Bridge River Project Water Use Plan

Seton Lake Resident Fish Habitat and Population Monitoring

Implementation Year 4

Reference: BRGMON-8

BRGMON-8 Seton Lake Resident Fish Habitat and Population Monitoring, Year 4 (2016) Results

Study Period: April 1 2016 to March 31 2017

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Executive Summary

Data collection for Year 4 of this proposed 10-year study was completed in 2016. Results for Years 1 to 3 are provided in the previous reports produced for this program (Sneep 2015; Sneep 2018). Where relevant, comparisons across monitoring years 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 both Seton and Anderson lakes. Starting as a pilot effort in Year 3 (2015), 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. In Year 4 (2016) sampling effort was more fully extended to Anderson Lake than in Year 3, including the full lake length for the annual fish population index sampling.

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 key 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 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 4 (2016) 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;
- Sedimentation rate and particle size monitoring;
- Bull trout migration monitoring by radio tagging and tracking;
- Resident fish population index survey in the lakes (by gill netting).

In 2016, sampling for the resident fish population index survey was conducted by gill netting which incorporated both nearshore and offshore habitats. In order to allow concurrent 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 (2013 and 2014).

Physical characteristics in the two lakes were described by characterizing the annual and seasonal characteristics of Carpenter diversion operations, temperature profiles, and sedimentation deposition. Analysis of this information documented differences in diversion inflow volumes among years and seasons, and differences in temperatures and sedimentation

that can be attributed to the diversion inputs. Overall, the diversion results in colder water temperatures and higher inputs of fine sediments at the inflow end of Seton Lake (relative to conditions in Anderson Lake), and there is a gradient of effects across the length of the lake.

Opportunistic monitoring of bull trout movements within the Seton/Anderson watershed by capitalizing on telemetry equipment deployed for the BRGMON-14 program (in Gates Creek) and Seton Entrainment study (outflow of Seton Lake and below) provided some information on this adfluvial and migratory species in the system during Year 4 (2016). A higher proportion of bull trout tagged in Anderson Lake tended to make upstream movements (i.e. to Gates Creek) than downstream movements. No Anderson Lake bull trout were detected by the receivers at the outflow end of Seton Lake. On the other hand, the majority of bull trout tagged in Seton Lake made downstream movements (20 of 30 tagged fish detected at the outflow or below), and only 2 were detected upstream of the lake (1 in Portage and 1 in Gates creeks).

Approximately 304 hours of gill netting effort were employed in Seton and Anderson lakes over 8 dates in late September and early October 2016. In total, 470 fish were captured from 64 sampling locations (33 on Seton Lake and 31 on Anderson Lake). The sites were distributed spatially throughout 3 longitudinal zones (i.e., Inflow, Mid, and Outflow) in each lake. Sampling depths ranged from 0 to 55 m below the surface, and included surface, mid-column, and bottom sets. Captured fish included 9 different species; target species made up 68% of the total.

Catch-per-unit-effort (CPUE) values were generated for target species in Year 4 (2016). Highest CPUE for gwenis was recorded in Seton Lake, and lowest values were in Anderson Lake in 2016. Gwenis were more numerous in nearshore sets in Seton Lake (nearshore= 57.7 fish·net-hour^{-10}; offshore= 8.5 fish·net-hour^{-10}), whereas the gwenis in Anderson lake were exclusively distributed in offshore habitats (nearshore= 0.0 fish·net-hour^{-10}; offshore= 2.1 fish·net-hour^{-10}). Highest CPUEs for bull trout and rainbow trout were in the nearshore zone of Anderson Lake (42.1 and 2.5 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.

During the fall fish sampling session (late September to early October) the majority of mature gwenis in spawning-ready condition were sampled in the bottom-set nets at depths ≥ 20 m, and ≥ 60 m horizontal distance from the lake edge in Seton Lake. As such, these spatial distribution characteristics may represent potential spawning habitat characteristics in this lake. Anderson Lake gwenis were not in spawning-ready condition due to the later spawn timing for this population, and they were distributed in the water column in pelagic habitats, reflecting the typical rearing and feeding distribution for this species.

Based on analysis of size, gwenis tended to be larger in Anderson Lake, particularly after Age 2, and reached a maximum age of 4 years. The Seton Lake gwenis were smaller and had a maximum age of 3 years (at which they were sexually mature), reflecting growth and development differences between these populations. Captured bull trout in Seton Lake (*n*= 7) ranged in age from 3 to 6 years (length range = 380 to 590 mm), and in Anderson Lake (n= 37) from Age 2 to Age 8 (length range = 213 to 550 mm).

Assessment of bull trout stomach contents in Year 4 (2016) further documented that the various lifestages of *O. nerka* (i.e., sockeye or gwenis; eggs, juveniles and adults) comprise the dominant food source for this species in both lakes at this time of year. Larger bull trout in Seton Lake are able to capitalize on the mature gwenis, which are smaller bodied in Seton Lake, whereas juvenile gwenis and sockeye eggs were the dominant food items in Anderson Lake.

Summary of BRGMON-8 Management Questions and Interim (Year 4 – 2016) Status

Primary Objectives	Management Questions	Year 4 (2016) Status Based on 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?	**Species Composition:** Sampling documented 10 resident fish species, which were present in both lakes. Gwenis, bull trout and rainbow trout have been identified as target species for monitoring. Sample sizes for rainbow trout have been consistently low, so the summary that follows focusses on gwenis and bull trout, for which there is more representative data. **<u>Gwenis</u>** **Relative Abundance:** Gwenis are the most abundant resident species in Seton Lake, but appear to be much less abundant in Anderson Lake. **Size:** Adult gwenis are substantially larger in Anderson Lake, particularly after Age 2. **Age/Maturity:** Gwenis in Seton Lake ranged in age from 1 to 3 years (and were sexually mature at Age 3); Anderson Lake gwenis had a maximum age of 4 years, similar to the typical spawning age for sockeye. **Distribution/Habitat Use:** At the time of the survey (late Sep to early Oct), gwenis in Seton Lake were more abundant in nearshore sets (between ~60 and 90 m from shore) and >20 m depth, which may coincide with spawning location characteristics for this population based on evidence of spawning-readiness. By longitudinal zone, abundance in Seton Lake was highest at the Outflow end and lowest at the Inflow end in Year 4 (2016). Gwenis in Anderson Lake were exclusively in the offshore sets (>100 m from shore) within the metalimnion thermal layer (i.e., 10 to 30 m depth. These locations likely correspond with their distribution in the lake for rearing/feeding. Highest catch rates were in the Outflow end of the lake, although differences among zones were much smaller than in Seton Lake. **Diet:** Zooplankton **<u>Bull Trout</u>** **Relative Abundance:** Bull trout were the fifth most abundance species in Seton Lake (behind gwenis, northern pikeminnow, *O. nerka* juveniles, & peamouth chub), and second in Anderson Lake (behind northern pikeminnow). **Size:** Larger bull trout have been captured in Seton Lake in some years, although this result has not been consistent every year and there is likely significant (if not total) size overlap for this species between lakes. Based on the available sample size, bull trout growth appears to slow after Age 4 in Anderson Lake. Sample size was too small to assess growth in Seton Lake for this species based on Year 4 (2016) data. **Age/Maturity:** Captured bull trout have ranged in age between 2 and 9 years old, and based on the minimum size of tagged fish that moved into Gates Creek during the spawning period, bull trout in this system may become mature by ~Age 3. **Distribution/Habitat Use:** Bull trout distribution in Seton Lake corresponding directly with gwenis distribution in this lake. In Anderson, they were distributed in nearshore habitats

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?	between 30 to 90 m from shore and across the full range of sampled depths. **Diet:** Gwenis adults, juveniles & O. nerka eggs **See Sections 3.4, 3.5 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?	**Annual CPUE (# of fish per 10 net-hours)** **Seton Lake Gwenis:** 28.4 (2015); 11.8 (2016) **Anderson Lake Gwenis:** 1.6 (2015); 2.0 (2016) **Seton Lake Bull Trout:** 0.5 (2015); 0.5 (2016) **Anderson Lake Bull Trout:** 1.7 (2015); 2.5 (2016) There are not enough data from this program currently to address this management question. However, the program is on track to answer MQ 2 by establishing an annual index of abundance for target species (focussing on gwenis and bull trout) by employing a standardized gill netting survey throughout Seton and Anderson lakes, 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 in Anderson Lake was continued in Year 4 (2016) 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 (i.e., control vs. impact) across the monitoring period. Overall trends in target fish catch rates (CPUE), in conjunction with assessment of correlation with diversion operations and physical habitat effects (temperature and sedimentation rate – see response to MQ3), will provide information for addressing this MQ at the end of the monitor. **See Sections 3.5 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?	Two of the anticipated effects of the Carpenter diversion on Seton Lake were on the thermal regime and the introduction of fine particulate sediments. Based on data available from Year 4 (2016) monitoring, the diversion operations have an effect on both temperature and sediment deposition in Seton Lake, particularly at the inflow end, with a gradient of effect across the length of the lake. MQ 3 will be addressed with the continuation of temperature profile and sedimentation rate monitoring (coincident with seasonal Carpenter diversion characteristics). Establishment of potential linkages with the fish abundance index information will continue to be explored, but potential correlations will not be evident until more annual data points are available. Relevant results & analysis from BRGMON-6 will also be incorporated with the results from this program by the end of the study period (i.e., 2022) to inform the response to this question. **See Sections 3.1, 3.2, 3.3 and 4**.
	4. Can refinements be made to the selected alternative to improve habitat conditions or	Cannot answer this MQ at this stage. The program is intended to provide relevant information, coupled with applicable results provided by other programs (i.e., BRGMON-6), for answering this MQ. Relevant inputs from BRGMON-8 include seasonal water temperature profile and sedimentation rate effects of the diversion, as well as general fish

	enhance resident fish populations in Seton Lake?	population trends* for target species across the monitoring period. Providing more conclusive inputs (based on observed effects and relationships among monitored variables) for making management decisions about diversion operations, will require the full 10-year data set (i.e., the full duration of data collection for this program). *Note: It is anticipated that this program would be able to detect large-scale changes in relative abundance of target species, but not likely small-scale changes. Finer resolution in the results would require different methods (i.e., hydroacoustics), effort and budget.

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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, inputs from regulated sources account for ~90% of total inflows, whereas natural inflows contribute ~10% by volume. 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 and lake turn-over 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 ≤0.6 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 4 of this proposed 10-year study was completed in 2016.

It should be noted that due to lessons learned during the first two years of sampling (2013 and 2014), 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 hypotheses changed from those in the original ToR and new methods for fish sampling were proposed (i.e., gill netting instead of boat electrofishing).

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 4 (2016; 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 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.

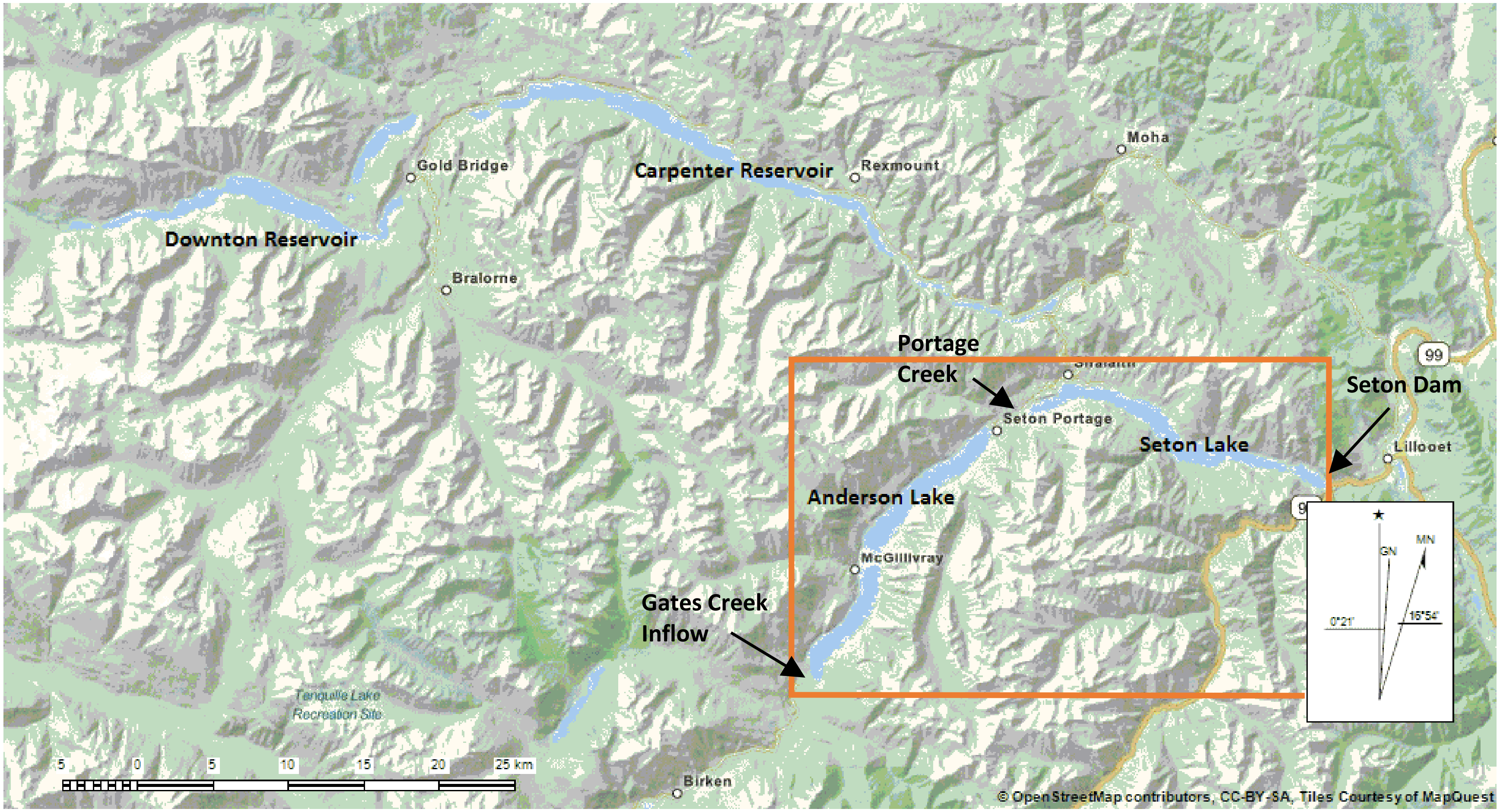

Figure 1.1 Overview of the Bridge and Seton watersheds. The extent of the BRGMON-8 study area, which includes all of Seton and Anderson lakes between the Gates Creek inflow and Seton Dam, is outlined by the orange rectangle.

1.4. Diversion Operations Context

In the context of the Bridge-Seton hydroelectric system, total average inflows to Downton and Carpenter reservoirs are approximately 40 $m^3 \cdot s^{-1}$ and 51 $m^3 \cdot s^{-1}$, respectively, for a combined total average diversion typically about 91 $m^3 \cdot s^{-1}$ into Seton Lake (BC Hydro 1993). Water is diverted through tunnels and penstocks from Carpenter Reservoir to two powerhouses on Seton Lake called Bridge River 1 (BR1) and Bridge River 2 (BR2). The maximum licensed discharge from these generating stations is 160 $m^3 \cdot s^{-1}$ (BR1 = 65.0 $m^3 \cdot s^{-1}$; BR2 = 95.0 $m^3 \cdot s^{-1}$) (BC Hydro 2011).

In the recent past, BC Hydro has identified issues with some of their infrastructure associated with water storage and flow conveyance within the Bridge-Seton hydroelectric complex. As a result, the storage of water in Downton Reservoir and conveyance of water through the system, including diversion of flows from Carpenter Reservoir to Seton Lake (via the diversion tunnels and generating units at Bridge 1 and 2), would be affected. A change from the typical N2-2P (i.e., post-Water Use Plan) operations will be required for a period of years to mitigate the issues and allow for the associated infrastructure to be fixed or replaced. The modified operations to account for the identified system constraints were first implemented in 2016. The changes that pertained specifically to Seton Lake in Year 4 (2016) were increased diversion flow volume from BR1 and BR2, particularly in spring, and reduced volume during fall, relative to previous monitoring years (Table 1.1).

Table 1.1 Summary of Diversion Flow Volumes from the Bridge Generating Stations (BR1 and BR2) and Outflow Discharge Rates at Seton Dam & Generating Station for BRGMON-8 Monitoring Years to-date.

Study Year	Diversion Volume (Mm^3)					Average Rate ($m^3 \cdot s^{-1}$)
	Spring [a]	Summer	Fall	Winter	All Seasons Total	
1 (2013)	537	631	719	757	**2,645**	**84**
2 (2014)	334	722	673	865	**2,593**	**82**
3 (2015)	585	830	658	805	**2,878**	**91**
4 (2016)	1284	812	514	839	**3,449**	**109**

[a] Seasonal periods were defined as follows: Spring = 21 Mar to 20 Jun; Summer = 21 Jun to 20 Sep; Fall = 21 Sep to 20 Dec; Winter = 21 Dec to 20 Mar.

1.5. Sampling Design and Implementation To-Date

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).

A summary of the methods employed across the years (to-date) for accomplishing the goals and objectives of the BRGMON-8 program are provided in Table 1.2, for reference. For more information about the methods employed during past years, and the rationale behind them, please refer to the appropriate annual monitoring reports for those years.

Table 1.2 Methods Implementation by Study Year To-date. For more details on the specific methods employed, refer to the annual monitoring report for each year.

Monitoring Method	Study Year			
	1 (2013)	2 (2014)	3 (2015)	4 (2016)[a]
BC Hydro Operations	X	X	X	X
Temperature Monitoring (Continuous)				
• Tributaries			X	X
• In-lake Profile Arrays			X	X
Sedimentation Rate Monitoring				X
Shoreline Habitat Mapping			X	
Fish Population Index Surveys				
• Nearshore Boat Electrofishing	X	X		
• Gill Netting (Littoral & Pelagic)			X	X
Suppl. Tagging of Target Species (Angling)	X	X		
Tributary Spawner Surveys				
• Rainbow Trout (RB)	X	X		
• Bull Trout (BT)			X	
Radio Tagging & Telemetry (RB & BT)				X
Stomach Contents Assessment (Bull Trout)			X	X
Scale & Otolith Ageing			X	X

[a] The specific dates that each of the Year 4 (2016) activities were completed are provided in Section 1.6, Table 1.3.

In Year 4 (2016), 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 4 (2016) included four main monitoring components:

- Thermal profile monitoring;
- Sedimentation rate and composition monitoring;
- Bull trout and rainbow trout movement monitoring using radio telemetry; and
- Resident fish population index survey (by gill netting).

Tributary spawner surveys were discontinued in Year 4 (2016) due to challenging conditions (e.g., turbidity, high flows) in the surveyed streams, and the limited information that they provided for answering the management questions (Sneep 2018). It was not possible to incorporate mark-resight methods to quantify observer efficiency and residence time within the available budget for this component, and documented use of surveyed areas by target species was not considered a representative means of tracking population trends in this context.

Instead the funds were used to add a radio tagging and tracking component during this year to capitalize on existing tagging efforts and tracking infrastructure already in place for the Seton Entrainment Study and BRGMON-14 program (see Methods Section 2.3 for more details). It was considered a useful endeavor, with in-kind contributions from these other programs, to opportunistically document movement of adfluvial bull trout and rainbow trout within the watershed to put their use of lake habitats impacted by the diversion in some context.

Another component that was added to the BRGMON-8 program in Year 4 (2016) was measurement of sedimentation rate related to inputs from the Carpenter diversion inflows. In order to monitor the extent of this sedimentation and more closely document it by season and diversion flow volume, a set of sedimentation samplers were deployed in each of the 3 longitudinal sections (inflow, mid, and outflow) of Seton Lake, and the outflow section of Anderson Lake, starting this year.

A habitat mapping survey was conducted in Seton Lake in Year 3 (2015), but not in Year 4. It was not considered necessary to repeat this survey in back-to-back years given the expectation of minimal variation in the results related to the minimal extent of surface elevation fluctuation (relative to Downton and Carpenter reservoirs) among seasons and years, and minimal change in habitat distribution across this period. A habitat mapping survey of Anderson Lake is planned for Year 5 (2017), to provide an equivalent set of shoreline habitat information for comparison between the two lakes. Other than these changes, all other monitoring components conducted in Year 3 (2015) were repeated in Year 4 (2016).

The fish sampling gear employed for this program (RIC gill nets; see Section 2.5) tends to sample a broad range of species and size classes of fish reasonably well; however, the smallest juveniles (e.g., Age-0+ and Age-1 bull trout, gwenis, or rainbow trout) are not sampled as effectively due to their small body size and habitat use. These juveniles were sampled more effectively by the trawling method incorporated for the fish sampling component of BRGMON-6 ("Seton Lake Aquatic Productivity Monitoring") on Seton and Anderson lakes, and were more effectively inventoried as a part of that work.

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 Methods (Section 2).

1.6. Year 4 (2016) 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 (2016) represents monitoring year 4. The general schedule of field sampling activities is presented in Table 1.3.

Table 1.3 Schedule of Field Sampling Sessions and Activities.

Field Activities	Dates (Year 4 - 2016)
Temperature array retrieval (R) and deployment (D)	28 Apr (R & D); 14 Jul (R & D); 28 Oct (R & D)
Sedimentation sampler retrieval (R) and deployment (D)	28 Apr (D); 14 Jul (R & D); 28 Oct (R & D)
Angling (A), Mobile tracking (M) & Fixed station monitoring (F)	5, 11 and 18 May (A); 11 Aug (A) 27 Sep (A); 14, 20, 29 Sep (M) 6, 13, 20, 27 Oct (M) 27 July to 12 Oct (F)
Resident Fish Population Index Survey	27 to 30 Sep (Seton); 4 to 7 Oct (Anderson)

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. Following successful pilot sampling in Year 3 (2015), collection of comparable data from Anderson Lake was also included in all Year 4 (2016) activities with the intention of providing additional context from a similar lake in the same watershed with shared ecology and analogous development impacts (i.e., railway, transmission lines, recreational cabins, and some residential), but no direct diversion impacts. Given the benefit of having comparable information from Anderson Lake to understand results and potential trends in context, attempts will be made to collect data from both lakes within the constraints of the existing budget for each monitoring year going forward.

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. Physical Conditions

BC Hydro Operations

Records of BR1 and BR2 discharge rates (i.e., Carpenter diversion inflows to Seton Lake in $m^3 \cdot s^{-1}$) and Seton Lake surface elevations (measured in the forebay of Seton Dam in metres above sea level) were provided by BC Hydro Power Records as hourly values for each study year. These data facilitated comparison of diversion inflows (rates and volumes) and management of lake levels among years. Diversion inflow volumes were also summarized by season to assess differences in flow delivery by time-of-year. The seasons were defined according to the following data ranges: Spring = March 21 to June 20; Summer = June 21 to September 20; Fall = September 21 to December 20; and Winter = December 21 to March 20.

Thermal Profile Monitoring

Continuing since initial deployment in Year 3 (2015), temperature logger arrays were deployed to monitor the thermal profiles of the water column at the outflow end of Anderson Lake and both the inflow and outflow ends of Seton Lake throughout the year. Individual temperature loggers were deployed in M'sut Creek, to monitor water temperatures from a natural inflow source, as well as in the Seton Dam forebay. The locations of the temperature arrays and other logger locations in the study area are provided in Figure 2.2 in Section 2.5, below. Universal Transverse Mercator (UTM) coordinates for each temperature profile array and individual temperature logger locations are provided in Table 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).

Table 2.1 Universal Transverse Mercator (UTM) coordinates for temperature monitoring locations in Seton and Anderson lakes.

Location	UTM Coordinates (Zone 10U)	
	Easting	Northing
In-lake Temperature Arrays		
• Anderson Lake Outflow	548140	5614932
• Seton Lake Inflow	555060	5618911
• Seton Lake Outflow	569860	5613582
Individual Temperature Loggers		
• Portage Creek	550340	5617682
• M'sut Creek	560562	5616154
• Seton Dam Approach Channel	572103	5613519

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. Starting in October 2016, the loggers at 5 m were moved down to 25 m to better define the depth range of the thermocline. A sinking line was 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 M'sut Creek and the Seton Dam forebay were fixed to a weight (i.e., a brick) that was connected to an anchor point on shore using a length of cable. Measurement depth for these individual loggers was ~0.5 m below the surface. 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.

Sedimentation Monitoring

In addition to potential changes in temperature, the diversion supplying the BR1 and BR2 generating stations has introduced turbid water from the glacier-headed Bridge River valley. Drawn near the bottom of Carpenter Reservoir, these inflows routinely contain fine sediment particulates that are delivered to Seton Lake resulting in changes to colour, turbidity and sediment deposition. While differences in seasonal turbidity characteristics in Seton Lake have been assessed under the BRGMON-6 program, we undertook to investigate the seasonal and spatial differences in sedimentation rate (i.e., the amount of fine particles that settle out of suspension by season and distance from the BR1 and BR2 outflows).

In order to monitor the extent of this sedimentation and more closely document it by season and diversion flow volume, a set of sedimentation samplers were deployed 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 (Table 2.2; and Figure 2.2 in Section 2.3). The samplers were suspended in the water column at ~40 m below the surface, which was just below the depths associated with highest gwenis spawner abundance (i.e., 20-35 m, based on the annual fish population index survey results from Year 3). The intention was to gather data that corresponds with potential spawning depths for this species. Samples were collected 3 times during the year (i.e., spring, summer, and fall).

Table 2.2 UTM coordinates for sedimentation monitoring locations in Seton and Anderson lakes.

Location	UTM Coordinates (Zone 10U)	
	Easting	Northing
Anderson Lake Outflow	548257	5615092
Seton Lake Inflow	555399	5618909
Seton Lake Mid	560750	5615572
Seton Lake Outflow	569664	5613606

The samplers were loaned to the project by Chris Perrin (Limnotek) and consisted of two open PVC tubes (dimensions: 40 cm long x 11 cm inside diameter) mounted side-by-side with metal brackets (Photo 2.1). Removable sampling cups (Photo 2.1 inset; 12 cm long x 11 cm inside diameter) were mounted to the bottom of each tube with a rubber gasket and two adjustable hose clamps. The top of each tube was fitted with a course plastic grate to keep large organic materials (e.g., leaves, etc.) out of the sample. The samplers were suspended vertically in the water column by two lines: one extended up to a submerged float, and the other extended down to a concrete anchor on the lake bottom.

Photo 2.1 Sedimentation sampler deployed in Seton and Anderson lakes in Year 4 (2016). The sampling cup from which the sediment sample was collected is shown (inset).

For Year 4, the samplers were initially deployed on 28 April 2016, and then retrieved and redeployed on 14 July (collection of spring sample), 28 October (summer sample), and 25 May 2017 (fall/winter sample). On each retrieval date, the samplers were pulled up from the sampling depth and lifted into the boat; care was taken to maintain the vertical orientation so the collected sample was not disturbed or lost. However, samples for summer in the outflow end of Anderson Lake and the mid section of Seton Lake were compromised because the samplers became entangled in rope and tipped sideways as they were being drawn up through the water column. The sampler retrieval procedure has since been adapted to reduce the risk of this happening going forward.

Once the samplers were secured in the boat, a hand pump, fitted with suction and discharge hoses, was used to draw the water in the tubes down to below the level of the rubber gasket at the top of the sampling cup. Then the sampling cup was removed and the water level was drawn further down to minimize the amount of water in the sample to facilitate subsequent drying at the lab. The remaining water and sediment sample was poured into a sample jar labelled with the sample date, location, and replicate number (tube 1 or 2). The bottom of the cup was scraped with a plastic spoon and all remaining sample was rinsed into the sample jar using a wash bottle. Following sample collection, the sample jars were sealed with water-tight lids.

Once the sample had been collected, the tubes and sampling cups were scrubbed with pipe brushes to clean off algae and any other residual material to ensure they were clean to start the next sample period. The samplers were then reassembled for re-deployment in approximately the same position and depth as previous. Once the boat was manoeuvered into position (based on GPS coordinates), the anchor was lowered over the side, the tubes were allowed to slowly fill with water, and then the float was submerged as the sampler slowly lowered back to it’s sampling depth.

All sediment samples were submitted to ALS Labs (Saskatoon, SK, Canada) for analyses, which included: total wet and dry weight in grams; percent contribution by particle size classes; and percent total organic carbon content. The total wet and dry weight of accumulated sediment was assessed for each sample; whereas, the percent size composition and organic carbon content were assessed by combining all the samples for the year (by location) since a minimum sample size of 50 g was required for these analyses, which exceeded the individual sample amounts. For the analyses of the dry weight data presented in this report, the average of the replicates (i.e., from each tube of the sampler) at each location was calculated, along with standard deviation.

2.2. Movement Monitoring Using Radio Telemetry

The bull trout and rainbow trout populations in Seton and Anderson lakes are adfluvial: migrating from the lakes into streams to spawn. In past monitoring years, spawning use of Seton Lake tributaries (i.e., Portage Creek, Whitecap Creek, Spider Creek, and M’sut Creek) by these species was assessed by weekly streamwalks during their respective spawning periods (April to May for rainbow trout; September to October for bull trout). However, spawners were only observed in relatively small numbers by this method due to conditions that reduced its effectiveness (e.g., seasonal turbidity, turbulence, wide stream channel for Portage Creek, etc.). As such the utility of this method to provide useful information for answering the management questions was limited, so a decision was made to discontinue the streamwalks in Year 4 (2016) and allocate the associated funds towards other potentially informative activities.

Bull trout spawning 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. However, the actual extent of migration throughout the system or, conversely, the potential fidelity of these fish to the lake where they were captured (and its associated tributaries) was unknown. For this reason, we set out to investigate potential movements of bull trout into and out of the study area using radio telemetry in Year 4 (2016). Radio telemetry programs are generally expensive as the costs associated with the necessary equipment combined with the ongoing maintenance of the gear in the field (i.e., for fixed stations), are relatively high. However, this method was opportunistically chosen for the BRGMON-8 program because radio telemetry work was simultaneously being conducted by two other programs in the same watershed during this year.

Instream Fisheries Research (IFR) had installed radio telemetry equipment (i.e., fixed stations) in the Seton River Corridor (between the outflow of Seton Lake and the Fraser River) and were radio and PIT tagging bull trout and rainbow trout in Seton Lake for their study of entrainment at Seton Dam and Generating Station. In addition, researchers from UBC were installing and maintaining a fixed station for radio tagged sockeye salmon in Lower Gates Creek (at the top end of Anderson Lake). As such the costs to the BRGMON-8 program for these data only required the purchase of radio tags (n= 20) and the technician labour for angling (to put the tags out) and weekly mobile tracking in Portage Creek during the bull trout spawning period. IFR offered additional in-kind support by providing their mobile receiver and antenna at no cost by piggy-backing the mobile tracking on the same days (and using the same technicians) as the BRGMON-3 surveys in the Lower Bridge River.

Since IFR efforts for the Seton Entrainment Study were already focussed on tagging a reasonable sample size of bull trout and rainbow trout in Seton Lake, the tagging efforts for BRGMON-8 were focussed on putting tags out in Anderson Lake (Figure 2.1). Angling (with lures or bait) by a team of two SER technicians was the method used for fish capture. Experienced staff from IFR conducted the tagging surgeries and provided training to the technicians. Fish capture efforts were expended on five dates in Year 4 (2016) as outlined in Table 1.1; However, tagging only occurred on three of those dates as target fish were not captured during the 11 August or 27 September angling efforts.

When a target fish of appropriate size was captured, it was assessed for condition (to ensure it was in adequate health for the tag implantation surgery) and then transferred to a flow-through holding bag in the water. After a period of recovery from capture and handling-induced stress, each fish was placed in a V-shaped trough and anaesthetized by delivering an ethanol:clove oil mixture (diluted with water) directly over the gills using a wash bottle.

Forklength (mm) and weight (g) were measured, and each fish was given a PIT tag inserted into the dorsal musculature.

To implant the radio tag, a small (~1.5 to 2.0 cm) incision was made parallel to the body axis along the ventral surface immediately in front of the pelvic fins. A second, even smaller (i.e., ~0.5 cm), incision was made directly behind the pelvic fins, in line with the first incision. The wire antenna (attached to the radio transmitter) was threaded through the front incision, over the pelvic girdle, and out of the rear incision using a curved needle. The curved needle was removed and the transmitter was inserted into the body cavity through the anterior incision. Then the incision was closed using three to four sutures. Capture and release date, anaesthesia time, surgery start and end times, and recovery times were recorded for each tagged fish.

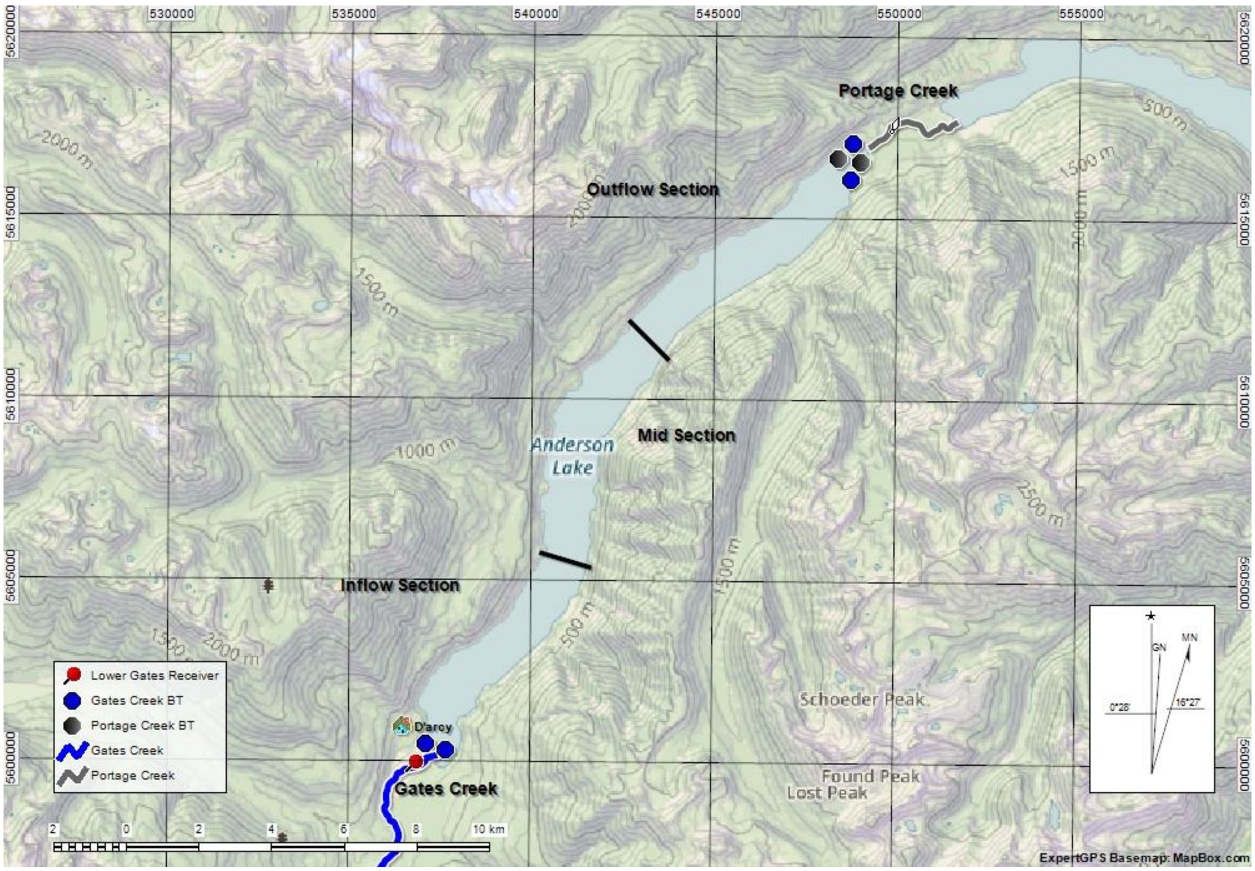

Figure 2.1 Map of the original capture locations for tagged fish subsequently detected by the fixed telemetry station in Lower Gates Creek (blue dots), or by mobile tracking in Portage Creek (grey dots) during Year 4 (2016) monitoring.

The radio tags were manufactured by Sigma Eight Inc. (Pisces model TX-PSC-I-160 programmable) with the following specifications:

- Type: Internal
- Dimensions: 41 mm x 10 mm x 10 mm
- Mass: 7.2 g

- Estimated battery life: up to 889 days

The radio receivers used for the fixed stations were manufactured by Sigma Eight Inc. (Orion model) which were connected to 3- or 5-element Yagi antennas and powered by sets of deep cycle batteries, or mains power (as available). Detection record downloads and battery changes were conducted frequently (by IFR, UBC, and SER technicians, as per protocols for the Seton Entrainment and BRGMON-14 studies) to reduce the risk of missed detections or data loss. The receiver used for mobile tracking was manufactured by Lotek Engineering Inc. (Model SRX 400 version 4.01/W5), which was coupled to a 3-element Yagi antenna.

The selected transmitter frequencies were 150.500 MHz (*n*= 10) and 150.520 MHz (*n*= 10), which were different from any of the frequencies used by IFR or UBC for the Seton Entrainment or BRGMON-14 studies to ensure that any tag detections could be clearly differentiated in the fixed station records.

2.3. 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 4 (2016) was also extended to include all of Anderson Lake, following the successful pilot sampling in Year 3 (2015). 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 58 m from the lake surface.

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; Gwenis orient around the thermocline depth for feeding purposes or near the substrate at depth for spawning in the fall. While in the lakes, bull trout may orient to the depths of prey species (e.g., gwenis, among others), and rainbows likely feed nearer the surface and at creek mouths.

In BC, standardized gear specifications have been developed for the use of gill nets in lakes for indexing-level surveys (B.C. Ministry of Environment, Lands and Parks 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 2.3), 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 2.3 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 33 sites in Seton Lake (24 nearshore and 9 offshore sets), and 31 sites in Anderson Lake (22 nearshore and 9 offshore sets). The distribution of sites spanned the three longitudinal zones (i.e., Inflow, Mid, and Outflow sections) in both lakes (Figure 2.2). Set duration was different for nearshore versus offshore sets in Year 4 (2016). This was due to the significantly higher catch rates and incidence of mortality observed for the nearshore sets compared to offshore sets in Year 3 (2015), most of which were fished overnight. To mitigate the rate of mortality, the nearshore zone was fished using short-duration sets (target = 15 to 30 minutes) throughout the day so that the fish could be removed from the nets and processed much more quickly. Due to the substantially lower catch rates, the offshore sets were still fished overnight (i.e., set late in the day and retrieved the following morning).

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 the lead line at the 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 ~ 85 to 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, 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.

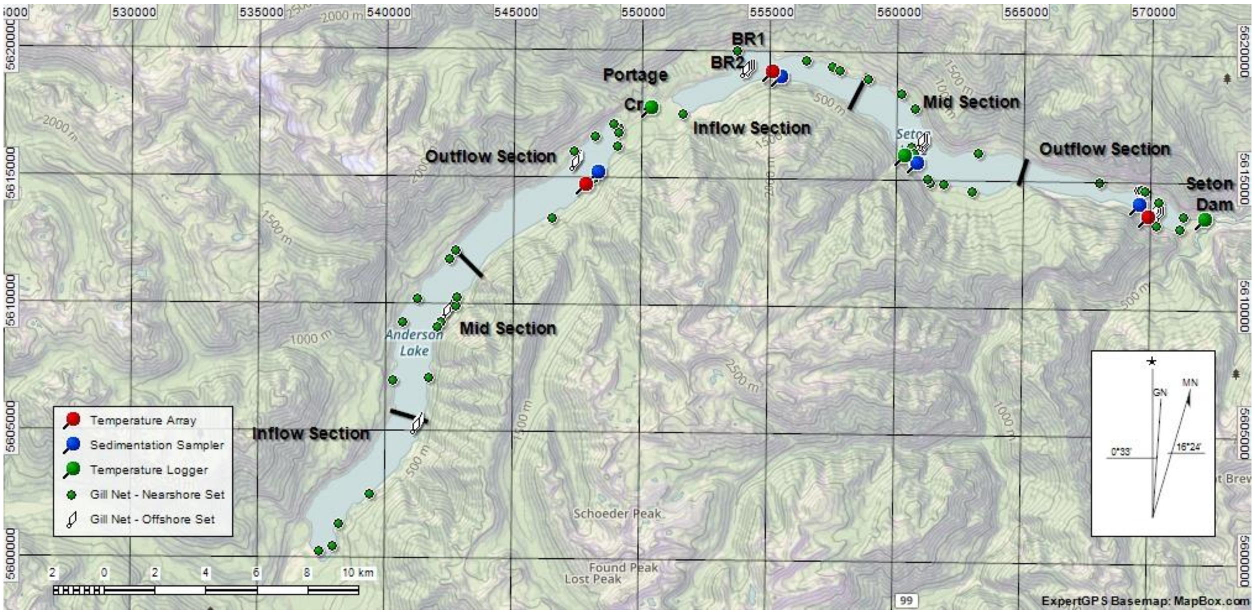

Figure 2.2 BRGMON-8 study area showing longitudinal sections and the locations of temperature arrays (red pins), sedimentation samplers (blue pins), and fish sampling locations (green dots and white markers) in Seton and Anderson lakes during Year 4 (2016). The locations of the Bridge 1 and 2 (BR1, BR2) 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.

2.4. Laboratory Analysis

To assist in developing an understanding of the life history and age class structure of the target resident fish populations in Seton and Anderson lakes, 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 Marylise Lefevre, M.Sc. (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.

2.5. 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 to 3 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 were provided by BC Hydro for the period 1 January to 31 December for each study year to-date (Figure 3.1).

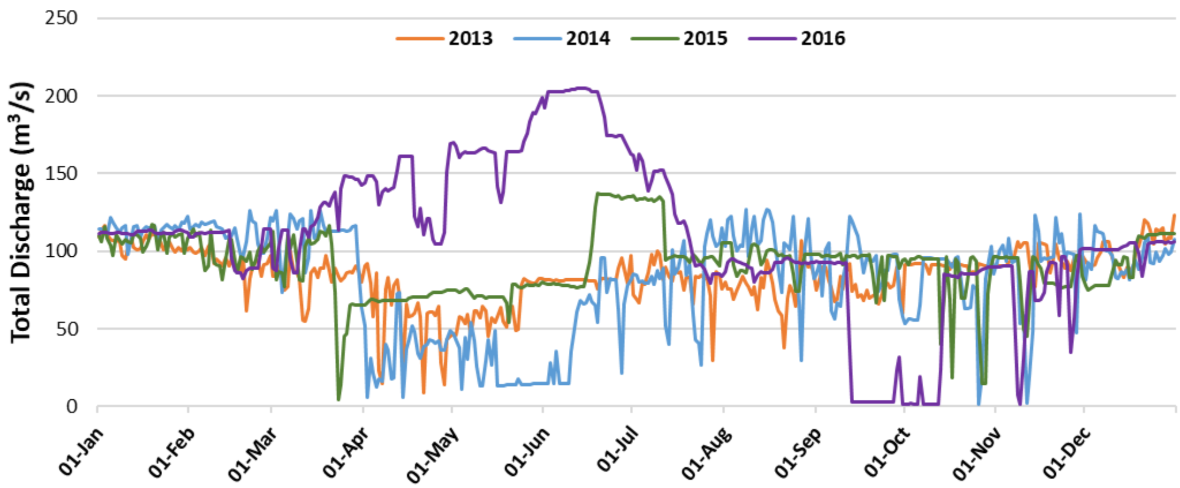

Figure 3.1 Mean daily discharges from Bridge 1 and Bridge 2 Generating Stations into Seton Lake, January to December (2013 - 2016).

Peak diversion discharges in Year 4 (2016) were between 202 and 204 $m^3 \cdot s^{-1}$ from late May to mid June, which was substantially higher than peak flows in any previous study year. On a daily basis, maximum and minimum outflow varied by 111 $m^3 \cdot s^{-1}$ on one date in Year 4 (13 March 2016) when the units were cycled between on and off. However, overall, the amount of daily cycling throughout the year was much lower than what has been implemented in past study years (i.e., 2013 to 2015; Sneep 2015). Outside of the peak discharge period in spring, mean diversion flows were fairly consistent between ~80 and ~120 $m^3 \cdot s^{-1}$, other than a period of very low discharges during fall (i.e. from mid September to mid October, and briefly in November).

BR1 and BR2 generating station discharges (i.e., Carpenter diversion inflows) in Year 4 (2016) reflected some differences in natural conditions (e.g., an earlier freshet timing) and management decisions related to mitigation of identified Bridge-Seton hydroelectric system constraints (described in Section 1.4), relative to previous study years. The higher discharges which started at the end of March and continued until the end of July in 2016 were caused by the magnitude and timing of inflows into the system that year, combined with reduced storage capacity in Downton Reservoir.

Reduced diversion inflow volumes in fall were related to an increased number of extended (i.e., ≥24-hour) station outages for that season than in previous years. Table 3.1 provides a summary of "outages" among study years for comparison. Since outages can be brief (i.e., <1-hour duration), they are not always reflected as a zero value in the hourly discharge record. For this reason, we conservatively tallied the number of hours per month when mean hourly discharge was <20 $m^3 \cdot s^{-1}$ (combined for all generating units) to reflect the relative number of hourly periods that included a shutdown (or near shutdown) of all units.

Table 3.1 Summary of the number of hourly "outages" (periods when mean hourly discharge was <20 $m^3 \cdot s^{-1}$ combined total for all generating units) and ≥24-hour outages (shown in brackets) by season and study year.

Season	# of Hourly Outages (and ≥24-hour Outages) by Study Year			
	Year 1 (2013)	Year 2 (2014)	Year 3 (2015)	Year 4 (2016)
Spring	416 (1)	1220 (27)	66 (1)	0 (0)
Summer	409 (0)	283 (0)	0 (0)	206 (8)
Fall	26 (0)	238 (2)	103 (2)	558 (21)
Winter	94 (0)	5 (0)	63 (0)	1 (0)
All Seasons	**945 (1)**	**1746 (29)**	**232 (3)**	**765 (29)**

These results were also reflected in the comparison of cumulative diversion discharge by season (Figure 3.2), which confirmed that the highest proportion of water was released during spring and the lowest during fall, with summer and winter seasons being about equal. Based on a comparison among years, the amounts for spring and fall in Year 4 (2016) were higher and lower, respectively, than the typical volumes for these seasons in past study years, and the total discharge volume (2016 = 3,449 million m^3) was the higher by 17% to 25% than any other year included in the comparison (2013 = 2,645; 2014 = 2,593; and 2015 = 2,878 million m^3).

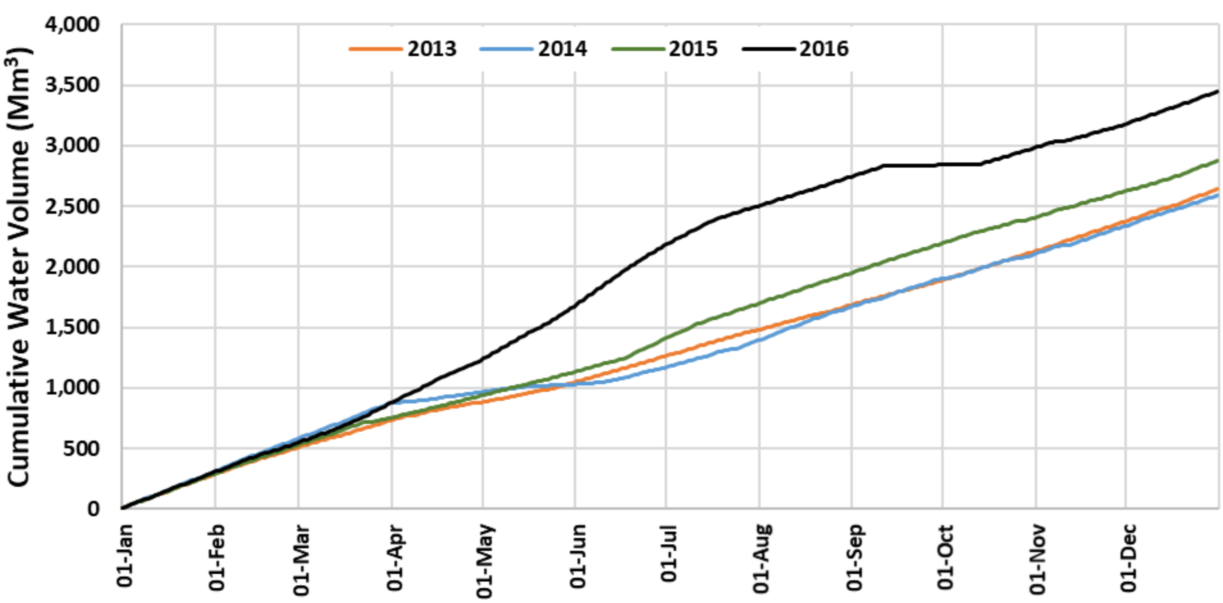

Figure 3.2 The daily cumulative inflow volume from the Bridge 1 and 2 Generating Stations, 2013 to 2016.

Under the terms included in the Water Use Plan, the licensed operating range for Seton Lake is between 235.76 and 236.36 m (measured in the vicinity of BR1) to manage water storage for generation, fish habitat, and to reduce foreshore erosion rates (BC Hydro 2011). Assessment of surface elevations in Seton Lake among years has not revealed any obvious seasonal patterns (Figure 3.3). The total range of elevations is low relative to other reservoirs in the system (i.e., Carpenter and Downton); the most observed was 0.48 m between minimum and maximum levels in 2016. The maximum *daily* rate of change observed has been between 16 and 21 cm for each study year. The lowest elevation in 2016 was recorded from 26 to 28 September (235.90 meters above sea level (masl)) and the highest was 236.38 masl for less than a day on 18 April 2016. Slight differences in elevation between reported values and the terms in the WUP may be due to differences between the current measurement location (forebay of Seton Dam) versus the compliance location (in the vicinity of BR1).

In terms of the range of elevations among years, Seton Lake levels were only below 236.1 masl (the approximate mid-point of the observed range) less than 10% of the time for study years 1 to 3 (2013 to 2015). In Year 4 (2016), the levels were below 236.1 masl about 17% of the time, largely due to an extended period of low levels from mid September to mid October (coinciding with the time period when BR1 and BR2 output was low that year). However, other than this period in the fall, the operation of lake levels was generally within the same range as past years (i.e., within the top 0.25 m from the maximum elevation most of the time).

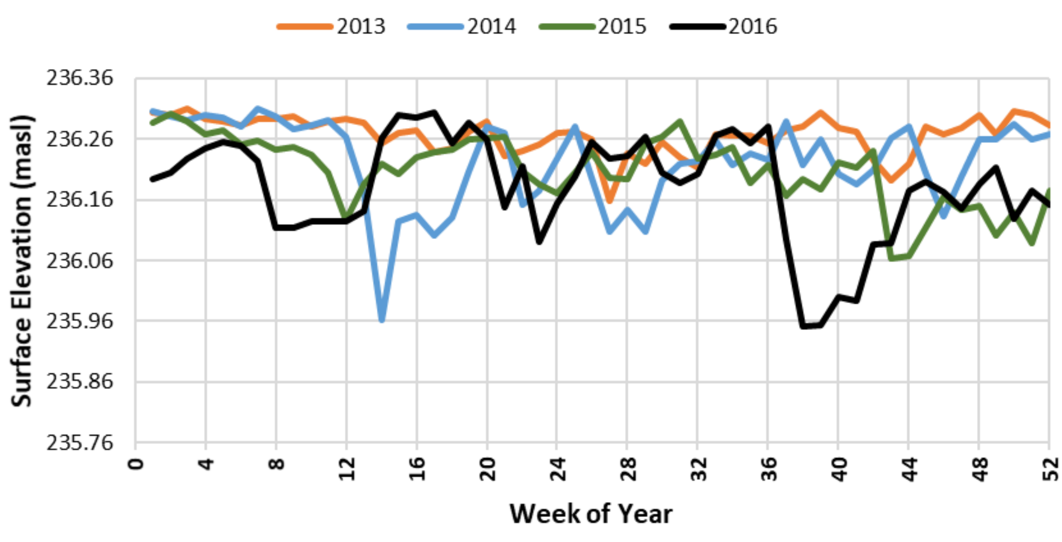

Figure 3.3 Mean weekly surface elevations of Seton Lake recorded in the forebay of Seton Dam across the year, 2013 to 2016. Note: the y-axis range spans the licensed operating range referenced in the Water Use Plan (BC Hydro 2011).

Thermal Profile Monitoring

Year 4 (2016) monthly water temperatures for the January to December period at a range of depths in the outflow end of Anderson Lake, and the inflow and outflow ends of Seton Lake, are displayed in Figure 3.4. Since temperature monitoring for the BRGMON-8 program was initiated at the end of July 2015 (i.e., mid-way through Year 3), there have not been enough data collected to make comparisons of any differences or trends among years, at this point yet.

Consistent with the normal lacustrine process of thermal stratification, significant temperature differences developed among the various depths across the seasons at each array location in both lakes. At the start of the year (in mid winter) temperatures within each lake were consistent at all depths, reflecting isothermic conditions of between 4° and 6°C. Beginning in April, the temperature profiles began to stratify. As expected, in both lakes the surface (or epilimnion) layer, had the highest degree of warming since it interfaces most directly with air temperatures and solar heating, relative to the deeper layers. Peak summer surface temperature was 24.0°C at the outflow end of Anderson Lake (on 25 August 2016), 17.4°C at the inflow end of Seton Lake (on 28 August 2016), and 21.8°C at the outflow end of Seton Lake (on 16 August 2016). At each monitoring location in both lakes, turn over in the fall (collapse of stratification) progressed across the month of November, as mixing among layers occurred and the lakes returned to a fully isothermic condition by early December.

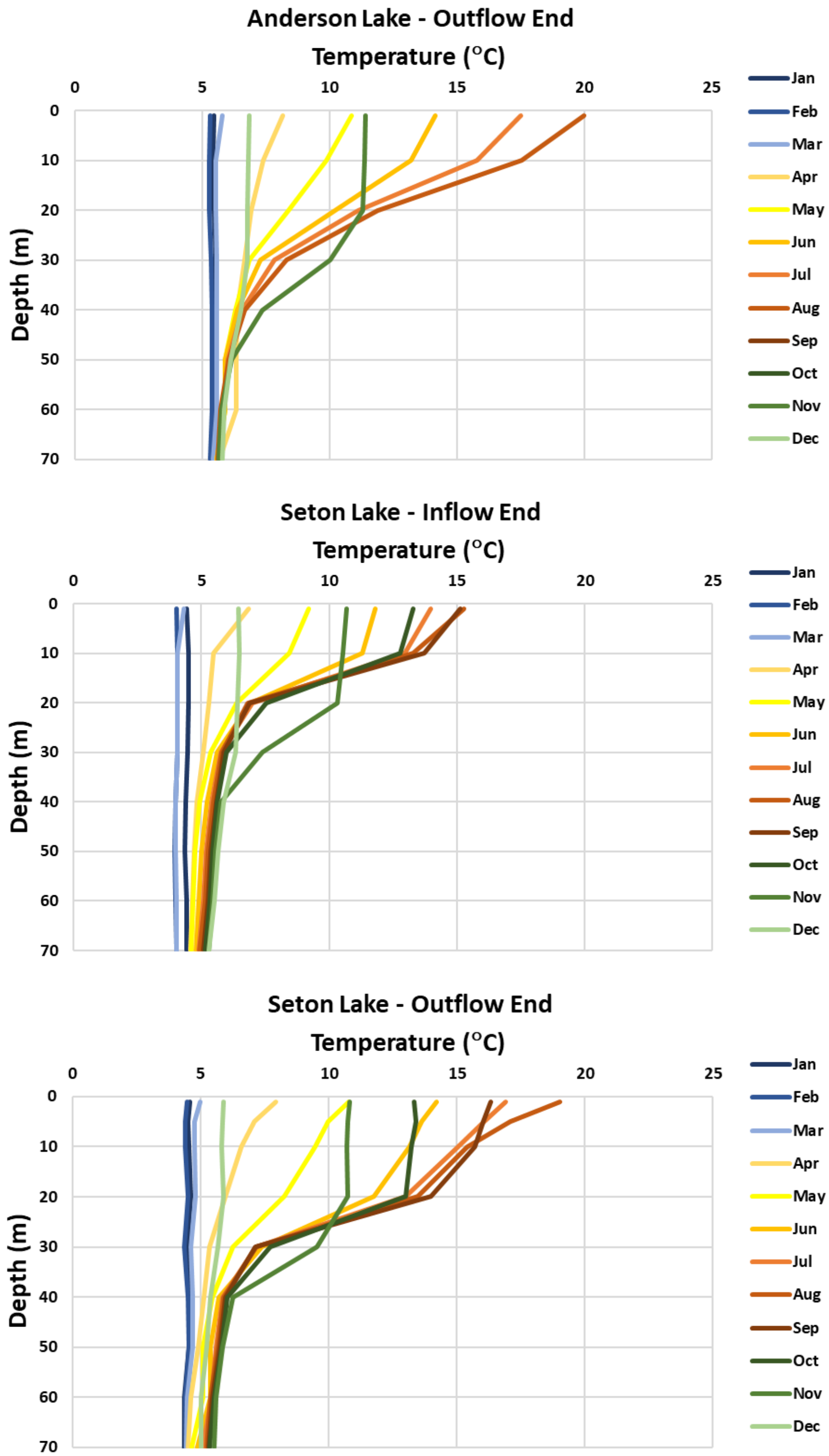

Figure 3.4 **Mean monthly water temperature profiles recorded in Anderson Lake (outflow end; top), and at the inflow (middle) and outflow (bottom) ends of Seton Lake from January to December 2016.**

In both Seton and Anderson lakes the mid (or metalimnion) layer had the greatest temperature differential by increment of depth of any layer, particularly from June to October when stratification was most established. However, the amount of warming and overall depth of this layer varied among array locations and between the lakes. The maximum differentials for the metalimnion were: 9.3°C (from 17.6° to 8.3°C between 10 m and 30 m depth) at the outflow end of Anderson Lake; 6.8°C (from 13.7° to 6.9°C between 10 m and 20 m depth) at the inflow end of Seton Lake; and 6.9°C (from 14.0° to 7.1°C between 20 m and 30 m depth) at the outflow end of Seton Lake. Temperatures in the deepest (hypolimnion) layer were the most stable, changing by ≤ 5°C across the entire year.

As noted in the Year 3 (2015) report, the depths of the epilimnion, metalimnion, and hypolimnion layers varied to some extent by location, within the limits of precision based on the logger depth intervals (Table 3.2). The epilimnion extended from the surface to ~10 m depth at both the outflow end of Anderson and the inflow end of Seton, whereas it extended deeper (to ~20 m) at the outflow end of Seton Lake. The metalimnion layer in Anderson Lake was thicker, spanning 20 m (from 10 m to 30 m below the surface), whereas it was narrower in Seton Lake (spanning 10 m below the depths of the epilimnion layer at each end of the lake). The top of the hypolimnion layer was shallower at the inflow end of Seton Lake (>20 m depth) than at the outflow end of either lake (>30 m depth).

Table 3.2 Summary of depths (in meters) for the epilimnion, metalimnion and hypolimnion at each monitoring location in Anderson and Seton lakes during the period of thermal stratification (May to November) in Year 4 (2016).

Month	Epilimnion			Metalimnion			Hypolimnion		
	SL Inflow	SL Outflow	AL Outflow	SL Inflow	SL Outflow	AL Outflow	SL Inflow	SL Outflow	AL Outflow
May	0-10	0	0	10-30	0-30	0-30	>30	>30	>30
Jun	0-10	0-20	0-10	10-20	20-30	10-30	>20	>30	>30
Jul	0-10	0-20	0-10	10-20	20-30	10-30	>20	>30	>30
Aug	0-10	0-20	0-10	10-20	20-30	10-30	>20	>30	>30
Sep	0-10	0-20	- [a]	10-20	20-30	-	>20	>30	-
Oct	0-10	0-20	-	10-20	20-30	-	>20	>30	-
Nov	0-20	0-20	0-20	20-40	20-40	20-40	>40	>40	>40
All	**0-10**	**0-20**	**0-10**	**10-20**	**20-30**	**10-30**	**>20**	**>30**	**>30**

[a] Data for September and October were not available for Anderson Lake in 2016 because array had been pulled ashore by a member of the public during that period.

Sedimentation Monitoring

The rate of sedimentation (mg dry weight accumulated per day) was highest at the inflow end of Seton Lake (66 to 133 mg/day), which is closest to the diversion inputs, and lowest in the Anderson Lake samples (6 to 10 mg/day), which are outside the influence of the Carpenter diversion (Figure 3.6). The rate of sedimentation diminished from the inflow to the mid section, and further from the mid to the outflow section. Rates in the mid section ranged from 38 to 76 mg/day, and in the outflow section from 25 to 56 mg/day. This sedimentation gradient was maintained across each sampled season.

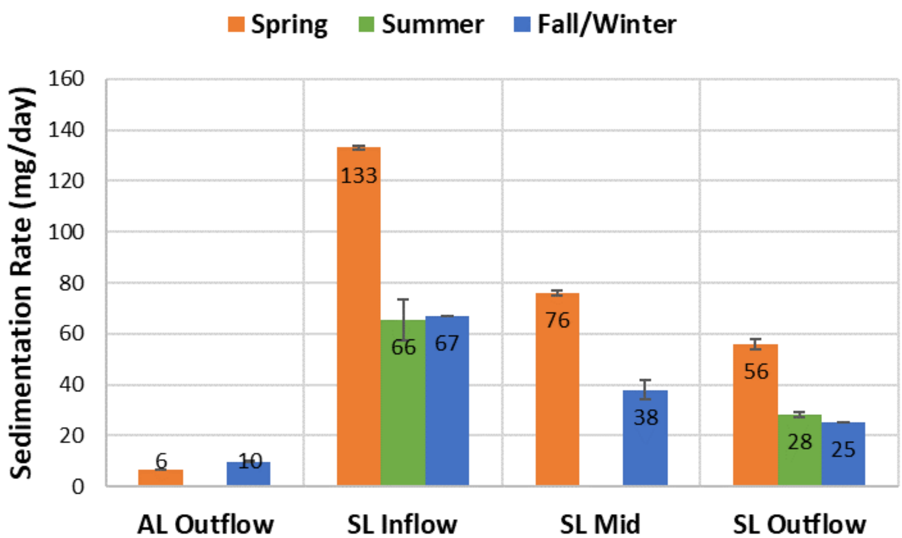

Figure 3.6 Mean sedimentation rate by sampler location (longitudinal zone) and season during Year 4 (2016). AL = Anderson Lake; SL = Seton Lake. The error bars represent ± 1 SD among the replicates for each sample. Spring samples were collected from 28 April to 14 July 2016; Summer samples were collected from 14 July to 28 October 2016; Fall/Winter samples were collected from 28 October 2016 to 25 May 2017.

In all Seton Lake sections, the rates of sedimentation were greatest in spring, corresponding with high water diversion rates from Carpenter Reservoir during that season in 2016 (mean = 162 $m^3 \cdot s^{-1}$; Section 3.1). Summer and fall/winter sedimentation rates were approximately half the spring rates in each lake section when Carpenter diversion rates were lower (means = 102 and 87 $m^3 \cdot s^{-1}$, respectively; Section 3.1). Sedimentation rates in the summer and fall/winter were equal. Sedimentation rate values for the summer samples in the outflow end of Anderson Lake and the mid section of Seton Lake were not available due to sampling error.

To supplement the analysis by season, a comparison of sediment accumulation (measured as dry weight of sediment in each sample) in Seton Lake with the total volume of water diverted from Carpenter Reservoir during each sampling interval was also generated (Figure 3.7). Although the results are limited to 2016, the accumulation of sediments is positively correlated with diversion volume, and the slope of the regressions varied according to longitudinal zone. The highest slope for this relationship was for the sampler nearest the diversion inflow, and the lowest was at the outflow end of Seton Lake. In fact, relative to the outflow end, the slope was ~3 times greater at the inflow end, and ~2 times greater in the mid section. In other words, the accumulation increases at a greater rate with diversion volume nearest the inflow than it does with increasing distance down the lake.

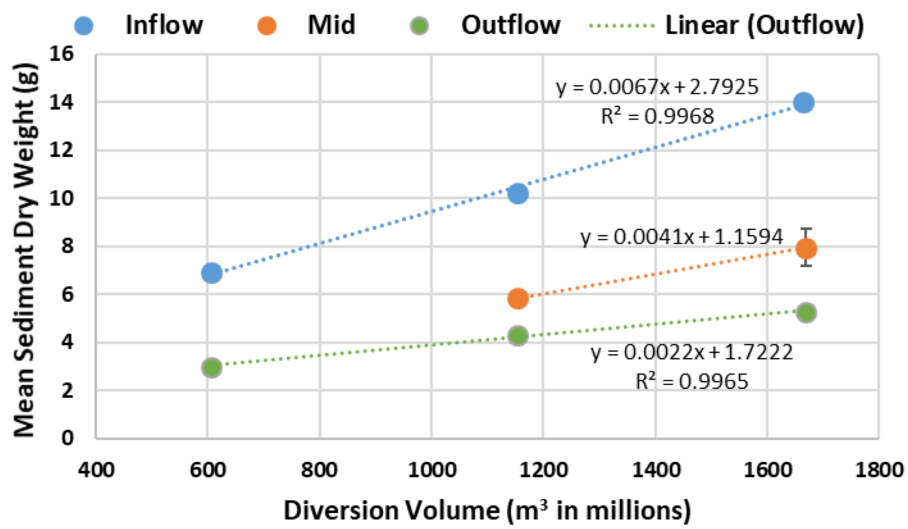

Figure 3.7 Sediment accumulation in each longitudinal zone (i.e., inflow, mid, and outflow) of Seton Lake according to diversion volume from Carpenter Reservoir. Linear regressions based on values for Year 4 (2016) samples and R^2 values are shown.

Particle size analysis, found that the majority of the sediment being deposited was comprised of the smallest particle size classes, with clay and silt particles forming the majority of the sediment (>97%; Figure 3.8). Since the samplers were deployed for the first time this year, there were not enough size composition data to reliably determine trends among locations at this point; however, clay was slightly more prevalent in the mid and outflow samplers, and silts were slightly more prevalent at the inflow end. These data were not available for Anderson Lake because the sample sizes from this context did not meet the minimum size requirements for this analysis at the lab.

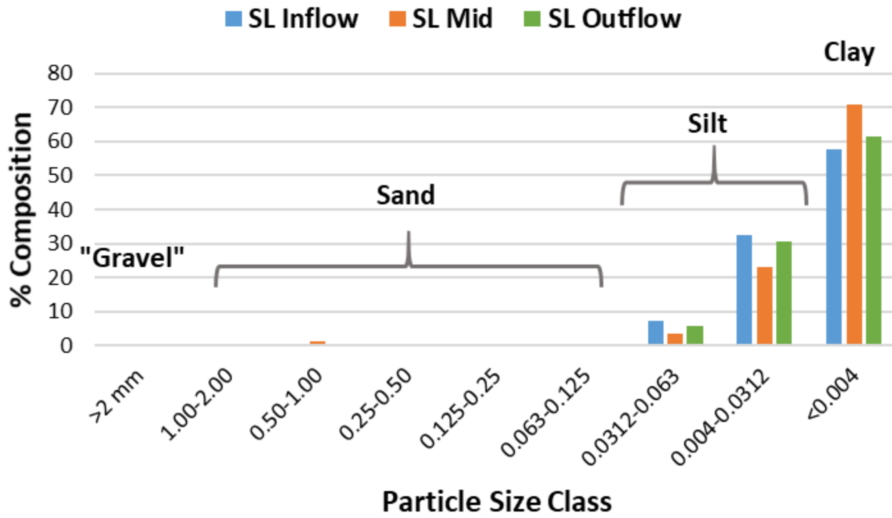

Figure 3.8 Sediment particle size distribution from samples collected in each longitudinal zone (inflow, mid, and outflow) of Seton Lake in Year 4 (2016). Samples for each season were aggregated to reach minimum sample size for this analysis.

Total organic carbon was also assessed by the lab to determine the percent contribution of carbon-based organic content to the sediment accumulation (Figure 3.9). Based on the results from the Year 4 (2016) samples, the pattern for organic content was the reverse of that described (above) for the inorganic (sediment) content. Highest organic contribution was in the Anderson Lake outflow samples, and the lowest was in Seton Lake, with a slightly increasing pattern from the inflow to the mid and outflow sections of the lake. The generally low organic content confirms that the accumulated materials, as measured by total dry weight, are predominantly comprised of inorganic sediments (as opposed to decaying organic materials), particularly for the Seton Lake samples.

Sedimentation rate data will continue to be collected in future years. Ideally, samples collected across a range of operational conditions will continue to augment these relationships and strengthen the conclusions drawn from them by the end of the monitor.

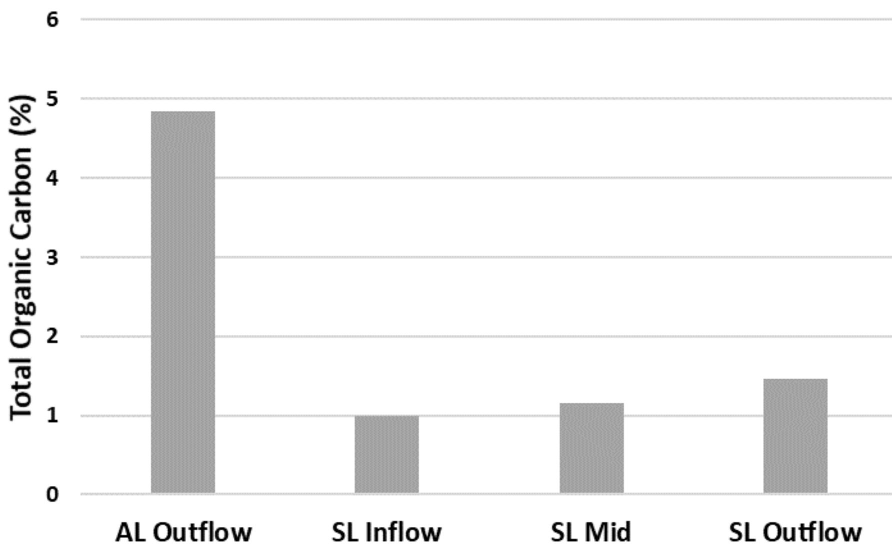

Figure 3.9 The contribution of total organic carbon by location to the Year 4 (2016) sedimentation samples.

3.2. Movement Monitoring Using Radio Telemetry

A total of 10 bull trout and 1 rainbow trout were implanted with radio tags in Anderson Lake during May of Year 4 (2016; Table 3.3). Of these fish, 3 bull trout were captured at the mouth of Gates Creek (at the inflow end of the lake), and 7 bull trout and the rainbow trout were captured at, or near, the outflow into Portage Creek. In addition, 30 bull trout and 15 rainbow trout were radio tagged in Seton Lake as a part of the Seton Entrainment study efforts (Burnett and Parkinson 2018). For the bull trout tagged in Seton Lake, 16 were captured in the approach channel above Seton Dam (outflow end of the lake) and 14 were captured below the BR1 Generating Station (inflow end of the lake). For the rainbows, 6 were captured in the approach channel above Seton Dam, and the remaining 9 were captured at various locations throughout Seton Lake. Refer to the Seton Entrainment report (referenced above) for more information on the results of that study.

Receivers in Lower Gates Creek detected 5 tagged bull trout in 2016; 4 of these were originally captured in Anderson Lake and 1 had been captured in Seton Lake (Figure 3.10). An additional 2 tagged bull trout were detected during the weekly mobile tracking surveys in Portage Creek; 1 of these was from Anderson Lake and 1 was from Seton Lake. Also, 1 bull trout tagged at the outflow end of Anderson Lake was subsequently detected in the inflow end of Seton Lake (directly across from the BR1 Generating Station) on one occasion in 2016 (30 September). The single rainbow trout radio tagged in Anderson Lake on 5 May (forklength = 390 mm; weight = 606 g; Age 7) was not subsequently detected by any of the telemetry equipment in Year 4.

Table 3.3 Capture information for bull trout radio tagged in Anderson Lake in Year 4 (2016). Detection information is noted for fish subsequently recorded by the fixed telemetry station in Gates Creek or mobile tracking in Portage Creek.

Capture Information					Detection Information	
Date (2016)	Lake Section	Length (mm)	Weight (g)	Age[a]	Date(s) (2016)	Location
5 May	AL Outflow	410	475	5	30 Sep	SL Inflow
5 May	AL Outflow	485	907	5	Not detected	
11 May	AL Outflow	600	2151		14 Sep to 6 Oct	Portage Cr.
11 May	AL Outflow	535	1387		6 Oct	Gates Cr.
11 May	AL Outflow	535	1158		Not detected	
11 May	AL Outflow	540	1319		9 to 12 Sep	Gates Cr.
11 May	AL Outflow	630	2150		Not detected	
18 May	AL Inflow	499	1340	6	25 Sep	Gates Cr.
18 May	AL Inflow	400	641	6	Not detected	
18 May	AL Inflow	527	1564	5	5 Oct	Gates Cr.

[a] Age provided where it was determined by lab analysis of fin ray section.

The timing of detections for the tagged bull trout in 2016 (9 Sep. to 6 Oct.) suggested that they likely reflected movements associated with spawning migration for at least 5 of the 6 Anderson Lake fish. Though the sample size was small, the detection locations indicated that a higher proportion migrated into Gates Creek than Portage Creek.

Of the fish captured in Seton Lake, 20 of 30 tagged bull trout and 4 of 15 rainbow trout were detected at the top of the approach channel (i.e., the Seton Lake outflow) or below. Three of these bull trout were entrained at Seton Dam and subsequently detected in the Seton River and 7 bull trout were entrained through the Seton Generating Station. None of the fish tagged in Anderson Lake were detected by the radio telemetry stations at the outflow end of Seton Lake.

To summarize, there was evidence that 4 out of 10 radio tagged bull trout in Anderson Lake moved in a generally upstream direction between capture and detection events, and 2 out of 10 moved in a downstream direction (but not further than the inflow end of Seton Lake; Figure 3.11). On the other hand, of the 30 tagged bull trout in Seton Lake, only 2 were detected upstream of that lake (1 in Portage Creek and 1 in Gates Creek), whereas movements for 20 were detected downstream of the outflow end (i.e., Seton Dam approach channel; Burnett and Parkinson 2018), suggesting a higher proportion of downstream movement out of Seton Lake than upstream movement for those fish.

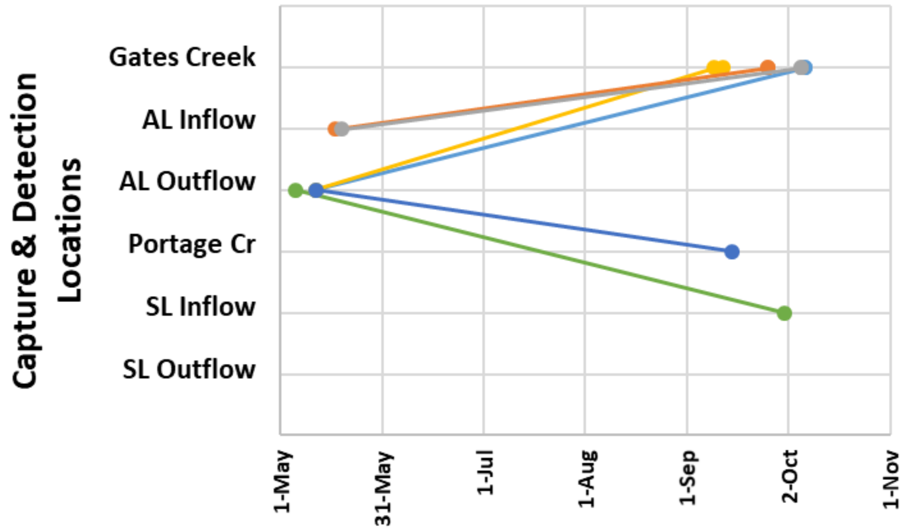

Figure 3.11 Record of dates and locations for Anderson Lake bull trout captures (dots on the left) and subsequent detection by telemetry equipment (dots on the right). Each set of coloured dots is for a uniquely tagged fish. Lines are included to show overall trajectory of movement between capture and detection events.

3.3. Resident Fish Population Index Survey

A total of 470 fish were captured by gill netting during the annual resident fish index survey in Year 4 (2016; Seton Lake *n*= 334; Anderson Lake *n*= 136), including 9 resident species (Table 3.4). Target species made up 68% of the catch, and the other 32% were non-target species including: northern pikeminnow, peamouth chub, redside shiner, mountain whitefish, and bridgelip sucker (in decreasing order of abundance). Thirty-three sites were sampled in Seton Lake, including 24 nearshore and 9 offshore sets; and 31 sites were sampled in Anderson Lake, including 22 nearshore and 9 offshore sets. The total sampling effort was 304.2 net-hours (Seton Lake = 154.2 net-hours; Anderson Lake = 150.0 net-hours), or approximately 50 net-hours for each longitudinal section in each lake.

Table 3.4 Catch totals for all resident fish species from gill net sampling in Seton and Anderson lakes in Year 4 (2016).

Lake	Species[a]								
	BT	GW	ON	RB	MW	PMC	NSC	BSU	RSC
Seton	7	182	45	0	3	32	52	3	7
Anderson	37	30	11	8	3	5	42	0	0
Totals	**44**	**212**	**56**	**8**	**6**	**37**	**94**	**3**	**7**

[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.

Thirty bull trout (Seton Lake *n*= 2; Anderson Lake *n*= 28), six rainbow trout (all in Anderson Lake), and five mountain whitefish (Seton Lake *n*= 2; Anderson Lake *n*= 3) 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 (i.e., 2013 to 2015; *n*= 70) were recaptured in Year 4 (2016).

The highest catch-per-unit-effort (CPUE, or catch rate) values for bull trout, gwenis (including O. nerka juveniles), and rainbow trout were generally in nearshore nets (Table 3.5). In Seton Lake, a substantially higher proportion of gwenis were sampled in nearshore sets because the survey timing corresponded with the start of spawning for that population. Spawning locations were in the range of the nearshore nets along the lake bottom. In Anderson Lake, juvenile gwenis were primarily captured in nearshore sets; whereas, mature gwenis were distributed in offshore (pelagic) habitats. Bull trout distribution reflected the locations of their dominant food items in each lake (i.e. mature gwenis in Seton Lake; juvenile O. nerka and sockeye eggs in Anderson Lake). See more on catches by depth and distance from shore, and bull trout stomach contents in the sub-sections that follow. Rainbow trout distribution tended to be oriented around creek mouths and shallower habitats (<25 m) in the littoral zone, but catches for this species were low in both lakes.

Table 3.5 Summary of fish catch-per-unit-effort results for target species during the annual resident fish population indexing survey, 27 September to 7 October 2016.

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	2.5	0.4	17.7	15.8	5.1	2.4	-	-
	Mid	3.1	0.2	72.3	2.9	3.1	5.5	-	-
	Outflow	-	0.4	93.5	6.7	-	0.7	-	-
Seton Lake Average		**2.0**	**0.3**	**57.7**	**8.5**	**2.9**	**2.9**	**0**	**0**
Anderson Lake	Inflow	61.5	0.2	-	2.3	-	-	10.3	0.2
	Mid	39.1	0.2	-	0.9	21.3	1.1	-	1.1
	Outflow	33.2	0.2	-	3.2		-	-	-
Anderson Average		**42.1**	**0.2**	**0**	**2.1**	**7.4**	**0.4**	**2.5**	**0.4**

[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 nearshore habitats at the outflow end of Seton Lake, followed by the mid section and then the inflow section, in decreasing order (Figure 3.12). Relative to the nearshore, gwenis were generally much less abundant in offshore catches in Seton Lake. Catches of gwenis in Anderson Lake were much lower in each section than in Seton Lake, and they were exclusively in offshore habitats. Juvenile *O. nerka* were also captured, and they were most abundant in the mid section of Anderson Lake (offshore habitat), followed by the inflow and mid sections of Seton Lake (in both nearshore and offshore habitats).

It was not possible to differentiate these juvenile *O. nerka* as gwenis vs. sockeye progeny in the field. However, the results of analyses included under BRGMON-6 provide a useful description of size classes based on scale ageing, and stock origin based on DNA analysis (Limnotek 2015). They determined a probability for each captured fish whether it belonged to one of three stocks: Portage Creek sockeye, Gates Creek sockeye, or gwenis (total P=100%). Most of their juvenile fish (195/204) collected during a summer survey were identified to a specific stock with a >80% probability and no identified fish had <56% probability of belonging to that stock. According to their assessment, all of the *O. nerka* greater than 75 mm were identified as gwenis (Limnotek 2015). Since all of the *O. nerka* captured for the BRGMON-8 program were ≥130 mm, all of these fish can likely be considered gwenis based on size.

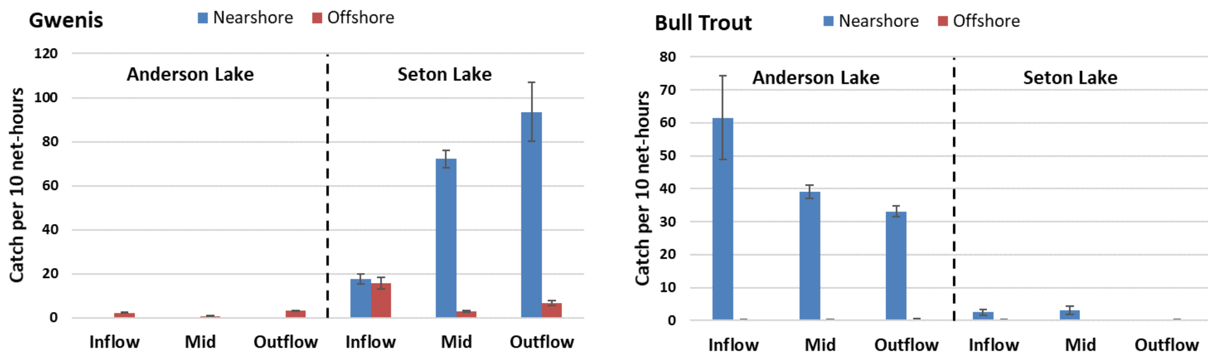

Figure 3.12 Catch-per-unit-effort summary for gwenis (left) and bull trout (right) comparing nearshore vs. offshore habitats in each longitudinal zone for Seton and Anderson lakes based on Year 4 (2016) sampling.

Between the two lakes, bull trout showed the opposite pattern of catch rates to gwenis. CPUEs were much lower in Seton Lake than in Anderson Lake. Nearly all of the catch for this species was in the nearshore sets in both lakes. In Seton lake, equivalent catches occurred in the inflow and mid sections, and lowest catches were in the outflow end. In Anderson Lake, catch rates for bull trout were highest at the inflow end of the lake, followed by the mid and outflow sections (Figure 3.12).

As in previous years, catches of rainbow trout were low with no rainbow trout captured in Seton Lake sampling in 2016. A total of eight rainbow trout were captured in Anderson Lake (198 to 431 mm). The highest CPUE for this species was in the inflow end of Anderson Lake (i.e., 10.3 fish per 10 net-hours), largely driven by catches at the mouth of Gates Creek. Due to the consistently low catches, particularly in Seton Lake, this species will likely not be assessed for trends in CPUE by monitoring year, lake section, or diversion inflows as performance metrics for this program.

A summary of CPUE values by longitudinal section of each lake, for the available monitoring years to-date, is provided in Figure 3.13. Fish sampling in Years 1 & 2 (2013 & 2014) was conducted by boat electrofishing around the perimeter of Seton Lake only. The catch rates for target species in those years were very low and not comparable with the gill netting method initiated in Year 3 (2015) and going forward, so they were not included in the figure.

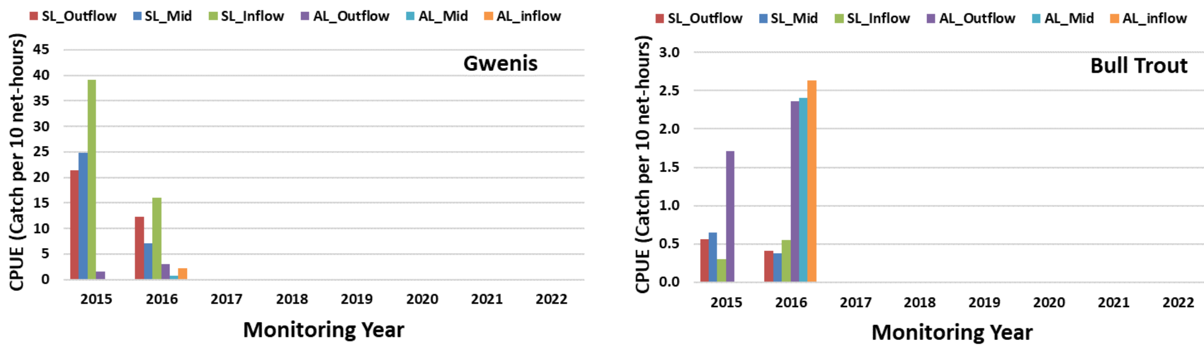

Figure 3.13 Catch-per-unit-effort summary for gwenis (left) and bull trout (right) by longitudinal zone in Seton and Anderson lakes for each monitoring year from 2015 (Year 3) to 2022 (Year 10). Values for years 1 and 2 (2013 & 2014) were not applicable to this summary because sampling was done by boat electrofishing in those years.

Catch rates for gwenis were higher for each longitudinal zone in Year 3 (2015) than in Year 4 (2016). However, all net sets were left in overnight in Year 3, which spans the diel period of vertical migration for gwenis, resulting in higher catch rates for this species by the passive gill net method, but coincidentally also much higher mortality rates (i.e., near 100%). In Year 4, sampling in nearshore habitats (where highest catch rates tend to occur) was changed to short-duration sets in the interest of reducing the mortality rate, given that this sampling is intended to continue for multiple years. This approach was effective for reducing mortality (and expanding the number of sites that could be sampled) in 2016; however, catch rates for gwenis were also lower as a result. For every year going forward, the plan is to maintain the sampling methods and effort employed in Year 4 (2016) to ensure the direct comparability of results across years, within the limits of our control.

Catches by depth and distance from shore

Bull Trout and gwenis were captured across a broad range of depths in Year 4 (2016; Figure 3.14). For gwenis in Seton Lake, their distribution spanned the range of sampling depths. Approximately 6% of the gwenis were captured in the epilimnion thermal layer (0 to 20 m depth), 69% were in the narrow metalimnion (20 to 30 m), and 25% were in the sampled portion of the hypolimnion (30 to 50 m); Over 90% tended to be below 20 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. Bull trout in Seton Lake also tended to be fairly deep and, though catch numbers were relatively small, their depth distribution appeared to correlate with the depths where gwenis abundance was the greatest (i.e., the metalimnion). This pattern was also evidenced in the distance from shore distribution, which reflected that the bull trout tended to be found in panels that also captured gwenis. Stomach content assessment also identified exclusively mature gwenis in bull trout stomachs, further documenting that Seton Lake bull trout are targeting gwenis (more on this in bull trout stomach contents sub-section, below).

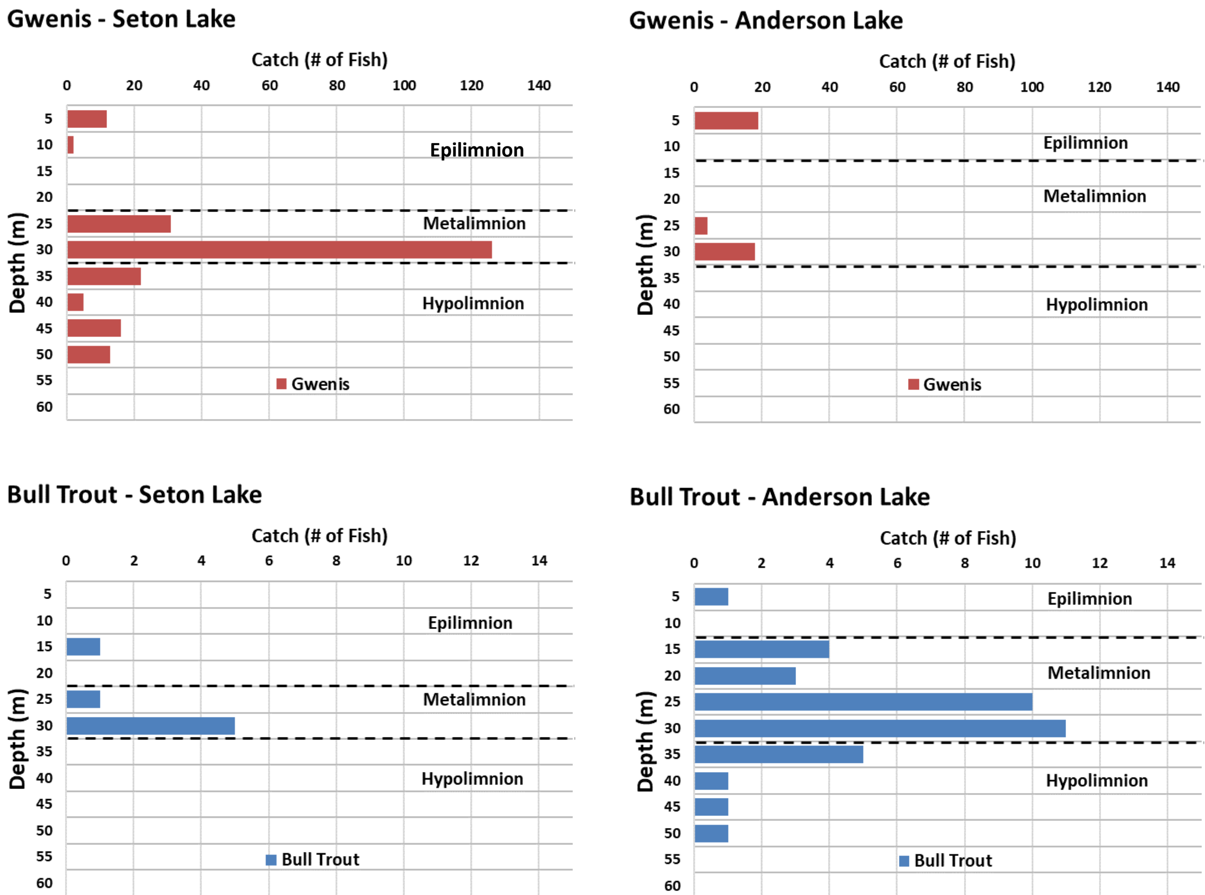

Figure 3.14 Numbers of gwenis (upper plots) and bull trout (lower plots) by capture depth in Seton Lake (left) and Anderson Lake (right) during the annual population indexing survey in Year 4 (2016). Note the different x-axis scales between upper and lower plots.

In terms of horizontal distribution from shore, the majority (90%) of gwenis in Seton Lake tended to be >60 m from the lake edge (Figure 3.15). The proportion that were ≤15 m from shore represented *O. nerka* juveniles, some of which rear in the shallows.

In Anderson Lake, adult gwenis (which were not in spawn-ready condition at the time of the survey) were exclusively captured within the metalimnion thermal layer in offshore net sets (>100 m horizontal distance from shore). As in Seton Lake, the *O. nerka* caught in <5 m depth and ≤15 m from shore were likely immature gwenis based on size (≥130 mm).

Anderson Lake bull trout were distributed across a much wider range of depths than in Seton Lake, but were similarly most abundant within the metalimnion layer (which is broader in Anderson Lake, spanning from ~10 m to ~30 m below the surface). They also tended to be fairly widely distributed across the range of sampled distance from shore, but the highest proportion (i.e., 79%) were between 45 and 75 m from the lake edge. The numbers tended to diminish with increasing distance beyond that and, notably, the distance from shore pattern reflected that the spatial distribution of bull trout and gwenis did not overlap in this lake at all.

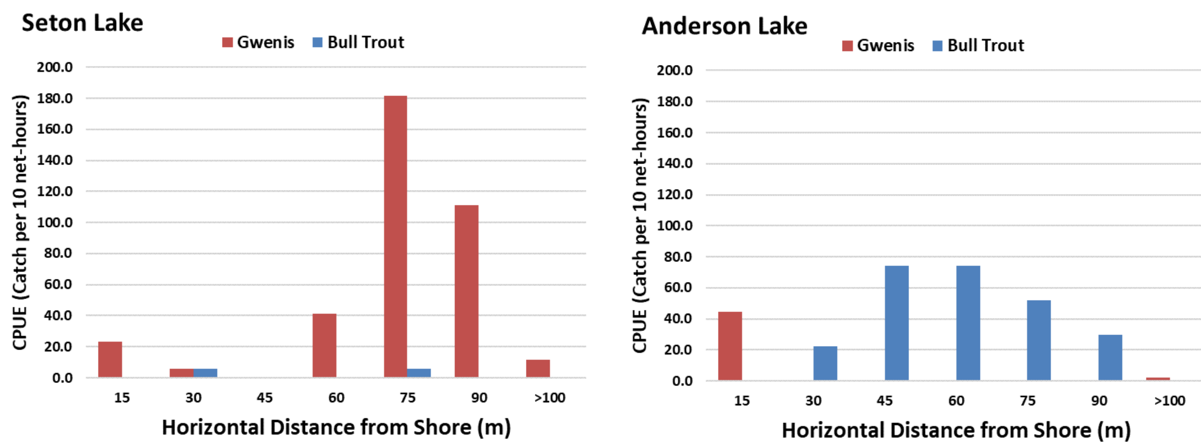

Figure 3.15 CPUE for gwenis (red columns) and bull trout (blue columns) by horizontal distance from shore in Seton Lake (left) and Anderson Lake (right) during the annual population indexing survey in Year 4 (2016). Note: Distances less than 100 m are from nearshore sets; offshore sets are represented by the >100 m column.

Size-at-Age

Juvenile gwenis (Age 1 and 2) based on the scale ageing results were all <180 mm in Seton Lake and <200 mm in Anderson Lake (Figure 3.16). Minimum sizes in the sample were 95 mm and 131 mm for each lake, respectively, which represented the minimum size limitation of the sampling gear rather than the smallest size of this species in the two lakes. In Seton Lake, all of the mature gwenis were Age 3, the same as what was reported for the Year 3 (2015) results, as well as the BRGMON-6 ageing results (Limnotek 2015), and ranged narrowly in size from 170 to 220 mm (median = 192 mm).

In Anderson Lake, the mature gwenis were up to 4 years old and larger than the Seton Lake fish, ranging in size from 203 to 342 mm (median = 234 mm and 305 mm for Ages 3 and 4, respectively). 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 (27 September to 7 October), further confirming that spawn-timing for this population is later (as previously reported in Morris et al. 2003, Limnotek 2015, and Sneep 2018) than the timing for the Seton Lake population.

Given that the gwenis spawn earlier in Seton Lake and temperatures at depth where they spawn are similar during the incubation period among the two lakes, it is likely that the new year class of gwenis emerge earlier in Seton Lake than in Anderson Lake. As a result, the Seton fish are larger than the Anderson fish in their first summer (Age 0+), owing to their earlier start in the growing season, as reported by BRGMON-6 (Limnotek 2015). However, the Anderson Lake gwenis appear to catch up in size after their first summer and are consistently larger at each age thereafter, likely due to much higher zooplankton abundance in Anderson Lake, which is their primary food source (Limnotek 2015). So, interestingly, the Seton Lake gwenis mature earlier (at Age 3) despite being smaller, and the Anderson Lake gwenis mature at Age 4 despite faster growth after Age 0+ (Figure 3.16).

For the bull trout sampled in Seton Lake (*n*= 7) in 2016, one was Age 3 (440 mm in length), four were Age 4 (380 to 535 mm), and two were Age 6 (400 & 590 mm) (Figure 3.17). More age classes were represented by the bull trout captured in Anderson Lake (i.e., Age 2 to Age 8), and they spanned a size distribution from 213 to 550 mm. We fitted a growth curve to the median values for the Anderson Lake fish using the von Bertalanffy growth equation:

$$L_t = L_\infty(1 - e^{-K(t-t_0)})$$

Where:

L_t = Length at Age $_t$
L_∞ (the "asymptotic length") = 597
K (the "curvature parameter") = 0.278
t_0 (the "initial condition parameter") = 0.477

The sample size of bull trout from Seton Lake was too small to estimate a growth curve or draw comparisons between lakes based on the combined set of Year 3 (2015) and Year 4 (2016) data. However, the median size values for bull trout have been consistently smaller in Anderson Lake than in Seton Lake (for each age that had a median length value for both lakes). As more length and age data become available for bull trout catches in future years, they will be added to this figure to update the von Bertalanffy growth curve for Anderson Lake, and possibly add a separate curve for Seton Lake bull trout so growth rates for the populations in each lake can be further compared.

A total of eight rainbow trout were captured in Year 4 (2016), and all of them were in Anderson Lake. They ranged in size from 198 to 431 mm. Scales were collected from 6 of them, but ages were not readable from 2 of those due to scale regeneration. The four fish that were aged were Age 4 (340 mm), Age 5 (325 and 369 mm), and Age 7 (431 mm).

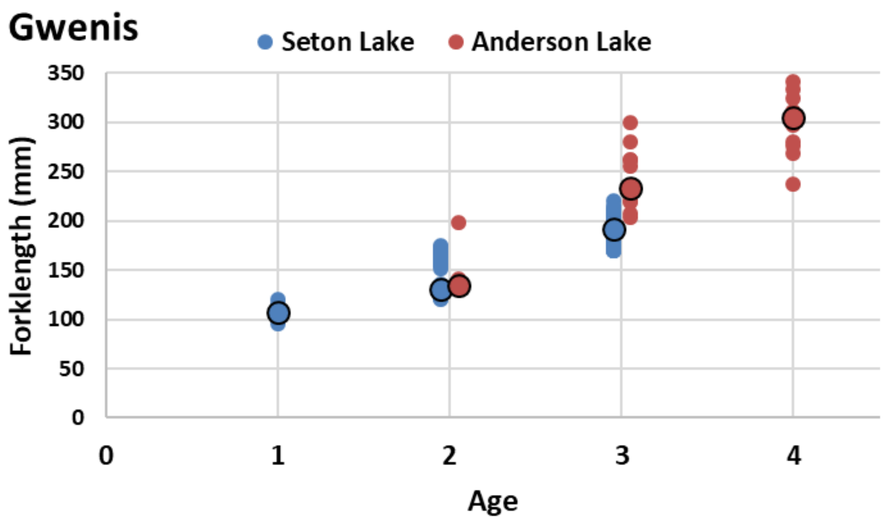

Figure 3.16 Size-at-age plot based on scale ageing data from selected gwenis captured during the annual gill net survey in Seton and Anderson lakes, September to October 2016. Larger dots with black border represent the median values.

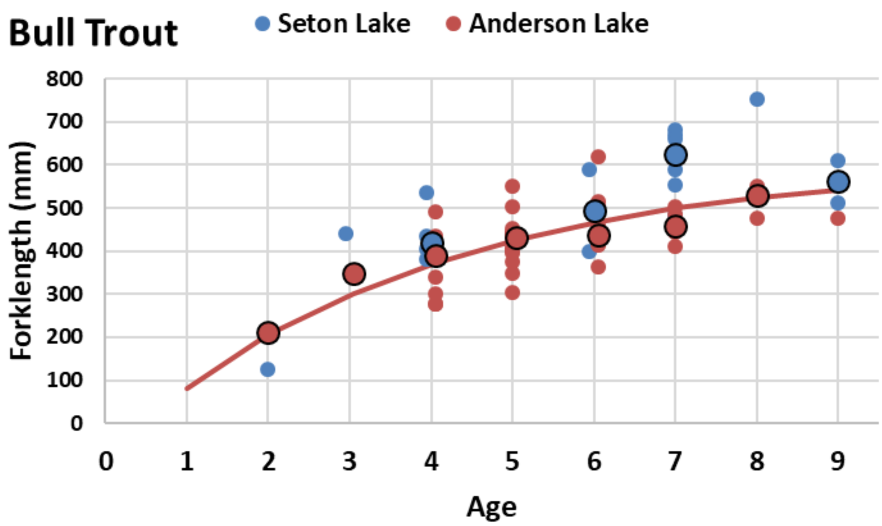

Figure 3.17 Size-at-age plot based on fin ray and otolith ageing data from bull trout captured during the annual gill net surveys in Seton and Anderson lakes, September to October 2015 and 2016. The line represents the von Bertalanffy growth curve based on median size values for each available age of Anderson Lake fish. There are not yet enough data points for each age class to develop a separate curve for the Seton Lake fish.

Bull trout stomach contents

Stomach contents were assessed in the field for 11 bull trout that had succumbed to the sampling in Year 4 (2016); 4 were from Seton Lake and 7 were from Anderson Lake (Table 3.6).

All identifiable prey items in bull trout from both lakes were various lifestages of the species *O. nerka* (i.e., sockeye or gwenis; eggs, juveniles and adults). Based on the assessed fish, the bull trout in Seton Lake had been feeding on both juvenile and adult gwenis, which were approximately 110 mm and 180 mm in length, respectively. The Anderson Lake bull trout had been feeding on juvenile gwenis (size range: 90 to 130 mm) and sockeye salmon eggs (likely originating from Gates Creek). In four cases the stomachs were completely empty or the contents had been so digested that there was no identifiable matter remaining.

Table 3.6 Summary of stomach contents assessed for bull trout from Seton and Anderson lakes during the annual gill netting survey, 27 September to 7 October 2016.

Lake	Bull Trout Size		Stomach Contents			
	Fork length (mm)	Weight (g)	Species	#	Approx. Prey Size (mm)	Comments
Seton	400	695	GW	1	110	Prey fish was a juvenile
	404	774	O. nerka	1	na	Juv.; Partially digested
	434	903	Stomach contents fully digested (empty)			
	440	981	GW	1	180	
Anderson	340	426	SK	na	5	Full of sockeye eggs
	362	476	Stomach contents fully digested (empty)			
	395	650	GW	3	100 - 120	Partially digested
	409	599	Stomach contents fully digested (empty)			
	433	839	GW	4	90 - 110	Also included SK eggs
	441	794	Stomach contents fully digested (empty)			
	503	1320	GW	3	110 - 130	2 partially digested

4. Discussion

Data were collected and analysed in 2016 (Year 4) 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 4 (2016) to contribute information towards addressing the first 3 of 4 management questions for this program. 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?

Gwenish

As in Year 3 (2015), gwenis were the most abundant species in the annual resident fish sampling in Year 4 (2016), and continued to be a well-suited target species for monitoring. Gwenis adults were substantially more numerous in Seton Lake, particularly in nearshore sets (between ~60 and 90 m from shore), than in Anderson Lake. For nearshore habitats, there was a gradient of CPUE values among the three longitudinal sections in Seton Lake: highest catch rates were in the outflow section, followed by the mid section and then the inflow section.

As in Year 3 (2015), the Seton Lake gwenis were noticeably smaller than the Anderson Lake gwenis, particularly after Age 2 (median sizes at Age 3 = 192 mm vs. 234 mm, respectively, in Year 4 (2016)). As reported by the BRGMON-6 program, zooplankton (which is the primary food item for gwenis) were less than half as abundant in Seton Lake than in Anderson Lake (Limnotek 2015). This smaller food base coupled with the larger population size in Seton Lake may be important factors contributing to the reduced growth relative to Anderson Lake gwenis.

As reported previously, the maximum assessed ages (based on scale ageing) were different between the lakes. Again in Year 4 (2016), 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). Also, the *O. nerka* juveniles (<180 mm) in the catch from both lakes were likely all gwenis offspring based on size at the time of sampling.

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). This suggests that spawning in Seton Lake by this species occurs around the time of the annual fish population index sampling, or shortly thereafter. Also, 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. As such, these locations of capture may reflect the spatial distribution of these fish during their spawning period in this lake.

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. Morris et al. (2003) estimated gwenis spawning in Anderson Lake to occur during December and January, based on the observation of carcasses on shorelines in January; however, this estimate has not been corroborated by other field studies to-date. Also, gwenis adults in Anderson Lake were exclusively in offshore habitats (i.e., >100 m from shore), and either near the surface (0 to 5 m depth) or between 20 and 30 m depth (in the metalimnion layer). These locations likely reflected the spatial distribution associated with rearing and feeding at the time of the survey in this lake. Other than for spawning, gwenis are generally a pelagic species that migrates above and below the thermocline (i.e., vertical movements among the thermal layers) between night and day periods for the purposes of feeding.

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. We wonder if the differences in apparent 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, Gates Creek sockeye that rear in Anderson Lake spawn approx. 1.5 months earlier than Portage Creek sockeye that presumably rear in Seton Lake. On the other hand, it's also possible that the spawn timing difference reflects localized adaptations to differing habitat conditions among the two lakes. At this point, none of the data currently available from the BRGMON-8 program would be able to address this, and sorting out the specific causes for the different spawn timing may not be necessary for meeting the objectives of this monitoring program.

The combination of differential spawn timing, maximum age (and possibly age-at-maturity), and adult body size differences presents both the possibility that a) the populations of gwenis in Seton and Anderson lakes may be distinct from one-another, or that b) they could be the same but have adapted to local conditions in each lake and don't mix. Earlier work by Moreira (2014) suggested that the two populations may be genetically distinct. The differences detected by that study were modest, but statistically significant. Further genetic analyses would be required to confirm stock identification, but this could not be accommodated within the existing scope and budget for the BRGMON-8 program.

Bull Trout

Relative to the gwenis, catch-per-unit-effort values for bull trout were lower, 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= 11 among both lakes). It was noted that all of the identifiable prey items in the bull trout stomachs at the time of the survey were various lifestages of the species *O. nerka* (i.e., sockeye or gwenis; eggs, juveniles and adults). In last year's (2015) sampling, some larger bull trout in Seton Lake were noted to have several (up to 5 or 6) mature gwenis in their stomachs at a time. As such, the relative abundance of bull trout over the course of the monitoring program may be a factor contributing to potential changes in the gwenis abundance index across years (in addition to potential operations effects); however, this relationship is difficult to characterize until more years of data are available.

Bull trout distribution in Seton Lake tended to overlap with the locations where gwenis were most prevalent (i.e., both vertically in the water column and spatially in the lake). Bull trout were more numerous in Anderson Lake, but unlike Seton Lake, their spatial distribution did not coincide with the habitats where gwenis tended to be most abundant: The bull trout were captured across the full range of sampled depths in Anderson Lake, but almost exclusively in nearshore sets. Also, bull trout were most abundant in the inflow section of Anderson Lake, followed by the mid section, and lowest at the outflow end. As noted in the Year 3 (2015) report, the body size of mature gwenis in Anderson Lake may be too large to be a prey item for the size range of bull trout in the lake, so they focus on the juvenile lifestage and/or other available prey items in this context.

Bull trout in Seton and Anderson lakes are adfluvial, migrating from the lakes into streams to spawn. In past years, spawning by this species was noted in Portage Creek (particularly at the top end near the outflow of Anderson Lake); however, the relative use of other streams within or outside of the Seton/Anderson watershed were unknown. Based on the radio telemetry monitoring that was available, bull trout movements in Seton Lake tended to have a downstream orientation during the monitored period, with the majority of detections at the fixed stations in the Seton Dam approach channel and below (Burnett and Parkinson 2018). Upstream movements were detected for only 2 of the 30 tagged fish from Seton Lake during the typical spawning period (i.e., mid September to end of October): 1 was detected in Portage Creek, and 1 was detected in Gates Creek.

On the other hand, a higher proportion of detected bull trout tagged in Anderson Lake (during the available monitoring period from July to mid October 2016) tended to migrate in an upstream direction for apparent spawning. Of the sample size of 10 fish, 4 made upstream movements into Gates Creek and 2 made downstream movements (1 into Portage Creek, and 1 into the inflow end of Seton Lake) during the spawning period. Four of the tagged bull trout were not detected after initial capture in Year 4 (2016), and may have remained in Anderson Lake. As there was no fixed telemetry station in Portage Creek, it was possible that Anderson Lake bull trout could have migrated to Seton Lake (or vice versa) between the weekly mobile tracking surveys in Portage Creek, undetected. None of the tagged Anderson Lake bull trout were detected by the receivers at the outflow end of Seton Lake during the continuous period of operation (June 2015 to Oct 2017).

Rainbow Trout

Rainbow trout have only been sampled in very low numbers during all four years of this monitoring program. No rainbow trout were captured in Seton Lake in 2016. The eight individuals captured in Year 4 (2016) were all captured within the epilimnion layer in the mid and inflow sections of Anderson Lake. The sizes of these fish ranged from 198 mm to 431 mm, and the aged individuals (*n*= 4) ranged from Age 4 to Age 7 based on scale reading. Like the bull trout, this population is likely adfluvial, migrating to nearby streams in the spring to spawn. The combination of small population size and their life history characteristics makes this species less suitable for trend monitoring and linking observed population characteristics to operations, relative to gwenis and bull trout. However, data for rainbow trout will continue to be collected to support an understanding of the basic biology of this species, and conclusions or recommendations at the end of the monitor, if possible.

Other Resident Fish Species

Northern pikeminnow (*Ptychocheilus oregonensis*), peamouth (*Mylocheilus caurinus*), redside shiner (*Richardsonius balteatus*), mountain whitefish (*Prosopium williamsoni*), and bridgelip sucker (*Catostomus columbianus*) are other resident species that have been documented in the catch.

Northern pikeminnow were the most abundant of this group (*n*= 94) and contributed fairly equally to the sample from each lake. They ranged in size from 106 to 425 mm. Like bull trout, pikeminnows are a piscivore that may feed on gwenis (among other prey items) in these lakes. For this reason, tracking their abundance across the duration of this monitor could be important (for the same reason as bull trout, as stated above). Pikeminnow are spring spawners (i.e., May and June), and spawning can occur in both flowing water (inlet streams) and in lakes (McPhail 2007).

Peamouth were the next most abundant (*n*= 37), but were more prevalent in the Seton Lake catch than the Anderson Lake catch. They ranged in size from 110 to 279 mm. Peamouth also spawn in the spring (threshold temperature is approx. 9°C). Some populations spawn in lakes over gravel beaches, but most lacustrine populations spawn in inlet or outlet streams. Peamouth are insectivores and are primarily water column foragers, but they can also take insect prey from the bottom and surface (McPhail 2007).

Mountain whitefish (*n*= 6) were captured in equally low numbers in each lake. They ranged in size from 264 to 390 mm. Mountain whitefish can exhibit different life history patterns: lacustrine, riverine, or adfluvial. They are fall spawners (October and November), and most lake populations migrate into streams to spawn. The main food items for mountain whitefish include plankton, snails, surface insects, and occasionally, young fish (McPhail 2007).

Redside shiner (*n*= 7) and bridgelip sucker (*n*= 3) were only captured in Seton Lake, and ranged in size from 90 to 122 mm, and 245 to 430 mm, respectively. Both of these species are spring spawners (mid April to mid June). Redside shiners can spawn in lakes or streams, whereas bridgelip suckers spawn in streams only. Shiners primarily eat aquatic and terrestrial insects from the bottom, mid-column, or surface of the littoral zone. Food sources for suckers include periphyton, filamentous algae, and detritus.

Each of these species have diverse life histories, are generally less directly sensitive to water quality and in-lake habitat changes than the target salmonid species, contribute limited abundance to the sample in most cases, and tend to have less social value relative to gwenis, bull trout and rainbow trout in this context. Due to the combination of these factors, none of these "other" species have been selected as target species for monitoring the effects of N2-2P operations by this monitoring program. Going forward, their catch information will continue to be fully documented; however, analyses and discussion of these other resident species will largely be limited to anecdotal or opportunistic observations from the collected data going forward.

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 in Years 3 and 4 (2015 and 2016) has proved much more effective for capturing target species, particularly gwenis and bull trout, 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 method for the annual population index of target species has only been employed for two years, it is not possible to determine whether the selected alternative has an effect on the abundance and diversity of fish populations in Seton Lake.

Once a consistent set of data are collected across the upcoming 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 to determine what effect the selected alternative is having on fish populations in Seton Lake. Size and age distribution metrics will also be tracked such that any potential correlations with Carpenter diversion operations can be assessed. For every year going forward, the plan is to maintain the sampling methods and effort employed in Year 4 (2016) to ensure the direct comparability of results across years, within the limits of our control.

Gwenis continued to be 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. In addition, the Seton and Anderson populations may not mix such that the indices of abundance and size, etc. may specifically link to the conditions within the respective lake where they reside.

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. However, it’s important to acknowledge that the bull trout in these lakes are adfluvial, and evidence suggests that they are migratory: opportunistically moving out of, and back into, Seton Lake according to where feeding opportunities are throughout the system at different times of year, or either lake for spawning purposes. Bull trout may move between Seton and Anderson lakes as well, but sample sizes have been limited for detecting these movements to-date. Because bull trout have a propensity to access habitats and resources outside of the study area as needs dictate, changes or differences in abundance or life history characteristics for this species may be less directly linked to impacts associated with the Carpenter diversion operations.

In terms of the species diversity aspect of MQ 2, gill netting is an effective method for sampling a broad range of species and size classes, and providing information on their relative abundance, distribution and habitat use. Results for all non-target 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.

A couple of important comments about implications of the scope, approach and methods being implemented for this program:

1) We are not monitoring a “before-after” treatment scenario with a distinct change in operations divided into representative sample sizes for each treatment. One of the main objectives defined for this program was to monitor *existing* operations (with inherent variability among years) and assess for any changes in fish population across the monitoring period (i.e., does the general trend appear to be increasing, decreasing or staying the same under N2-2P operations). However, this does not specifically set up any known amount of replication for the potential range of operations (diversion magnitude and timing) that may be required for confirming differences or changes.

2) The resolution for detecting change may also be an issue. Within the limits of the existing scope and budget, the program may be able to detect large-scale changes (which are not necessarily likely from operations effects within the study timeframe), but not smaller ones that may be more likely. This is possibly true regardless of which specific age class(es) we focus on for gwenis, and operations effects on bull trout are likely more indirect (than for gwenis) due to life history differences among these species.

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?

With 2 years of replicate fish sampling (using the gill netting method) and less than 2 years of water quality monitoring (i.e., in-lake temperature profiles and sedimentation patterns), it is premature to attempt to answer this management question at this stage in the program. Diversion volume from BR1 and BR2 into Seton Lake during spring 2016 was high relative to previous monitoring years. These high inflows may provide a signal that is unique to the conditions in previous years, and may be detectable in the various parameters being monitored for this program. However, because we don't yet have enough replicate data to compare it with, we do not know yet if that is the case. The following discussion provides some of the information pertaining to this question that we do know to-date.

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 spawn in shallow habitats near the shoreline, as occurs for some lake spawning populations of kokanee). Gwenis spawn timing has been observed to occur in fall (Morris et al. 2003, Limnotek 2015, and this program) in Seton Lake. To-date there is no evidence for shore-spawning use in Seton Lake; but, rather, that gwenis spawn at depth and would not be directly impacted by the degree of surface elevation changes implemented by N2-2P operations.

Based on thermal profile monitoring, temperatures tended to be warmest at the outflow end of Anderson Lake, which also had the broadest metalimnion layer (~10 to 30 m below the surface). The inflow end of Seton Lake was the coolest overall across the range of depths, and the metalimnion layer was narrowest at this location (~10 to 20 m below the surface). Temperatures at the outflow end of Seton Lake were most similar to the outflow of Anderson Lake, but slightly cooler across most of the profile, and the metalimnion layer was deeper (~20 to 30 m below the surface).

The main source of natural inflows to the top end of Seton Lake are from Portage Creek which draws directly from the epilimnion layer at the outflow end of Anderson Lake (also receiving inputs from Whitecap and Spider creeks). As such, the temperatures from this source could be expected to be similar to the Anderson Lake regime. However, Portage Creek and other natural inputs only contribute approximately 10% of the inflows to Seton Lake relative to the Carpenter diversion flows from BR1 and BR2, which contribute 90% of total volume. Therefore, it is clear that the colder temperatures documented at the inflow end of Seton Lake are a direct result of the diversion influence. The diversion effects on temperature in Seton Lake are most acute at the inflow end nearest the BR1 and BR2 Generating Station inputs and there is a gradient of effect across the length of the lake. The influence is still apparent at the outflow end of Seton Lake, but is mitigated by normal lacustrine thermal processes relative to the inflow end.

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. Based on a single year of data collection to-date, sedimentation rate was lowest in Anderson Lake and highest at the inflow end of Seton Lake. Also, there was a gradient of effect across the length of Seton Lake. These patterns were consistent across seasons, but sediment inputs to

Seton Lake were highest in spring (i.e., mass per day and mass per diversion volume). Sedimentation rates during summer and fall/winter periods were fairly equivalent in Year 4 (2016).

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 and 4 (2015 and 2016) datasets. While the potential for effects of sedimentation on gwenis production seems fairly direct (e.g., deposition on spawning substrates on the lake bottom), the effects on bull trout, which are adfluvial and migratory, may be less direct relative to the availability and spatiality 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 light on these linkages for these two focus species.

Specifically, 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). Also, evaluating gwenis distribution patterns (i.e., possible spawning distribution in Seton Lake during the survey period) with temperature characteristics and sediment deposition will also be informative for determining effects of the diversion operations on this target species.

Going forward, the continued collection of temperature and sedimentation data in Seton and Anderson lakes will support analysis of correlations between temperature characteristics or sedimentation rate with the inflow volume of the Carpenter diversion on both seasonal and annual bases. This analysis will be useful for characterizing the seasonality of diversion effects and support recommendation of potential refinements to the N2-2P operating alternative as a part of addressing management question 4 (below) by the end of the monitoring period. Relevant results & analysis from BRGMON-6 will also be incorporated with the results from this program by the end of the study period (i.e., 2022) to inform the response to these questions.

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.

5. Recommendations

The following recommendations are provided based on the learning generated by this monitoring program to-date. Implementation of the proposed changes are intended to improve the program for answering the management questions within the allocated budget framework.

- Repeat fish population index sampling using gill nets in pelagic and littoral habitats of both Seton and Anderson Lakes. Ensure that sample timing, effort, and methods remain as consistent and comparable as possible for all remaining monitoring years.
- Focus analysis efforts on gwenis and bull trout as target species for assessing potential linkages with operations effects. Continue documenting sampling results for other resident species to support species composition and biological characteristics information under MQ 1.
- Collect stomach content samples from all captured bull trout and rainbow trout by utilizing gastric lavage. Currently, stomach samples have only been collected from individuals that succumbed to the sampling (by removing their stomachs, post-mortem, to assess contents), but this limits the available sample size each year. Gastric lavage is a fairly simple, non-lethal method that would increase the sample size to better facilitate comparison of foraging habits for bull trout and rainbow trout between Seton and Anderson lakes.
- Continue year-round thermal profile monitoring and sedimentation rate monitoring as initiated in 2015 and 2016, respectively. Ensure sample timing, effort, and methods remain as consistent and comparable as possible for all remaining monitoring years to facilitate comparisons among years and operational ranges.
- Consider moving loggers on temperature arrays from the hypolimnion (i.e., >40 m depth) up, to supplement spacing for loggers in epilimnion and metalimnion so temperatures and depth ranges for these layers can be defined with more precision. Alternatively, could consider regular temperature and depth readings from CTD profiles, but this would require additional labour and gear expenses above what is available in the budget currently. Budget would need to be increased to accommodate it.
- Conduct a shoreline habitat mapping survey in Anderson Lake to collect a comparable data set to the one documented for Seton Lake in Year 3 (2015) to facilitate comparisons of total shoreline length, distribution and % contribution of habitat types, and total vegetated length.
- Continue to evaluate the success of BRGMON-8 data collection methods for their capacity to provide relevant information for answering the management questions. Potential issues include unknown replication of different operations among years (i.e., no designated "treatments"), coupled with potentially limited precision or resolution to detect small changes in the abundance of target species, which may limit the strength of conclusions.

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