: 22
Code: 23
Code: 24
Code: 25
Code: 26
47+
40–47
30–40
20–30
10–20
0–10

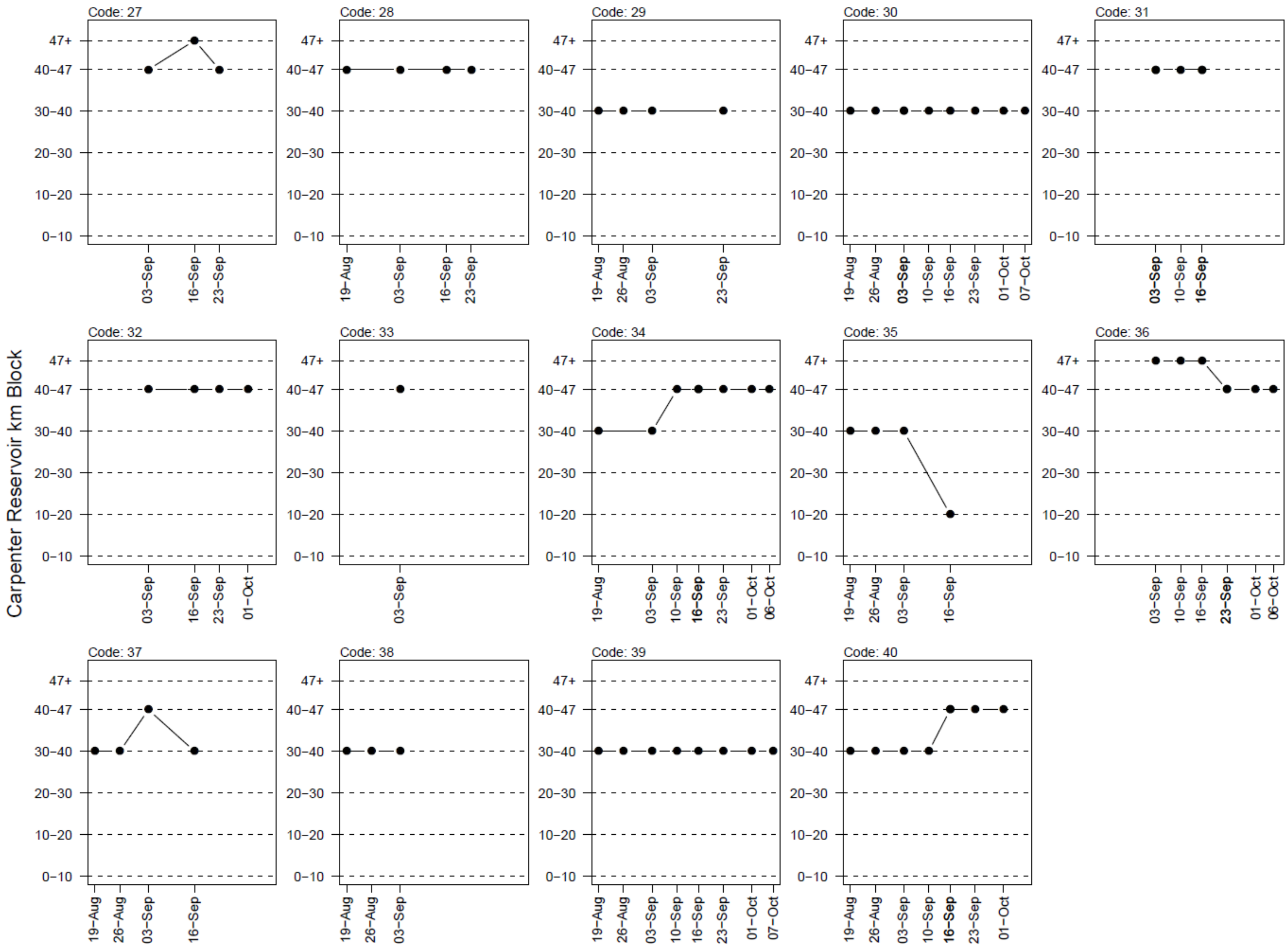


Figure 4-9. Manual detections of Bull Trout across time in Carpenter Reservoir and the Middle Bridge River, separated into approximately 10 km reservoir and river sections.

4.4 Short-set Gill Netting in Carpenter Reservoir

One day of short set gill netting took place in Carpenter Reservoir on October 16, 2014. A total of 5 nets were set in shallow sloped areas and fluvial fans within 10 km of the confluence of Marshall Creek. Due to high mortality rates during 30 minute net sets, maximum set times were reduced to 15 minutes to produce adequate catches while minimizing mortality. A total of 16 Bull Trout, 7 Mountain Whitefish, and 5 Bridgelip Suckers were captured, weighed and measured during the 5 gill net sets (Bull Trout were also tagged with PIT tags).

4.5 Mountain Whitefish Spawning Survey in Middle Bridge River

Results of Mountain Whitefish spawning assessments in 2005 and 2009 (Tisdale 2010; Table 4-7) and field data from Year 1 indicate that Mountain Whitefish spawning in the Middle Bridge River begins in mid-November and peaks near the end of November at temperatures of ~6°C. Tisdale observed spawning in the Middle Bridge River mainstem during both 2005 and 2009, and no activity was observed in tributaries or side channels of the river. Tisdale (2010) predicted Mountain Whitefish eggs to hatch approximately 2 months after spawning (beginning mid-January and peaking near the end of February) based on an accumulated thermal unit requirement (ATU; i.e., the accumulated heat required for egg development and hatching) of 327 (from Tisdale 2010).

In 2009, 30 male and female Mountain Whitefish were aged by Tisdale (2010) and 83% of both males and females were 4-year old first time spawners (Tisdale 2010). Egg mats were deployed in 2009 and 2012 in 5 locations identified as spawning sites to capture free-floating eggs released by spawning Mountain Whitefish. Based on observed spawning locations, relative abundances of Mountain Whitefish, and flow characteristics of the Middle Bridge River, Tisdale (2010) concluded that critical spawning habitat in the Middle Bridge River would not be dewatered without substantial decreases in river elevation, and the existing flow regime therefore is not likely to be negatively affecting Mountain Whitefish spawning success.

Table 4-7. Summary of fish captured during the 2009 Middle Bridge River Mountain Whitefish spawning assessment (adapted from Tisdale 2010).

Date	Total Captured	Immature	Mature Males	Mature Green Females	Kelt Females	Mature Ripe Females	% of Ripe Females
Oct 5, 2009	30	24	0	6	0	0	0%
Oct 13, 2009	30	22	2	6	0	0	0%
Oct 19, 2009	30	17	3	10	0	0	0%
Oct 26, 2009	30	10	8	12	0	0	0%
Nov 3, 2009	7	2	2	3	0	0	0%
Nov 9, 2009	31	2	11	17	0	1	6%
Nov 16, 2009	33	0	15	5	0	13	72%
Nov 23, 2009	50	2	25	6	0	17	74%
Nov 30, 2009	51	1	18	3	0	29	91%
Dec 7, 2009	25	0	13	1	5	6	50%
Dec 14, 2009	11	0	10	0	1	0	0%
Dec 21, 2009	6	0	5	0	0	1	100%

4.6 Kokanee Enumeration in Middle Bridge River

A BlueView Sonar camera was tested on August 26, 2014 in two locations in the Middle Bridge River mainstem to evaluate its potential for enumerating migrating kokanee (Figure 3-2). An initial testing site located below the Goldbridge Bridge was selected because the Middle Bridge River forms a single channel approximately 30 m wide beneath the bridge, making it possible for the camera to capture the entire river profile. Although kokanee were observed beneath the bridge during camera testing, there was evidence of kokanee spawning at the site and the location was deemed too far upstream to observe the full spawning migration. A second location was tested closer to the top end of Carpenter Reservoir that would be more likely to capture the kokanee migration. No fish were observed during testing at the second site, likely because the spawning migration was already complete. Although preliminary testing suggests that it would be possible to use a sonar camera in the Middle Bridge River to enumerate migrating kokanee in turbid conditions, there are a number of issues that would need to be addressed: the Middle Bridge River close to Carpenter Reservoir is highly braided and the whole channel cannot be observed with one camera; maintaining camera equipment and batteries would be challenging and expensive; and the hydrological characteristics of the channel may vary each year, making standardization of counts difficult.

5 Discussion

Data collected Years 1 and 2 in Carpenter Reservoir and the Middle Bridge River provide insight into fish community structures and inform the development of an effective study design for the monitor. Management questions, hypotheses, and sample plans outlined in the Terms of Reference (TOR) were developed with minimal background information, and preliminary field work and data collection can be used to evaluate the ability of current methods to adequately answer management questions.

Preliminary data analysis from Year 1 and Year 2 suggest that the Carpenter Reservoir fish community is dominated by Mountain Whitefish and Bull Trout, and that kokanee and Rainbow Trout are present at lower densities. Rainbow Trout fry survival may be low in the reservoir due to Bull Trout predation, and a large portion of the Rainbow Trout population may be recruiting from small lakes that drain to Carpenter Reservoir (i.e., Tyaughton Lake and Marshall Lake). Results from Years 1 and 2, and research during the water use planning process suggest that the kokanee population in the reservoir is small and characterized by substantial inter-annual differences in abundance. Kokanee were not observed during a 2000 survey by Chamberlain et al (2001) and TEC observed kokanee in only two Carpenter Reservoir tributaries in Year 1. Kokanee were observed in a number of tributaries at higher densities in Year 2 than Year 1, indicating that the kokanee population abundance in Carpenter Reservoir and the Middle Bridge River may be characterized by patterns of cyclical dominance.

General population indexing using electrofishing was a primary survey method outlined in the current TOR (BC Hydro 2012); however, results from the Year 1 and Year 2 field seasons suggest electrofishing is not appropriate in Carpenter Reservoir as an indexing tool. For indexes to be comparable over time, physical conditions at standard sites must remain stable between sampling events (Bonar et al. 2009). When physical conditions are consistent, gear capture efficiencies are likely to be the same from year to year and changes in index values can be attributed to biological factors such as food availability, fish behaviour, biochemical characteristics, etc (Bonar et al. 2009). Turbidity and reservoir elevation at sampling sites in Carpenter Reservoir exhibit substantial year to year variation, making it difficult and misleading to use general population indexing as a means of detecting temporal changes in fish populations. For example, during electrofishing in the fall of Year 2 turbidities were so high at the top of the reservoir that electrofishing was not possible. Angling in the same areas had been very successful during the same time period, suggesting that electrofishing efficiency was near zero at such high turbidities. In addition, reservoir elevation is unpredictable, and depths of standard sites may change from year to year. Habitat characteristics such as bank slope, substrate type, and vegetation may change if depth changes, affecting electrofishing efficiency and confounding changes in population index values. Because of issues related to turbidity and variable reservoir elevation, general population indexing using electrofishing is not recommended as a sampling method in Carpenter Reservoir. Although it is not useful as an indexing tool in Carpenter Reservoir, electrofishing is a very efficient capture method in the reservoir and will continue to be used during Bull Trout open mark-recapture monitoring.

The TOR for BRGMON-04 references indexing programs in the Peace and Columbia Rivers, Kootenay Lake, and Arrow Reservoir as examples of monitoring programs in large rivers and lakes that use electrofishing to obtain biological data, relative densities of fish, and abundance estimates (BC Hydro 2012). These programs combine general population indexing with closed mark-recapture models to determine population abundances. Closed mark-recapture models provide independent estimates of population abundance, but can also be used to determine electrofishing capture efficiencies (Mainstream Aquatics Ltd. and Gazey Research 2007). If capture efficiencies are known, densities obtained from general population indexing can be adjusted and compared to mark-recapture estimates for a more robust understanding of fish abundances (Mainstream Aquatics Ltd. and Gazey Research 2007). In an effort to account for some of these physical characteristics during electrofishing indexing we attempted to determine electrofishing efficiency in the reservoir in Year 2 using a closed mark-recapture method, but we were unsuccessful due to violations to the closed site assumptions. Capture efficiency can also be derived from depletion sampling, where an area is isolated from a water body and repeatedly sampled to depletion; however, isolating an area in Carpenter Reservoir would not be practical or cost effective due to its large size and bathymetry, and depletion methods have been shown to be biased in many systems (Peterson, Thurow, and Guzewich 2004).

Closed mark-recapture methods likely failed in Carpenter Reservoir because the assumption that sites were closed (i.e., no births, deaths, immigration, or emigrations) between marking and recapture periods was violated. Recapture rates may have been low because marked fish left the study area between marking and recapture events. Low recapture rates are also an issue in large river indexing programs in the Peace and Columbia rivers (Ford and Thorley 2012; Mainstream Aquatics Ltd. and Gazey Research 2007); however, the scale of these programs allow for larger sites that are less likely to violate the assumption of closure and effort levels high enough to obtain adequate numbers of recaptures. Even with multiple sampling events and very high effort, population estimates in these studies have a high degree of uncertainty (Ford and Thorley 2012; Mainstream Aquatics Ltd. and Gazey Research 2007). Considering the issues faced by large river indexing programs, closed mark-recapture methods are not cost effective in Carpenter Reservoir and cannot be confidently used to estimate abundance or to determine electrofishing capture efficiency.

Although electrofishing may not be appropriate for general indexing or closed mark-recapture methods in Carpenter Reservoir, it may still be a useful capture method when used as part of an open mark-recapture model. Open mark-recapture models, which account for births, deaths, and movement in and out of the study area, have been used with success in large lakes and rivers to estimate population abundances (Berg, Allen, and Sulak 2007; Mills, Chalanchuk, and Allan 2000). In an open mark-recapture model, the total number of marks released and recaptured determines the accuracy of population estimates, and multiple methods can be combined to obtain the highest rates of recapture possible. Results from fieldwork in Years 1 and 2 suggest that electrofishing at tributary confluences is an efficient method of Bull Trout capture in Carpenter Reservoir (Table 4-4). When shocking along the shoreline it is possible for fish to evade capture by moving ahead of the electrical field or by moving into waters deeper than the penetration of the field. At tributary confluences, however, fish are herded into shallow enclosed waters where they are vulnerable to shocking and capture. Gill netting and angling were also successful in capturing Bull Trout, and a combination of angling, gill netting, and electroshocking at tributary confluences can be combined in an open mark-recapture model of Bull Trout in Carpenter Reservoir. Obtaining population estimates in Carpenter Reservoir may be challenging or even impossible for all species, but lessons learned from sampling in Year 1 and Year 2 can be used to design a monitoring program capable of determining abundances of critical species in the reservoir.

5.1 Recommendations

Given the objectives of BRGMON-04 and the results from Years 1 and 2, IFR recommends the following for Year 3[3]:

- Adjust management hypotheses to target specific management questions and to be answerable using methods tested during Years 1 and 2 (completed in March of 2015).
- Focus enumeration efforts on Bull Trout due to their high relative abundance, top-predator status, and ability to withstand tagging with low mortality.
- Implement a systematic open mark-recapture tagging program of Bull Trout annually in Carpenter Reservoir using electroshocking, angling, and short-set gill netting to target all habitat areas in the upper reservoir.
- Use acoustic telemetry to monitor Bull Trout movement in Carpenter Reservoir and the Middle Bridge River and determine whether Bull Trout are spawning in the Middle Bridge and/or Hurley Rivers, or if they are spawning in Carpenter Reservoir tributaries.
- Continue visual surveys of spawning Rainbow Trout and kokanee, and examine alternative methods of determining the spawning success of these species.
- Continue to evaluate the success of BRGMON-04 data collection methods for their ability to provide data directed towards answering management questions. The size and complexity of Carpenter Reservoir and the Middle Bridge River make it necessary to use an adaptive strategy to develop knowledge of the system and understand how BC Hydro operations may be affecting fish populations.

[3] Not all management questions are covered in these recommendations as it is not possible to perform all monitoring activities on an annual scale (only Year 3 recommendations are included). For detailed methods throughout the project duration see BRGMON-04 project proposal (available through BC Hydro).

6 References

Barker, O., Miller, N., and A. Foos. 2011. Peel watershed fish habitat assessment. Yukon Fish and Wildlife Branch Report TR-11-12, Whitehorse, Yukon, Canada.

BC Hydro. 2015. Bridge Seton Water Use Plan Monitoring Program No. BRGMON-04 Carpenter Reservoir and Middle Bridge River Fish Habitat and Population Monitoring. Bridge-Seton Water Use Plan Monitoring Program Terms of Reference Addendum 1. 10p.

BC Hydro. 2014. Bridge River Recreation Areas. Accessed online December 6, 2014: www.bcydro.com/community/recreation_areas/bridge_river.html.

BC Hydro. 2012. Bridge Seton Water Use Plan Monitoring Program No. BRGMON-04 Carpenter Reservoir and Middle Bridge River Fish Habitat and Population Monitoring. Bridge-Seton Water Use Plan Monitoring Program Terms of Reference. 10 p.

BC Hydro. 2011. Bridge River Power Development Water Use Plan. 79 p.

Berg, J.J., Allen, M.S., & Sulak, K.J. 2007. Population assessment of the Gulf of Mexico sturgeon in the Yellow River, Florida. American Fisheries Society Symposium, 56.

Blackman, B.G., Murphy, E.B., & Cowie, D.M. 2004. 2003 Dinosaur Reservoir Littoral Fish Population and Habitat Enhancement Assessments. Peace/Williston Fish and Wildlife Compensation Program. No. 298. 13 p plus appendices.

Bonar, S.W., Hubert, W.A. & Willis, D.W., editors. 2009. Standard methods for sampling North American freshwater fishes. American Fisheries Society. Bethesda, Maryland.

Chamberlain, M.W., O'Brien, D.S., Caverly, A., & Morris, A.R. 2001. 2000 Middle Bridge River Bull Trout (Salvelinus confluentus) and Kokanee (Oncorhynchus nerka) Investigation. British Columbia Ministry of Environment, Lands and Parks, Fisheries Branch, Southern Interior Region.

Ford, D & Thorley, J.L. 2012. CLBMON-45 Lower Columbia River Fish Population Indexing Surveys – 2011 Investigations. Report prepared for BC Hydro Generations, Water Licence Requirements, Castlegar, BC. Golder Report No. 1014920102-R-Rev0: 56 p.

Franklin, A.B. 2002. Exploring ecological relationships in survival and estimating rates of population change using program MARK. Pages 350-356 in R. Fields, R.J. Warren, and H. Okarma, editors. *Integrating people and wildlife for a sustainable future: Proceedings of the Second International Wildlife Management Congress*. Godollo, Hungary.

Griffith, R.P. 1999. Assessment of fish habitat and production in Carpenter Lake Reservoir relative to hydroelectric operations. Prepared for B.C. Hydro, Kamloops BC. 216 p.

Kendall, W.L. & Bjorkland, R. 2001. Using robust design models to estimate temporary emigration from capture-recapture data. *Biometrics* 57, 113-1122.

Mainstream Aquatics Ltd. & Gazey Research. 2007. Peace River Fish Community Indexing Program – Phase 6 Studies. Prepared for BC Hydro Report No. 06011F: 116 p.

McPhail, J.D. 2007. Freshwater Fishes of British Columbia. The University of Alberta Press. Edmonton, AB. 620 p.

Mills, K.H., Chalanchuk, S.M. & Allen, D.J. 2002. Abundance, annual survival, and recruitment of unexploited and exploited lake charr, *Salvelinus namaycush*, populations at the Experimental Lakes Area, northwestern Ontario. *Environmental Biology of Fishes* 64: 281-292.

Mills, K.H., Chalanchuk, S.M. & Allan, D.J. 2000. Recovery of fish populations in Lake 223 from experimental acidification. *Canadian Journal of Fisheries and Aquatic Sciences* 51(1): 192-204.

Ombredane, D., Bagliniere, J., & Marchland, F. 1998. The effects of Passive Integrated Transponder tags on survival and growth of juvenile brown trout (*Salmo trutta* L.) and their use for studying movement in a small river. *Hydrobiologia*, 371, p 99-106.

Peterson, J.T., Thurow, R.F., & Guzevich, J.W. 2004. An evaluation of multipass electrofishing for estimating the abundance of stream-dwelling salmonids. *Transactions of the American Fisheries Society*, 133:462-475.

Pollock, K.H., Nichols, J.D., Brownie, C. & Hines, J.E. 1990. Statistical inference for capture-recapture experiments. *Wildlife Monographs*, 107, p 1-97.

Sebastian, D. and T. Weir. 2014. CLBMON-2. Kinbasket and Revelstoke Reservoirs Kokanee Population Monitoring. Columbia River Project Water Use Plan. Submitted to BC Hydro November 2014.

Sebastian, D., Andrusak, G., Scholten, G. & Langston, A. 2009. An index of fish distribution and abundance in Peace Arm of Williston Reservoir based on hydroacoustic and gillnet surveys. Peace Project Water Use Plan GMSMON-13, 99 p.

Sebastian, D.C., Scholten, G.H. and P.E. Woodruff. 2003. Williston Reservoir fish assessment: Results of hydroacoustic, trawl and gill net surveys in August 2000. Peace/Williston Fish and Wildlife Compensation Program Report No. 274. 34pp plus appendices.

St'at'imc Eco-Resources Ltd. 2014. A Proposal: Carpenter Reservoir Productivity Model Validation and Refinement. Bridge-Seton Water Use Plan Study Number BRGMON-10. Submitted to BC Hydro Water License Requirements. Burnaby, BC. 62 p.

Tisdale, G.A.E. 2010. 2009 Middle Bridge River Rocky Mountain Whitefish (Prosopium williamsoni) Exploratory Spawning Assessment October 4, 2009 – December 21, 2009. Prepared for B.C. Hydro and Power Authority, Shalalth B.C. 40 p.

Wagner, G.N., Cooke, S.J., Brown, R.S. and Deters, K.A. 2011. Surgical implantation techniques for electronic tags in fish. *Rev Fish Biol Fisheries*. 21: 71-81.

Zwart, I., Andrusak, G. and H. McGregor. 2013. DDMMON-10 Duncan Reservoir Fish Habitat Use Monitoring. Duncan Dam Project Water Use Plan. Submitted to BC Hydro February 27, 2013.