Bridge River Project Water Use Plan

Seton Lake Resident Fish Habitat and Population Monitoring

Implementation Year 3

Reference: BRGMON-8

BRGMON-8 Seton Lake Resident Fish Habitat and Population Monitoring, Year 3 (2015) Results

Study Period: April 1 2015 to March 31 2016

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Executive Summary

Data collection for Year 3 of this proposed 10-year study was completed in 2015. Results for Years 1 and 2 of this program are provided in the previous data report produced for this program in 2015 (Sneep 2015). Where relevant, comparisons across monitoring years for this program have been included in this report. A full synthesis of all results will be conducted following the final year of data collection which is scheduled for 2022. The primary objective of this monitoring program is to "collect better information on the relative abundance, life history and habitat use of resident fish populations in Seton Lake" (BC Hydro 2012).

Field studies for the Seton Lake Resident Fish Habitat and Population Monitoring Program (BRGMON-8) were conducted in Seton Lake, as well as Anderson Lake for the first time this year. Data collection in Anderson Lake was included to provide context and comparison for the Seton Lake results. The two lakes are comparably sized, located within the same watershed, and have similar natural inflows; however, Seton Lake is impacted by the diversion from Carpenter Reservoir whereas Anderson Lake is not. Sampling in Anderson Lake was considered a pilot effort in Year 3 (2015), focussed on the outflow end of the lake only, and will be expanded to include 3 longitudinal zones (the same as in Seton Lake) starting in Year 4 (2016).

The general approach to this monitoring program is to collect a multi-year data set on the populations of selected resident fish species as well as habitat conditions in these lakes in order to resolve data gaps and better inform the trade-off decisions made during the Water Use Planning process. The target species initially selected for this program were bull trout, rainbow trout and gwenis based on their ecological and social value in this context, and their potential for response to diversion effects. Four methods were employed in Year 3 (2015) to document the biological characteristics of the resident fish population, generate an annual abundance index, and characterize relevant fish habitats. These methods included:

- Thermal profile monitoring;
- Habitat mapping around the perimeter of Seton Lake;
- Tributary spawner surveys (for bull trout in the fall); and
- Resident fish population index survey in the lakes (by gill netting).

In 2015, sampling for the resident fish population index survey shifted from nearshore boat electrofishing and angling (employed in Years 1 & 2) to gill netting which incorporated both nearshore and offshore habitats. Given the limitations of the boat electrofishing method for capturing target species in this context, standardized gill netting will continue to be used for establishing the annual abundance indices going forward. In order to allow sampling coverage of both Seton and Anderson lakes with the available budget, fish indexing effort was concentrated into one longer session in early fall, rather than dividing effort across two shorter sessions (spring and fall) as was the case in Years 1 and 2.

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 Year 3 (2015).

Some concern was raised during the WUP process that fluctuations in the lake surface elevation may have the potential to impact Gwenis spawning locations based on the assumption that selected spawning habitats may occur at elevations within the lake surface elevation range (i.e., that they are shore spawners). Gwenis spawn timing has been observed to occur in fall (Morris et al. 2003 and this program) in Seton Lake. During the fall sampling session (late September to early October) at least 90% of mature gwenis in spawning-ready condition were sampled in the bottom-set nets at depths ≥ 20 m, and over 30 m horizontal distance from the lake edge. These data suggest that gwenis spawn at depth in Seton Lake and would not be directly impacted by the degree of surface elevation changes observed.

Approximately 269 hours of gill netting effort were employed in Seton and Anderson lakes over 8 dates in late September and early October 2015. In total, 913 fish were captured from 22 sampling locations (18 on Seton Lake and 4 on Anderson Lake). The sites were distributed spatially throughout 3 longitudinal zones in Seton Lake (Inflow, Mid, and Outflow), and in the outflow (North) end only in Anderson Lake. Sampling depths ranged from 0 to 45 m below the surface, and included surface, mid-column, and bottom sets. Captured fish included 11 different species; target species made up 68% of the total, which was a substantial improvement from boat electrofishing results in years 1 and 2 (see Sneep 2015).

Catch-per-unit-effort (CPUE) values were generated for target species in Year 3 (2015). Highest total CPUE was recorded at the inflow end of Seton Lake, and lowest total CPUE was at the outflow end of Anderson Lake in 2015. These results were driven by catches of gwenis, which were by far the most numerous species captured in Seton Lake (nearshore= 79.8 fish·net-hour^{-10}; offshore= 11.2 fish·net-hour^{-10}) and overall. Highest CPUEs for bull trout and rainbow trout were in the nearshore zone at the outflow end of Anderson Lake (5.5 and 2.1 fish·net-hour^{-10}, respectively). Generation of these catch statistics for each year going forward will be used to establish whether the population trends for target species are increasing, staying the same, or decreasing across the period of monitoring years.

Based on analysis of size, gwenis tended to be larger in Anderson Lake and captured bull trout tended to be larger in Seton Lake. Assessment of bull trout stomach contents revealed that in Seton Lake they had been feeding primarily on *mature* gwenis (up to 5 in one stomach; >180 mm each), whereas gwenis or sockeye *juveniles* (<120 mm) were dominant food items in Anderson Lake. Fin rays from 22 bull trout and scales from 24 gwenis and 4 rainbow trout were analyzed for ageing. Bull trout from the sample ranged from Age 2 to Age 9; gwenis ranged from Age 1 to Age 4; and the rainbow trout were between Age 3 and Age 8.

Summary of BRGMON-8 Management Questions and Interim (Year 3 – 2015) Status

Primary Objectives	Management Questions	Year 3 (2015) Results To-Date
To collect better information on the relative abundance, life history and habitat use of resident fish populations in Seton Lake.	1. What are the basic biological characteristics of resident fish populations in Seton Lake and its tributaries?	The program is on track to answer Management Question (MQ) 1 by documenting species composition and relative abundance; size, age and maturity data for target species; distribution patterns both vertically and longitudinally in the lake or in tributaries, habitat use, as well as diet for bull trout (by assessing stomach contents). In Year 3 (2015), these data were collected during the annual population indexing survey (gill netting) and weekly bull trout spawner surveys in the fall. **See Sections 3.3, 3.4 and 4.**
	2. Will the selected alternative (N2-2P) result in positive, negative or neutral impact on abundance or index of abundance and diversity of target fish populations in Seton Lake?	The program is on track to answer MQ 2 by establishing an annual index of abundance for target species by employing a standardized gill netting survey throughout the lake in both nearshore and offshore areas at a range of sampling depths. A before-after treatment comparison was not possible for this monitor due to the prior implementation timing of operating alternative N2-2P. However, comparable sampling was initiated in Anderson Lake in Year 3 (2015) to facilitate comparison of a lake impacted by the diversion vs a non-impacted lake within the same watershed. This will help to put the Seton Lake results in context across the monitoring period. Overall trends in target fish catch rates, in conjunction with assessment of correlation with diversion operations, will provide information for addressing this MQ at the end of the monitor. **See Sections 2.2, 3.4, and 4.**
	3. Is there a relationship between the quality, quantity, and timing of water diverted from Carpenter Reservoir on the productivity of Seton Lake resident fish populations?	MQ 3 will be addressed with the continuation of the temperature monitoring data collection (coincident with Carpenter diversion characteristics) and the inclusion of sedimentation monitoring in both lakes to commence in Year 4. **See Sections 3.1 and 4**.
	4. Can refinements be made to the selected alternative to improve habitat conditions or enhance resident fish populations in Seton Lake?	The program is on track to providing the relevant information for answering this MQ; however, the compilation of annual fish abundance index, biological characteristics data, and diversion operations information for all years of the monitoring program will be required for addressing this MQ.

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1. Introduction

1.1. Background

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 east 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 narrow range (i.e., ≤0.6 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.

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.

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 by late 2012, and field data collection activities were initiated in 2013. Under the WUP, monitoring for this program is scheduled to continue annually until 2022. Data collection for Year 3 of this proposed 10-year study was completed in 2015.

It should be noted that due to lessons learned during the first two 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 per the ToR addendum (March 2015): the management questions remained the same, but the revised hypotheses referenced in this report have changed from those in the report for Years 1 and 2.

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 hypotheses (and sub-hypotheses) associated with these management questions from the Terms of Reference Addendum are:

H_1: The index of target species abundance in Seton Lake is stable over the monitoring period.

H_2: The measured habitat variables (temperature, turbidity) do not explain observed patterns of fish distribution in Seton Lake.

- **H_{2a}:** Patterns of fish distribution are not correlated with temperature profile.
- **H_{2b}:** Fish are distributed evenly within the lake (upstream vs. downstream).
- **H_{2c}:** Patterns of fish distribution are not correlated with turbidity.

H_3: The measured habitat variables (described in H_{2a} and H_{2c} above) do not substantially change between operation and shutdown events of the BR1 and BR2 plants over the monitoring period.

H_4: Potential food source variables explain observed patterns of target fish distribution in Seton Lake.

- **H_{4a}:** Patterns of Gwenis distribution are correlated with zooplankton abundance.
- **H_{4b}:** Patterns of bull trout distribution are correlated with *Oncorhynchus nerka* distribution.

H_5: The annual abundance index of target species is independent of discharge from the BR1 and BR2 plants.

- **H_{5a}:** The annual abundance index (by species) is independent of total BR1 and BR2 discharge.
- **H_{5b}:** The annual abundance index (by species) is independent of the within-year variability in BR1 and BR2 discharge.

These hypotheses reflect the generalized effects of BC Hydro operations that were understood to influence habitat suitability and resident fish population abundance in Seton Lake. The goal is to test these hypotheses by analyzing general fish population trends, habitat use, and general habitat characteristics in the lake, and making comparisons with data collected in Anderson Lake. Inferences about the impacts of the diversion from Carpenter Reservoir will be based on a weight-of-evidence approach that ultimately incorporates findings from the BRGMON-6 study with the time-series data collected under this program once all of the data are available.

1.3. Study Area

Field studies for the Seton Lake Resident Fish Habitat and Population Monitoring Program (BRGMON-8) were conducted in Seton and Anderson lakes in Year 3 (2015; Figure 1.1). For the purposes of monitoring the relative influence of the Carpenter Diversion inflows, as well as the main natural inflows and outflows (Gates Creek, Portage Creek and Seton River), the lakes were divided into three, approximately equal sections along their longitudinal axes. These are referred to as the: Inflow, Mid and Outflow sections. It was assumed that the diversion influence would generally be correlated with proximity to the Bridge 1 and Bridge 2 Generating

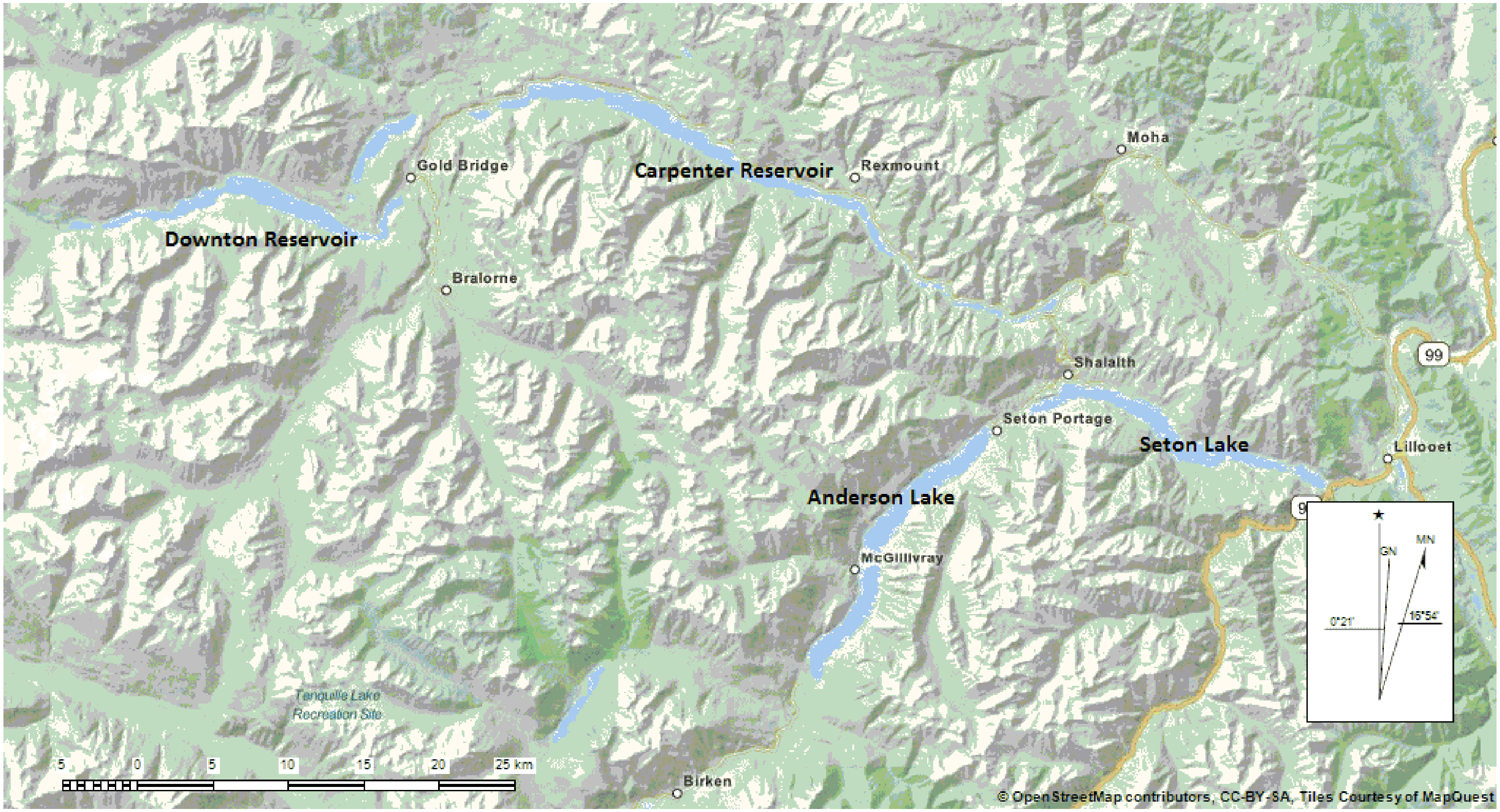


Figure 1.1 Overview of the Bridge and Seton watersheds.

Station outflows, and that there could be different temperature, sediment deposition, and fish distribution patterns according to distance from these inputs. Each lake was divided up in the same way to facilitate comparison of the results.

1.4. Sampling Schedule

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 year covered by this report (2015) represents monitoring year 3. The general schedule of field sampling activities is presented in Table 1.1.

Table 1.1 Schedule of Field Sampling Sessions and Activities.

Field Studies	Dates (Year 3 - 2015)
Resident Fish Population Index Survey	29 Sep to 7 Oct
Tributary Spawner Surveys	9 Sep; 22 Sep; 8 Oct; 21 Oct; 28 Oct; 5 Nov; 18 Nov
Habitat Mapping	2 to 3 Sep
Temperature array deployment & retrieval	24 & 28 Jul; 22 & 24 Sep; 18 Nov

2. Methods

The general approach to this monitoring program is to collect a long-term data set on selected resident fish species and physical habitat conditions in Seton Lake in order to detect trends, resolve data gaps, and better inform the trade-off decisions made during the WUP process. Starting in Year 3 (2015), collection of comparable data from the outflow end of Anderson Lake was included with the intention of providing additional context from a similar lake in the same watershed with analogous development impacts (i.e., railway, transmission lines, recreational cabins, and some residential), but no direct diversion impacts. Given the potential benefit of having comparable information from Anderson Lake to understand results and potential trends in context, attempts will be made to collect data from each section of both lakes within the constraints of the existing budget going forward (i.e., starting in Year 4).

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 (presented in Section 1.2) 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, and their potential for response to diversion effects. 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.

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,' and a complex inter-relationship of variables affecting recruitment, growth and survival of fish populations. Despite these challenges, these programs can collect important inventory, life history and general trend information that is valuable to better understand the populations of interest and potential effects of operations.

A great deal of learning about sampling conditions and fish distribution, densities, and catchability occurred during the first two years of monitoring, which 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 necessitated revision to the original approach; these revisions were described in a ToR addendum completed by BC Hydro and submitted to the provincial Comptroller of Water Rights in March 2015 (BC Hydro 2015).

In Year 3 (2015), field activities for this program were focussed on providing data to meet the primary objectives and management questions, and contribute an annual data point towards trends analysis to be completed at the conclusion of the 10-year monitoring program. Given the challenges and limitations outlined above, efforts are being focussed on establishing an annual index of abundance rather than attempting to quantify population sizes within the study area.

The study design in Year 3 (2015) included four main monitoring components:

- Thermal profile monitoring;
- Shoreline habitat mapping;
- Tributary spawner surveys conducted by stream walks; and
- Resident fish population index survey (by gill netting).

Sediment input to Seton Lake from the Carpenter Diversion flows has been recognized as another important factor that could affect recruitment and production of target fish populations (particularly gwenis which spawn in the lake bottom and carry out their entire life cycle within the lake). Samplers to monitor sedimentation rate were initially deployed in Year 3 (2015), but the first set of samples were not available for laboratory analysis until field activities recommenced in Year 4 (2016). As such, these data were not available for this report, but will be included in annual reports going forward (starting with the Year 4 (2016) report).

In addition to the field sampling elements listed above, laboratory ageing analysis of structures (scales or fin rays) collected from target species was also completed. More detailed descriptions of each of the monitoring components, as well as data management, are provided in the sections that follow.

2.2. Thermal Profile Monitoring

Starting in Year 3 (2015), temperature logger arrays were placed at the outflow end of Anderson Lake and both the inflow and outflow ends of Seton Lake to monitor the thermal profiles of the water column throughout the year. Individual temperature loggers were deployed in M'sut Creek and Portage Creek to monitor water temperatures from these natural inflow sources. The locations of the temperature arrays and other logger locations in the study area are provided in Figure 2.1. Since thermal profile monitoring was initiated in Year 3 (2015), temperature data are not available for years 1 and 2 (2013 and 2014).

The temperature loggers were TidbiT v2 loggers (model UTBI-001) manufactured by Onset Computer Corporation. For each array, 9 loggers were attached at prescribed intervals to a line suspended vertically between a concrete anchor at the bottom and a float just below the surface. When deployed, the depth intervals for the loggers were: 1, 5, 10, 20, 30, 40, 50, 60, and 70 m. This arrangement was intended to span the thermal layers when the water column is stratified. A sinking line was also run along the bottom from the anchor to a fixed point on shore (i.e., tree trunk) to facilitate retrieval of the arrays.

Thermal layers that naturally form within a lake during the period of stratification (spring to fall in the northern hemisphere), are called the epilimnion, metalimnion, and hypolimnion. These terms are defined as follows:

Epilimnion: the mixed layer nearest the surface of the lake. It is the warmest layer during the period of stratification, and typically has a higher pH, dissolved oxygen concentration, and receives more sunlight than the lower layers.

Metalimnion: (also known as the thermocline) the distinct layer in which temperature changes more rapidly with depth than in the layers above or below. Seasonal weather changes and wind events can affect the depth and thickness of this layer.

Hypolimnion: the calm, dense layer that extends below the thermocline to the bottom of the lake. Temperatures in this layer are the lowest and most consistent across the year. Being the deepest layer, it is isolated from wind-mixing and receives little to no irradiance (light).

The thermal profile monitoring was intended to document the depths and temperature characteristics of each of these layers in Seton and Anderson lakes during each monitoring year going forward. Documenting the specific depths and extents of these layers is relevant to the resident fish sampling because pelagic fish species (such as gwenis) migrate among these thermal layers on a diel cycle for the purposes of feeding and could be useful for evaluating the effect of Carpenter Reservoir inflows (timing, magnitude and duration) on temperature profiles across the length of Seton Lake by the end of the monitor.

Loggers deployed in the creeks were fixed to a weight (i.e., a brick) that was connected to an anchor point on shore using a length of cable. All of the temperature loggers were retrieved, downloaded, and redeployed approximately every 3 to 4 months. Data were downloaded onto a waterproof shuttle in the field and then transferred to a computer upon return to the office.

2.3. Shoreline Habitat Mapping

A habitat mapping survey was conducted to document the distribution and abundance of habitat types in Seton Lake to ultimately facilitate assessment of habitat similarities/differences with Anderson Lake once a comparable set of data are collected in that context as well (planned for Year 5). Documenting littoral habitat availability in each of the lakes may provide a useful input for interpreting potential differences in population trends at the end of the monitor and was helpful for selecting nearshore fish sampling locations during the annual resident population indexing survey.

Habitat mapping involved characterizing and georeferencing the entire shoreline of Seton Lake by boat. The habitat mapping was conducted on 2 and 3 September at 236.3 m surface elevation, which was near the top of the range of elevations observed for the lake in 2015. To accomplish the survey, the boat was propelled forward at slow speed adjacent to the shoreline. The habitat type was recorded for each unit and breaks between units were marked as waypoints on a GPS device. The GPS unit also recorded the boat track, which conformed to the shape of the shoreline in each unit, enabling more accurate measurement of shoreline length once GPS data were transferred to mapping software in the office.

The parameters recorded for the habitat mapping included: shoreline habitat type (i.e., creek mouth, fan, shallow slope <15°, or steep slope >15°); habitat sub-type (colluvium or bedrock) for steep habitats only; UTM coordinates for the start and end of each unit; boat track; and presence/absence of adjacent terrestrial vegetation. The collection of these data allowed for calculation of total shoreline length, the length and number of units for each habitat type and sub-type, as well as the proportion of shoreline that interfaces with adjacent terrestrial vegetation (which may be a potentially important source of nutrient inputs to the lake).

2.4. Tributary Spawner Surveys

Bull trout spawner surveys were conducted in three selected tributaries within the study area (Portage Creek, Spider Creek, and Whitecap Creek) where spawning by this species is understood to occur based on anecdotal reports. The surveys were intended to provide confirmation of spawning use, a qualitative index of spawner numbers, as well as the approximate start, peak, and end timing of the run. Portage Creek connects Anderson and

Seton lakes, and Spider and Whitecap creeks are each smaller tributaries of Portage Creek (Figure 2.2).

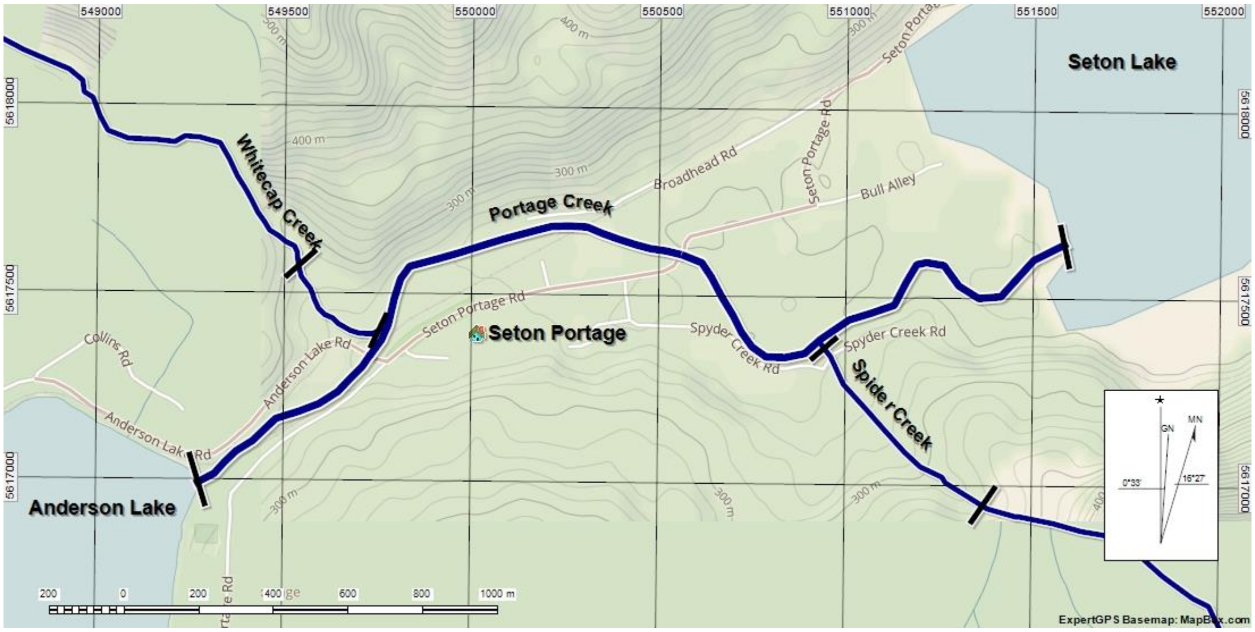


Figure 2.2 Selected tributaries for the bull trout spawner surveys in Year 3 (2015) between the outflow end of Anderson Lake and the inflow end of Seton Lake. The surveyed sections are demarcated by black lines on the map.

The surveys focussed on bull trout, as the gwenis population is known to spawn in the lake and the size of the rainbow trout population in Seton Lake appears to be quite low (and no spawners were enumerated during spawner surveys for this species in Years 1 and 2). Spawner surveys were conducted (or at least attempted) on a weekly basis during fall from 9 September to 18 November 2015 to get a relative weekly count. Access and survey conditions in these tributaries were severely hampered by a major bank failure in lower section of Whitecap Creek in late September of this year, which completely filled a section of the Portage Creek channel for a period of time. This event precluded some surveys and may have affected spawner distribution and timing this year.

Observed bull trout spawners in each surveyed stream were enumerated by one person on each shoreline of the creek starting at the mouth and walking upstream until either reaching a fish migration boundary or until no further fish had been observed (for several hundred meters). Each crew member wore a hat and polarized sunglasses to minimize glare and ambient light interference. Numbers of fish observed and enumerated in each stream were reconciled between the two observers in the field and recorded on standardized data sheets for each survey. The other recorded parameters included: date, time of day, water temperature, qualitative assessment of visibility (good, fair, or poor) and stage level (high, moderate, low, dry), and any comments pertaining to the conditions of the survey.

Under visibility conditions rated as “good”, water clarity was high enough that observers were able to see to the bottom of all habitats in the channel. Under “fair” conditions, visibility extended to the bottom of shallower habitats, but generally not to the bottom of the deepest pools. Under “poor” conditions, it was not possible to see to the bottom of any mid-channel habitats.

2.5. Resident Fish Population Index Survey

The resident fish population index surveys are intended to provide information on the inter-annual variation in the relative abundance, distribution and size-at-age for target species (i.e., bull trout, rainbow trout and gwenis) in the study area. In addition to the focus on Seton Lake, sampling in Year 3 (2015) was also conducted in the Outflow section of Anderson Lake to confirm the feasibility of expanding the scope to include monitoring in this lake within the project budget. The index survey data were collected in both the nearshore and offshore zones (i.e., within 100 m and greater than 100 m horizontal distance from shore, respectively) of each lake by a standardized gill netting method, which covered a range of depths from 0 to 45 m from the lake surface.

In Year 3 (2015), sampling effort was combined into one extended survey in the fall (late September to early October). This timing was selected because fish would have completed another season of growth and the lakes remain thermally stratified during this period; Some of the target species orient around the thermocline depth for feeding purposes or near the substrate at depth for spawning (i.e., gwenis).

In the first two years of monitoring, index surveys were conducted during both spring and fall periods as directed in the original ToR (BC Hydro 2012); however, this meant splitting effort across two sessions and limiting the effort that could be employed during each survey. In addition, fish sampling was conducted by boat electrofishing to a maximum effective depth of only ~ 3 m and width of ~ 5 to 10 m horizontal distance from shore, which resulted in minimal catches of target species. Based on the results from Years 1 and 2, it was clear that maximizing effort into a single session and employing the gill net method was critical for establishing a representative population index for the target species in this context.

In BC, standardized gear specifications have been developed for the use of gill nets in lakes for indexing-level surveys (RIC 1997). The standard gill nets are 91.2 m long and 2.4 m deep and consist of six panels (each 15.2 m long) of different mesh sizes that are strung together in a "gang". The mesh size is measured from knot to knot of a single, diagonally stretched mesh. Each mesh size is generally selective for certain size fish (Table 2.1), therefore, the individual panels used in the net have been chosen so the net is capable of catching a wide range of species and size classes across panels.

Table 2.1 The standard order of the panels based on mesh size, the corresponding filament size used in the construction of the net and the mean fork length of the fish typically caught by each of the mesh sizes.

Panel Order	Mesh Size (mm)	Filament Size (mm)	Mean Fork Length (mm)
1	25	0.20	114 mm
2	76	0.25	345 mm
3	51	0.20	228 mm
4	89	0.30	380 mm
5	38	0.20	178 mm
6	64	0.25	280 mm

Gill nets were fished at 18 sites in Seton Lake (6 nearshore and 12 offshore sets), and 4 sites in Anderson Lake (1 nearshore and 3 offshore sets). The distribution of sites in Seton Lake spanned the three longitudinal zones – i.e., Inflow, Mid, and Outflow sections (Figure 2.1). The Anderson Lake sites were all in the Outflow end as this was the first (pilot) year of index sampling in this lake for the BRGMON-8 program. Most sets (both nearshore and offshore; *n*= 16) were deployed in the afternoon, fished overnight, and were retrieved the following morning to process the catch. Six sets (3 nearshore and 3 offshore) were short duration deployments ranging from 2 to 3 hours during the day.

Nearshore nets were set perpendicular from shore. A length of rope connected one end of a sinking RIC gill net to a secure anchor point on shore (i.e. tree trunk) and ensured that the shallow end of the net was deployed in an adequate depth of water (>2 m) for proper net deployment. The net was deployed off the bow of the boat as it was operated at slow-speed away from the shoreline in reverse. A concrete anchor was attached to offshore end to hold the net in place and align it with the slope of the lake bottom. A line with a large orange buoy was attached between the anchor and the surface to facilitate net retrieval. Panel order was generally alternated between nearshore sets (panel 1 vs. panel 6 nearest to shore).

Offshore nets were set parallel to the longitudinal axis of the lake where water column depths ranged from ~ 70 to 130 m in Seton Lake and ~ 200 m in Anderson Lake. At each location, three six-panel gangs of RIC nets were deployed in a row, each set at a different sampling depth between the surface and the thermocline (i.e., 0, 15, 20, or 25 m below the surface). Once the crew was in position to begin deployment, a large concrete anchor was lowered off the front of the boat to the bottom of the lake and was connected by an adequate length of rope to a large orange buoy at the surface. The nets were deployed from the buoy using pre-measured dropper lines (attached to small foam floats) to control the sampling depth across the length of each net. Buoys were also deployed between each net gang, and another concrete anchor with buoy was deployed at the end of the third net. Flashing lights were deployed with each buoy for overnight sets to make them visible to boaters during the hours of darkness.

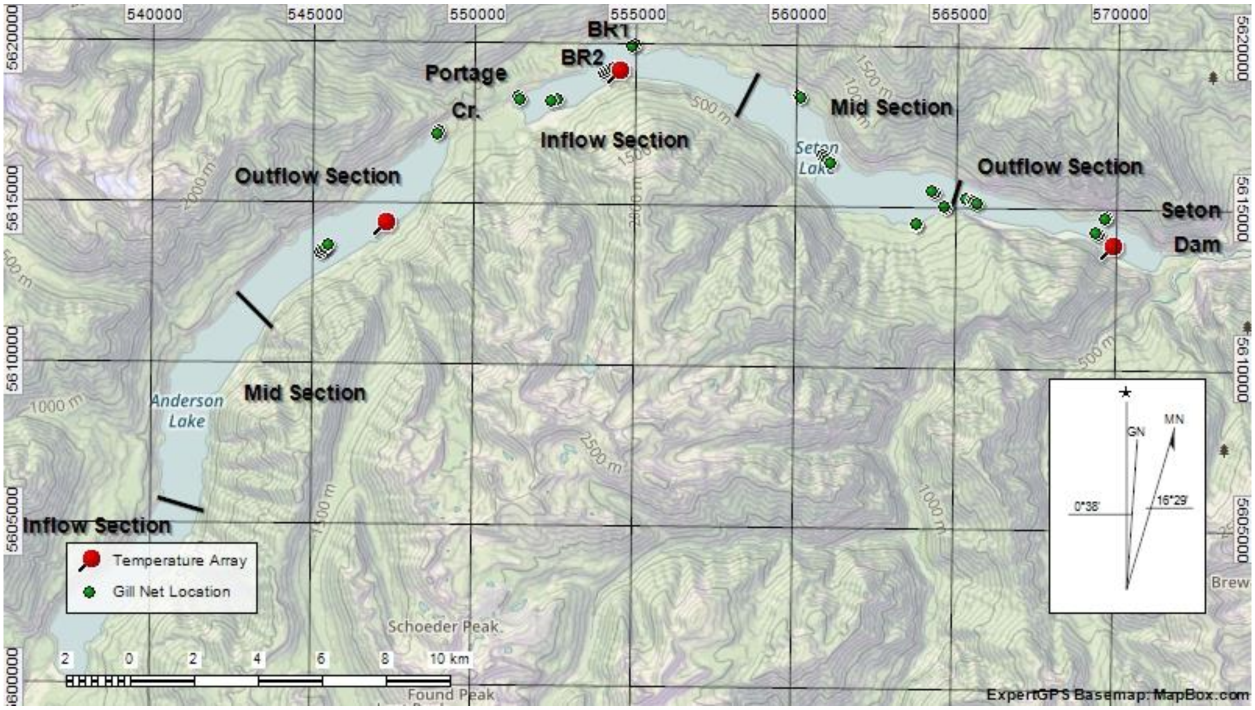


Figure 2.1 **BRGMON-8 study area showing longitudinal sections, fish sampling locations (green dots), and temperature array locations (red pins) in Seton and Anderson lakes in Year 3 (2015). The locations of the Bridge 1 and 2 (BR1, BR2) Generating Stations and Seton Dam are also shown.**

Offshore nets were generally retrieved in the same order that they were deployed (start buoy to end buoy – unless a change of wind direction dictated otherwise). Nearshore nets were retrieved from the offshore buoy end towards shore (opposite of how they were deployed). Fish were removed from the nets as they were retrieved and placed into separate holding containers for each gill net panel. Each container of fish was labelled with the net identifier and panel number which were subsequently recorded on the catch data sheets for each captured fish. Bucket aerators were used to maintain oxygen levels for live fish until release. Following processing, fish mortalities were cut open to assess sex and returned to the lake near the point of capture.

All captured fish were identified to species, measured for length and weight, and evaluated for sex and sexual maturity (as possible); appropriate aging structures were collected from a subset of fish for target species (see Section 2.6 for more information). Bull trout and rainbow trout that were in good condition, and could be released alive, were marked with PIT tags to facilitate identification of any recaptures during future surveys. Gwenis were not marked as the majority were mature spawners that would die following the subsequent spawning period. Stomach content samples and otoliths were opportunistically collected from bull trout that had succumbed to the sampling. Additional data recorded at each sampling location included set and retrieval times for the nets, UTM coordinates, water temperature and secchi depth.

2.6. Laboratory Analysis

To assist in developing an understanding of the life history and age class structure of the target resident fish populations in Seton Lake, fish sampling included collection of age structures (i.e., scales, fin rays and otoliths) from captured fish. Approximately five to ten scales were collected from selected gwenis and rainbow trout from the preferred area above the lateral line and immediately behind the dorsal fin. Pectoral fin rays were collected from all captured bull trout and otoliths were additionally collected from any bull trout mortalities to provide a secondary ageing structure. The ageing structures were placed in coin envelopes marked with appropriate data for cross-reference.

Ageing analysis was conducted on the scale samples by Cynthia Fell (Instream Fisheries Research). After a period of air-drying, scales were pressed under heat to transfer precise images onto soft plastic strips. The images were magnified using a microfiche reader following the methods of Mackay et al. (1990). Processing and age-reading for fin ray and otolith samples was completed by Mike Stamford (Stamford Environmental). After a period of air-drying, the fin ray samples were trimmed, set in epoxy, and cut into transverse cross-sections. The sections and otoliths were polished using 400 to 1200 grit wet-dry sandpaper and then affixed to a microscope slide for reading.

2.7. Data Management

All field data collected for this project were recorded into field notebooks or on standardized datasheets specifically developed for this program. 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 an active Microsoft Excel (2013) database that already includes the data from years 1 and 2 of this monitoring program. As this program proceeds, 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 document files have been backed up to ensure data security and integrity.

3. Results

3.1. Physical Conditions

BC Hydro Operations

Records of BR1 and BR2 discharge and Seton Lake surface elevations have been provided by BC Hydro for the period 1 January to 31 December for each study year to-date, and are illustrated in Figures 3.1 to 3.3.

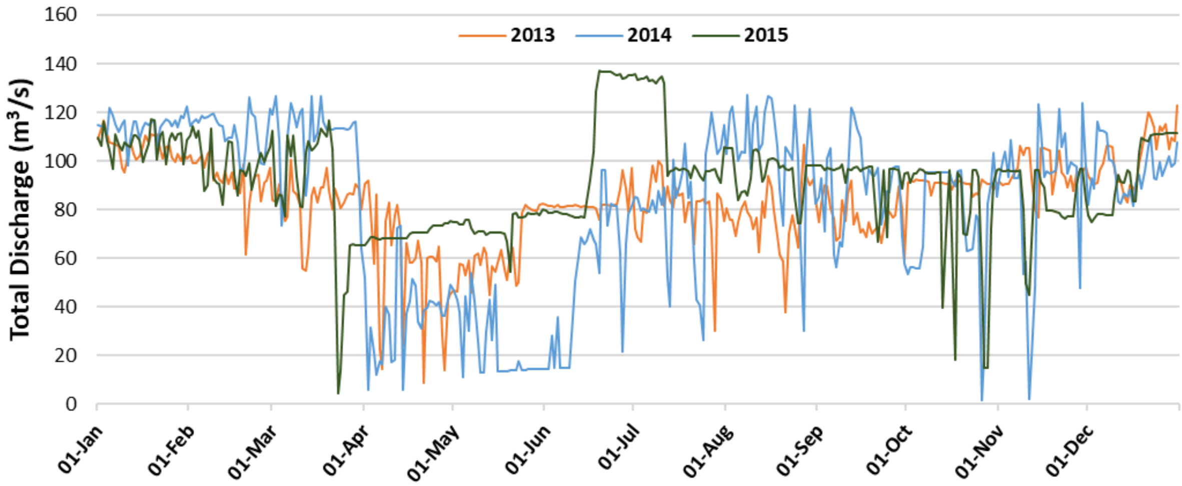


Figure 3.1 Mean daily discharges from Bridge 1 and Bridge 2 Generating Stations into Seton Lake, January to December (2013 - 2015).

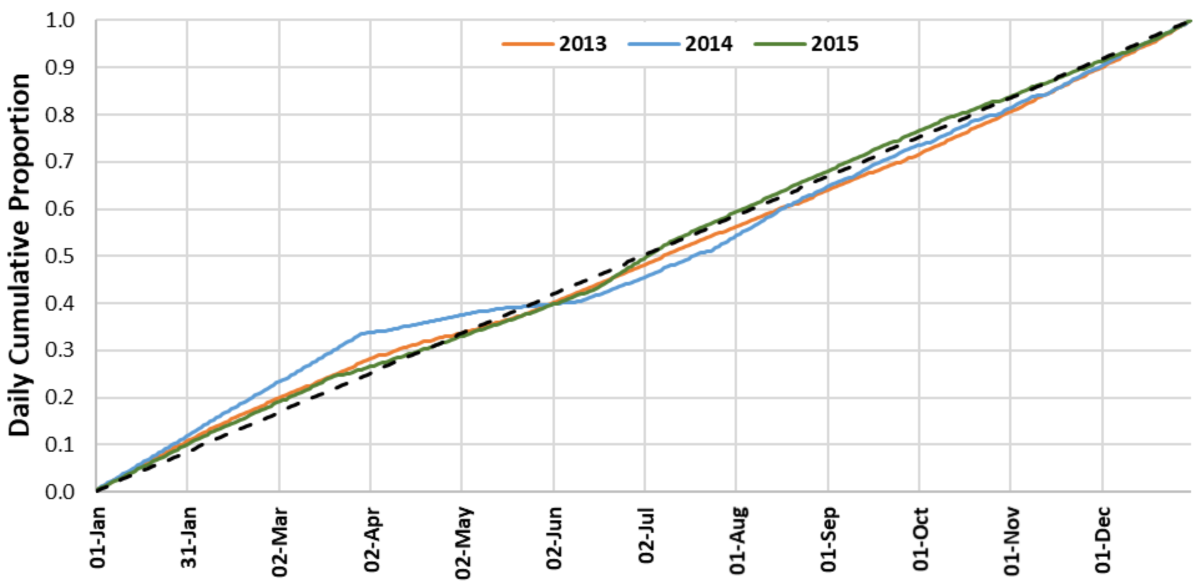


Figure 3.2 The daily cumulative proportion of total annual discharge from the Bridge 1 and 2 Generating Stations, 2013 to 2015. The black dashed line represents an exact linear trajectory.

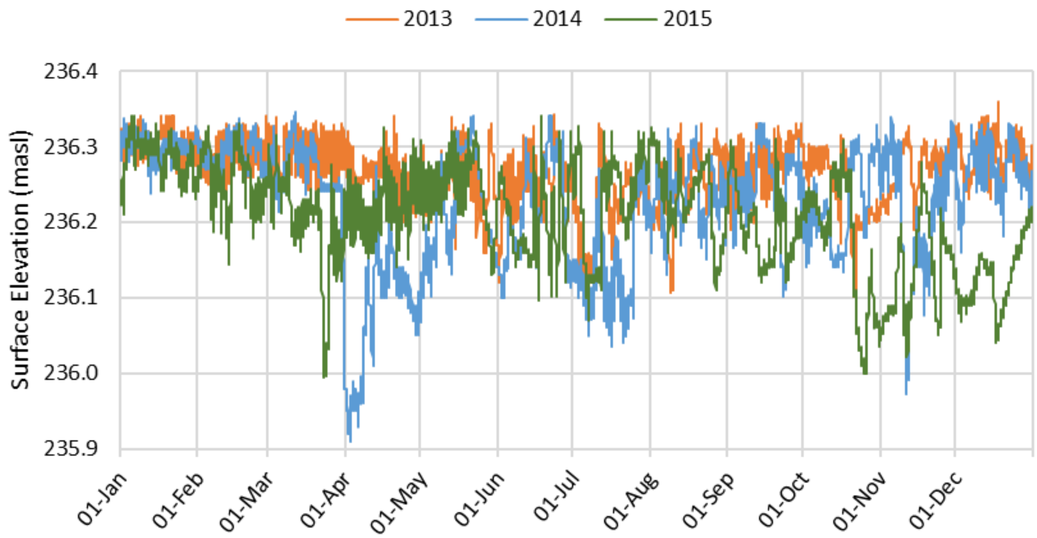


Figure 3.3 Hourly surface elevations of Seton Lake recorded in the forebay of Seton Dam across the year, 2013 to 2015.

Relative to Years 1 and 2 (2013 and 2014), within-day variability in discharges from the BR1 and BR2 Generating Stations was far lower in 2015, with hourly and mean daily values being virtually the same for most of the year. Peak diversion discharges were between 136 and 139 $m^3 \cdot s^{-1}$ in June and early July, and the outflow varied at times by up to 125 $m^3 \cdot s^{-1}$ on a daily basis (particularly in February and March) when the units cycle between shutdown and full output. As in the previous study years, there didn't appear to be any form of consistent seasonal pattern; however, in 2015 the timing of peak flows aligned with the freshet period and there were longer periods of relatively stable discharge across more of the year.

The total volume of the diversion discharge was 2.88×10^9 m^3 in 2015; a difference of 0.23×10^9 m^3 from 2013 and 0.29×10^9 m^3 from 2014. In other words, the total volume of water diverted into the lake from Carpenter Reservoir in Year 3 (2015) was approximately 8% and 10% greater than the diversion releases in Years 1 and 2 (2013 and 2014), respectively. Figure 3.2 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 both 2013 and 2015; whereas it displayed a slight s-shaped curve in 2014: daily discharge proportions were slightly higher in late winter and spring, and slightly lower in summer that year.

The management of surface elevation in Seton Lake also did not reveal any obvious seasonal pattern (Figure 3.3). 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, 0.44 m, and 0.35 m between minimum and maximum levels in 2013, 2014, and 2015, respectively. The maximum *daily* rate of change observed has been between 16 and 18 cm for each study year. The lowest elevations in 2015 were recorded on 23 March (235.99 meters above sea level (masl) and 25

October (236.0 masl), although elevations were within 0.25 m of the maximum elevation over 90% of the time.

Thermal Profile Monitoring

Monthly water temperatures for the August to January period at a range of depths at the outflow end of Anderson Lake, and the inflow and outflow ends of Seton Lake, are displayed in Figures 3.4 and 3.5, respectively.

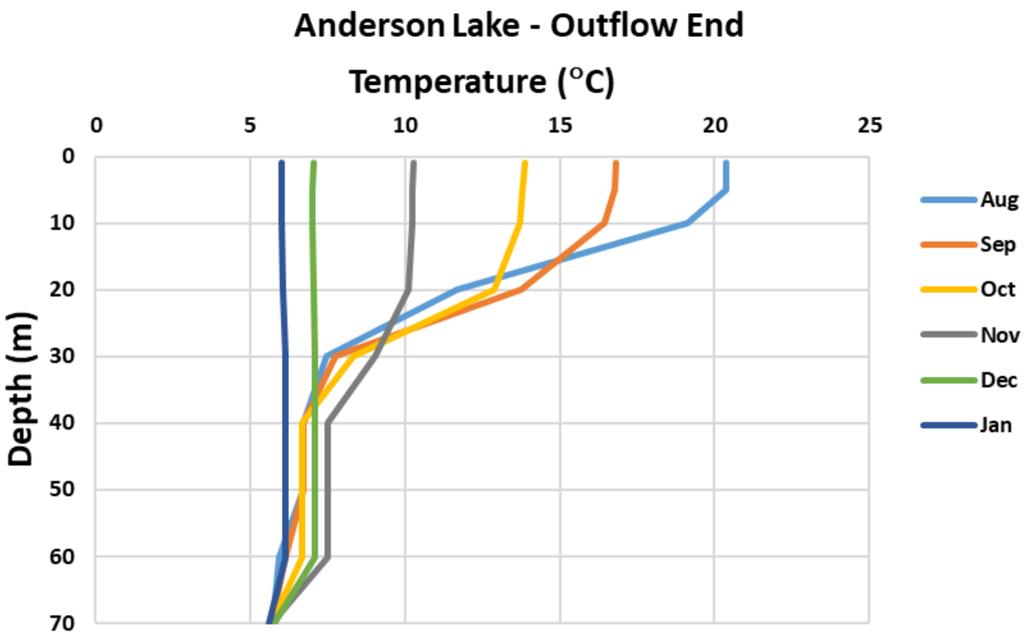
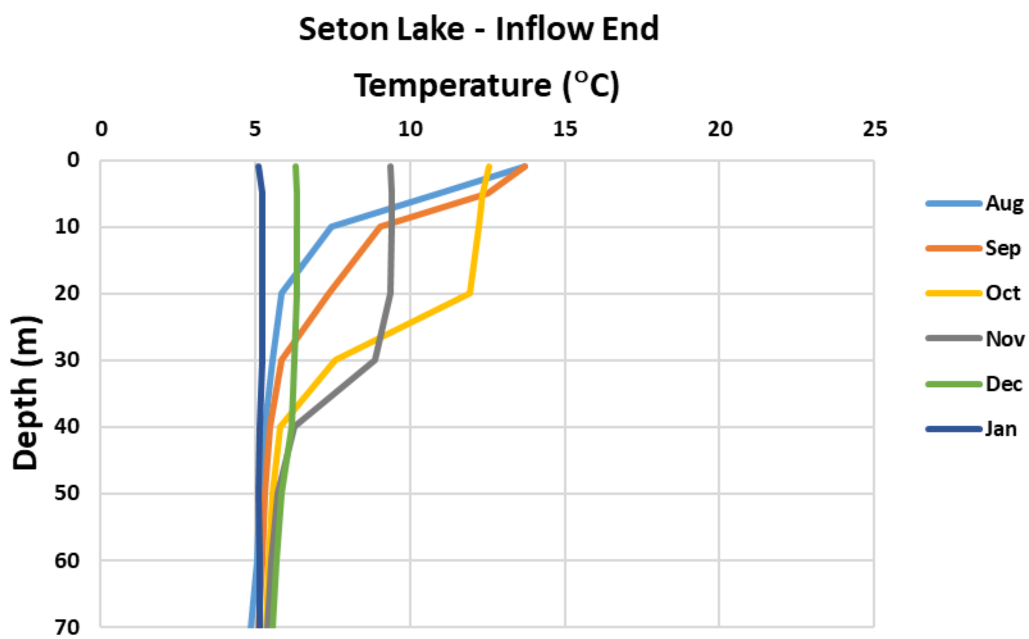


Figure 3.4 Mean monthly water temperature profiles recorded in the outflow end of Anderson Lake from August 2015 to January 2016.

At the outflow end of both lakes, surface temperatures cooled from a high of ~20°C in mid-summer to ~5° or 6°C in winter. Maximum and minimum observed temperatures (surface and at depth) were both about 1-2°C warmer each month at the outflow end of Anderson Lake than the outflow end of Seton Lake; however, otherwise temperature trends were quite similar between these locations during the monitored period in 2015.

Within Seton Lake, some of the monthly temperature profiles at the inflow end were noticeably different than at the outflow end, particularly during the months of August and September. At the inflow end of the lake, the epilimnion layer was very narrow during those months and temperatures in the metalimnion were substantially cooler (by up to 8.2°C according to depth in August, and up to 5.6°C in September), relative to the outflow end. Temperatures below the thermocline (i.e., the hypolimnion) at the inflow end were also approximately 0.5 to 1.0°C cooler than at the outflow end.



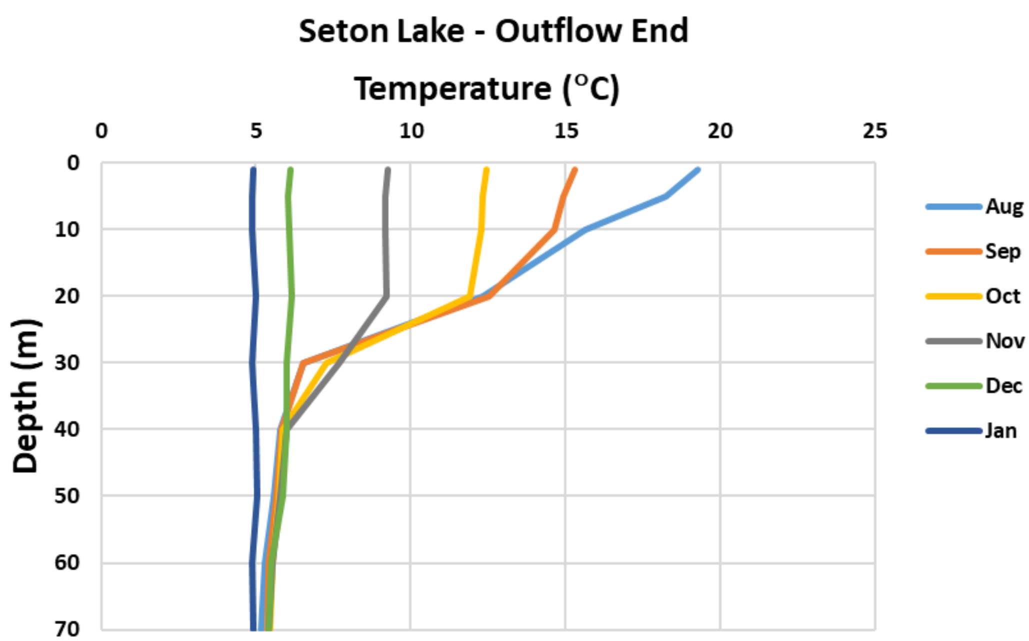


Figure 3.5 Mean monthly water temperature profiles recorded at the inflow end (top) and outflow end (bottom) of Seton Lake from August 2015 to January 2016.

Consistent with the normal lacustrine process of thermal stratification, both Seton and Anderson lakes were thermally stratified when temperature loggers were initially installed at the end of July, and they remained stratified until the end of November, after which the thermal layers collapsed and they became isothermic (i.e., consistent temperature from top to bottom). The depths of the epilimnion, metalimnion, and hypolimnion layers varied each month and by location (Table 3.1). The patterns of thermal stratification were generally consistent at the outflow ends of both lakes (within the limits of precision based on the logger depth intervals); however, there were some differences noted between the inflow and outflow ends of Seton Lake.

In August, the epilimnion and metalimnion at the inflow end were shallower and spanned a narrower band of depths than at the outflow end. In September, the epilimnion deepened by ~4 to 5 m (to 5 m and 10 m depth for the inflow and outflow ends, respectively), and the metalimnion extended to ~30 m depth, at both ends of Seton Lake. As temperatures began to cool over the next couple of months, the epilimnion and metalimnion layers deepened further at all monitored locations. Water temperatures in the hypolimnion were quite consistent, changing by only a few degrees across the monitored period. The depth range of the hypolimnion layer narrowed as the other layers expanded through the fall period.

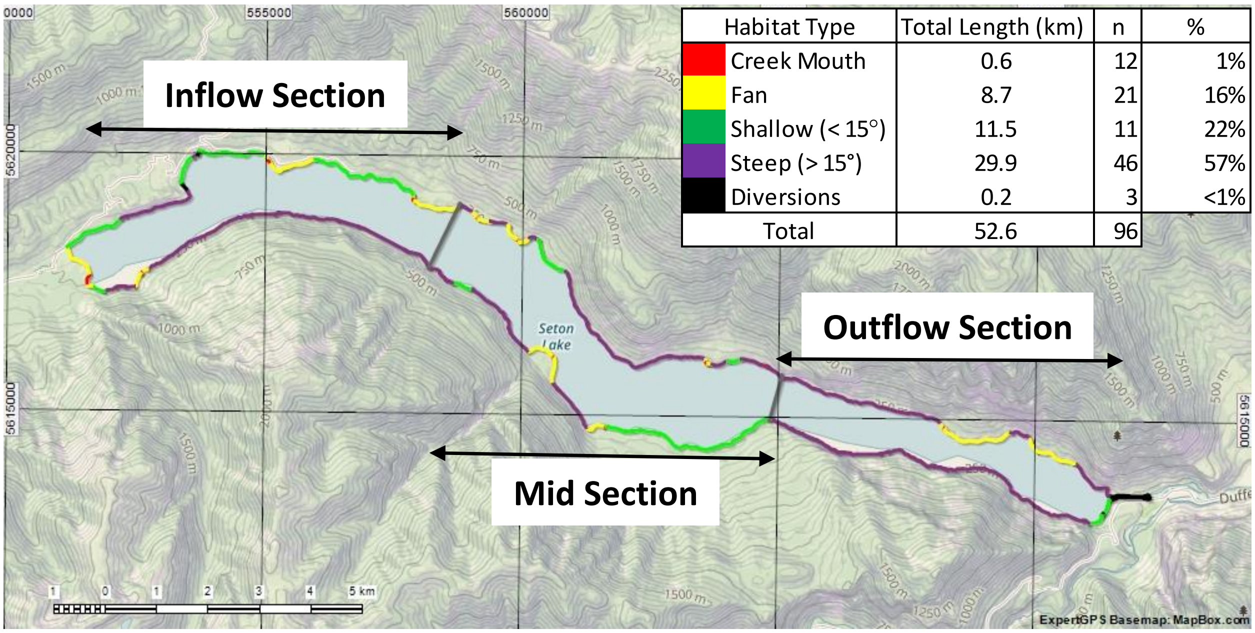
Table 3.1 Summary of depths (in meters) for thermal strata at the inflow and outflow ends of Seton Lake for each month during a period when the lakes were thermally stratified (August to November) in Year 3 (2015). Note: the depths of each layer were generally the same at the outflow end of Anderson Lake as reported here for the outflow end of Seton Lake.

Month	Epilimnion		Metalimnion		Hypolimnion	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
August	0-1	0-5	1-20	5-30	>20	>30
September	0-5	0-10	5-30	10-30	>30	>30
October	0-20	0-20	20-40	20-30	>40	>30
November	0-30	0-20	30-40	20-40	>40	>40

3.2. Shoreline Habitat Mapping

The shoreline habitat mapping in Year 3 (2015) documented the proportional distribution of general meso-habitat types around the entire perimeter of Seton Lake in August (Figure 3.6). On the dates of the survey, the elevation of the lake (measured at the Seton Dam forebay) was 236.3 m, the mid-line length of the lake along it's east-west axis was 22.2 km, and the total shoreline length was 52.6 km. A comparable habitat mapping survey is planned for Anderson Lake in an upcoming monitoring year (i.e., Year 5), after which these results can be compared between the lakes to assess similarities and differences in basic habitat characteristics.

The total length of shoreline associated with adjacent or overhanging terrestrial vegetation was 27.5 km (or 52% of the lake perimeter). The south and west shores of the lake were the most vegetated (81% and 100% by shoreline length, respectively); whereas, the north and east shores are more heavily impacted by development (e.g., railway, BC Hydro facilities, community residences, swimming beach) and are characterized by 26% to 28% vegetation cover, respectively. Terrestrial vegetation can be an important source of allochthonous nutrients to littoral food webs in aquatic systems (Perrin et al. 2016). Ultimately, comparing differences in the availability of overhanging and adjacent terrestrial vegetation between Seton and Anderson lakes may provide relevant information for contrasting the availability of this nutrient source between the two lakes. In turn, this information may be useful to inform any observed differences in productivity or growth rates of target fish species.



Habitat Type	Total Length (km)	n	%
Creek Mouth	0.6	12	1%
Fan	8.7	21	16%
Shallow (< 15°)	11.5	11	22%
Steep (> 15°)	29.9	46	57%
Diversions	0.2	3	<1%
Total	52.6	96	

Figure 3.6 Results of a shoreline habitat mapping survey conducted at 236.3 m lake elevation on 2 and 3 September 2015.

There was a total of 96 habitat units classified during the shoreline habitat mapping survey on Seton Lake. Of the habitat types identified for this monitoring program, steep shorelines (slope >15°; *n*= 46 units) were by far the most prevalent, contributing 29.9 km (57%) to the total perimeter length (see table included in Figure 3.6). Approximately two-thirds (21.2 km) of this steep terrain was made up of alluvial or colluvial material (rocks, boulders and other sediment particles), and one-third (8.7 km) was bedrock. Shallow shorelines (slope <15°; *n*= 11 units) were the next most prevalent habitat type in the littoral zone, contributing 11.5 km (22%) to the total shoreline length.

The remaining shoreline habitats in Seton Lake were fans (*n*= 21), creek mouths (*n*= 12), and diversions (*n*= 3), which contributed 8.7 km (16%), 0.6 km (1%), and 0.2 km (<1%) to the total perimeter length, respectively. Fans, which are formed by alluvial processes associated with streams, were more abundant than the actual number of creek mouths during the survey since many drainages in the valley are intermittent, with surface flows available for only a portion of the year (i.e., the snow-melt period in spring). For the purposes of the shoreline habitat mapping, diversions referred to developments that regulate particular inflows and outflows associated with Seton Lake. They included: the regulated inputs from the BR1 and BR2 Generating Stations, the Cayoosh diversion from Walden Power, and the 800 m long approach channel above Seton Dam. While less numerous than the natural inflow sources, they collectively convey the majority of flows into and out of the lake.

3.3. Tributary Spawner Surveys

Seven bull trout spawner surveys were conducted in Year 3 between 9 September and 18 November 2015. Surveys were conducted in Spider Creek, Whitecap Creek and Portage Creek (which are each suspected spawning tributaries based on anecdotal reports). Counts for Spider and Whitecap creeks were consistently zero on each survey date; however, survey conditions in these creeks were rated “fair” or “poor” on several of the survey dates due to turbulence throughout the survey section and/or turbidity. In addition, a significant storm event caused a massive bank failure in the lower reach of Whitecap Creek on 20 September, which resulted in extremely poor survey conditions for over a week and substantially altered the Whitecap and Portage Creek channels. The total numbers of bull trout spawners observed for each survey in Year 3 (2015) are presented in Figure 3.7.

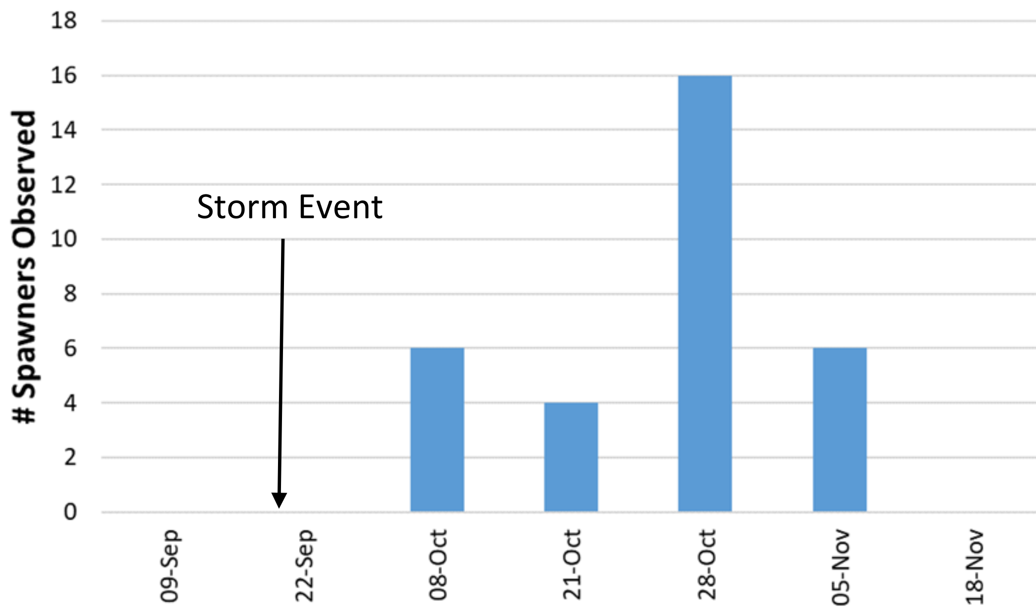


Figure 3.7 Results of visual surveys to enumerate bull trout spawners in selected tributaries to Seton Lake, September to November 2015. The timing of a storm event that resulted in a massive bank failure that significantly altered the Whitecap and Portage Creek channels is indicated.

Based on the data collected, the spawning period spanned from early October to early November, and the peak occurred in late October (peak *n*= 16 spawners on 28 October). This is generally in line with the timing of bull trout spawning noted in other areas of BC as well (McPhail 2007); however, the actual start timing may have been affected by the massive channel disturbance in late September 2015, or the fish may have been obscured by the poor survey conditions on some of the earlier dates. Most of the fish were typically observed in the glide section between the outflow of Anderson Lake and the Whitecap Creek confluence where visibility conditions were also typically rated as "good".

It's important to note that the results of these surveys are uncalibrated by methods such as mark-recapture so observer efficiency is not quantified and the numbers don't take into account the variable effects on "sight-ability" of the fish among surveys. As such, they represent a rough index of spawner timing and abundance in one key tributary. Also, given that bull trout can be highly migratory, as evidenced by some of the Seton Entrainment Study results (Nich Burnett, Instream Fisheries Research, pers. comm.), it is unknown where the Portage Creek spawners come from (i.e., Seton Lake, Anderson Lake, or elsewhere), and what proportion of the Seton and Anderson lake populations may spawn in other parts of the watershed (e.g., Gates Creek).

3.4. Resident Fish Population Index Survey

A total of 913 fish were captured by gill netting during the annual resident fish index survey in Year 3 (2015; Seton Lake *n*= 815; Anderson Lake *n*= 98), including 9 resident species (Table 3.2). Target species made up 68% of the catch, and the other 32% were non-target species including: peamouth chub, northern pikeminnow, redside shiner, bridgelip sucker, sculpin spp., and mountain whitefish (in decreasing order of abundance). Eighteen sites were sampled in Seton Lake, including 6 nearshore and 12 offshore sets, and 4 sites at the outflow end of Anderson Lake, including 1 nearshore and 3 offshore sets. The total sampling effort was 268.7 net-hours (Seton Lake = 198.5 hours; Anderson Lake = 70.2 hours).

Table 3.2 Catch totals for all resident fish species from gill net sampling in Seton and Anderson lakes in Year 3 (2015).

Lake	Species[a]									
	BT	GW	ON	RB	MW	PMC	NSC	BSU	RSC	CC
Seton	10	563	20	2	2	77	49	27	46	14
Anderson	12	11	2	3	3	36	23	3	3	2
Totals	**22**	**574**	**22**	**5**	**5**	**113**	**72**	**30**	**49**	**16**

[a] Species codes: BT = bull trout; GW = gwenis; ON = *Oncorhynchus nerka* juveniles; RB = rainbow trout; MW = mountain whitefish; PMC = peamouth chub; NSC = northern pikeminnow; BSU = bridgelip sucker; RSC = redside shiner; CC = sculpin spp.

Eight bull trout and four rainbow trout were marked with PIT tags. Only fish that were alive and in robust condition were tagged. No fish that had been tagged during previous study years (2013 and 2014) were recaptured in Year 3 (2015).

The highest catch-per-unit-effort (CPUE) values for bull trout, gwenis, and rainbow trout were in nearshore nets during Year 3 (2015) sampling (Table 3.3). The nearshore nets were set from shore along the bottom spanning a depth range of between 2 m to 45 m from the surface. Offshore nets were set mid-lake at 0 m, 15 m, 20 m, and 25 m below the surface (to the top of the net). These depths were selected based on the diel vertical migration data collected and reported for the BRGMON-6 diel vertical migration analysis (Limnotek 2015).

Table 3.3 Summary of fish catch-per-unit-effort results for target species during the annual resident fish population indexing survey, 29 September to 7 October 2015. Blank cells indicate zero catch.

Location	Zone	Catch per 10 Net-Hours for Target Species							
		Bull Trout		Gwenis		*O. nerka* juv.[1]		Rainbow Trout	
		Nearshore	Offshore	Nearshore	Offshore	Nearshore	Offshore	Nearshore	Offshore
Seton Lake	Inflow	1.2		137.3	4.1		0.4		
	Mid	2.5		91.8	1.1		0.4		
	Outflow	0.3	1.0	62.4	19.9		9.6	1.3	0.7
Seton Lake Average		**0.8**	**0.5**	**79.8**	**11.2**	**0**	**5.0**	**0.8**	**0.3**
Anderson Lake	Outflow	5.5	0.7	0.7	1.8		0.4	2.1	

[a] Values in these columns represent immature *Oncorhynchus nerka* that could not be differentiated between juvenile sockeye and gwenis in the field.

Highest catch rates for gwenis were in the inflow end of Seton Lake, followed by the middle section and then the outflow section, in decreasing order. Small numbers of juvenile *O. nerka* were also captured in the offshore net sets, though it was not possible to differentiate them as gwenis vs. sockeye progeny in the field. However, based on the BRGMON-6 *O. nerka* stock origin analysis, all of these fish can likely be considered gwenis based on size, since they were all >75 mm (Limnotek 2015). These *O. nerka* juveniles were most abundant in offshore catches at the outflow end of Seton Lake.

Catches by depth and distance from shore

Target fish were captured across a fairly broad range of depths (Figure 3.8). For gwenis in Seton Lake, their distribution spanned the entire range of sampling depths in Year 3 (2015). Approximately 20% of the gwenis were captured in the epilimnion thermal layer, 35% were in the narrow metalimnion, and 45% were in the upper portion of the hypolimnion; Over 90% tended to be below 15 m from the surface. The majority of these gwenis were sampled near the lake bottom at these depths (just above the lead line of the net) in the nearshore sets and were assessed to be mature and in spawn-ready (i.e., gravid or ripe) condition at the time of the survey. In terms of horizontal distribution from shore, the majority (70%) of gwenis in Seton Lake tended to be between 30 and 75 m from shore (Figure 3.9).

Bull trout were also fairly deep in Seton Lake and, though catch numbers were relatively small, their depth distribution appeared to correlate with the depths where gwenis abundance was the greatest (i.e., 20 to 35 m). This pattern was also evidenced in the distance from shore distribution.

These patterns appeared different in Anderson Lake where catch numbers of gwenis were lower and bull trout were higher. However, due to the limited extent of sampling effort in Anderson Lake this year, it is not feasible to draw any conclusions from this limited data set at this point.

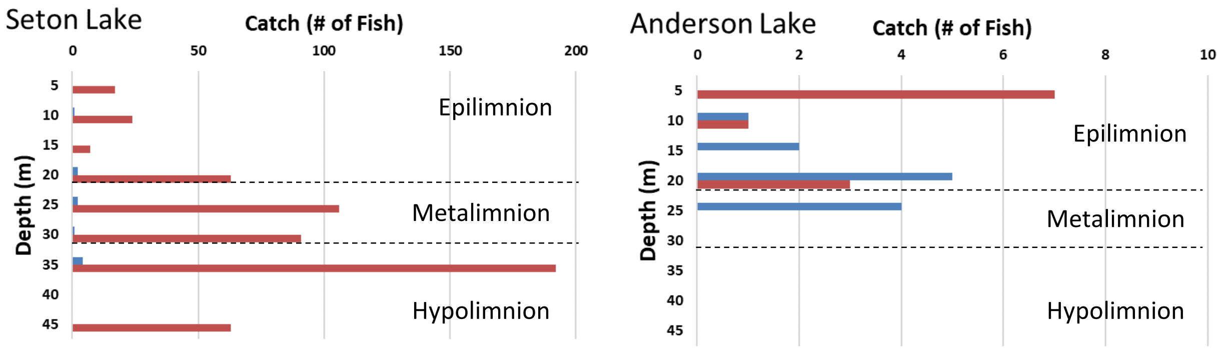


Figure 3.8 **Numbers of gwenis (red bars) and bull trout (blue bars) by capture depth in Seton Lake (left) and Anderson Lake (right) during the annual population indexing survey in Year 3 (2015). Note: the x-axis scales for each plot are different.**

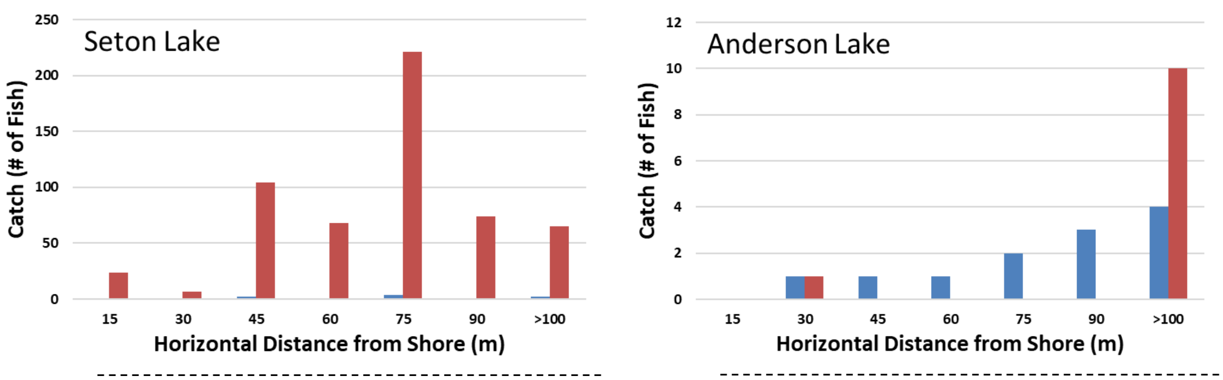


Figure 3.9 **Numbers of gwenis (red columns) and bull trout (blue columns) by horizontal distance from shore in Seton Lake (left) and Anderson Lake (right) during the annual population indexing survey in Year 3 (2015). Note: Distances less than 100 m are from nearshore sets; offshore sets are represented by the >100 m column. Y-axis scales for each plot are not the same.**

Length-Frequency and Size-at-Age

Length-frequency histograms for gwenis and bull trout captured by gill netting in Year 3 (2015) are presented in Figures 3.10 and 3.11. The different coloured bars in these figures represent the various age classes determined by analysis of ageing structures spanning the range of available sizes in the catch. The assigned ages from the scale reading were applied to all of the captured fish according to size.

Juvenile gwenis (Age 1 and 2) based on the scale ageing results were all <180 mm in both lakes. In Seton Lake, all of the mature gwenis were Age 3, the same as what was reported for the BRGMON-6 ageing results (Limnotek 2015), and ranged narrowly in size from 180 to 210 mm (median = 195 mm). In Anderson Lake, the mature gwenis were up to 4 years old and larger, ranging in size from 195 to 334 mm (median = 290 mm). All of the gwenis captured in Anderson

Lake were also very chrome-coloured and not in spawn-ready condition at the time of the survey (29 September to 7 October), confirming that spawn-timing for this population is later (based on BRGMON-6 reporting) than the timing for the Seton Lake population.

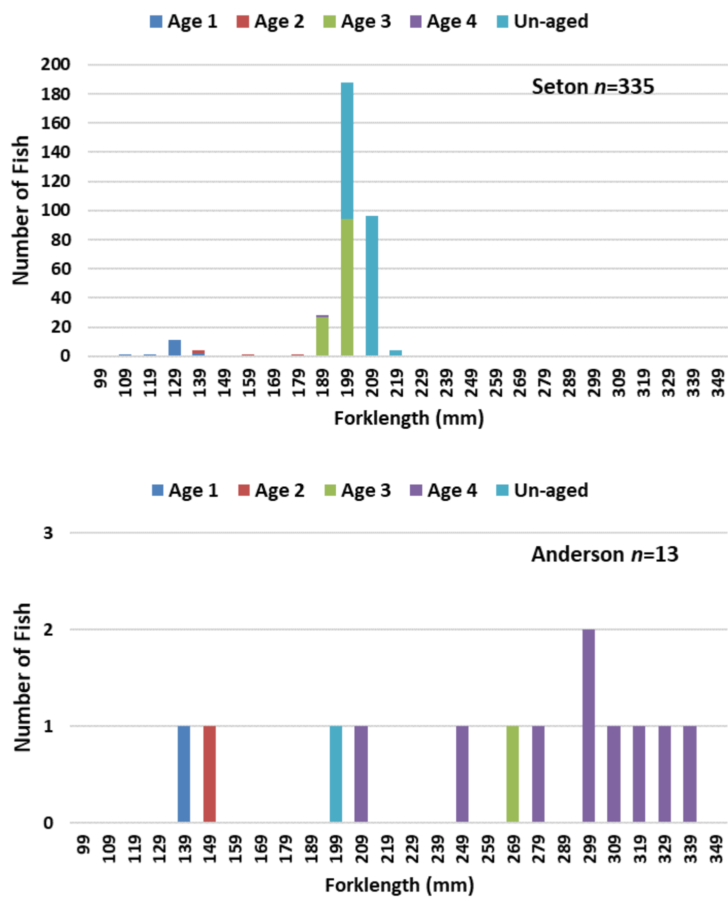


Figure 3.10 Length and age frequency histograms based on scale ageing data from selected gwenis captured during the annual gill net survey in Seton Lake (top) and Anderson Lake (bottom), September to October 2015.

All of the bull trout sampled in Seton Lake were between Age 7 and Age 9 and ranged in size from 483 to 754 mm, other than one Age 2 fish (126 mm). More age classes were represented by the bull trout captured in Anderson Lake (i.e., Age 4 to Age 9), and they spanned a size distribution from 227 to 620 mm. In general, most of the Anderson Lake bull trout were smaller than the Seton Lake bull trout, although the sample sizes (*n*= 12 and *n*= 10, respectively) were fairly small.

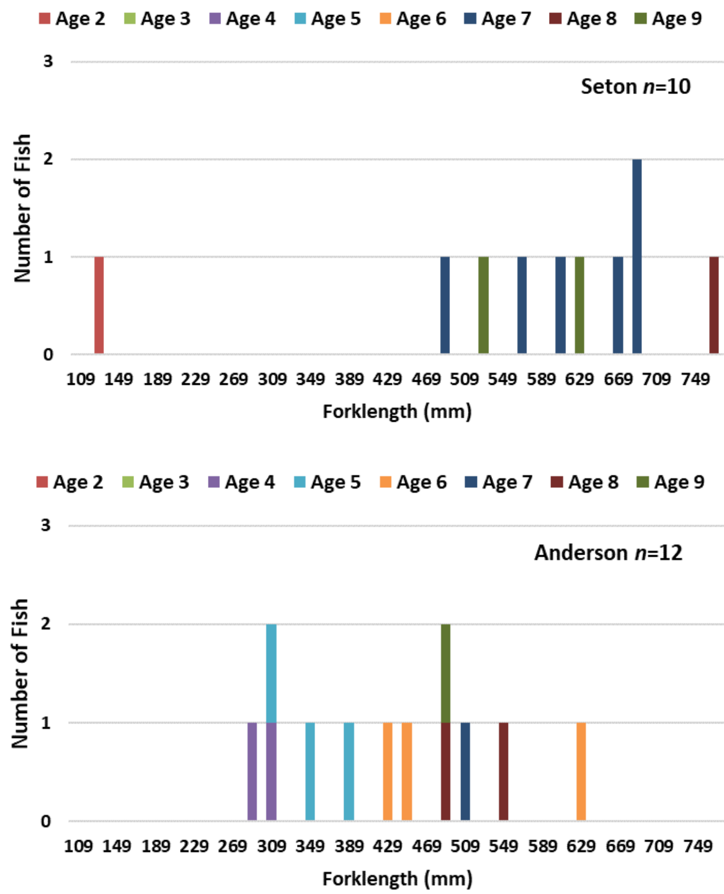


Figure 3.11 Length and age frequency histograms based on fin ray and otolith ageing data from bull trout captured during the annual gill net survey in Seton Lake (top) and Anderson Lake (bottom), September to October 2015.

Bull trout stomach contents

Stomach contents were assessed in the field for 8 bull trout that had succumbed to the sampling in Year 3 (2015); 4 were from Seton Lake and 4 were from Anderson Lake (Table 3.4).

Based on the small sample size available, it appeared that the generally larger bull trout in Seton Lake were feeding on mature gwenis (approximate size range 180 to 200 mm), whereas in Anderson Lake they appeared to be feeding more on the juvenile size classes of gwenis (approximate size range 100 to 120 mm). In three cases the stomachs were completely empty or the contents had been so digested that there was no identifiable matter remaining.

Table 3.4 Summary of stomach contents assessed for bull trout from Seton and Anderson lakes during the annual gill netting survey, 29 September to 7 October 2015.

Lake	Bull trout Size		Stomach Contents			
	Fork length (mm)	Weight (g)	Species	#	Approx. Prey Size (mm)	Comments
Seton	483	1251	GW	1	180	Whole fish
	590	2268	Stomach contents fully digested			
	610	2268	GW	2	180 - 190	1 partially digested
	660	3175	GW	5	180 - 200	3 partially digested
Anderson	374	515	Stomach contents fully digested (empty)			
	475	948	Stomach contents fully digested (empty)			
	531	1497	GW	1	100 - 120	Partially digested
	620	2312	GW	2	100 - 120	1 partially digested

4. Discussion

Data were collected and analysed in 2015 (Year 3) that will contribute to answering the management questions by the end of the monitoring program in 2022 after 10 years of study. Field and laboratory work was completed in Year 3 (2015) to contribute information towards answering the first 2 of 4 management questions for this program. The third management question will be addressed with the continuation of the temperature monitoring data collection (coincident with Carpenter diversion characteristics) and the inclusion of sedimentation monitoring results for both lakes to commence in Year 4. Data and interpretations to address question 4 will be possible once a longer time-series of data are available, and a possible synthesis of relevant information from the BRGMON-6 program can be integrated into the analyses.

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

Gwenis were the most abundant species in the annual resident fish sampling for this program in Year 3 (2015). Nearshore and offshore gill netting proved effective as a method for establishing an annual index of abundance for this species, and gill net surveys will be expanded to include all of Anderson Lake to facilitate comparisons between lakes going forward. Gwenis adults were more numerous in Seton Lake, but were noticeably smaller than the Anderson Lake gwenis (median size = 195 mm vs. 290 mm in Year 3 (2015)). Maximum age from scale reading for gwenis was Age 3 in Seton Lake (*n*= 13) and Age 4 in Anderson Lake (*n*= 11). Based on information from the BRGMON-6 program, the *O. nerka* juveniles (<180 mm) in the catch from both lakes were likely all gwenis offspring based on size (Limnotek 2015).

The majority of the gwenis sampled in Seton Lake during the late September to early October survey were mature and in some stage of spawning readiness (assessed as gravid, ripe, or spent by gently squeezing the belly to express gametes). Whereas in Anderson Lake, none of the gwenis were considered spawning-ready (i.e., chrome colouration, tight bellies, no gametes expressed), reflecting the later spawn-timing for this population.

Different spawn timing has also been documented for the two populations of sockeye (i.e., Gates Creek and Portage Creek runs) in the Seton/Anderson watershed. It is possible that the differences in spawn timing for the resident gwenis populations in each lake could be related to the differential spawn timing of their respective parent populations of sockeye. However, none of the data currently available from the BRGMON-8 program would be able to address this.

Also, the maximum assessed ages (based on scale ageing) were different between the lakes: the oldest fish in Seton Lake were Age 3 (and sexually mature) versus Age 4 in Anderson Lake, which is the same as what was reported for BRGMON-6 (Limnotek 2015). The combination of differential spawn timing, maximum age (and possibly age-at-maturity), and maximum body size differences suggest the possibility that the populations of gwenis in Seton and Anderson lakes may be distinct. However, genetic analyses would be required to actually determine this, which could not be accommodated by the existing BRGMON-8 budget.

In terms of spatial distribution, the highest proportions of gwenis catches in Seton Lake were in the nearshore sets along the bottom between 30 and 90 meters from shore, and at 15 to 30 m depth (coinciding with the metalimnion thermal layer), suggesting that these could be attributes of selected spawning areas. In Anderson Lake, more gwenis were captured in the water column from offshore sets; however, the data for this lake are still limited at this stage.

Catch-per-unit-effort values for bull trout were low in Year 3 (2015), particularly in Seton Lake. However, bull trout are known to be an effective piscivore that opportunistically prey on gwenis (among other species). This was confirmed by assessment of stomach contents from bull trout that had succumbed to the sampling procedure (n= 4 for each lake). The bull trout captured in Seton Lake tended to be larger, but they were more numerous in Anderson Lake (reverse of the results for gwenis). It was noted that most of the bull trout captured in Seton Lake were large enough to feed on the adult gwenis (one individual had five of them in its stomach at the time of sampling and similar results were noted by the BRGMON-6 study), whereas the gwenis noted in the stomachs of the Anderson Lake bull trout were in the juvenile size range. It was noted for each lake that the bull trout distribution tended to overlap with the locations where gwenis were most abundant (i.e., both vertically in the water column and spatially in the lake).

Bull trout in Seton and Anderson lakes are adfluvial, migrating from the lakes into streams to spawn. Spawning by this species was noted in Portage Creek (particularly at the top end near the outflow of Anderson Lake) in Year 3 (2015), with a peak spawner count of 16 in late October. The spawning period likely commenced in September; however, surveys during that month were hampered by a major storm event and bank failure on 20 September that washed out the lower portion of Whitecap Creek and plugged the Portage Creek channel until it could be manually re-opened using excavators. The last spawners were observed in early November.

Due to the challenging survey conditions in this context (i.e., wide channel for Portage Creek, consistent turbulence and episodic turbidity for Spider and Whitecap creeks), shore-based spawner counts that are uncalibrated by methods such as mark-recapture (which are necessary for assessing observer efficiency and spawner residence time) cannot be relied upon to confirm spawning use or estimate spawner escapement size. At best, it has provided confirmation of the use of Portage Creek by bull trout for spawning, as well as the general start, peak and end spawn timing in this context. In addition, the spawner survey data do not contribute to addressing the current set of management questions for this program beyond what has already been learned or understood. As such, we recommend discontinuing the spawner surveys going forward, and reallocating the project budget for this component towards more informative activities (e.g., expanding the fish indexing program to include all of Seton and Anderson lakes, and monitoring sedimentation rate in the different sections of each lake – see more on this for MQ 3, below).

Rainbow trout have only been sampled in very low numbers during all three years of this monitoring program to-date. The five individuals captured in Year 3 (2015; Seton Lake *n*= 2; Anderson Lake *n*= 3) were 191 and 193 mm (Age 3 based on scale ageing), 406 mm (Age 4), 421 mm (Age 6), and 440 mm (Age 8). Like the bull trout, this population is likely adfluvial, migrating to nearby streams in the spring to spawn. However, due to a combination of small population size and challenging survey conditions during their spawning period, rainbow trout spawners were not observed during spawner surveys in tributary streams to Seton Lake during Years 1 & 2 (Sneep 2015). Both of the rainbow trout captured in Seton Lake were sampled from within the metalimnion layer, and the three from Anderson Lake were within the epilimnion layer.

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

Relative to the Year 1 and 2 results, the gill netting method employed for the first time in Year 3 (2015) proved much more effective for capturing target species, particularly gwenis, and will be much better suited for establishing an annual index of abundance for target species that can be compared across the duration of the program. Since this was the first year this method was employed for the annual population index of target species, it is not possible to assess possible trends in the data beyond the level of descriptive analysis at this point. Once a consistent set of data are collected in future years of this monitoring program, it will be possible to evaluate potential patterns in the annual catch rates between lakes and sections within each lake across years.

Going forward, CPUE metric values (pooled by longitudinal section and total for each lake) will continue to be generated annually and compared as a reflection of trends in population index for the target resident species across monitoring years. Size and age distribution metrics will also be tracked such that any potential correlations with Carpenter diversion operations can be assessed. Ultimately, once a sufficient set of data across all of the years of monitoring have been collected, relevant information about diversion effects on productivity and the Seton Lake food base evaluated for the BRGMON-6 program can be synthesized with the BRGMON-8 analyses as potential explanatory variables for the trends observed.

Gwenis are likely the best-suited resident species for trend monitoring in Seton Lake for the following reasons: a) their ecological and social value in this context, b) the fact that they carry out their entire life cycle within the lake, and c) their potential for response to diversion effects. Due to their importance as a top predator species, and direct interaction with gwenis as a prey species in both lakes, bull trout are considered the next most important of the target resident species to directly monitor as a part of this program. Information on all other species sampled will continue to be collected, but will be considered more as incidental and supplementary information relative to the results for gwenis and bull trout.

MQ 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?

Some concern was raised during the WUP process that fluctuations in the lake surface elevation may have the potential to impact Gwenis spawning locations based on the assumption that selected spawning habitats may occur at elevations within the lake surface elevation range (i.e., that they are shore spawners). Gwenis spawn timing has been observed to occur in fall (Morris et al. 2003 and this program) in Seton Lake. During the fall sampling session (late September to early October) at least 90% of mature gwenis in spawning-ready condition were sampled in the bottom-set nets at depths ≥ 20 m, and over 30 m horizontal distance from the lake edge. These data suggest that gwenis spawn at depth in Seton Lake and would not be directly impacted by the degree of surface elevation changes observed.

Sediment inputs from the Carpenter diversion that settle on the bottom of the lake have the potential to impact gwenis production by covering or infiltrating spawning substrates over time. In order to monitor the extent of this sedimentation and more closely document it by season and diversion flow volume, we recommend deploying a set of sedimentation samplers in each of the 3 longitudinal sections (inflow, mid, and outflow) of Seton Lake, and the outflow section of Anderson Lake, starting in Year 4. The samplers will be suspended in the water column at the depths associated with highest gwenis spawner abundance to gather data that corresponds with potential spawning locations. Samples will be collected 3 times per year (spring, summer, and fall). Once several years of this data are in hand, it may be possible to investigate any correlation between gwenis abundance index in Year_t with sedimentation rate in Year_{t-3} (i.e., spawning year based on the evidence that mature fish in Seton Lake are 3 years old).

It is likely that the introduction of fine sediment particulates into Seton Lake associated with the diversion from Carpenter Reservoir contributes to the different biological characteristics and spatial distribution patterns of gwenis and bull trout observed between the lakes, as described for the Year 3 (2015) dataset. While the potential for effects of sedimentation on gwenis production seems fairly direct (as described above), the effects on bull trout, which are adfluvial and migratory, may be less direct relative to the availability of feeding opportunities in each context. Ideally, the cumulative dataset on physical habitat parameters (including diversion volume and sediment inputs) and population abundance indices collected by this monitoring program will shed some light on these linkages for these two focus species.

Carpenter diversion operation data will continue to be gathered from BC Hydro and summarized to document the annual and seasonal magnitude and timing of diversion flows into the lake. Once a long enough time-series of temperature profile and sedimentation rate data are collected, these can be correlated with the diversion operation metrics to characterize those relationships across the monitoring period.

MQ 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. It is not expected that this question will be able to be answered until late in the monitoring period, or at it's completion in 2022.

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