Bridge River Water Use Plan

Seton Lake Resident Fish Habitat and Population Monitoring

Implementation Years 1 & 2

Reference: BRGMON-8

Study Period: 2013-2014 Annual Data Report

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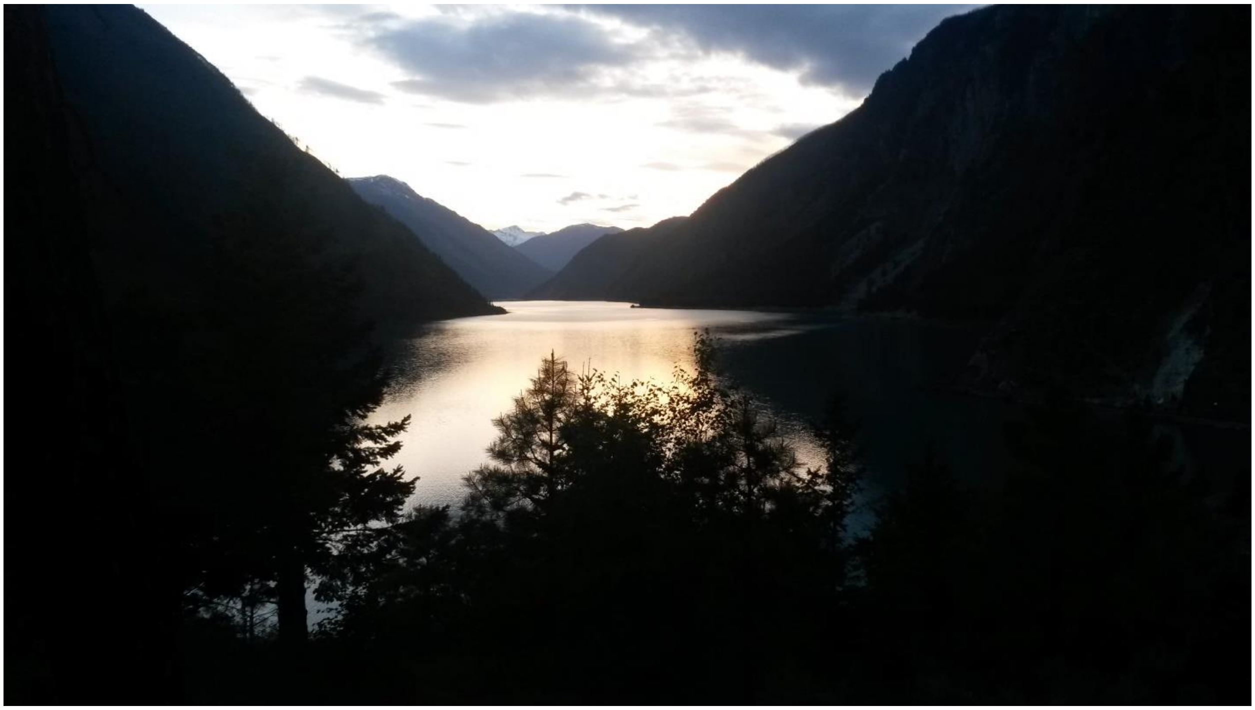
March 2015

BRGMON-8 Seton Lake Resident Fish Habitat and Population Monitoring, 2013 and 2014 Results



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Executive Summary

Data collection for Years 1 and 2 of this proposed 10-year study were completed in 2013 and 2014. A report was not completed following Year 1 of this program, so this data report contains the methods and a summary of results for both years of monitoring completed to-date. The primary objectives of this monitoring program are: 1) to collect scientifically rigorous information on the relative abundance, life history and habitat use of resident fish populations in Seton Lake; and 2) to provide information required to link the effects of the Carpenter Reservoir diversion on fish populations. The target species selected for this program are bull trout, rainbow trout and gwenis based on their ecological and social value in this context.

Four methods were employed to document the biological characteristics of the resident fish population, and generate an annual abundance index. These included:

- Tributary spawner surveys;
- General fish population index surveys in the reservoir (by boat electrofishing);
- Supplementary tagging surveys (by angling); and
- Habitat mapping.

In 2013, the index surveys followed a stratified random design similar to boat EF pilot sampling conducted on Carpenter Reservoir in 2001. In 2014 some significant changes were made to the electrofishing approach employed in Year 1. Attempts were made in Year 2 to determine if habitat-stratified capture probabilities could be quantified in this context using a mark-recapture approach to better inform the index results going forward.

Surface elevations in Seton Lake are managed within a small range (i.e., 0.4 m) relative to other reservoirs in the Bridge-Seton Generation System. Daily and seasonal elevations are driven by a wide range of factors: Bridge 1 and Bridge 2 operation; Seton Dam discharge; Seton Generating Station operation; Cayoosh Creek diversion inflows; and tributary inflows. As a result, there was no obvious seasonal trend or pattern apparent in lake elevations in either Year 1 or Year 2.

Some concern was raised during the WUP process that fluctuations in the lake surface elevation may have the potential to impact shore spawning locations of Gwenis that occur at elevations within the drawdown range, when drawdown occurs during the spawning or incubation period. Gwenis spawn timing has been observed to occur in late fall (i.e., November to early December; Morris et al. 2003 and this program) in Seton Lake. Some potential shore spawning sites have been identified around the perimeter of Seton Lake (based on suitable habitat characteristics), though direct evidence of spawning use in these locations or drawdown impacts have not yet been documented.

Three tributary spawner surveys (focussed on rainbow trout) were conducted in Year 1 between 30 May and 19 June 2013. In Year 2, four surveys were conducted between 15 May and 26 June 2014. Unfortunately, spawners were not observed during any of the surveys. Observation of

spawners or their redds was difficult by shore-based assessment in many of the selected tributaries due to steep gradients, turbulence, or seasonal high flow and turbidity conditions. The streams with the most suitable and accessible spawning habitats observed were Portage Creek, particularly at the top end (outflow of Anderson Lake) and the lower-most reach of M'sut Creek.

For both index sampling sessions in 2013, the distribution of sites was selected based on the relative proportions of habitat types from a GIS mapping exercise. Approximately 12 kilometres of shoreline was sampled during both June and September sessions. Totals of 670 fish were captured by boat electrofishing (EF) in June and 593 were captured in September; however only 28 and 5 were target species, respectively. Just over 100 sites were sampled during each session. In total, 39 fish were marked with PIT tags (29 in June; 10 in September) and none were recaptured within Year 1. Six of these marked fish were non-target whitefish, which were tagged to augment the limited number of target species for the mark-recapture component.

In 2014, fish sampling followed a two-pass mark-recapture approach with the goal of documenting habitat-stratified capture efficiency. Totals of 406 fish were captured by two-pass boat EF at 15 intensive sites in June 2014 (Marking pass *n*=125; Recapture Pass *n*=281). In October 2014, 7 sites were sampled using a mark-recapture approach (marking was conducted by angling; recapture pass was conducted by boat EF), plus an additional 14 sites sampled by a single pass of boat EF in order to cover additional shoreline area (Table 7). Totals of 122 fish were captured by angling, and 311 were captured by boat EF during the October survey. As in 2013, target species represented a very small proportion of the catch (i.e., 3%). In total, 276 fish were marked with PIT tags (132 in June; 144 in October). Three fish from the marking pass were subsequently recaptured in the second pass during the June session (i.e., 1 whitefish and 2 suckers), and 1 rainbow trout was recaptured during the October session. However, these recapture rates (and associated capture probabilities) were so low, that population sizes were not estimated given the high degree of error in the resulting estimates.

Individual catch-per-unit-effort (CPUE) values were generated for each sample session in Year 1 and Year 2. CPUEs for target species in the littoral zone were very low in both years. Total CPUE values (based on catches of all species combined) were fairly similar between spring and fall sessions in 2014. Highest habitat-specific CPUEs were recorded at tributary confluences and fan habitats in June, but were more evenly distributed across habitat types in October.

Three fish that had been tagged during previous sessions were recaptured during 2014, at or very close to their original location. The recaptured bull trout had grown 114 mm in the 382 days between capture events (average growth = ca. 0.3 mm per day). The two bridgelip suckers had grown 30 mm (43 g) and 4 mm (9 g), respectively, between capture events which were 121 days apart. This represents average growth rates of ca. 0.25 and 0.03 mm/day, or 0.36 and 0.07 g/day, respectively, over the summer months.

Length-frequency histograms for rainbow trout and bull trout captured during fish sampling surveys in 2013 and 2014 were generated. Given the limited sample size for all target species from the littoral zone, it was not feasible to estimate the age class breaks for these species based on this limited data set. Also, age data from the scale and fin ray analysis were not available at the time of writing for this report, but will be included in the next annual report.

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1) Introduction

1.1. Background

The Bridge-Seton Water Use Planning Consultative Committee (BRG CC) developed aquatic ecosystem objectives for Seton Lake that were established in terms of abundance and diversity of fish populations present in the lake. The Seton-Anderson watershed provides habitat for a wide range of anadromous and resident species, which are valued from a commercial, recreational, and cultural perspective. Use of the Seton-Anderson watershed by anadromous species, and trends in their relative abundance, are being assessed as a part of some of the other Bridge/Seton monitoring programs (i.e., BRGMONs #6, #13 and #14). However, there is also a lot of uncertainty about the basic biological characteristics of the *resident* fish species inhabiting Seton Lake, particularly Gwenis, rainbow trout and bull trout.

The BRG CC agreed that resident species play a significant role in the functioning and overall productivity of the ecosystem, and are of special importance because they have long been valued by First Nations as a source of food and for the significant cultural values that they embody (i.e., Gwenis). While there were no systematic studies on these populations prior to hydroelectric development, observations and oral testimony from local St'at'imc people have suggested that there has been a significant decline in the abundance of resident species associated with the operation of the Bridge River Generating Stations. However, there was a fundamental lack of any data confirming the current species composition, relative abundance, habitat requirements, and life history of resident fish, as well as the impacts of the Carpenter Reservoir diversion, to directly support decision making during the WUP.

During the BRG WUP process it was decided that changes to the operation of Seton Lake elevations (operating range ~0.4 m) would not be considered because of physical constraints associated with discharge facilities and the power canal at Seton Dam. Thus, consideration of potential changes to BC Hydro operations were focussed on the seasonal timing of diversion flows from Carpenter Reservoir into Seton Lake. Trade-off decisions to define the preferred operating alternative were made using generalized ecosystem level indicators rather than explicit performance measures. The general ecosystem indicators were:

1) expected changes in productivity in Seton Lake associated with the Bridge River diversion are believed to be linked to the food base for resident species of Seton Lake, and
2) the estimated transfer of suspended sediment which was hypothesized to impact the success of lake/shore spawning species (e.g., Gwenis).

The application of the general performance measures allowed trade-off decisions to be made however they required an extensive amount of qualitative judgment about which factors limited fish population abundance and diversity. As these judgments could not be supported with technical data or observation, there remains significant uncertainty and risk associated with how well the assessments actually reflect resident fish population response to different operating strategies at the Bridge Generating Stations. To resolve these data gaps, reduce uncertainties, and reduce risk of further impacts to resident fish populations the BRG CC recommended monitoring to obtain more comprehensive information on Seton Lake habitats and the biological characteristics of the fish populations that use them.

Data collection for Years 1 and 2 of this proposed 10-year study were completed in 2013 and 2014. There was a changeover of consultants managing the project starting in May 2014 (i.e., early in Year 2). A report was not completed by the initial consultant following Year 1 of this program, so an attempt has been made in this data report to include the methods and results for both of the years completed to-date to ensure that all available data are reported. It should also be noted that due to lessons learned during these initial years of sampling, key deficiencies in data collection methodologies and issues with the testability of some of the hypotheses included in the original study Terms of Reference (ToR) were identified. As a result, revisions have been made to the original study hypotheses and sampling approach which are described in a ToR addendum (BC Hydro 2015). The revised hypotheses and the methods adapted to test them will be incorporated starting with the Year 3 program activities.

1.2. Objectives, Management Questions and Study Hypotheses

The primary objectives of this monitoring program are: 1) to collect scientifically rigorous information on the species composition, relative abundance, life history and habitat use of resident fish populations in Seton Lake; and 2) to provide information required to link the effects of the Carpenter Reservoir diversion on fish populations to a) document impacts of the operating alternative on resident fish populations, and, b) support future decisions regarding the operation of BC Hydro facilities.

A set of management questions related to fisheries management goals and associated hypotheses regarding potential environment responses to the selected WUP operations were also defined to provide direction for the study.

The primary management questions to be addressed by this monitoring program are:

1. **What are the basic biological characteristics of resident fish populations in Seton Lake and its tributaries?**

This management question will be evaluated using fish population abundance or index of abundance, fish distribution and biological characteristics data. Target species include rainbow trout, bull trout and Kokanee (Gwenis).

2. **Will the selected alternative (N2-2P) result in positive, negative or neutral impact on abundance and diversity of fish populations in Seton Lake?**

This management question will be evaluated using weight-of-evidence as exhibited by trends in fish abundance indices and trends in their biological characteristics in conjunction with the range of Carpenter diversion characteristics. The underlying operational cause-effect relationship associated with any response may not be evident from this analysis alone. However, results from BRGMON-6 (Seton Lake Aquatic Productivity Monitoring) will be used to evaluate WUP operations impacts on lake productivity that could in turn be linked to impacts on productivity of the resident fish population.

3. **Is there a relationship between the quality, quantity, and timing of water diverted from Carpenter Reservoir on the productivity of Seton Lake target resident fish populations?**

This management question will be evaluated using basic habitat quality and diversion timing data collected in the lake in conjunction with trends in fish abundance and productivity data collected through BRGMON-6 study.

4. **Can refinements be made to the selected alternative to improve habitat conditions or enhance resident fish populations in Seton Lake?**

This management question will be evaluated based on insights gained from results under management questions 1-3.

The primary hypothesis (and sub-hypotheses) associated with these management questions from the original study Terms of Reference are:

H_1: The abundance and diversity of Seton Lake fish populations are directly limited by habitat impacts directly related to the operation of the Bridge Generating Station.

- **H_{1A}:** Diversions from Carpenter Reservoir reduce the temperature, light penetration, and euphotic volume of Seton Lake.
- **H_{1B}:** Daily fluctuations in Seton Lake levels result in reduced effectiveness of shoreline spawning habitat.
- **H_{1C}:** Daily fluctuations in Seton Lake levels result in reduced effectiveness of spawning.

These hypotheses reflect the generalized effects of BC Hydro operations that were understood to influence habitat productivity and resident fish population abundance in Seton Lake. The monitoring program was designed to test these hypotheses by analyzing general fish population trends and making inferences based on a weight-of-evidence approach. Each of these hypotheses could have significant consequences for the predicted impacts of diversion operations on fish in Seton Lake; however, they could not be resolved with scientific data during the WUP process. In particular hypotheses H_{1A} and H_{1B} were critical in making decisions about the final chosen operating alternative for the BRG WUP.

1.3. Study Area

Field studies for the Seton Lake Resident Fish Habitat and Population Monitoring Program (BRGMON-8) were conducted around the entire perimeter of Seton Lake from Seton Portage at the west end to Seton Dam at the east end, including the lower reaches of tributary streams within this area (Figures 1 and 2). The tributary streams that were surveyed for spawning included: M'sut (aka Machute) Creek, Spider Creek, Whitecap Creek and the Creek at Retaskit. Sections of Portage Creek were opportunistically surveyed in Year 2; however, much of the stream length was either inaccessible or too wide to survey by the shore-based observer method.

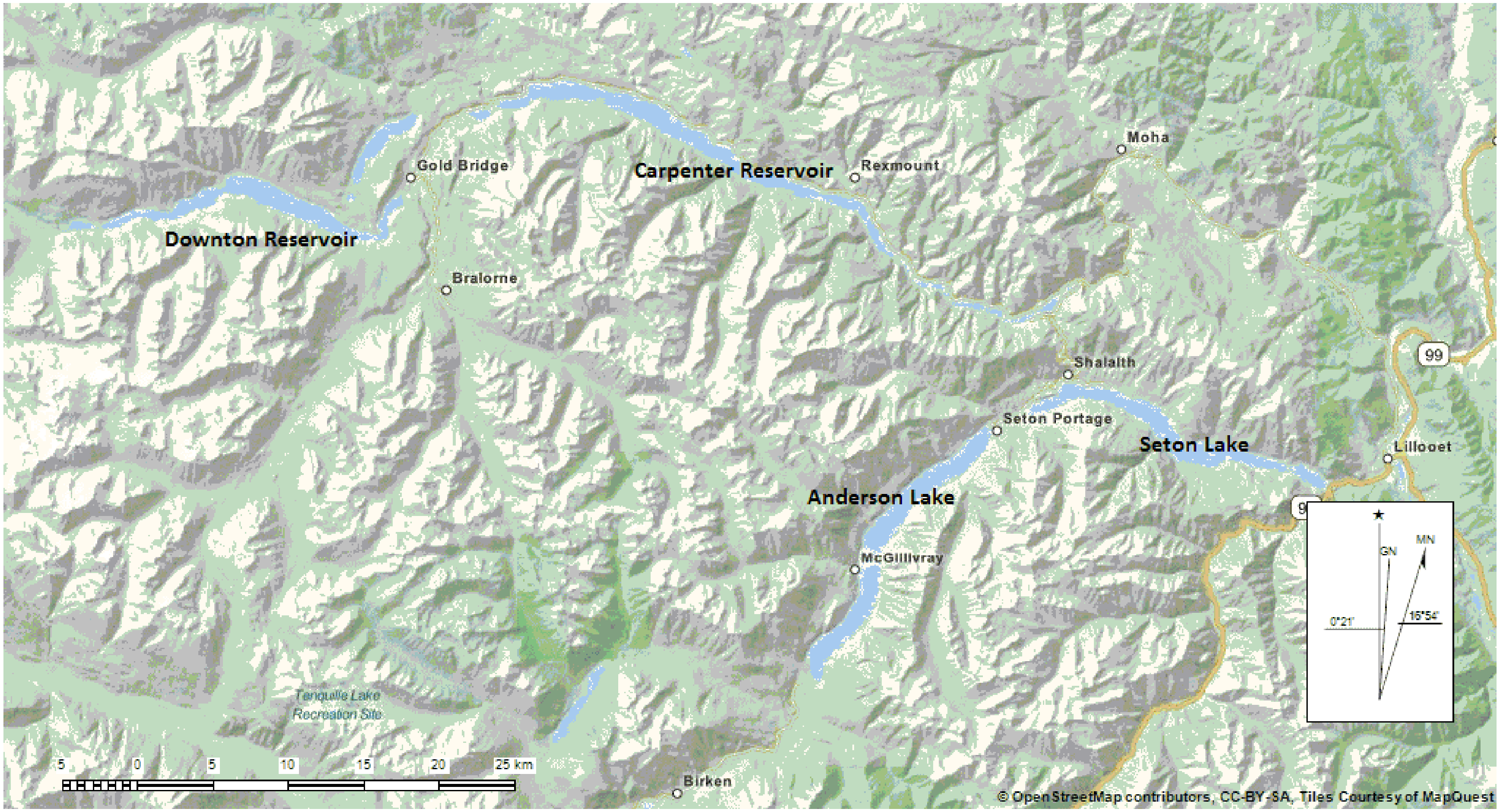

Figure 1. Overview of the Bridge and Seton watersheds.

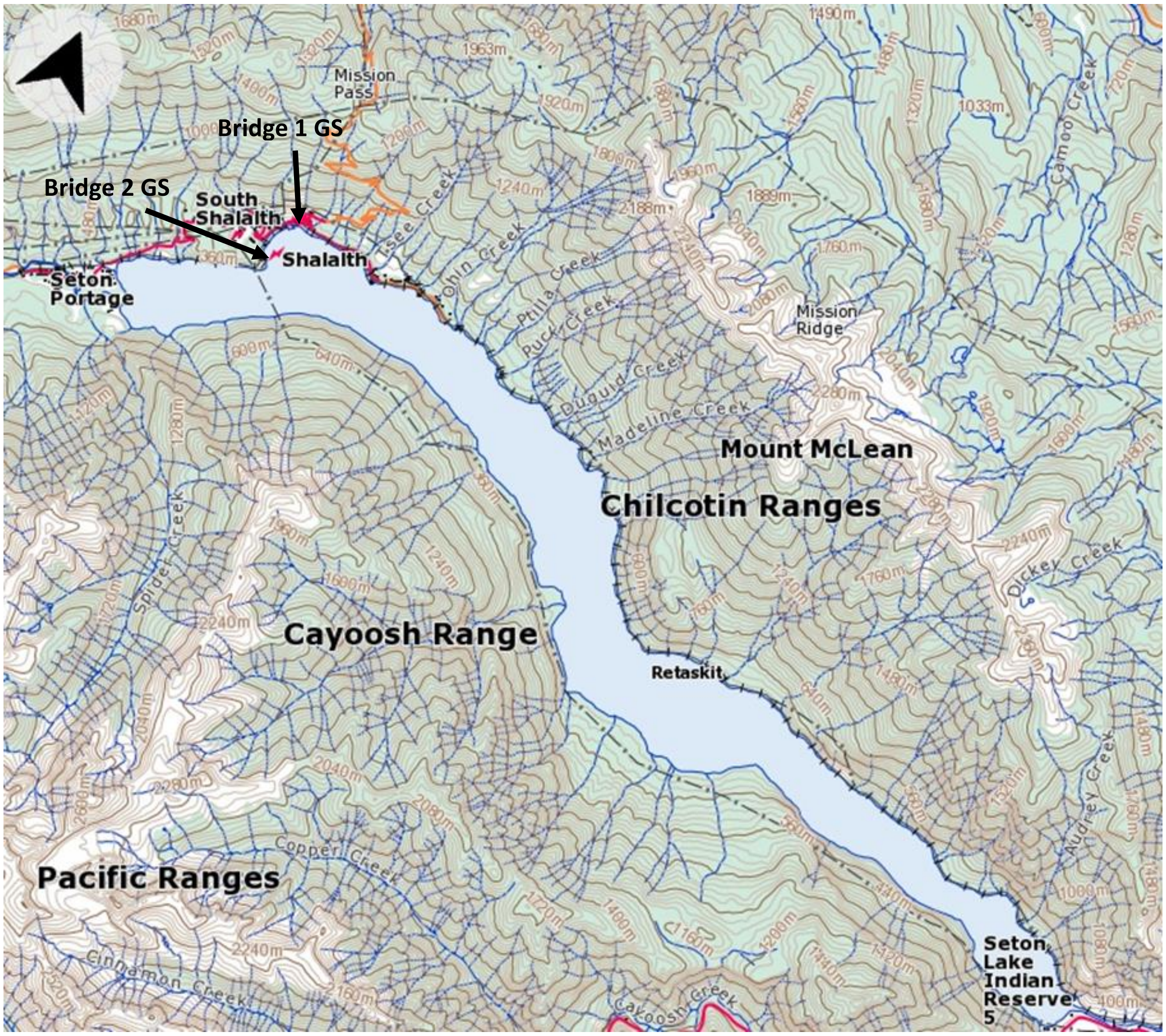

Figure 2. Seton Lake and the relative location of tributaries. Note: the location of the Bridge 1 and 2 Generating Stations are indicated (at Shalalth), and Seton Dam is situated in the lower right corner of this map.

1.4. Sampling Schedule

The Bridge River Power Development Water Use Plan was accepted by the provincial Comptroller of Water Rights in March 2011. Terms of Reference for the Seton Lake Resident Fish Habitat and Population Monitoring program were developed and approved in 2012, and field data collection activities were initiated in 2013.

As per the original ToR, the activities associated with this monitoring program were recommended by the BRG WUP Consultative Committee for a total of 10 years. The study years covered by this report (2013 and 2014) represent monitoring years 1 and 2. The schedule of field sampling activities for years 1 and 2 is presented in Table 1.

Table 1 Schedule of Field Sampling Sessions and Activities.

Task	Apr	May	Jun	Jul	Aug	Sep	Oct
1. Project Management	X	X	X	X		X	X
2. Field Studies							
a Fish Population Index Surveys			XX			XX	
b Supplementary Fish Tagging		X	X			X	X
c Tributary Spawner Surveys		XX	XXXX				
d Habitat Monitoring		X	X			X	

2) Methods

The general approach to this monitoring program is to collect a long-term data set on the resident fish population and physical habitat conditions within Seton Lake in order to resolve data gaps and better inform the trade-off decisions made at the WUP table. Collection of coincident information on diversion operations from Carpenter Reservoir, in-lake habitat conditions, and the resident fish population (including life history information, age structure and an index of abundance) is intended to allow identification of potential broad scale changes over the 10-year monitoring period. Trends in these changes over time can be used to test hypotheses about the relationship between diversion operations and population response using a weight-of-evidence approach.

The target species selected for this program are bull trout, rainbow trout and gwenis based on their ecological and social value in this context. Bull trout are a species of regional concern, rainbow trout are popular with recreational anglers, and gwenis are a historically significant winter food source for St'at'imc communities. However, based on the first two years of sampling focussed on the littoral zone of the lake (i.e., inshore of the ca. 6 m depth contour), the abundance of each of these species was very limited in the catch relative to other non-sportfish species (such as: bridge-lip sucker, northern pikeminnow, and peamouth chub). It is likely that the pelagic environment may be more heavily utilized by the target species given the distribution and availability of food resources and/or preferred habitats in that zone.

2.1. Sampling Design

Monitoring programs in large lake contexts such as this one face significant challenges in that, despite extensive, rigorous sampling effort, they commonly fail to achieve the statistical certainty required to obtain precise population estimates and determine cause and effect. Challenges typically include low capture and re-capture rates, migration and 'open populations' for mark-recapture estimates, and difficulty accurately ageing fish to estimate the abundance and survival of individual cohorts. Despite these challenges, these programs collect important inventory, life history and trend information that is valuable to better understand the populations and potential effects of operations.

In 2013 and 2014, field activities for this program were focussed on providing data to meet the following monitoring components described in the original study ToR (BC Hydro 2012):

1) Collecting time series information on the abundance and biological characteristics of resident fish populations and reservoir habitat conditions;
2) Examination of trends in growth or distribution changes with operations.

It must be noted that a great deal of learning about sampling conditions and fish distribution, densities, and catchability occurred during the first two years of monitoring, which has helped inform the approach and strategy for this monitoring program going forward. There has also been key learning about deficiencies in data collection methodologies and issues with the testability of some of the hypotheses included in the original ToR. These issues have necessitated revision to the original approach; these revisions were described in a ToR addendum (BC Hydro 2015) submitted to the provincial Comptroller of Water Rights in January 2015 and will be addressed in the Year 3 monitoring activities and report. While further changes of this magnitude are not expected, the sampling design will continue to be reviewed annually to account for new learning in this large and challenging context.

The proposed study design in monitoring years 1 and 2 included four main components:

- General fish population index surveys by boat electrofishing using a stratified random sampling approach (Year 1) and mark-recapture approach (Year 2);
- Supplemental tagging of target species by angling;
- Tributary spawner surveys conducted by stream walks; and
- Laboratory ageing analysis of structures (scales or fin rays) collected from target species.

More detailed descriptions of each of these components are provided in the sections that follow.

2.2. General Fish Population Index Surveys

The general fish population index surveys were intended to provide information on the seasonal and inter-annual variation in the relative abundance, distribution and growth rates of target species. The index survey data was collected in near shore areas of the littoral zone by a standardized boat electrofishing (boat EF) method, which is generally most effective within the ca. 0.5 to 3.0 m range of water depths. Index surveys were conducted during both the spring (June) and fall (September/October) periods in 2013 and 2014.

Boat EF is conducted by running an electrical current through the water between a set of boom-mounted anodes extended off the front of the boat and a cathode array, while propelling the boat forward at slow speed (ca. 1 to 2 km/h). Within the electrical field that this generates, a proportion of fish are stunned and drawn up to the surface where they can be netted by crew members standing on a bow platform and transferred to an on-board fish holding tank. Not all fish within the sampling zone are successfully stunned by the electrical field, and not all of the observed fish are successfully netted, particularly in the open, slack-water conditions prevalent along the shorelines of Seton Lake (Section 6: Photos – Plate 1). As such catches likely represent a relatively small (but undefined) proportion of the total fish available.

Boat EF was conducted at night (Section 6: Photos – Plate 2). At each site, the boat was maneuvered to a pre-designated starting point (GPS coordinate) from which a section of edge habitat was electrofished (see year-specific details below). The habitat type of each site was confirmed in the field. The following boat EF settings were used: Electrofisher = Smith-Root 5.0 GPP; Voltage Range = High (50 – 1000 V); % of Power = 100%; Output = ca. 6 to 8 amps; DC Current Mode; 60 DC pulses/sec.

Monitoring Year 1 (2013)

In 2013, the surveys followed a stratified random design similar to boat EF pilot sampling conducted on Carpenter Reservoir in 2001 (Paul Higgins, pers. comm.). As a part of this method, the entire shoreline of the reservoir was pre-classified (by a GIS mapping exercise) according to a set of habitat types that can be correlated with factors that influence fish use. For Seton Lake, the shoreline habitat was classified into the following four types:

1) Tributary mouth
2) Fluvial fans
3) Shallow slope (< 15% bank gradient)
4) Steep slope (> 15% bank gradient)

A set of GPS coordinates for ca. 100 boat EF sites were randomly selected according to these types, with the relative number representing the total length contribution of each type. For example, ca. 6% of the shoreline length is represented by tributary mouths, so 6 of the 100 sites were in Type 1 habitat. Whereas 44% of the shoreline length is represented by steep slopes (Type 4), so 44 of the 100 sites were selected in this habitat type.

Sites were also distributed throughout the lake so that each of the longitudinal zones (dubbed: West end, West-Mid lake, Mid-East lake, and East end) were represented. For the purposes of the data analyses, the West end has been arbitrarily defined as the 2.3 km section of the lake area west of the Bridge 2 Generating Station (approx. UTM easting line 554000); the Mid-West zone has been defined as the 6.5 km section between the Bridge 2 Generating Station and M'sut Creek fan (near UTM easting line 560000); the Mid-East zone is from the M'sut Creek fan to approx. easting line 566000 (length = 6.0 km); and the East end extends 6.2 km from there to Seton dam (at ca. 572200). One set of sites was randomly selected for the spring session, and a different set was randomly selected for the fall session (See maps in Appendix A).

Sampling effort was based on a target duration of electrofishing (i.e., 300 seconds) for each site; however, the actual number of seconds and the distance sampled were not recorded, so the effort applied for this year needed to be estimated. Each site was sampled in a single pass.

Monitoring Year 2 (2014)

In 2014 some significant changes were made to the electrofishing approach employed in Year 1. Given the slackwater conditions and unconfined shorelines in Seton Lake (which are typical of most lake environments), there were very limited means to *contain* the fish to be sampled at most sites. As a result, it was suspected that capture probabilities by boat EF may be low in this context; however, they could not be defined based on the approach in Year 1. As such, it would be difficult if not impossible to derive an annual population estimate from the results, or determine quantitative differences in abundance between habitat types. Therefore, attempts were made in Year 2 to determine if habitat-stratified capture probabilities could be quantified in this context using a two-pass mark-recapture approach to better inform the index results going forward.

The intent was to test the feasibility of a two-phase sampling design whereby mark-recapture experiments could be implemented up front to characterize detection probabilities which could then be used to expand counts at a large number of index sites sampled by a single pass in subsequent years (similar to Korman et al. 2010). In order for this method to be successful, a sufficient sample size of fish must be available for marking and subsequent recapture, and the approach must allow for reasonable assumption of site "closure" (meaning that all marked fish are available within the sample sites for recapture during the second pass) by incorporating adequate site length and limited time between passes. However, it is important to note that these sites were not physically enclosed using nets due to their size and the nature of the terrain.

Instead of single pass sampling at a large set of randomly selected sites, an extended length of shoreline (i.e., several kilometers) was repeat-sampled during each session following a standardized mark-recapture method. A trade-off with mark-recapture is that less shoreline area can be covered since each site must be sampled twice (a marking pass and a recapture pass). In the spring session, both the marking and recapture passes were conducted by boat EF. However, during the fall session, marking was done by angling followed by a recapture pass by boat EF. This change was to account for the limited recaptures during the spring session and the possibility that capturing fish for marking by boat EF may alter fish behaviour, habitat use and/or condition in the short term, thereby violating the site "closure" assumption for the recapture pass. For this mark-recapture experiment, the recapture pass was conducted approximately 24 hours after the fish were marked.

The total sampled length at each location was divided up into consecutive sections according to habitat type as designated during the Year 1 habitat mapping. Each section spanned only one habitat type and was generally about 300 m in length. Shoreline sections associated with catches of target fish species in Year 1 were preferentially selected in an attempt to maximize the sample size for the mark-recapture experiment. However, given the limited availability of target species in the littoral zone in general, all captured fish of an appropriate size and condition were marked (i.e., including non-target species such as bridge-lip sucker, northern pikeminnow, and peamouth chub). Typically three consecutive 300 m sections were sampled (back-to-back) to extend the sampled length at each location and account for some fish movement along the shoreline between passes.

Fish collection efforts were accompanied by detailed sampling of the biological characteristics of the captured fish, as well as measurement of general sampling conditions (i.e., temperature, turbidity and secchi depth). Fish were measured for length and weight, and evaluated for sex and sexual maturity (as possible based on external characteristics). Ageing structures were collected from target species. Individual coded (PIT) tags were applied to all captured fish of appropriate size and condition during the marking pass (target fish only from the recapture pass) to provide information on capture efficiency, as well as movement and growth patterns.

2.3. Supplementary Tagging of Target Species

Based on the proposed approach, the recapture of tagged fish is important for defining growth rates and movement patterns within and between study years. However, given the size of the study area and the numbers of target fish species sampled during the index surveys, it was recognized that the number of tagged fish available for recapture in subsequent sessions and years was going to be limited. Therefore, some supplemental tagging for bull trout and rainbow trout was also proposed. These supplementary tagging surveys were conducted on an opportunistic basis between May and October.

For these supplemental tagging surveys, fish were captured by angling from a boat using lures or hooks baited with cured salmon roe. To improve capture success, angling effort was focussed on areas of the littoral zone where target fish tend to congregate to feed. These areas included: tributary mouths, outflow of the BR1 and BR2 Generating Stations, Cayoosh Diversion outflow, and the outlet of the lake above Seton Dam. As with the boat EF surveys: forklength and weight were measured, sex and maturity were assessed, ageing structures were collected, and a PIT tag was applied to all captured fish.

2.4. Tributary Spawner Surveys

Tributary spawner surveys were conducted in Year 1 and Year 2 to document use of select tributaries of Seton Lake and Portage Creek for spawning. The surveys focussed on the timing of rainbow trout spawning as this species is adfluvial: migrating from the lake to stream habitats for spawning where they are vulnerable to shore-based counting methods, and likely spawns within the study area.

Gwenis and bull trout spawn in the fall (i.e., Oct and Nov in the Seton system). Gwenis reportedly utilize shoal areas deep within the lake for spawning which cannot be surveyed using the visual-based methods employed in the tributaries. Spawning surveys for bull trout were not conducted in Years 1 and 2 because spawning use of the study area by this species is likely not representative of overall population trends. Bull trout are known to be highly mobile and migrate large distances in and out of the study area as life history requirements and feeding opportunities change throughout the year (Caroline Melville, Seton Entrainment Study coordinator, pers. comm.). Going forward, it may be useful to collaborate with the Entrainment Study program to tag and track bull trout throughout the Bridge and Seton systems to better define their spawning areas and timing of movements in order to inform potential spawning surveys in future years for the BRGMON-8 program.

Tributary spawner surveys were conducted on a ca. weekly basis between May and June with the intention of establishing a relative weekly count. Three tributaries were assessed in both Year 1 and Year 2. These included: M'sut Creek, Spider Creek, and Whitecap Creek. Another unnamed tributary at a location called Retaskit (Figure 2) was initially visited in Year 1, but determined to flow to ground before reaching the lake edge (Section 6: Photos – Plate 3). Accessible sections of Portage Creek were opportunistically surveyed in Year 2 in order to establish spawning use of this significant tributary by the target species for this program since it wasn't surveyed in Year 1. Given the size of this stream, however, it was difficult to achieve comprehensive counts using a shore-based assessment methodology. In future, consideration could be given to a snorkel-based assessment method to potentially improve coverage and observer efficiency.

Each spawner survey was conducted by two persons: one observer walked along each shoreline of the creek (i.e., across from each other) where possible, starting at the mouth and walking upstream until either reaching a fish migration boundary (e.g., falls) or until no fish had been observed for several hundred meters. Each observer wore a hat and polarized sunglasses to minimize glare and ambient light interference. Given that there are two observers, their individual counts must be reconciled in real time in the field to preclude the potential for double-counting when spawners are observed. The total, reconciled count was recorded in the field notes for each surveyed tributary.

2.5. Laboratory Analysis

To assist in developing an understanding of the life history, growth characteristics and age class structure of the resident fish population in Seton Lake, fish sampling included collection of age structures (i.e., scales or fin rays) from captured fish. Laboratory analysis (fish ageing) will be conducted on these samples by Mike Stamford to assess the age of specimens to facilitate characterization of age classes and size-at-age analysis. Once a sufficient sample size is collected, these data will allow estimation of average growth rates of the different life stages of target species and contribute to an understanding of how different habitats, zones, or diversion operations may influence fish condition in Seton Lake.

Scales were collected from bull trout, rainbow trout, and mountain whitefish captured in Year 1 and Year 2.

2.6. Data Management

All field data collected for this project were recorded into field notebooks or on standardized datasheets specifically developed for this program (Appendix B). A standardized data entry template was developed in MS Excel, and all data entry was conducted by SER technicians. Data quality assurance (QA) checks were completed by the Project Manager.

All entered data were compiled into a database developed collaboratively with IFR staff for housing the BRGMON-4 (Carpenter Reservoir), BRGMON-7 (Downton Reservoir), BRGMON-8 (Seton Lake), and BRGMON-9 (Seton River) Fish Habitat and Population Monitoring data. This database will: facilitate data sharing between monitoring programs; continue to be updated each year as new data are collected and entered; and be stored in multiple locations (i.e., office computer, external hard drive, and online storage such as "Dropbox"). All data and text files have been backed up to ensure data security and integrity.

3) Results

3.1. Physical Conditions

BC Hydro Operations

Seton Lake receives inflows from a combination of natural and regulated sources; however, since development of the hydroelectric infrastructure, inflows from regulated sources are larger than the natural inflows. Natural inflow sources include small tributaries that drain directly into the lake from the north and south sides of the valley, as well as Portage Creek at the west end, which conveys all of the attenuated inflows from the upper portion of the watershed. Regulated inflow sources include the Carpenter Reservoir diversion flows which are harnessed by BC Hydro's Bridge 1 (BR1) and Bridge 2 (BR2) Generating Stations for power production, and discharge into Seton Lake at Shalalth; and the Cayoosh diversion outflow at the public beach on the lake's west end. Outflows are regulated by BC Hydro's Seton Dam and Generating Station, which discharge into the Seton River and Fraser River, respectively.

The entire Bridge-Seton hydroelectric complex is integrated and the operations of each reservoir and facility are managed based on storage, conveyance, and generation decisions that account for water management priorities, electricity demands, plant maintenance requirements, fisheries impacts, as well as other values. Seton Lake and its associated BC Hydro facilities are situated at the downstream end of the Bridge-Seton system. Surface elevations in Seton Lake are managed within a small range (i.e., 0.4 m) relative to other reservoirs in the system. Daily and seasonal elevations are driven by a wide range of factors: BR1 and BR2 operation; Seton Dam discharge; Seton Generating Station operation; Cayoosh Creek diversion inflows; and tributary inflows.

Records of BR1 and BR2 discharge and Seton Lake surface elevations were provided by BC Hydro for the periods 1 January 2013 to 31 December, 2014 and are illustrated in Figures 3 to 6.

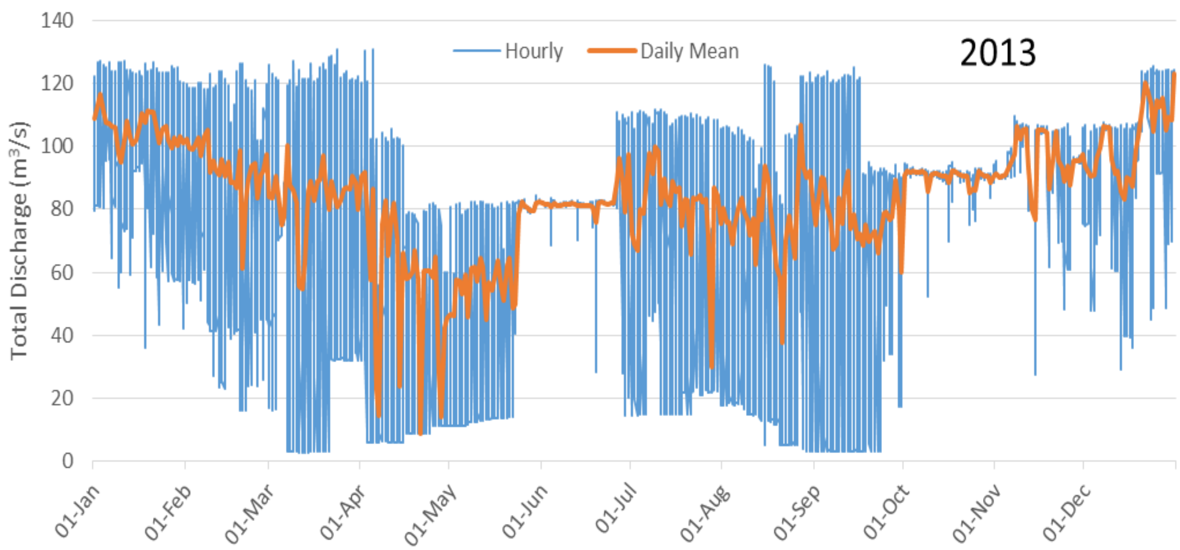

Figure 3 Total hourly and mean daily discharge rates from Bridge 1 and Bridge 2 Generating Stations into Seton Lake, January to December 2013.

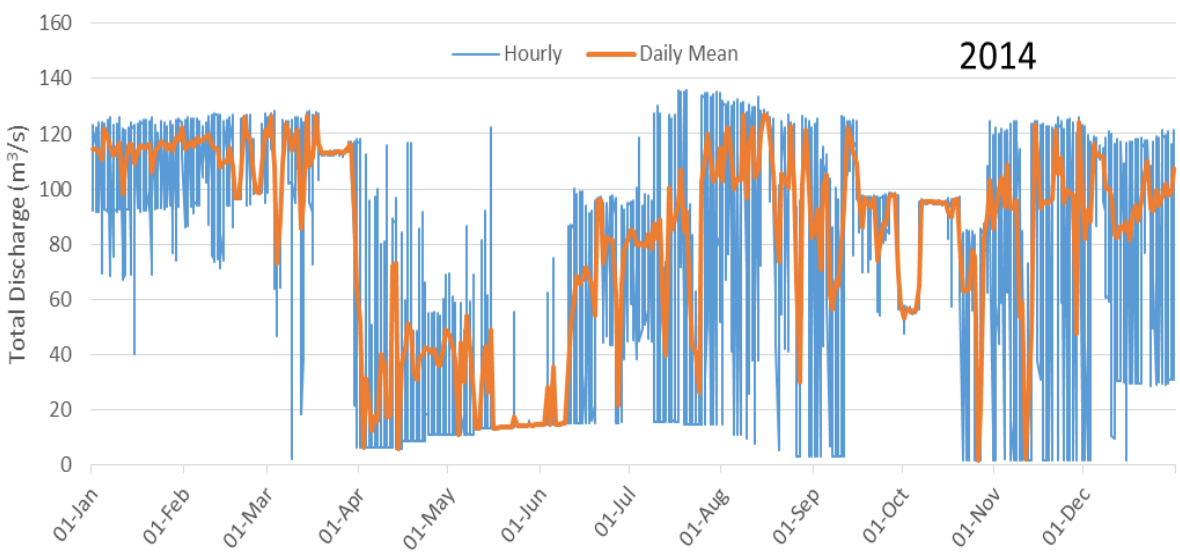

Figure 4 Total hourly and mean daily discharge rates from Bridge 1 and Bridge 2 Generating Stations into Seton Lake, January to December 2014.

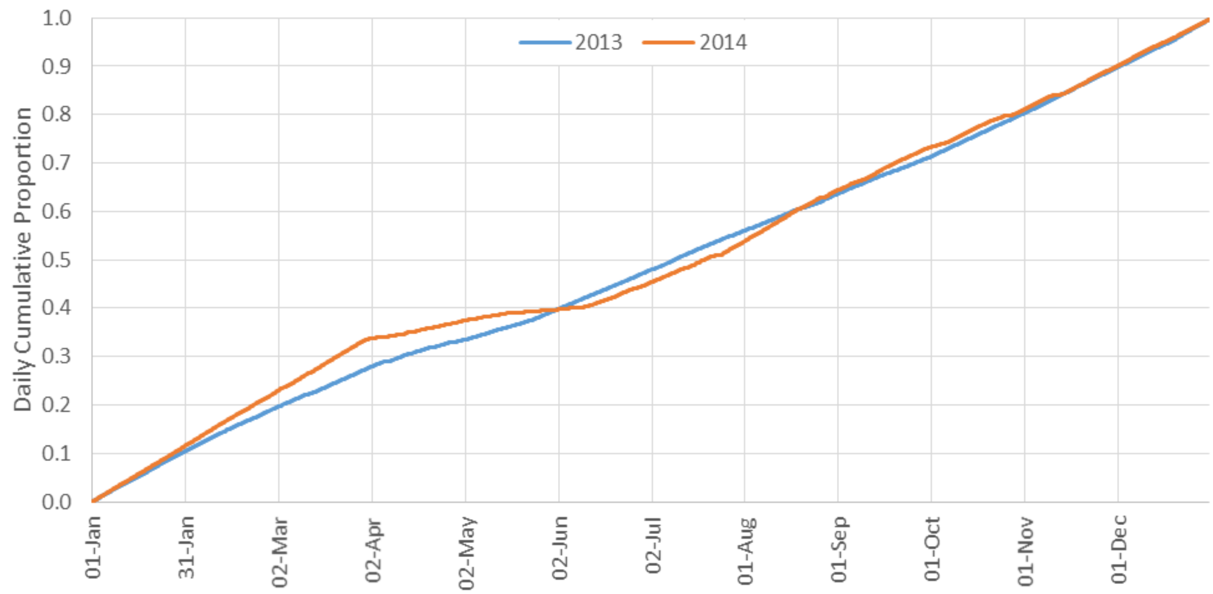

Figure 5 The daily cumulative proportion of total annual discharge from the Bridge 1 and 2 Generating Stations, 2013 and 2014.

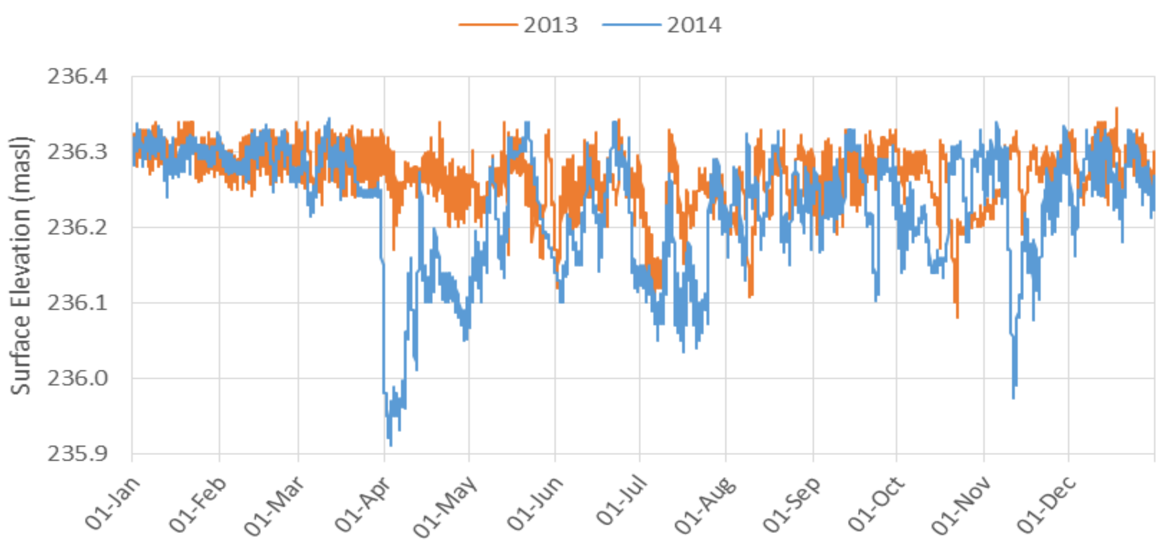

Figure 6 Hourly surface elevations of Seton Lake recorded in the forebay of Seton Dam, January to December 2013 and 2014.

As the data in Figures 3 and 4 indicate, discharge from the BR1 and BR2 Generating Stations is highly variable throughout most of the year. Peak discharge is ca. 136 $m^3 \cdot s^{-1}$ and the outflow can vary by up to 125 $m^3 \cdot s^{-1}$ on a daily basis as the units cycle between shutdown and full output to meet peak energy demands. In 2013 and 2014, there didn't appear to be any form of consistent seasonal pattern; however, there were two ca. 30-day periods of more stable discharge; one in spring (May-June) and one in fall (Oct) which occurred in both years.

The total volume of the diversion discharge was 2.64 × 10^9 m^3 in 2013 and 2.59 × 10^9 m^3 in 2014; a difference of ca. 51.7 Mm^3 or 2%. In other words, the total volume of water diverted into the lake from Carpenter Reservoir was not significantly different between the first two monitoring years. Figure 5 displays the discharge as a cumulative daily proportion of the total discharge for each year. The cumulative discharge appeared nearly linear across the year in 2013; whereas it displayed a slight s-shaped curve in 2014: daily discharge proportions were slightly higher in spring and fall, and slightly lower in summer that year.

The management of surface elevation in Seton Lake also did not reveal any obvious seasonal pattern. The total range of elevations is low relative to other reservoirs in the system (i.e., Carpenter and Downton); the maximum observed was 0.28 m and 0.44 m between minimum and maximum in 2013 and 2014, respectively. The period of most consistent lake elevations was in winter, from December to the end of March. The lowest elevations were recorded on 3 April 2014 (235.91 masl) and 11 November 2014 (235.97 masl).

Some concern was raised during the WUP process that fluctuations in the lake surface elevation may have the potential to impact shore spawning locations of Gwenis that occur at elevations within the drawdown range, when drawdown occurs during the spawning or incubation period. Gwenis spawn timing has been observed to occur in late fall (i.e., November to early December; Morris et al. 2003 and this program) in Seton Lake. Some potential shore spawning sites have been identified around the perimeter of Seton Lake (based on suitable habitat characteristics), though direct evidence of spawning use in these locations or drawdown impacts have not yet been documented. Further work will be done in Year 3 of this program to determine the areal extent and substrate size distribution within these potentially vulnerable areas.

Lake Temperatures

Monthly water temperatures for the May to October period at a range of depths from mid-lake locations in Seton and Anderson lakes are displayed in Figures 7 and 8, respectively.

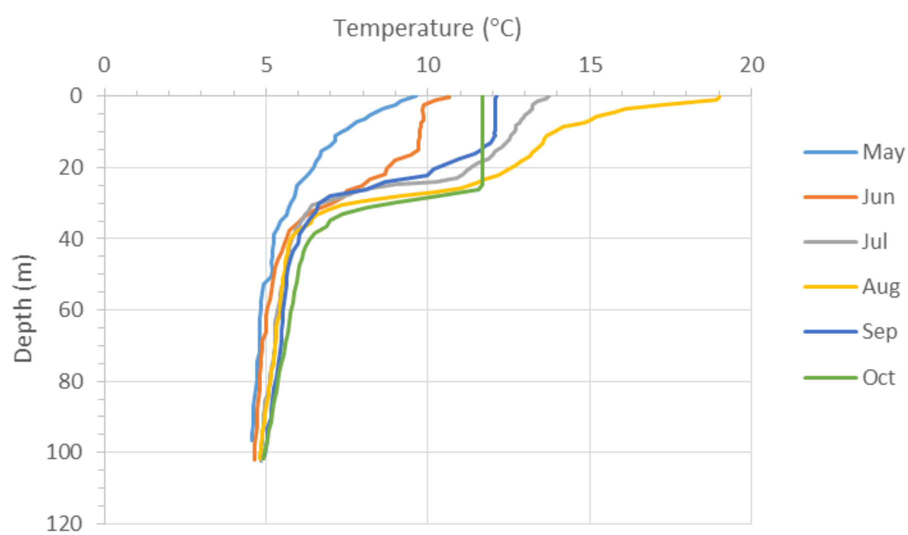

Figure 7 Monthly water temperature profiles recorded at a mid-lake location in Seton Lake, from May to October 2002.

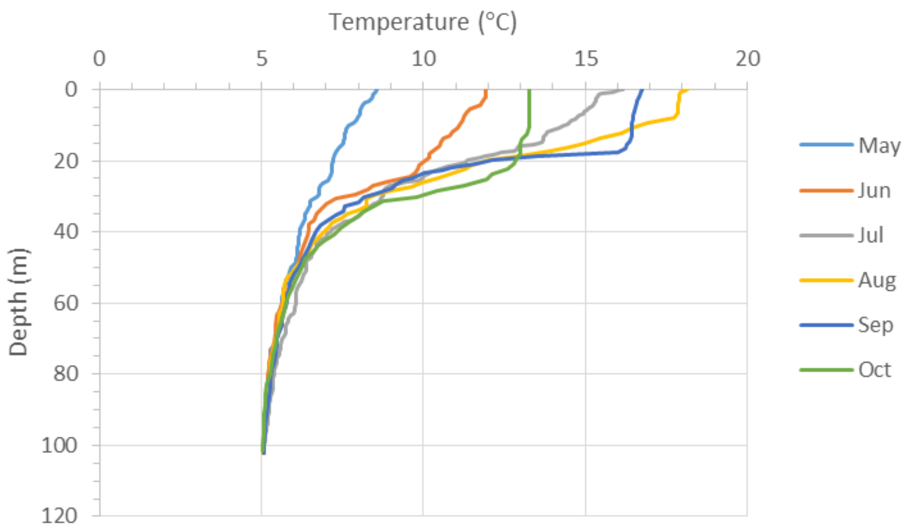

Figure 8 Monthly water temperature profiles recorded at a mid-lake location in Anderson Lake, from May to October 2002.

In both lakes, surface temperatures warmed from ca. 9° to 18° or 19°C between May and August, and then cooled to 12° or 13°C by October. Maximum and minimum observed surface temperatures were both about a degree warmer in Seton Lake than in Anderson Lake during the monitored period. The biggest seasonal surface temperature differences occurred in the months of June, July, and September. The surface of Anderson warmed more quickly through the beginning of summer, and cooled more slowly in September. These differences may be associated with the operation of the Carpenter Reservoir diversion into Seton Lake during these periods, but more data are required to better characterize this potential effect. Water temperatures at 100 m depth were quite consistent at ca. 5°C across the months in both lakes. The process of thermal stratification develops over the course of the summer and into fall. By October, the thermocline was at ca. 27 m below the surface in Seton Lake, and at ca. 23 m in Anderson Lake.

3.2. Tributary Spawner Surveys

Three tributary spawner surveys were conducted in Year 1 between 30 May and 19 June 2013. In Year 2, four surveys were conducted between 15 May and 26 June 2014. Characteristics of the surveyed streams are summarized in Table 2. Spawners were not observed during any of the surveys likely due to sub-optimal visibility conditions on all survey dates (further described below).

Table 2 Summary of characteristics for spawner survey streams within the Seton Lake study area, 2013 and 2014.

Stream	UTM Coordinates	Year Surveyed	Gradient[a]	Accessible Length (m)	Barriers?[b] (Type)	Comments
Portage Cr.	549347E 5617044N	2014	Low	~ 3000	No	Good habitat at top end
Whitecap Cr.	549417E 5617738N	2013 2014	Moderate	~ 500	Yes (Falls)	Turbulent, Turbid
Spider Cr.	550928E 5617359N	2013 2014	Moderate	400	Yes (Gradient)	Turbulent, Turbid
M'sut Cr.	560599E 5616153N	2013 2014	Low-Mod.	300	Yes (Gradient)	Suitable habitat in lowest reach
Bear Cr.	561616E 5614780N	2013 2014	High	50	Yes (Gradient)	Limited accessible habitat
Speer Cr.	559948E 5618353N	2013 2014	High	~ 25	Yes (Falls)	Access limited
Trib. at Retaskit	563598E 5616043N	2013 2014	High	50	Yes (Culvert)	Ephemeral

[a] This refers to gradient of the accessible section; Low = 1-2%; Moderate = 3-6%; High = 7-10%
[b] Barriers present at the upstream end of the accessible stream length (Y/N)

Seton Lake sits within a steep-sided valley, so the accessible length of its tributary streams is relatively short, often being limited by steep gradients or falls after a short distance (Section 6: Photos – Plate 4). Observation of spawners or their redds was difficult by shore-based assessment in many of the selected tributaries within the study area due to steep gradients, turbulence, or seasonal high flow and turbidity conditions. Visibility in the surveyed creeks was generally rated either moderate or poor. Under moderate conditions, visibility extended to the bottom of shallower habitats, but generally not to the bottom of deeper pools (where a proportion of fish may hold during the day). Under poor conditions, it was not possible to see to the bottom of any mid-channel habitats.

The streams with the most suitable and accessible spawning habitats observed were Portage Creek, particularly at the top end (outflow of Anderson Lake) and the lower-most reach of M'sut Creek. Some habitat likely exists in Spider and Whitecap creeks as well, although the extent of suitable spawning gravels is limited by the steeper gradients and limited low-velocity (e.g., pool) areas. Visibility to the bottom of these creeks was also poor due to turbulence and high turbidity, particularly during the spring survey period (Section 6: Photos – Plate 5).

Two options to potentially improve results for this study component could include: 1) conducting snorkel-based surveys in Portage Creek where habitat area is larger and visibility is generally better than in the side streams; and 2) collaborate with the Entrainment Study program to tag and track bull trout throughout the system to better define their spawning areas and timing of movements in order to inform potential spawning surveys in future years. However, it remains uncertain whether the results of uncalibrated visual-based surveys will be meaningful for tracking population trends and answering the management questions.

3.3. Fish Indexing Surveys

2013 Random Index Sampling

In 2013, totals of 28 fish (of target species) were captured by boat EF at 103 sites in June and 5 were captured at 102 sites in September. These included rainbow trout (*n*=23 in Jun; *n*=5 in Sep) and bull trout (*n*=5 in Jun; *n*=0 in Sep). In addition, 638 and 582 fish of non-target species were captured but not processed in June and September, respectively (Table 3). The relative distribution of sites among habitat types is summarized in Table 4.

Table 3 Catch totals by species for both target and non-target fish during indexing surveys in monitoring Year 1.

Index Session	Fish Species[a]									Total
	RB	BT	MW	O. nerka	CH juv.	CO juv.	BSU	NSC	PMC	
June	23	5	4	22	2	4	364	165	81	670
September	5	0	6	2	1	1	148	359	71	593

[a] RB = rainbow trout; BT = bull trout; MW = mountain whitefish; O. nerka = gwenis/sockeye juv.; CH = chinook; CO = coho; BSU = bridgelip sucker; NSC = northern pikeminnow; PMC = peamouth chub

Table 4 Relative numbers of sites by habitat type for boat electrofishing index surveys in Seton Lake, June and September 2013.

Index Session	# of Sites	Proportion of Sites by Habitat Type[a]			
		Trib. Confl.	Fluvial Fans	Shallow Slope	Steep Slope
June	103	3 (3%)	31 (30%)	25 (24%)	44 (43%)
September	102	3 (3%)	30 (29%)	25 (25%)	44 (43%)

[a] Relative contribution of each type to the total number provided in brackets.

In total, 5 bull trout, 27 rainbow trout and 7 mountain whitefish were marked with PIT tags (seasonal totals = 29 in June; 10 in September) and none were recaptured during the boat EF index surveys within Year 1. Fish that were too small (< 100 mm fork length) or in poor condition when processed, were not tagged. A summary of catch statistics for target fish (rainbow trout and bull trout) in Year 1 is provided in Table 5.

Effort (site length in meters, or number of electrofishing seconds) was not recorded for index sampling sites in 2013; however, 300 seconds of electrofisher time was the target effort for each site (Gene Tisdale, pers. comm.). Based on this approximate value, and incorporating the average speed (i.e., meters-per-second) of electrofisher sampling by habitat type in 2014, Catch-per-unit-effort (CPUE) values were estimated. For both index sampling sessions in 2013, the distribution of sites was selected based on the relative proportions of habitat types from a GIS mapping exercise. Approximately 12 kilometres of shoreline was sampled during both June and September sessions (average site length = ca. 120 m est.).

Table 5 Summary of capture results for target species (rainbow trout + bull trout) from boat electrofishing index surveys in Seton Lake during June and September 2013.

Metric	Units	Index Sessions							
		June				September			
		Confl.	Fan	Shallow	Steep	Confl.	Fan	Shallow	Steep
Sites	#	3	31	25	44	3	30	25	44
Effort[a]	total seconds	~900	~9300	~7500	~13200	~900	~9000	~7500	~13200
Catch	# of fish	6	4	9	9	0	2	0	3
	# of fish marked	27				5			
	# of recaptures	0				0			
CPUE[b]	fish/site	**2.0**	**0.1**	**0.4**	**0.2**	**0.0**	**0.1**	**0.0**	**0.1**
		0.3				**0.0**			
	(fish/sec)·100	**0.7**	**0.0**	**0.1**	**0.1**	**0.0**	**<0.1**	**0.0**	**<0.1**
		0.1				**<0.1**			
	(fish/meter)·100	**2.1**	**0.1**	**0.3**	**0.2**	**0.0**	**0.1**	**0.0**	**0.1**
		0.2				**<0.1**			

[a] Sampling effort was not recorded in 2013 so values are based on a target of ca. 300 seconds of electrofishing time per site (Gene Tisdale, pers. comm.).

[b] Number of meters per site for this calculation was estimated based on meters-per-second covered by habitat type during 2014 sampling.

During both index sampling sessions in 2013, the majority of effort (ca. 13,200 seconds est.) was directed at Steep (Type 4) habitats, followed in decreasing order by Fluvial Fans (Type 2; ca. 9,000 s), Shallow habitats (Type 3; 7,500 s) and Tributary Confluences (Type 1; ca. 2400 s). This distribution of effort corresponded with the relative availability of each of these habitat types around the shorelines of Seton Lake. The CPUE (by all measures) was very low for target species during both sessions; highest values were for Type 1 habitats in June at ca. 2 rainbow trout + bull trout per tributary confluence site. CPUEs for every other habitat type was < 1 fish per 100 m of sampled distance. CPUE values were even lower during the September session.

Given the low capture success for target species in the littoral zone it is not feasible to draw any conclusions regarding distribution, habitat use, or relative abundance based on these data. It is possible that the pelagic zone of the lake plays a more important role for these species given the availability of food sources there (e.g., gwenis, sockeye juveniles, zooplankton).

A summary of the distribution of effort (# of sites), catch, and CPUE by longitudinal zone of the reservoir (as defined in Section 2.2) is provided in Table 6. Again, the CPUE values were low in each of these zones, and differences between them were very modest. The numbers of target species available in the littoral zone are likely too small to differentiate these kind of distributional differences.

Table 6 Summary of the seasonal distribution of catches for target species (rainbow trout + bull trout) according to longitudinal zone of Seton Lake, June and September 2013.

Sample Session	Metric	Longitudinal Zone of the Lake[a]			
		West	West-Mid	Mid-East	East
June	# of Sites	14	37	27	25
	Catch (# of Fish)	4	13	7	4
	CPUE (fish/m)·100	**0.3**	**0.4**	**0.3**	**0.2**
September	# of Sites	14	36	27	25
	Catch (# of Fish)	0	2	3	0
	CPUE (fish/m)·100	**0.0**	**0.1**	**0.1**	**0.0**

[a] As defined in Section 2.2; West is furthest from the dam and East is closest to the dam.

2014 Targeted Mark Recapture

In 2014, the boat EF sampling followed a two-pass mark-recapture approach with the goal of documenting habitat-stratified capture efficiency for fish in the littoral zone (inclusive of all available species). If capture probabilities could be quantified, they could then be applied to catch results in order to generate more robust population estimates. To improve the chances of success for the mark-recapture experiments, an increased focus was placed on habitats with the highest fish densities (and catch rates) based on the 2013 results: tributary confluence areas (Type 1) and shallow habitats (Type 3). The idea was that if capture efficiencies could be quantified in these areas, then the mark-recapture experiments would be extended to the other (Type 2 and 4) habitats. On the other hand, if it was not possible to establish capture probabilities in 'preferred' habitats, it likely isn't feasible in the lower density areas.

In total, 406 resident fish were captured by two-pass boat EF at 15 intensive sites in June 2014 (Marking pass *n*=125; Recapture Pass *n*=281). In October 2014, 7 sites were sampled using a mark-recapture approach (marking was conducted by angling; recapture pass was conducted by boat EF – see methods), plus an additional 14 sites sampled by a single pass of boat EF in order to cover additional shoreline area (Table 7). Totals of 122 fish were captured by angling, and 311 were captured by boat EF during the October survey (Table 8).

As in 2013, target species represented a very small proportion of the catch (i.e., 3%; Table 9). In total, 276 fish were marked with PIT tags (132 in June; 144 in October); As in 2013, only fish > 100 mm fork length and in good condition were tagged. Tagged fish included non-target species in order to increase the number of marks available for the mark-recapture component. Three fish from the marking pass were subsequently recaptured in the second pass during the June session (i.e., 1 MW, 2 BSU), and 1 rainbow trout was recaptured during the October session. However, these recapture rates were so low (Pcap = 0.02 and 0.007, respectively), that population sizes were not estimated given the high degree of error in the resulting estimates. As a result, the mark-recapture approach was considered unsuccessful in this context, and sampling results in 2014 reinforced the limited availability of target species in the littoral zone.

Table 7 Relative numbers of sites by habitat type for resident fish sampling surveys, June and October 2014.

M-R Session	# of Sites	Proportion of Sites by Habitat Type[a]			
		Trib. Confl.	Fluvial Fans	Shallow Slope	Steep Slope
June	15	1 (7%)	1 (7%)	9 (60%)	4 (27%)
October	7+14[b]	6 (29%)	5 (24%)	3 (14%)	7 (33%)

[a] Relative contribution of each type to the total number provided in brackets.
[b] 7 sites were two-pass (mark-recapture approach) and 14 sites were single-pass sampled.

Table 8 Summary of fish capture results (all species combined) from boat electrofishing surveys in June and October 2014.

Metric	Units	Mark-Recapture Sessions							
		June				October			
		Confl.	Fan	Shallow	Steep	Confl.	Fan	Shallow	Steep
Sites	#	1	1	9	4	6	5	3	7
Effort	total seconds	1750	2150	14029	5938	4559	3619	2197	4750
	total meters	436	600	5456	2410	1642	1496	839	1953
Catch	# of fish	45	74	197	90	106	85	58	62
	# of fish marked	23	31	44	34	52[a]	85[a]	1[a]	6[a]
	# of recaptures	0	2	0	1	1	0	0	0
CPUE	fish/site	**22.5**	**37.0**	**10.9**	**11.3**	**17.7**	**17.0**	**19.3**	**8.9**
		13.5				**14.8**			
	(fish/sec)·100	**2.6**	**3.4**	**1.4**	**1.5**	**2.5**	**2.3**	**2.8**	**1.3**
		1.7				**2.1**			
	(fish/meter)·100	**10.3**	**12.3**	**3.6**	**3.7**	**6.8**	**5.7**	**7.3**	**3.3**
		4.6				**5.4**			

[a] Note: these marked fish were captured by angling prior to the boat EF recapture pass during the October 2014 sampling session.

Table 9 Catch totals by species for both target and non-target fish during mark-recapture surveys in monitoring Year 2.

M-R Session	Fish Species[a]							Total
	RB	BT	MW	CARP	BSU	NSC	PMC	
June	6	5	14	2	241	46	92	406
October	11	3	24	0	135	131	129	433

[a] RB = rainbow trout; BT = bull trout; MW = mountain whitefish; CARP = common carp (Section 6: Photos – Plate 6); BSU = bridgelip sucker; NSC = northern pikeminnow; PMC = peamouth chub

Total CPUE values (based on catches of all species combined) were fairly similar between spring and fall sessions in 2014. Highest habitat-specific CPUEs were recorded at tributary confluences and fan habitats in June, but were more evenly distributed across habitat types in October. The higher numbers at tributary mouths and fan areas in spring likely corresponds with spawning-related movements (as several of the littoral species are spring-time spawners), as well as feeding opportunities as salmon smolts and drifting invertebrates are flushed out of streams. The more even distribution in fall likely reflects that minnow and sucker species (which dominated the catch) are able to exploit a broad range of shallow habitat types.

Between-Season and Between-Year Recaptures

Three fish that had been tagged during previous sessions were recaptured during 2014. Original capture and recapture information is summarized in Table 9. One fish was recaptured a little over a year after the original capture date; the other two were recaptured the subsequent season. All of them were recaptured at or very close to the same location where they were originally captured (BR2 outflow and Portage Creek fan).

Table 9 Summary of inter-session fish recaptures (monitoring Year 1 to Year 2). Note: Both of these recaptured fish were bridge-lip suckers.

Species [a]	Original Capture Data				Recapture Data				Dist. (km)
	Date	Zone[b]	FL (mm)	Wt (g)	Date	Zone	FL (mm)	Wt (g)	
BT	28-Jun-13	West-Mid	376	-	15-Jul-14	West-Mid	490	680	0.0
BSU	4-Jun-14	West	181	82	3-Oct-14	West	211	125	0.9
BSU	4-Jun-14	West	148	50	3-Oct-14	West	152	59	0.0

[a] BT = bull trout; BSU = bridgelip sucker

[b] The longitudinal zones of the lake are described in Section 2.2; Monitoring Year 1 (2013).

The recaptured bull trout had grown 114 mm in the 382 days between capture events (average growth = ca. 0.3 mm per day). The two bridgelip suckers had grown 30 mm (43 g) and 4 mm (9 g), respectively, between capture events which were 121 days apart. This represents average growth rates of ca. 0.25 and 0.03 mm/day, or 0.36 and 0.07 g/day, respectively, over the summer months. Ageing data were not available for this report (see Section 3.5 below) in order to provide the age for this bull trout at this time, and there were insufficient bull trout catches to estimate ages based on length-frequency analysis for this species after Year 2.

Length-Frequency and Size-at-Age Assessment

Length-frequency histograms for rainbow trout and bull trout captured during fish sampling surveys in 2013 and 2014 are presented in Figures 9 to 12. Given the limited sample size for all target species from the littoral zone, it was not feasible to estimate the age class breaks based on this limited data set. Age class 'headings' were included on figures 9 and 10 to represent the approximate size mid-points for several age classes based on rainbow trout data from Downton Reservoir and the Lower Bridge River (Sneep 2015; Sneep and Hall 2012). The size range bounds for each age class need to be better defined by analysis of ageing structures (i.e., scales and fin rays), since there is typically overlap (in some cases, significant) between age classes. This will be possible with the results of the ageing analysis in the next annual report.

Figure 9 Length frequency histogram for rainbow trout captured during fish sampling surveys in Seton Lake, June 2013 (*n*=23; orange bars) and 2014 (*n*=6; blue bars).

Based on the data in Figure 9, there was a higher proportion of rainbow trout in the Age 0+ to Age 2 size range in the boat EF catch relative to the larger and older classes of this species. Though the sample size is certainly small, it is possible that in the open-site, slackwater conditions that characterize the sampling areas in Seton Lake, these larger and more mobile fish are better able to swim away from the electrical field and evade capture. Unfortunately, due to the low capture rates, it was not possible to sort this out with mark-recapture. This potentially skewed size distribution lends support to employing a different sampling methodology that would be better suited to sampling target species in this context. To that end, a shift to gill net sampling has been proposed starting in Year 3.

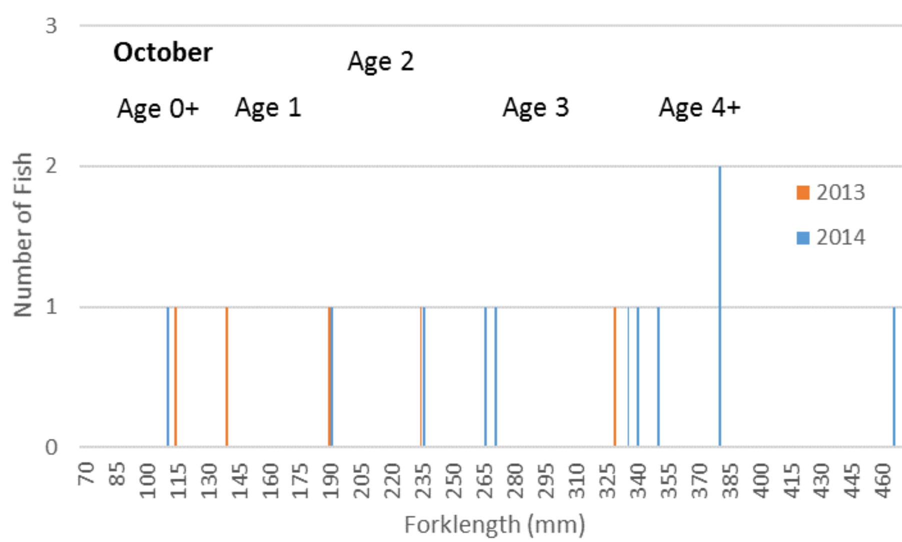

Figure 10 Length frequency histogram for rainbow trout captured during fish sampling surveys in Seton Lake, October 2013 (*n*=5; orange bars) and 2014 (*n*=11; blue bars).

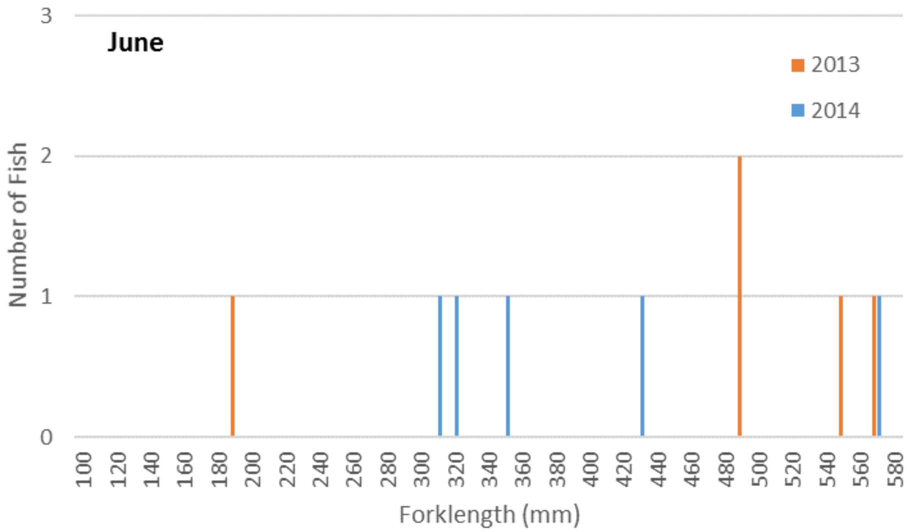

Figure 11 Length frequency histogram for bull trout captured during fish sampling surveys in Seton Lake, June 2013 (*n*=5; orange bars) and 2014 (*n*=5; blue bars).

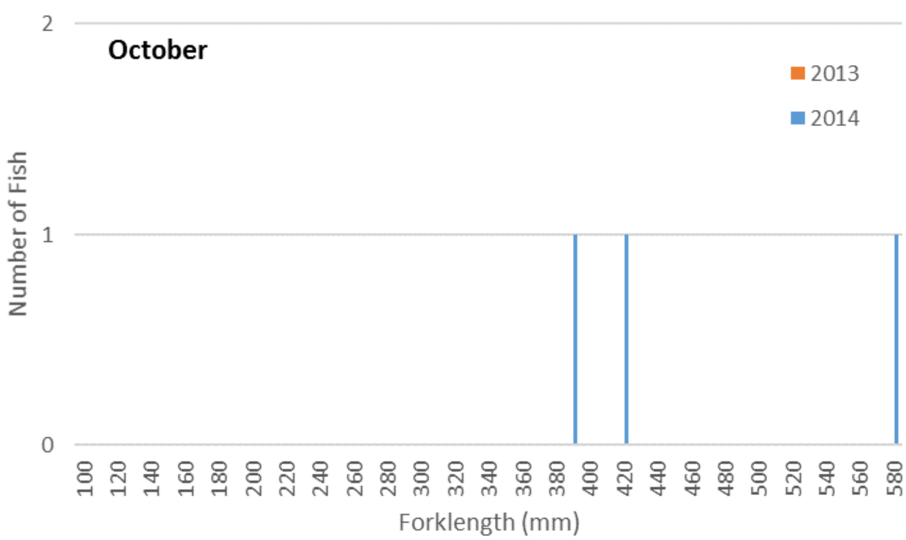

Figure 12 Length frequency histogram for bull trout captured during fish sampling surveys in Seton Lake, October 2013 (*n*=0) and 2014 (*n*=3; blue bars).

3.4. Supplemental Tagging Surveys

Eleven supplemental tagging events were conducted in Year 1 and six were conducted in Year 2. In addition to the number of fish tagged during the fish indexing surveys (described in Section 3.3), totals of 18 bull trout, 3 mountain whitefish, and 15 rainbow trout were caught by angling in 2013. Totals in 2014 were 3 bull trout and 12 rainbow trout. All fish captured during these surveys were a tag-able size and in good condition (Table 10). The sizes of angled bull trout ranged from 345 to 577 mm across years; the rainbow trout were between 220 and 480 mm.

Angling is thought to subject the fish to less sampling-induced stress, which is why this method was chosen for marking fish during the October 2014 mark-recapture survey. These angling surveys also provided additional scale samples for ageing purposes.

Table 10 Numbers of PIT tags applied by sampling method (for all species) during 2013 and 2014. Note: the numbers applied to fish captured by Boat EF are included for comparison purposes.

	2013		2014		Total (To-Date)
	Boat EF	Angling	Boat EF	Angling	
# of PIT tags applied	29	36	161	123	349

The angling surveys were conducted in the lake near the following locations: Bear Creek, M'sut Creek, Creek at Retaskit, Portage Creek confluence, Seton Dam approach channel, outflow from BR1 and BR2 generating stations, Cayoosh Creek diversion.

3.5. Laboratory Analyses (Scale Ageing)

Scales were collected from bull trout, rainbow trout, and mountain whitefish captured in Year 1 and Year 2; however, ageing analysis was not completed on these samples in time for inclusion in this data report.

Ageing structures (fin rays or scales) have been collected from 12 bull trout, 19 mountain whitefish and 51 rainbow trout across both monitoring years to-date. All of these samples will be submitted for ageing analysis. Scale and fin ray samples will continue to be collected from target species in future years of the program to build on this data set. Unfortunately, the lab isn't available to begin reading the scales until May 2015. As such, these data were not available at the time of writing for this report.

4) Management Questions, Study Hypotheses and Interim Status

Status of Management Questions following Years 1 and 2

Primary Objectives	Management Questions	Year 2 (2014) Status
1) To collect scientifically rigorous information on the species composition, relative abundance, life history and habitat use of resident fish populations in Seton Lake; and 2) to provide information required to link the effects of the Carpenter Reservoir diversion on fish populations to a) document impacts of the operating alternative on resident fish populations, and, b) support future decisions regarding the operation of BC Hydro facilities.	1. What are the basic biological characteristics of resident fish populations in Seton Lake and its tributaries?	The capacity of the program to answer these Management Questions following Years 1 and 2 is limited. The target species selected for this program are bull trout, rainbow trout and gwenis based on their ecological and social value in this context. However, based on the first two years of sampling focussed on the littoral zone of the lake, the contribution of target species to the catch was very low relative to other non-sportfish species (such as: bridge-lip sucker, northern pikeminnow, and peamouth chub). It is likely that the pelagic environment may be more heavily utilized by the target species given the distribution and availability of food resources and/or preferred habitats within that zone of Seton Lake. Due to the low capture success for target species in the littoral zone it is not feasible to draw conclusions at this stage regarding trends in the distribution, habitat use, or relative abundance of target species, nor how these trends or characteristics may be linked to BC Hydro operations. Therefore, due to lessons learned during these initial years of sampling, key methodological deficiencies and issues with the testability of the original hypotheses have been identified. As a result, revisions were made to the original study hypotheses and sampling approach which are described in a ToR addendum (BC Hydro 2015). The revised hypotheses and the methods adapted to test them will be incorporated starting with the Year 3 program activities. It is anticipated that this revised approach will better orient this program to address the management questions by the end of the monitoring period.
	2. Will the selected alternative (N2-P) result in positive, negative or neutral impact on abundance and diversity of fish populations in Seton Lake?	
	3. Is there a relationship between the quality, quantity, and timing of water diverted from Carpenter Reservoir on the productivity of Seton Lake target resident fish populations?	
	4. Can refinements be made to the selected alternative to improve habitat conditions or enhance resident fish populations in Seton Lake?	

Responses to Study Hypotheses following Years 1 and 2

Primary Objectives	Management Hypotheses	Year 2 (2014) Status
1) To collect scientifically rigorous information on the species composition, relative abundance, life history and habitat use of resident fish populations in Seton Lake; and 2) to provide information required to link the effects of the Carpenter Reservoir diversion on fish populations to a) document impacts of the operating alternative on resident fish populations, and, b) support future decisions regarding the operation of BC Hydro facilities.	**H_1:** The abundance and diversity of Seton Lake fish populations are directly limited by habitat impacts directly related to the operation of the Bridge Generating Station.	H_1: not rejected; more data needed. Requires abundance index for key species (i.e., bull trout, rainbow trout, and gwenis) and diversion operations data across multiple years (i.e., the 10-year monitoring period) in order to assess the existence of a potential linkage. Continued monitoring activities are intended to establish an index starting with a modified sampling approach in Year 3.
	H_{1A}: Diversions from Carpenter Reservoir reduce the temperature, light penetration, and euphotic volume of Seton Lake.	H_{1A}: not rejected. This hypothesis is not directly addressed by the data that has been collected for this monitoring program to-date – but may be answered by data collected under the BRGMON-6 program. Temperature and turbidity monitoring will be incorporated as a part of the revised sampling approach in Year 3.
	H_{1B}: Daily fluctuations in Seton Lake levels result in reduced effectiveness of shoreline spawning habitat.	H_{1B}: not rejected. This hypothesis has not been directly addressed by the sampling approach employed for this monitoring program to-date. This will be revised by incorporating shoreline habitat surveys into the sampling plan starting in Year 3 which will, in part, document and characterize shoreline spawning habitats.
	H_{1C}: Daily fluctuations in Seton Lake levels result in reduced effectiveness of spawning.	H_{1C}: not rejected. This hypothesis is not directly addressed by the data collected for this monitoring program – To be revised as a part of the ToR addendum.

5) References

BC Hydro. 2012. Bridge-Seton Water Use Plan – Monitoring Program Terms of Reference. BRGMON-8 Seton Lake Resident Fish Habitat and Population Monitoring. Prepared for the BC Comptroller of Water Rights, January 23, 2012.

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Korman, J., J. Schick and A. Clark. 2010. Cheakamus River Steelhead Juvenile and Adult Abundance Monitoring; Implementation Year 2. Reference CMSMON-3. Report prepared for BC Hydro and the Deputy Comptroller of Water Rights, February 2010.

Morris, A.R., E. Braumandl, H. Andrusak, and A. Caverly. 2003. 2002/2003 Seton and Anderson Lakes Kokanee Assessment – Feasibility Study and Study Design. Prepared for British Columbia Conservation Foundation and Ministry of Water, Land and Air Protection.

Sneep and Hall 2012. Lower Bridge River Aquatic Monitoring – Year 2011 Data Report. Prepared for BC Hydro and the Deputy Comptroller of Water Rights, August 2012.

Sneep, J. 2015. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, 2013 and 2014 Results. Draft data report prepared for St’at’imc Eco-Resources, March 2015.

6) Photos

Plate 1 Open, slack-water conditions were prevalent at all of the boat EF sites around the perimeter of Seton Lake.

Plate 2 Boat electrofishing operations on Seton Lake were conducted at night when fish tend to occupy shallower habitats to feed.

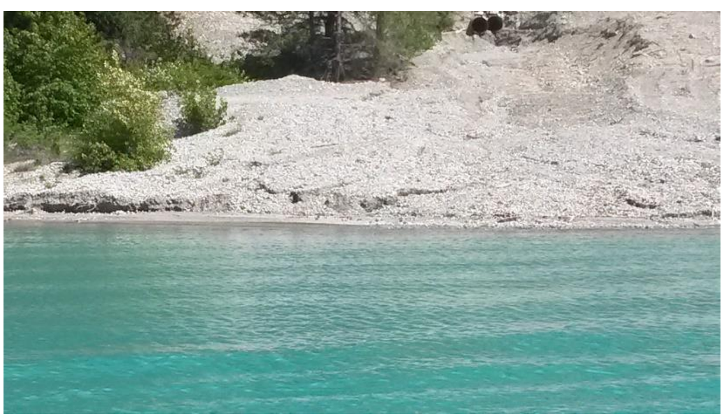


Plate 3 A couple of tributaries did not have surface flow connectivity to the lake during the rainbow trout spawning period (due to low flows and porous substrate), May 2014.

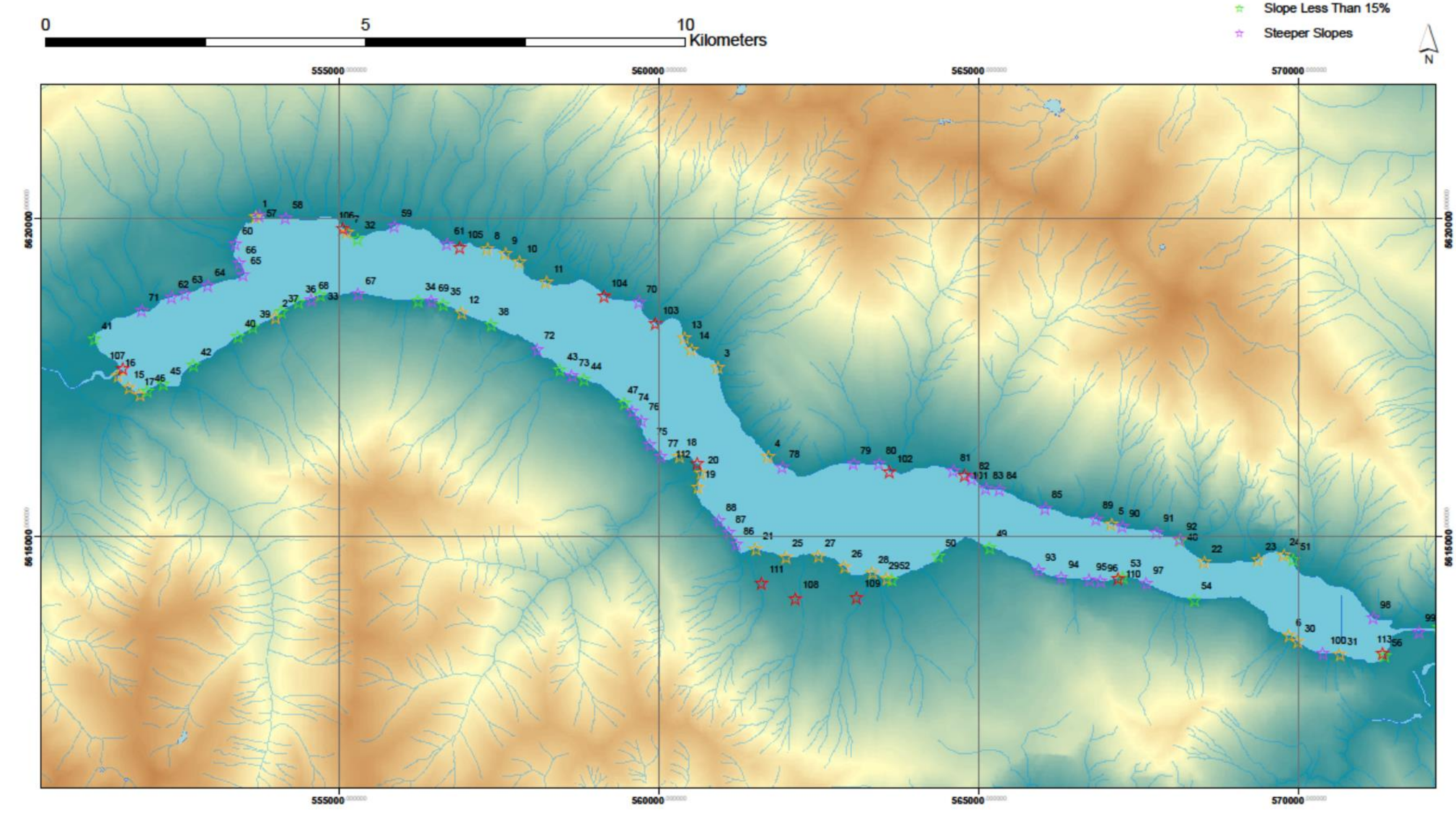
Plate 4 Some of the tributaries in the study area have a relatively short accessible length below a barrier, such as this falls on Whitecap Creek.

Plate 5 Visibility to the bottom of many creeks was also poor due to turbulence and high turbidity, particularly during the spring survey period.

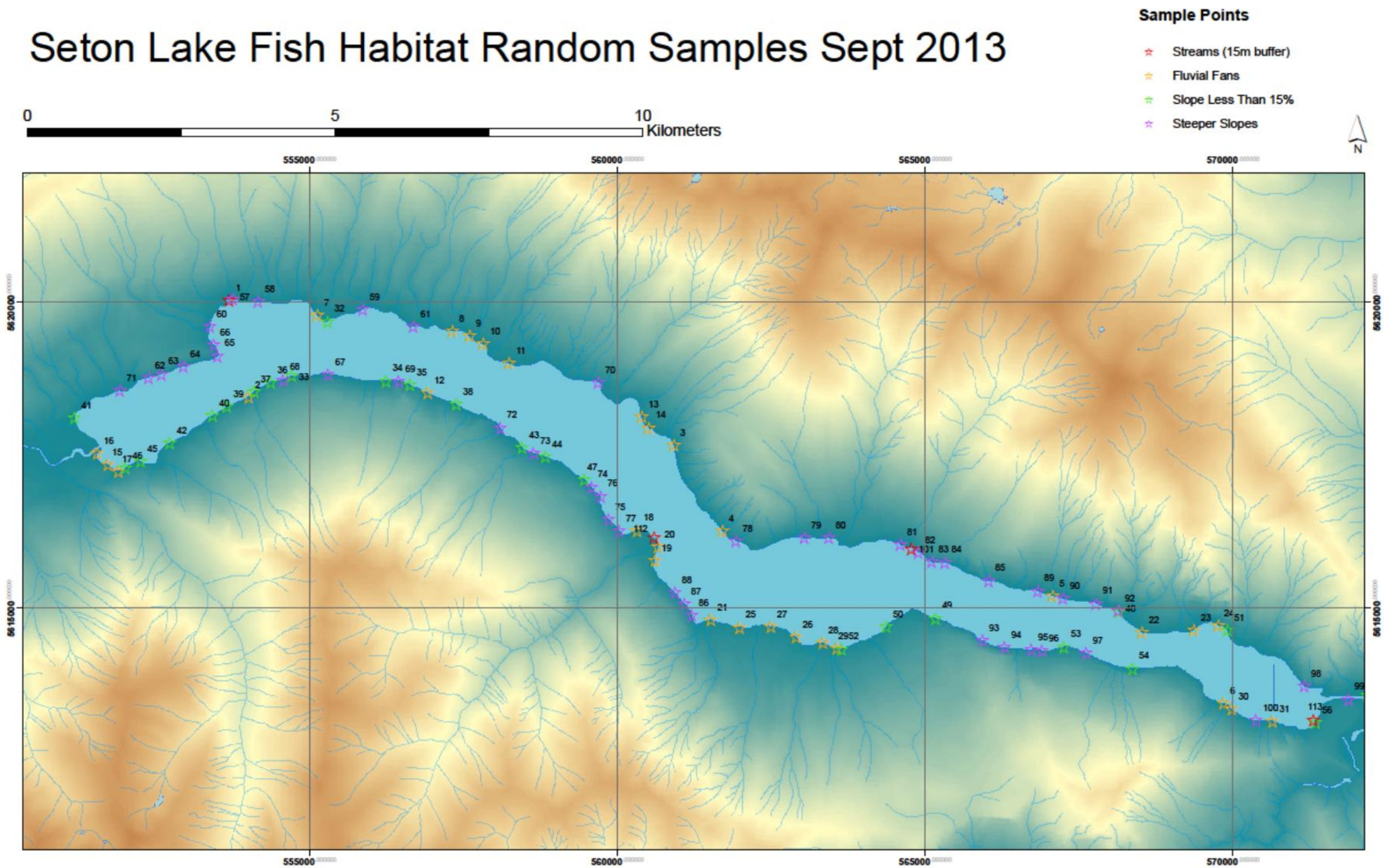
Plate 6 Two common carp were a surprise contribution to the catch near the Bridge 1 Generating Station outflow in June 2014. These fish likely migrated into the lake from the Fraser River via the fishway at Seton Dam.

Appendix A – Year 1 Site Distribution Maps for Boat EF Index Surveys

Seton Lake Fish Habitat Random Samples June 2013



Seton Lake Fish Habitat Random Samples Sept 2013



Appendix B – Sample Data Forms

Sample Site Form

Waterbody: ____

Date (dd-mmm-yy)	Site ID	Habitat Type	Waypoint ID		UTM (Downstream)		UTM (Upstream)		Site Marked	Site Ln (m)	Crew	Comments
			Downstream	Upstream	Easting	Northing	Easting	Northing				
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Habitat Type: **1** = Stream Mouth (+/- 15 m) **2** = Fluvial Fan **3** = Shallow Slope (<15%) **4** = Steep Slope (>15%)

Fish Sampling & Biological Information Form

Waterbody: ____________________ Capture Method: ____________________

Date (dd-mmm-yy)	Site ID	Species	Length (mm)	Weight (g)	Scale Sample		Recap	PIT Tag Data		Sex (M/F)	Maturity (Mat/Imm)	Spawning Condition (Green/Gravid/Ripe/Spent)	Comments
					✓	Code		Type	Code				
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Bycatch Tally Form

Waterbody: ____________________ Capture Method: ____________________

Date	Site	Fish Species Tally									
(dd-mmm-yy)	ID	RB	BT	MW	KO	CH	CO	BSU	PMC	NSC	Other