Bridge River Project Water Use Plan

Seton Lake Resident Fish Habitat and Population Monitoring

Implementation Year 5

Reference: BRGMON-8

BRGMON-8 Seton Lake Resident Fish Habitat and Population Monitoring, Year 5 (2017) Results

Study Period: April 1 2017 to March 31 2018

Jeff Sneep and St'at'imc Eco-Resources

January 22, 2019

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Prepared for:

St'at'imc Eco-Resources

Prepared by:

Jeff Sneep

Lillooet, BC

File no. BRGMON-8

January 2019

Executive Summary

Data collection for Year 5 of this proposed 10-year study was completed in 2017. Results for Years 1 to 4 are provided in the previous reports produced for this program (Sneep 2015; Sneep 2018a, Sneep 2018b). 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. As in Year 4 (2016), sampling effort was fully extended to Anderson Lake in Year 5 (2017), 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 5 (2017) 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;
- Habitat mapping around the perimeter of Anderson Lake;
- Resident fish population index survey in the lakes (by gill netting).

Since Year 3 (2015), sampling for the resident fish population index survey has been 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. Relative to conditions in Anderson Lake, the diversion resulted in colder water temperatures throughout the water column (by up to 4°C) and higher inputs of fine sediments (by 57 to 114 mg/day), according to depth and seasonal period at the inflow end of Seton Lake in 2017. There was also a gradient of effects across the length of Seton Lake (i.e., according to depth and season, temperatures were up to 6°C warmer, and there was 42 to 84 mg/day less sediment deposition at the outflow end, relative to the inflow end).

Mapping the nearshore habitat types around the entire perimeter of Anderson Lake provided a comparison with mapping results from Seton Lake collected in 2015. Both lakes are very similar in mid-line length (differing by only 200 m); however, the shoreline length of Anderson Lake was nearly 3 km less than Seton Lake. Steep shoreline habitats were the most abundant, followed by fans, shallow slope shorelines, and then creek mouths. The contribution of each habitat type did not vary greatly from the results for Seton Lake (differing by only 1% to 7%); however, there were more fans and creek mouths in Anderson Lake, and a higher proportion of the shoreline was vegetated (77% compared with 52% for Seton Lake) due to differences in the extent of development impacts.

Approximately 314 hours of gill netting effort were employed in Seton and Anderson lakes over 8 dates in late September and early October 2017. In total, 725 fish were captured from 60 sampling locations (33 on Seton Lake and 27 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 60 m below the surface, and included surface, mid-column, and bottom sets. Captured fish included 8 different resident species; target species made up 76% of the total (gwenis, bull trout, and rainbow trout comprised 67%, 6%, and 2% of the catch, respectively).

Catch-per-unit-effort (CPUE) values were generated for target species in Year 5 (2017). As reported past years, highest CPUE for gwenis was recorded in Seton Lake, and lowest values were in Anderson Lake in 2017. Gwenis were more numerous in nearshore sets in Seton Lake (nearshore= 75.3 fish·net-hour^{-10}; offshore= 18.9 fish·net-hour^{-10}), whereas the gwenis in Anderson lake were more abundant in offshore habitats (nearshore= 2.0 fish·net-hour^{-10}; offshore= 4.6 fish·net-hour^{-10}). Highest CPUEs for bull trout and rainbow trout were in the nearshore zone of Anderson Lake (46.6 and 4.1 fish·net-hour^{-10}, respectively). Generation of these catch statistics for each year going forward will be used to establish whether the population trends for target species are increasing, staying the same, or decreasing across the period of monitoring years.

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 (estimated to be in November or December; Morris et al. 2003), 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 age-at-maturity differences between these populations. Captured bull trout in Seton Lake (*n*= 7) ranged in age from 3 to 7 years (length range = 268 to 683 mm), and in Anderson Lake (n= 35) from Age 3 to Age 9 (length range = 300 to 760 mm).

Assessment of bull trout stomach contents in Year 5 (2017) 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 were the dominant food items in Anderson Lake.

Summary of BRGMON-8 Management Questions and Interim (Year 5 – 2017) Status

Primary Objectives	Management Questions	Year 5 (2017) 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 has documented 9 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. **Gwenis** **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 again in Year 5 (2017). Gwenis in Anderson Lake were either <15 m from shore near the surface (juveniles), or in the offshore sets (>75 m from shore) within the metalimnion thermal layer (i.e., 10 to 30 m depth) for adults. These locations likely correspond with their distribution in the lake for rearing and feeding. Highest catch rates were in the outflow end of the lake, although differences among zones have been much smaller than in Seton Lake in some years. **Diet:** Zooplankton **Bull Trout** **Relative Abundance:** Bull trout were the sixth most abundance species in Seton Lake (behind gwenis, northern pikeminnow, peamouth chub, bridgelip sucker, and redside shiner), and second in Anderson Lake (behind gwenis). **Size:** Larger bull trout have been captured in Seton Lake in some years, and analysis of median size-at-age and growth rates across years seems to confirm that bull trout grow faster in Seton Lake. Based on the available sample size, bull trout growth appears to slow after Age 4 in Anderson Lake or Age 5 in Seton Lake. Additional size and age data will be incorporated in the analysis as more years of data are collected. **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.

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?	**Distribution/Habitat Use:** Bull trout distribution in Seton Lake corresponded directly with gwenis distribution in this lake. In Anderson, they were distributed in nearshore habitats between 10 and 90 m from shore and across the full range of sampled depths. **Diet:** Gwenis adults, juveniles & O. nerka eggs **See Sections 3.3 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) 24.0 (2017) **Anderson Lake Gwenis:** 1.6 (2015); 2.0 (2016) 6.5 (2017) **Seton Lake Bull Trout:** 0.5 (2015); 0.5 (2016) 0.4 (2017) **Anderson Lake Bull Trout:** 1.7 (2015); 2.5 (2016) 2.5 (2017) 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 5 (2017) 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 3.3 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 Years 4 and 5 (2016 and 2017), 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 and 4**.

To collect better information on the relative abundance, life history and habitat use of resident fish populations in Seton Lake.	4. Can refinements be made to the selected alternative to improve habitat conditions or enhance resident fish populations in Seton Lake?	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 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 5 of this proposed 10-year study was completed in 2017.

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 5 (2017; 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 in the same way to facilitate comparison of the results.

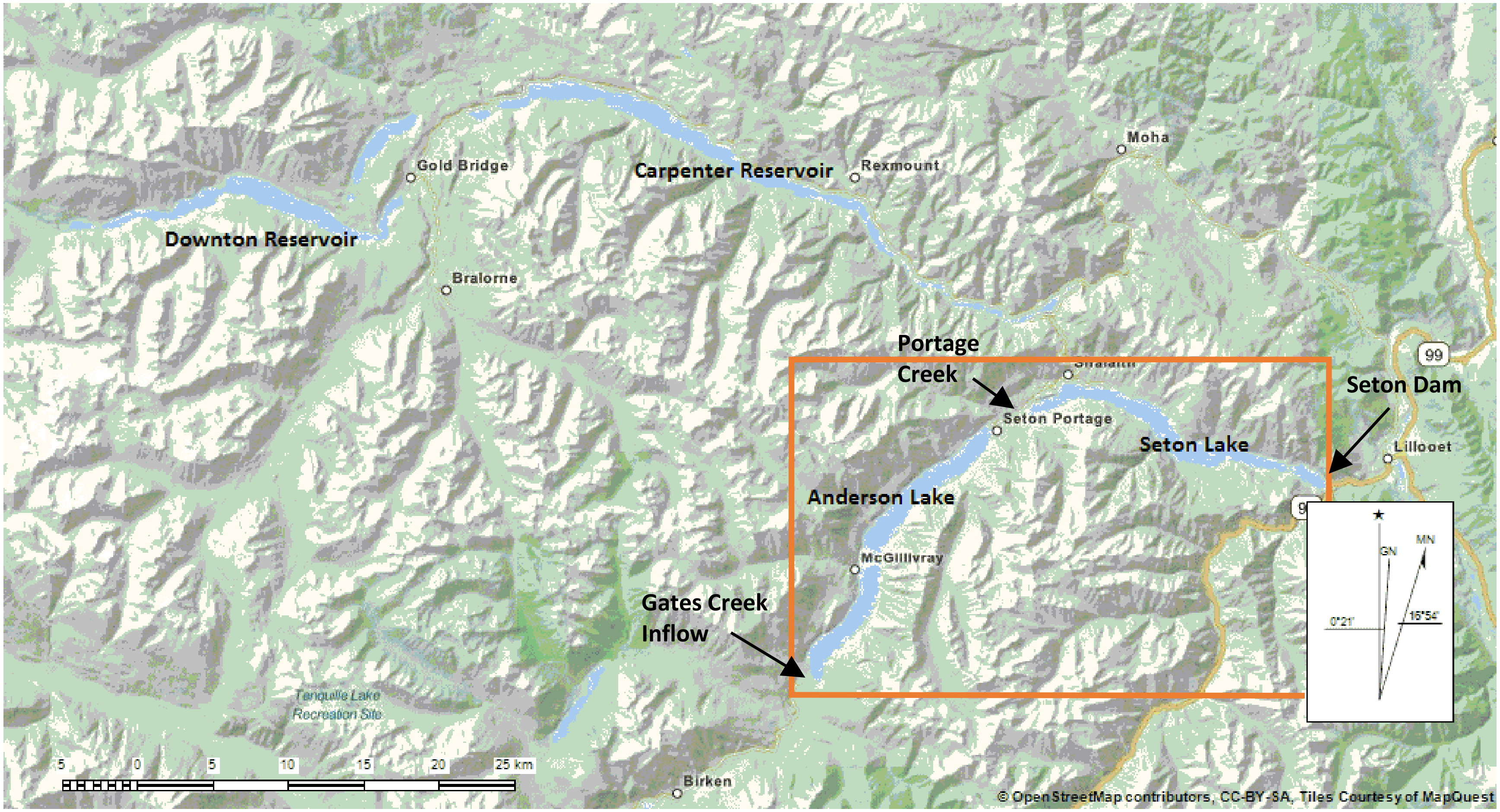


Figure 1.1 Overview of the Bridge and Seton watersheds. The extent of the BRGMON-8 study area, which includes all of Seton and Anderson lakes between the Gates Creek inflow and Seton Dam, is outlined by the orange rectangle.

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 capacity of Downton Reservoir has been reduced 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), has been affected. This has resulted in a change from the typical N2-2P (i.e., post-Water Use Plan) operations to modified operations to compensate for the identified system constraints. Modified operations were first implemented in 2016 and are expected to continue for a number of years to mitigate the storage and conveyance issues and allow for the associated infrastructure to be fixed or replaced. The changes that pertained specifically to Seton Lake since the modified operations have been implemented include substantially 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 and Average Discharge Rates from the Bridge Generating Stations (BR1 and BR2) for the BRGMON-8 Monitoring Years to-date based on hourly data provided by BC Hydro.

Study Year	Diversion Volume (Mm^3)					Average Discharge 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**
5 (2017)	818	854	625	791	**3,088**	**98**

[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.

In Year 5 (2017), 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 5 (2017) included four main monitoring components:

- Thermal profile monitoring;
- Sedimentation rate and composition monitoring;
- Habitat mapping around the perimeter of Anderson Lake;
- 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 2018b). 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.

The radio tagging and tracking component that was trialed in Year 4 (2016) was not repeated in Year 5 (2017) because it relied on in-kind contributions and existing tagging efforts and telemetry infrastructure from the Seton Entrainment Study and BRGMON-14 programs that were not available this year.

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)	5 (2017)[a]
BC Hydro Operations	X	X	X	X	X
Temperature Monitoring (Continuous)					
• Tributaries			X	X	X
• In-lake Profile Arrays			X	X	X
Sedimentation Rate Monitoring				X	X
Shoreline Habitat Mapping			X		X
Fish Population Index Surveys					
• Nearshore Boat Electrofishing	X	X			
• Gill Netting (Littoral & Pelagic)			X	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	X
Scale & Otolith Ageing			X	X	X

[a] The specific dates that each of the Year 5 (2017) activities were completed are provided in Section 1.6, Table 1.3.

Temperature monitoring in Seton and Anderson Lakes, and measurement of sedimentation rate related to inputs from the Carpenter diversion inflows continued in Year 5 (2017). Initiated in Year 4 (2016), the set of sedimentation samplers were deployed in each of the three longitudinal sections (inflow, mid, and outflow) of Seton Lake, and the outflow section of Anderson Lake. The purpose is to monitor differences in the thermal profiles and the extent of sedimentation among locations by season and diversion flow volume.

A habitat mapping survey was conducted in Anderson Lake in Year 5 (2017), equivalent to the survey of Seton Lake that was completed in Year 3 (2015), to provide a comparable set of shoreline habitat information for the two lakes. Other than these changes, all other monitoring components conducted in Years 3 and 4 (2015 and 2016) were repeated in Year 5 (2017).

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 (2017) represents monitoring Year 5. 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 5 - 2017)
Temperature array retrieval (R) and deployment (D)	25, 26 May (R & D); 25, 26 Jul (R & D); 3, 17 Oct (R & D)
Sedimentation sampler retrieval (R) and deployment (D)	25, 26 May (R & D); 25, 26 Jul (R & D); 3, 17 Oct (R & D)
Anderson Lake Habitat Mapping Survey	26 to 27 Jul
Resident Fish Population Index Survey	22 to 25 Sep (Seton); 3 to 6 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 the successful extension of sampling in Years 3 and 4 (2015 and 2016), collection of comparable data from Anderson Lake was continued for all Year 5 (2017) activities. The intent is to provide 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 continue collecting 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 to-date. 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 and Portage Creek, to monitor water temperatures from these natural inflow sources, as well as in the Seton Dam forebay. To more directly monitor the temperature of the diversion inflows, the plan is to place a logger in the BR1 tailrace in Year 6 (2018); however, these data were not available for this report. The locations of the temperature arrays and other logger locations in the study area are provided in Figure 2.1 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, 10, 20, 25, 30, 40, 50, 60, and 70 m. This arrangement was intended to span the thermal layers when the water column is stratified. A sinking line was 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 Portage Creek, 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 continuously deployed in each of the three longitudinal sections (inflow, mid, and outflow) of Seton Lake, and the outflow section of Anderson Lake, as initiated in Year 4 (Table 2.2; and Figure 2.1 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 Years 3 and 4). 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 since Year 4 (2016). The sampling cup from which the sediment sample was collected is shown (inset).

For Year 5, the samplers were continuously deployed for the entire year, other than the dates they were retrieved for sample collection (25-26 May, 25-26 July, and 3, 17 October 2017). 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, the summer sample at the inflow end of Seton Lake was compromised because the anchor was snagged on the bottom upon retrieval and some of the sample was lost by the efforts from the surface to get it free. The location was adjusted slightly when the sampler was redeployed to avoid snagging in the same spot 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. Shoreline Habitat Mapping

A habitat mapping survey was conducted to document the distribution and abundance of habitat types around the entire perimeter of Anderson Lake. This survey was intended to facilitate comparison of habitat similarities/differences with Seton Lake, which had been surveyed by the same methods in Year 3 (2015). Documenting nearshore habitat availability in each of the lakes may provide a useful input for interpreting potential differences in population trends at the end of the monitor and was helpful for selecting nearshore fish sampling locations during the annual resident population indexing survey.

Habitat mapping involved characterizing and georeferencing the entire shoreline of Anderson Lake by boat, and was completed on 26 and 27 July 2017. To accomplish the survey, the boat was propelled forward at slow speed adjacent to the shoreline. The habitat type was recorded for each unit and breaks between units were marked as waypoints on a GPS device. The GPS unit also recorded the boat track, which conformed to the shape of the shoreline in each unit, enabling more accurate measurement of shoreline length once GPS data were transferred to mapping software in the office.

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

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 included all of Anderson Lake, as was done in Year 4 (2016). 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 69 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 27 sites in Anderson Lake (18 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 2.1). Set duration was different for nearshore versus offshore sets in Years 4 and 5 (2016 and 2017). This was due to the significantly more abundant catches 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.

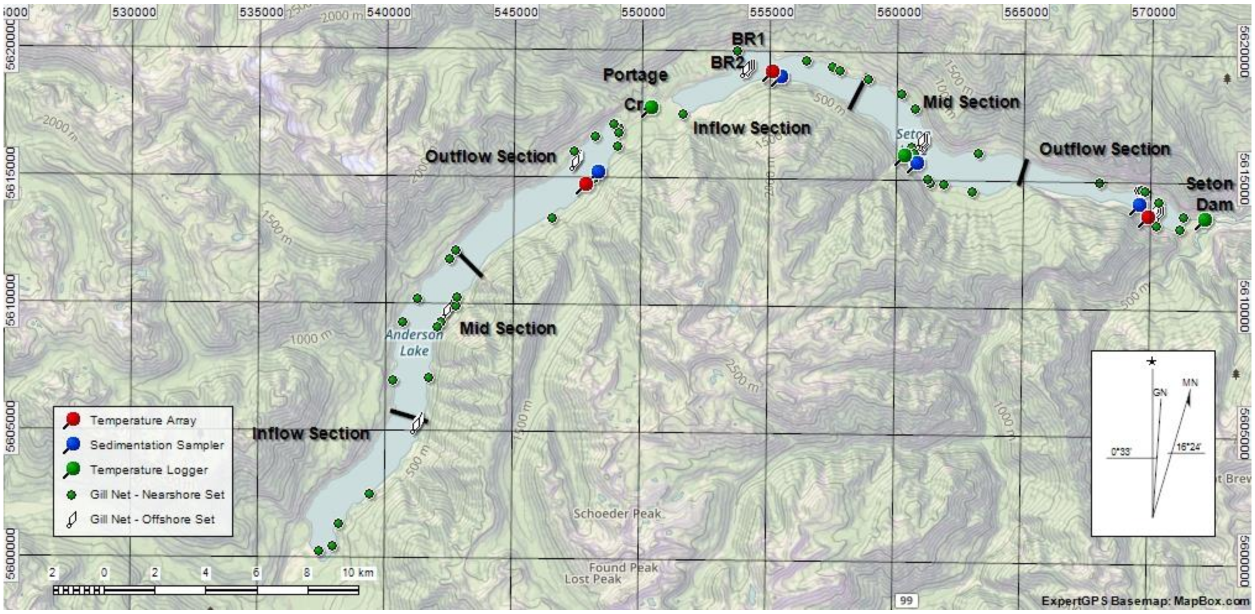


Figure 2.1 BRGMON-8 study area showing longitudinal sections and the locations of temperature arrays (red pins), sedimentation samplers (blue pins), and fish sampling locations (green dots and white markers) in Seton and Anderson lakes during Year 5 (2017). The locations of the Bridge 1 and 2 (BR1, BR2) 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 2.4 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 subsequent surveys. Gwenis were not marked as the majority were mature spawners that would die following their 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 Jennifer Buchanan and Dani Ramos-Espinoza (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 4 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).

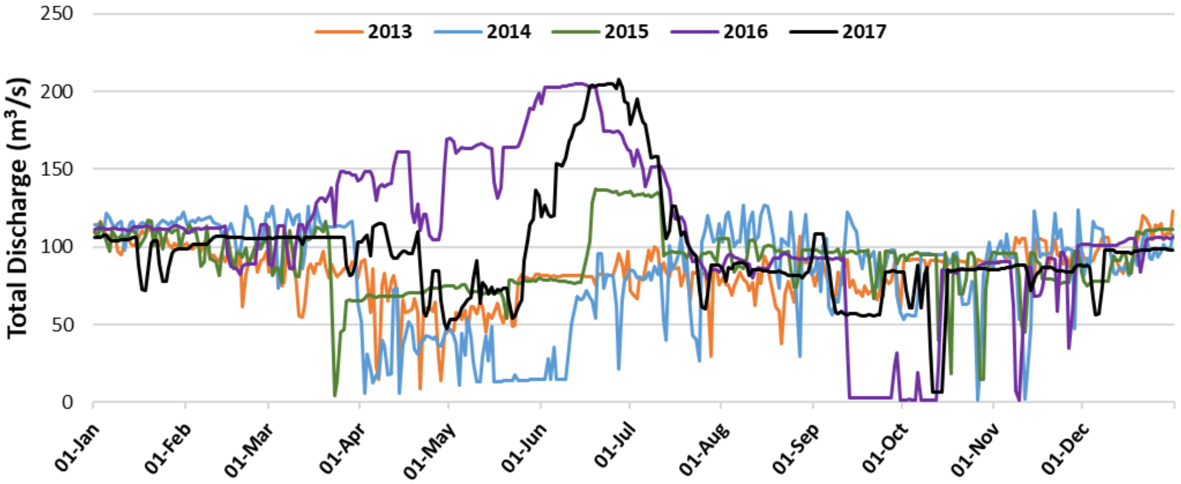


Figure 3.1 Mean daily discharges from Bridge 1 and Bridge 2 Generating Stations into Seton Lake, January to December (2013 - 2017).

Peak diversion discharges in Year 5 (2017) were between 204 and 212 $m^3 \cdot s^{-1}$ from mid to late June, which were similar to peak rates in Year 4 (2016), and substantially higher than peak flows in years 1 to 3 (2013 to 2015). The duration of the high diversion inflows in 2017 (i.e., above previous maxima; 38 days) was shorter than in 2016 (105 days). On a daily basis, maximum and minimum outflow varied by 104 $m^3 \cdot s^{-1}$ on one date in Year 5 (12 March 2017) when the units were cycled between on and off. However, overall, the amount of daily cycling throughout the year in both 2016 and 2017 was much lower than what has been implemented in the earlier 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 brief period of very low discharges (i.e., shutdown) in mid-October.

BR1 and BR2 generating station discharges (i.e., Carpenter diversion inflows) in Years 4 and 5 (2016 and 2017) reflected some differences in 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 ran from late March to late July in 2016 and from late May to late July in 2017, were caused by the magnitude and timing of inflows into the system in each of those years, combined with reduced storage capacity in Downton Reservoir.

The total number of station outages (or shutdown of the generating units) at BR1 and BR2 were markedly reduced in Year 5 (2017) relative to every previous monitoring year. The highest number occurred during fall; shutdowns were virtually non-existent in any other season that year. 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)	Year 5 (2017)
Spring	416 (1)	1220 (27)	66 (1)	0 (0)	0 (0)
Summer	409 (0)	283 (0)	0 (0)	206 (8)	0 (0)
Fall	26 (0)	238 (2)	103 (2)	558 (21)	121 (4)
Winter	94 (0)	5 (0)	63 (0)	1 (0)	1 (0)
All Seasons	**945 (1)**	**1746 (29)**	**232 (3)**	**765 (29)**	**122 (4)**

These results were also reflected in the comparison of cumulative diversion discharge by season (Figure 3.2 and Table 1.1 in Section 1.4), which confirmed that the highest proportion of water was released during spring and summer, and the lowest during fall. Based on a comparison among years, the amounts for spring in Year 5 (2017) were lower than in Year 4 (2016), but were still higher than the typical volumes for this season in earlier study years. The total discharge volume in 2017 (3,088 million m^3) was 10% lower than 2016 (3,449 million m^3), but still higher by 7% to 16% than any other year included in the comparison (2013 = 2,645; 2014 = 2,593; and 2015 = 2,878 million m^3).

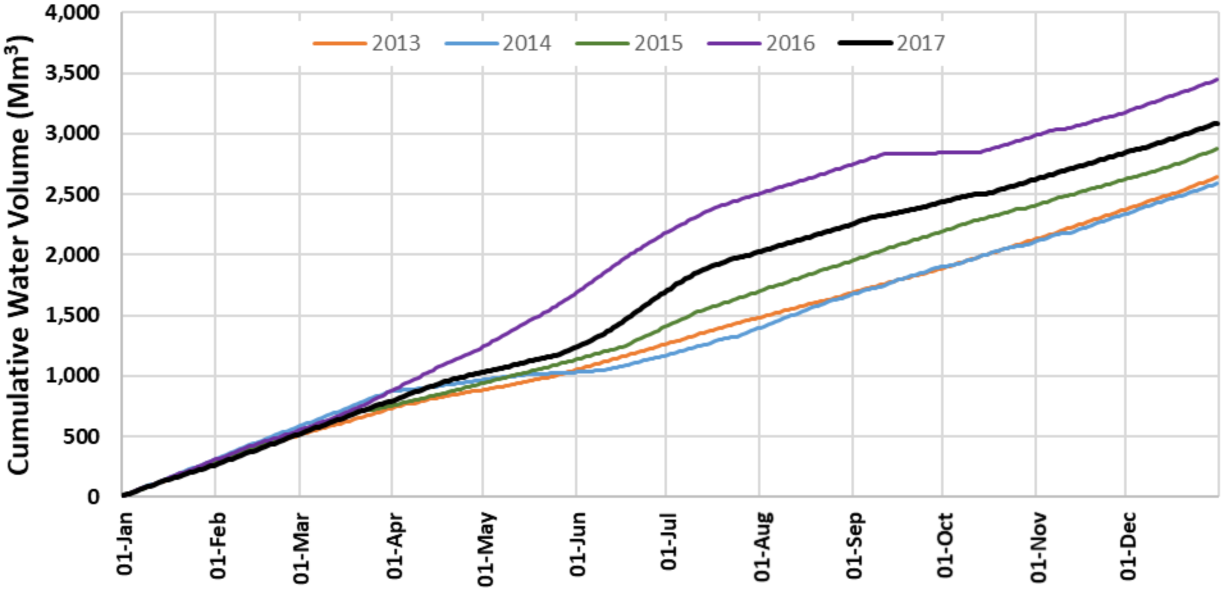


Figure 3.2 The daily cumulative inflow volume from the Bridge 1 and 2 Generating Stations, 2013 to 2017 (Monitoring Years 1 to 5).

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 0.51 m between minimum and maximum levels in 2017. The maximum *daily* rate of change observed has been between 16 and 26 cm for each study year. The lowest elevation in 2017 was recorded from 9 to 11 October (235.84 meters above sea level (masl)) and the highest was 236.35 masl for less than a day on 23 May 2017. 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 Years 4 and 5 (2016 and 2017), the levels were below 236.1 masl approx. 17% and 33% of the time, respectively, due to an increased number or duration of “drawdown” events in those two years. However, the range of lake surface elevations has been within the licensed range in all cases. Based on observed patterns of fish distribution (see Section 3.3), the range of variation in observed surface elevations was not expected to impact resident fish populations in the lake.

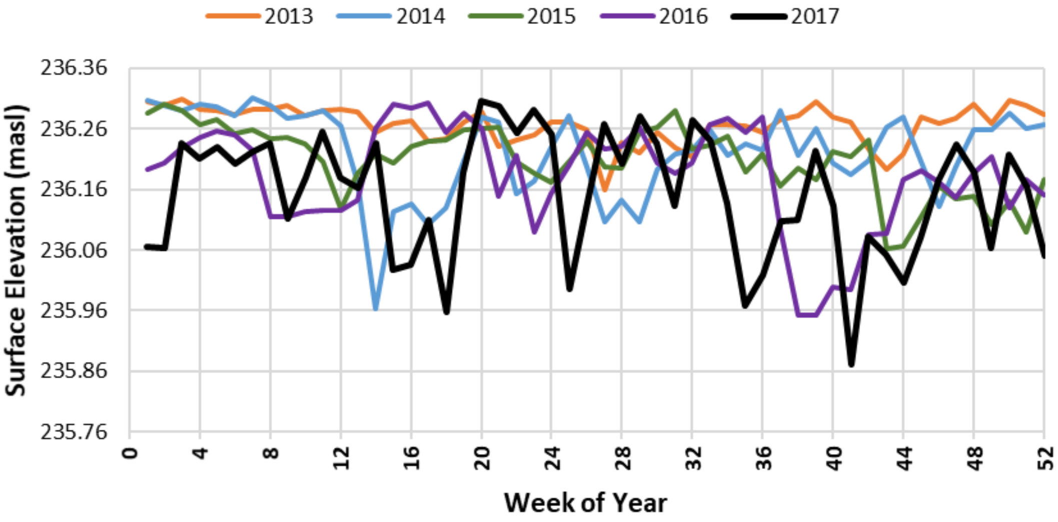
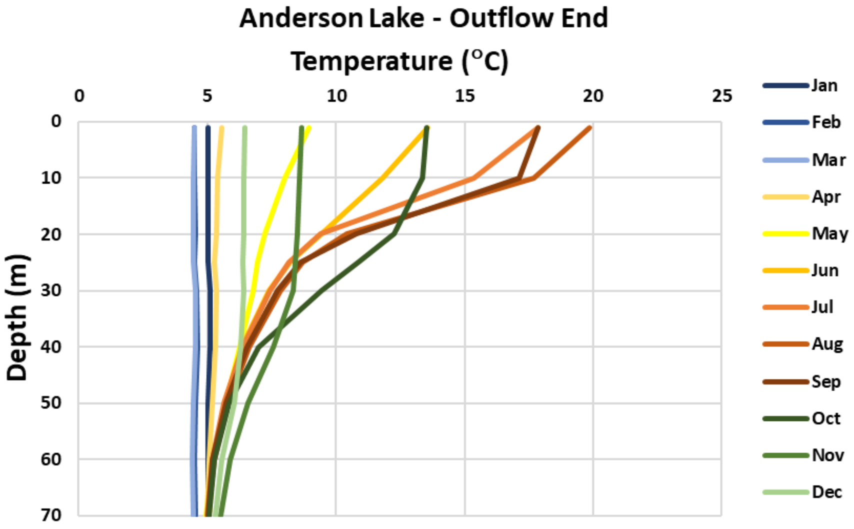


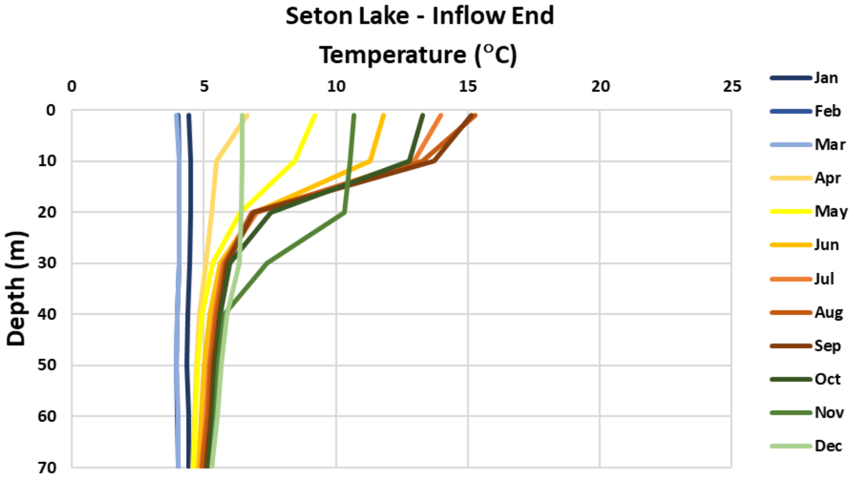
Figure 3.3 Mean weekly surface elevations of Seton Lake recorded in the forebay of Seton Dam across the year, 2013 to 2017. Note: the y-axis range spans the licensed operating range referenced in the Water Use Plan (BC Hydro 2011).

Thermal Profile Monitoring

Year 5 (2017) 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. Patterns in the temperature profile data were very similar to those described for Year 4 (2016). Since temperature monitoring for the BRGMON-8 program was initiated at the end of July 2015 (i.e., mid-way through Year 3), it was not possible to make comparisons with the earlier monitoring years.

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 or early May, the temperature profiles begin 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 22.1°C at the outflow end of Anderson Lake (on 11 August 2017), 18.3°C at the inflow end of Seton Lake (on 5 August), and 21.3°C at the outflow end of Seton Lake (on 11 August). 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.





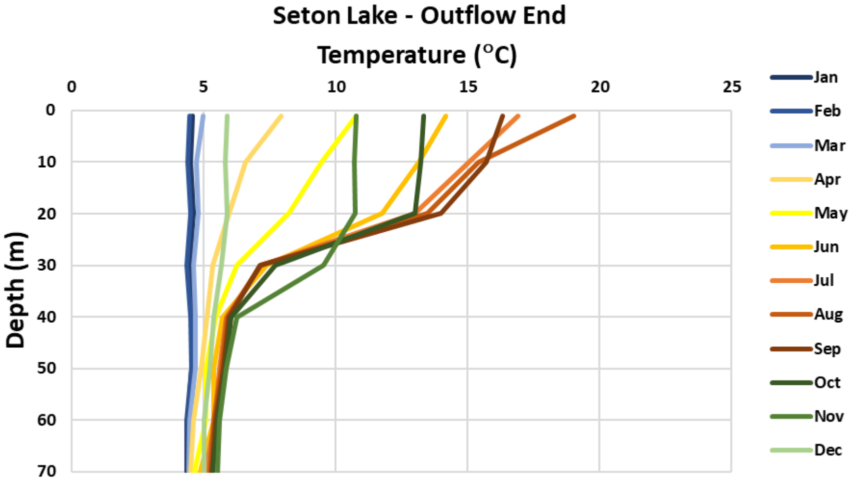


Figure 3.4 **Mean monthly water temperature profiles recorded in Anderson Lake (outflow end; top), and at the inflow (middle) and outflow (bottom) ends of Seton Lake from January to December 2017.**

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: 9.9°C (from 17.7° to 7.8°C between 10 m and 30 m depth) at the outflow end of Anderson Lake; 7.0°C (from 14.1° to 7.1°C between 10 m and 20 m depth) at the inflow end of Seton Lake; and 7.1°C (from 13.7° to 6.6°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 past reports, 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 15 m (from 10 m to 25 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 (>25 or 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 5 (2017).

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	10-20	20-30	0-30	>20	>30	>30
Jul	0-10	0-20	0-10	10-20	20-30	10-20	>20	>30	>20
Aug	0-10	0-20	0-10	10-20	20-30	10-25	>20	>30	>25
Sep	0-10	0-20	0-10	10-20	20-30	10-25	>20	>30	>25
Oct	0-10	0-20	0-20	10-20	20-30	20-40	>20	>30	>40
Nov	0-20	0-20	0-30	20-40	20-40	30-50	>40	>40	>50
All	**0-10**	**0-20**	**0-10**	**10-20**	**20-30**	**10-25**	**>20**	**>30**	**>25**

Sedimentation Monitoring

The rate of sedimentation (mg dry weight accumulated per day) was highest at the inflow end of Seton Lake (67 to 150 mg/day), which is closest to the diversion inputs, and lowest in the Anderson Lake samples (7 to 36 mg/day), which are outside the influence of the Carpenter diversion (Figure 3.5). The rate of sedimentation in Seton Lake tended to diminish 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 103 mg/day, and in the outflow section from 19 to 66 mg/day. This sedimentation gradient was maintained across each sampled season (where data were available). Total accumulations tended to be approx. 11% to 26% higher during spring in 2017 compared to 2016 at each location. Accumulation rates during the other seasons were more similar among years.

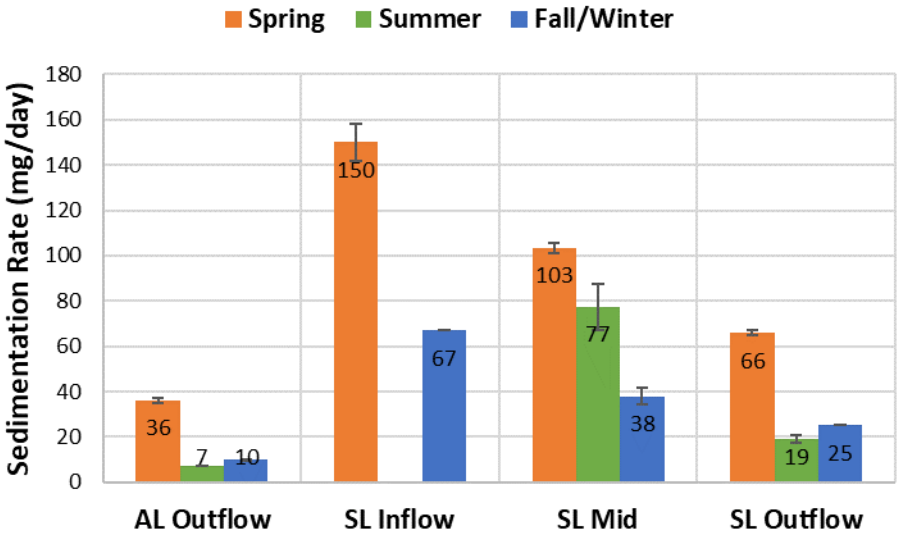


Figure 3.5 Mean sedimentation rate by sampler location (longitudinal zone) and season during Year 5 (2017). AL = Anderson Lake; SL = Seton Lake. The error bars represent ± 1 SD among the replicates for each sample. Spring samples were collected from 25 May to 25 July; Summer samples were collected from 25 July to 17 October; and Fall/Winter samples were collected from 28 October to 25 May.

In all Seton Lake sections, the rates of sedimentation were greatest in spring, corresponding with high water diversion rates (mean = 153 $m^3 \cdot s^{-1}$; see Section 3.1) and low drawdown elevations in Carpenter Reservoir (minimum = 615 masl) during that sampling period in 2017. Summer and fall/winter sedimentation rates were reduced in each lake section when Carpenter diversion rates were lower (means = 74 and 87 $m^3 \cdot s^{-1}$, respectively; Section 3.1) and Carpenter elevations were higher. Sedimentation rates in the summer were higher than fall/winter in the mid section of Seton Lake, but were relatively equal across those seasons at the outflow end of both lakes. A sedimentation rate value for the summer sample at the inflow end of Seton Lake was not available due to sample loss.

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 3.6). Based on the data available to-date, 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 was lower in the middle and outflow sections of Seton Lake. In fact, relative to the mid and outflow sections, the slope was 4.8 and 2.3 times greater at the inflow end, respectively. In other words, the accumulation increases at a greater rate with diversion volume nearest the inflow than it does at further longitudinal distances down the lake.

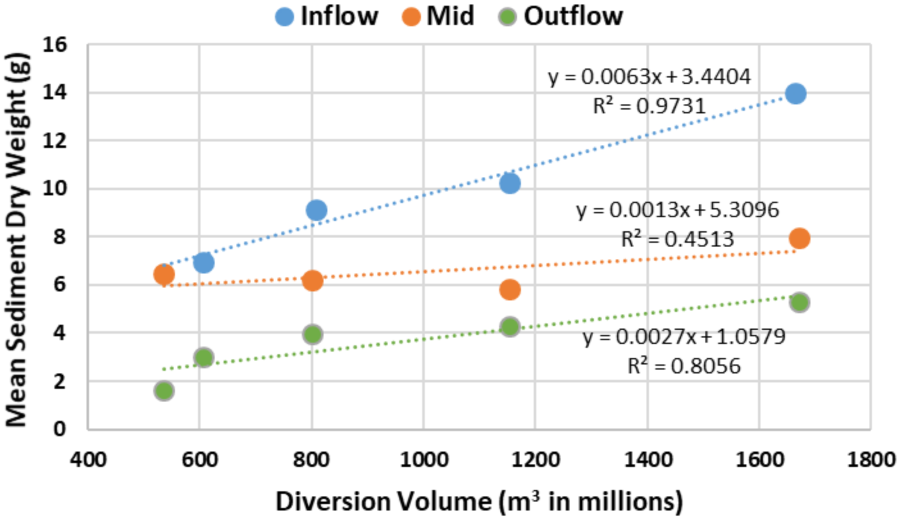


Figure 3.6 Sediment accumulation in each longitudinal zone (i.e., inflow, mid, and outflow) of Seton Lake according to diversion volume from Carpenter Reservoir based on Year 4 and 5 (2016 and 2017) results. Linear regressions and R^2 values are shown.

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 3.7). Since the samplers were deployed for the first time last 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. This is probably because larger particles fall out of suspension faster (i.e., closer to the diversion source at the inflow end) than smaller particles. 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.

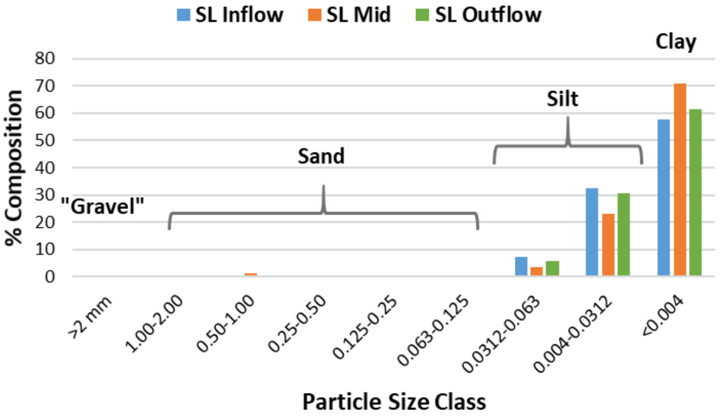


Figure 3.7 Sediment particle size distribution from samples collected in each longitudinal zone (inflow, mid, and outflow) of Seton Lake in Year 5 (2017). Samples for each season were aggregated to reach minimum sample size for this analysis.

Total organic carbon was also assessed by the lab to determine the percent contribution of carbon-based organic content to the sediment accumulation (Figure 3.8). 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 (i.e., diversion release volumes and Carpenter Reservoir elevations) will continue to augment these relationships and strengthen the conclusions drawn from them by the end of the monitor.

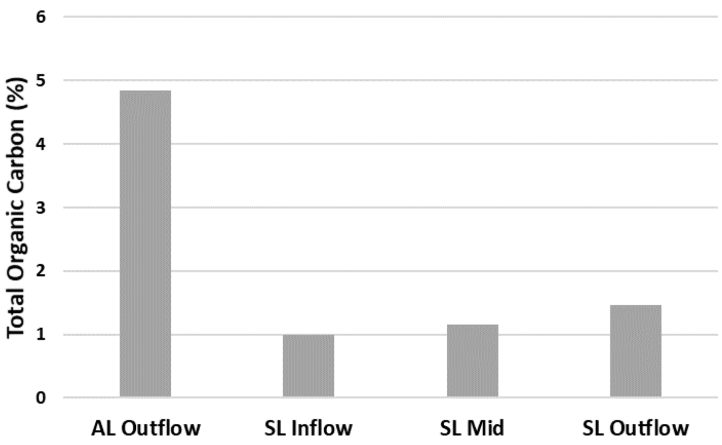


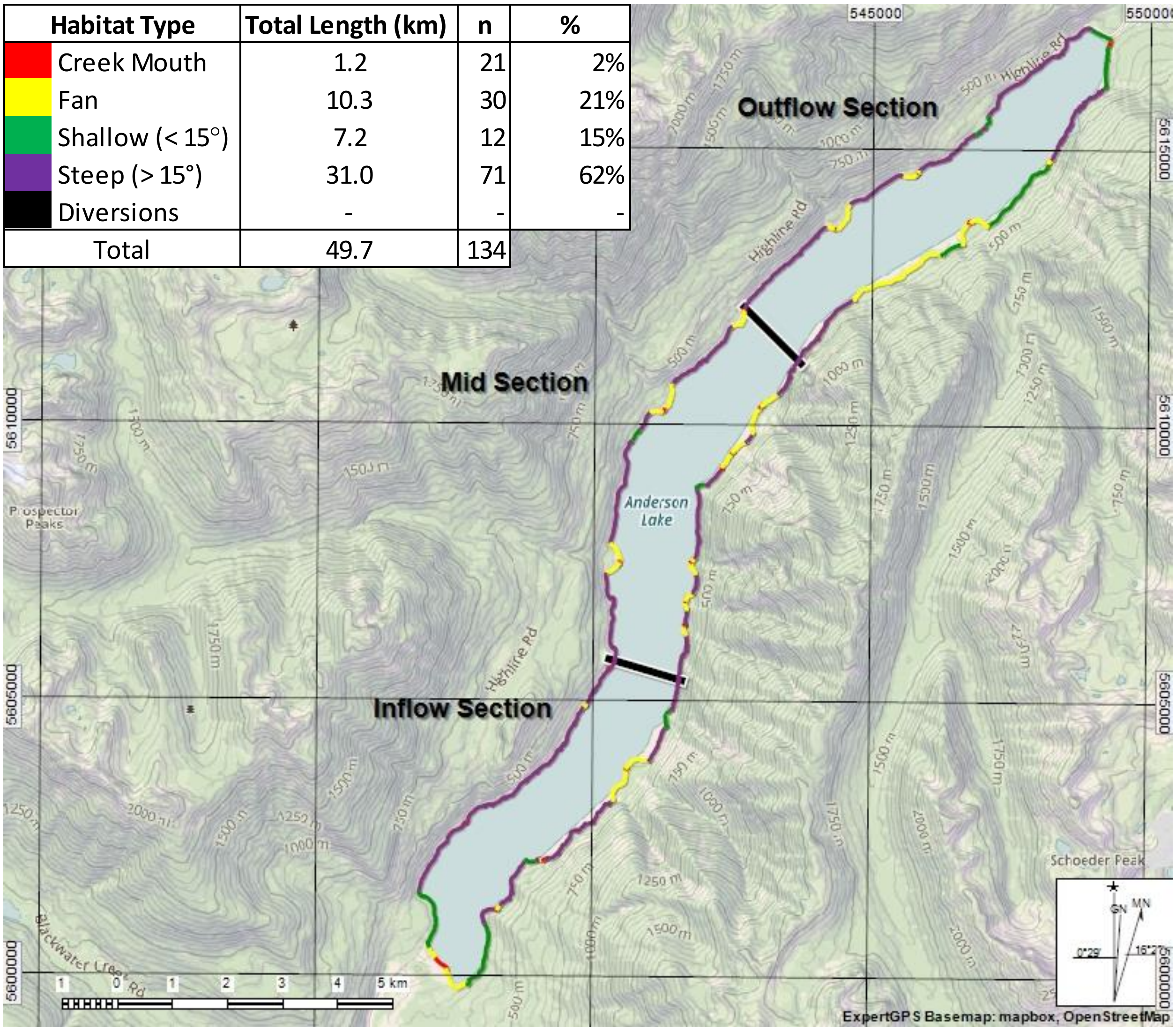
Figure 3.8 The contribution of total organic carbon by location to the Year 5 (2017) sedimentation samples.

3.2. Shoreline Habitat Mapping

The shoreline habitat mapping in Year 5 (2017) documented the proportional distribution of general meso-habitat types around the entire perimeter of Anderson Lake in July (Figure 3.9), which were directly comparable to the survey results collected for Seton Lake in August 2015. The mid-line length of Anderson Lake was 22.0 km, and the total shoreline length was 49.7 km. This measured mid-line length was very similar to Seton Lake (only 200 m shorter); however, the total shoreline length was nearly 3 km less in Anderson Lake. Seton lake lies along an east-west axis, whereas Anderson Lake has more of a northeast-to-southwest orientation.

The total length of shoreline associated with adjacent or overhanging terrestrial vegetation was 38.0 km (or 77% of the lake perimeter). The total vegetated length in Seton Lake was 27.5 km (or 52% of the lake perimeter). The lower value in Seton Lake is because the north and east shores are more heavily impacted by development (e.g., railway, BC Hydro facilities, community residences, swimming beach). There are development impacts on Anderson Lake also (e.g., railway, cottages and homes, swimming areas), but these have been less cumulatively impactful on vegetation at the lake edge. In Anderson Lake, the north, south and east shores were almost entirely vegetated (99% to 100% by shoreline length); whereas, the west shore was the most impacted (characterized by 50% vegetation cover).

Terrestrial vegetation can be an important source of allochthonous nutrients to littoral food webs in aquatic systems (Perrin et al. 2016). Anecdotally, the differences in the availability of overhanging and adjacent terrestrial vegetation between Seton and Anderson lakes may provide relevant information for contrasting the availability of this nutrient source between the two lakes. In turn, this information may contribute to the weight-of-evidence approach by potentially informing any observed differences in productivity or growth rates of target fish species.



	Habitat Type	Total Length (km)	n	%
🟥	Creek Mouth	1.2	21	2%
🟨	Fan	10.3	30	21%
🟩	Shallow (< 15°)	7.2	12	15%
🟪	Steep (> 15°)	31.0	71	62%
⬛	Diversions	-	-	-
	Total	49.7	134	

ExpertGPS Basemap: mapbox, OpenStreetMap

Figure 3.9 Results of a shoreline habitat mapping survey conducted around the perimeter of Anderson Lake on 26 and 27 July 2017.

There was a total of 134 habitat units classified during the shoreline habitat mapping survey on Anderson Lake. Of the habitat types identified for this monitoring program, steep shorelines (slope >15°; *n*= 71 units) were by far the most prevalent, contributing 31.0 km (62%) to the total perimeter length (see table included in Figure 3.9). Approximately 60% (18.4 km) of this steep terrain was made up of alluvial or colluvial material (rocks, boulders and other sediment particles), and 40% (12.6 km) was bedrock. Fans (*n*= 30) were the next most prevalent habitat type in the littoral zone, contributing 10.3 km (21%) to the total shoreline length.

The remaining shoreline habitats in Anderson Lake were shallow slopes (<15°; *n*= 12 units) and creek mouths (*n*= 21), which contributed 7.2 km (15%) and 1.2 km (2%) to the total perimeter length, respectively. Fans, which are formed by alluvial processes associated with streams, were more abundant than the actual number of creek mouths during the survey since many drainages in the valley are intermittent, with surface flows available for only a portion of the year (i.e., the snow-melt period in spring). The same phenomenon was also noted for Seton Lake in summer.

There were some differences in the contributions of the various habitat types between Seton and Anderson lakes, but in general the habitat mapping results highlighted that there are many similarities as well (Table 3.3). Total steep habitats were very similar, whereas there were more fans and fewer shallow shorelines in Anderson than in Seton. Anderson Lake has almost double the number of creek mouths (which is also why there are more fans); however, these natural inflow sources only contribute 1% and 2% to the shoreline habitat in Seton and Anderson lakes, respectively. In all, differences in the contributions of each habitat type were only between 1% and 7% between the two lakes.

An additional "habitat type" in Seton Lake were the diversion inflow sources. For the purposes of the shoreline habitat mapping, diversions referred to developments that regulate particular inflows or outflows. They included: the regulated inputs from the BR1 and BR2 Generating Stations, the Cayoosh diversion from Walden Power, and the 800 m long approach channel above Seton Dam. While less numerous than the natural inflow sources, they collectively convey the majority of flows into and out of Seton Lake. There are no significant diversion or flow regulating developments associated with Anderson Lake.

Table 3.3 Summary and comparison of habitat strata contributions to total shoreline length in Seton and Anderson Lakes based on habitat mapping surveys conducted in Year 3 (2015) and Year 5 (2017), respectively.

Habitat Type	**Habitat Sub-type**	**Total Length (km) and % Contribution**				**Difference between lakes**
		Seton Lake		**Anderson Lake**		
Creek Mouth		0.6	**1%**	1.2	**2%**	**1%** (0.6 km)
Fan		8.7	**16%**	10.3	**21%**	**5%** (1.6 km)
Shallow (< 15°)		11.5	**22%**	7.2	**15%**	**7%** (4.3 km)
Steep (> 15°)	Bedrock	8.7	29%	12.6	41%	12**%** (3.9 km)
	Colluvium	21.2	71%	18.4	59%	12% (2.8 km)
	Total Steep	29.9	**57%**	31.0	**62%**	**5%** (1.1 km)
Diversions		0.2	**<1%**	-	**-**	**<1%** (0.2 km)
Totals (km)		**52.6**		**49.7**		**2.9 km**

Lake Length (km)	22.2		22.0		**1% (0.2 km)**
Terrestrial Veg. (km)	27.5	**52%**	38.1	**77%**	**25% (10.6 km)**

3.3. Resident Fish Population Index Survey

A total of 711 fish were captured by gill netting during the annual resident fish index survey in Year 5 (2017; Seton Lake *n*= 500; Anderson Lake *n*= 211), including 8 resident species

(Table 3.4). Target species made up 77% of the catch, and the other 23% were non-target species including: northern pikeminnow, peamouth chub, redside shiner, bridgelip sucker, and mountain whitefish (in decreasing order of abundance). Thirty-three sites were sampled in Seton Lake, including 24 nearshore and 9 offshore sets; and 27 sites were sampled in Anderson Lake, including 18 nearshore and 9 offshore sets. The total sampling effort was 313.9 net-hours (Seton Lake = 160.5 net-hours; Anderson Lake = 153.5 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 5 (2017).

Lake	Species[a]								
	BT	GW	ON	RB	MW	PMC	NSC	BSU	RSC
Seton	7	349	36	1	3	38	35	17	14
Anderson	38	70	30	17	2	11	30	1	12
Totals	**45**	**419**	**66**	**18**	**5**	**49**	**65**	**18**	**26**

[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.

Twenty-seven bull trout (Seton Lake *n*= 3; Anderson Lake *n*= 24) and two rainbow trout (both in Anderson Lake) were marked with PIT tags. Only fish that were alive and in robust condition were tagged. Three bull trout that had been tagged during previous study years (i.e., 2013 to 2016) were recaptured in Year 5 (2017). Original capture and recapture information for these fish is summarized in Table 3.5. The two recaptured bull trout in Anderson Lake were in the same location as the previous year and grew 29 and 46 mm/year between capture events. The bull trout in Seton Lake was recaptured 8.8 km from its original capture location (from inflow section to mid section) and had grown 93 mm.

Table 3.5 Summary of inter-year recaptures in Year 5 (2017).

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)	Growth (mm/yr)
	Date	Zone	FL (mm)	Date	Zone	FL (mm)		
888688	5-Oct-16	AL-Mid	445	4-Oct-17	AL-Mid	474	0.0	29
888710	6-Oct-16	AL-Mid	350	5-Oct-17	AL-Mid	396	0.0	46
888933	30-Sep-16	SL-Inflow	590	24-Sep-17	SL-Mid	683	8.8	93

[a] The prefix to each of these tag codes is: 900 226000

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 3.6). 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 (*O. nerka*) 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 nearshore zone of Anderson Lake; catches for this species continued to be particularly low in Seton Lake (as in past years).

Table 3.6 Summary of fish catch-per-unit-effort results for target species during the annual resident fish population indexing survey, 22 September to 6 October 2017.

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	-	-	29.0	14.8	-	5.8	-	0.2
	Mid	11.7	0.2	87.4	26.5	-	1.2	-	-
	Outflow	3.8	0.2	96.2	15.6	-	-	-	-
Seton Lake Average		**6.2**	**0.1**	**75.3**	**18.9**	**0.0**	**2.4**	**0.0**	**0.1**
Anderson Lake	Inflow	84.8	1.0	-	2.5	39.1	0.6	-	0.2
	Mid	48.2	0.6	-	2.3	85.7	0.2	5.4	0.2
	Outflow	6.5	1.4	6.5	9.0	-	0.8	6.5	0.2
Anderson Average		**46.6**	**1.0**	**2.0**	**4.6**	**44.6**	**0.5**	**4.1**	**0.2**

[a] Values in these columns represent immature *Oncorhynchus nerka* that could not be differentiated between juvenile sockeye and gwenis in the field. Based on scale ageing results, juvenile *O. nerka* (Age 1 and 2) were all <180 mm in Seton Lake and <200 mm in Anderson Lake.

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 3.10). 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 primarily in offshore habitats. Juvenile *O. nerka* were also captured, and they were most abundant in the inflow and mid sections of Anderson Lake (nearshore habitat), followed by the inflow and mid sections of Seton Lake (offshore habitat). Small numbers of *O. nerka* juveniles were also captured in the offshore sets in each section of Anderson Lake.

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.

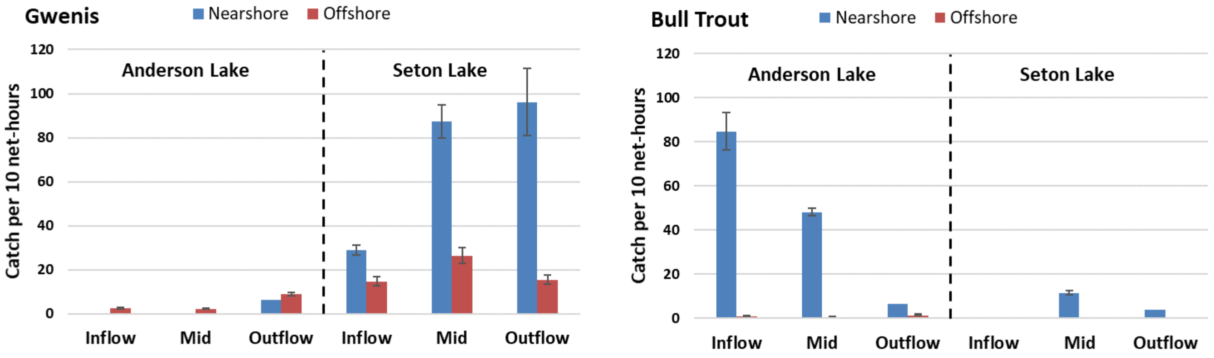


Figure 3.10 **Catch-per-unit-effort summary for gwenis (left) and bull trout (right) comparing nearshore vs. offshore habitats in each longitudinal zone for Seton and Anderson lakes based on Year 5 (2017) sampling.**

Between the two lakes, bull trout showed the opposite pattern of catch rates to gwenis. CPUEs were generally 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, highest catches occurred in the mid section, followed by the outflow section. Bull trout were not captured at the inflow end of Seton Lake in Year 5 (2017). In Anderson Lake, catch rates for bull trout were highest at the inflow end of the lake, followed by the mid and then outflow sections (Figure 3.10).

As in previous years, catches of rainbow trout were low with only 1 of this species (272 mm forklength) captured in Seton Lake sampling in 2017. A total of 17 rainbow trout were captured in Anderson Lake (ranging from 117 to 348 mm). The highest CPUE for this species was in the outflow end of Anderson Lake (i.e., 6.5 fish per 10 net-hours), which was different than the Year 4 (2016) result when they were most abundant in the catch at the inflow end (10.3 fish per 10 net-hours). 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 3.11. 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.

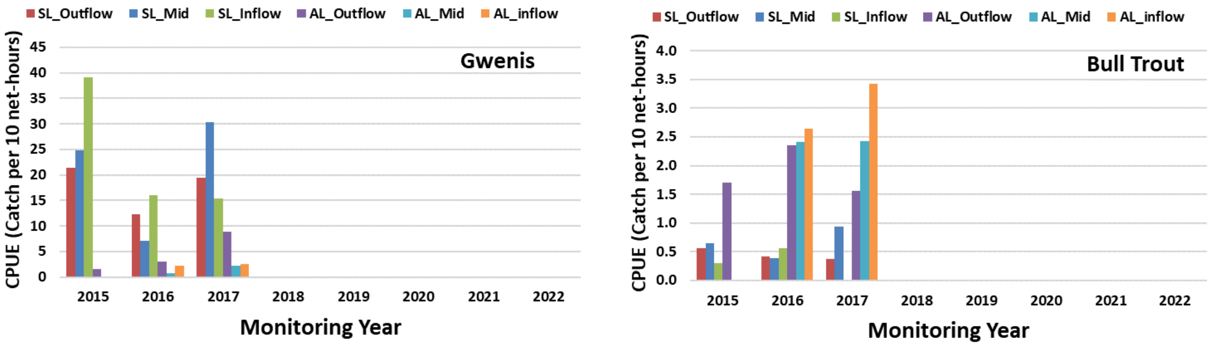


Figure 3.11 **Catch-per-unit-effort summary for gwenis (left) and bull trout (right) by longitudinal zone in Seton and Anderson lakes for each monitoring year from 2015 (Year 3) to 2022 (Year 10). Values for years 1 and 2 (2013 & 2014) were not applicable to this summary because sampling was done by boat electrofishing in those years. Anderson Lake inflow and mid zones were not sampled in 2015.**

Overall, total catch rate for gwenis was highest in Seton Lake in 2015 (119.7 fish/10 net-hours). However, all net sets were left in overnight that year, 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 Years 4 and 5, 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 has been effective for reducing mortality (and expanding the number of sites that could be sampled) in 2016 and 2017; however, catch rates for gwenis were also lower as a result (57.7 and 75.3 fish/10 net-hours, respectively). 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 5 (2017; Figure 3.12). For gwenis in Seton Lake, their distribution spanned the range of sampling depths. Approximately 4% of the gwenis were captured in the epilimnion thermal layer (0 to 20 m depth), 85% were in the narrow metalimnion (20 to 30 m), and 11% 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).

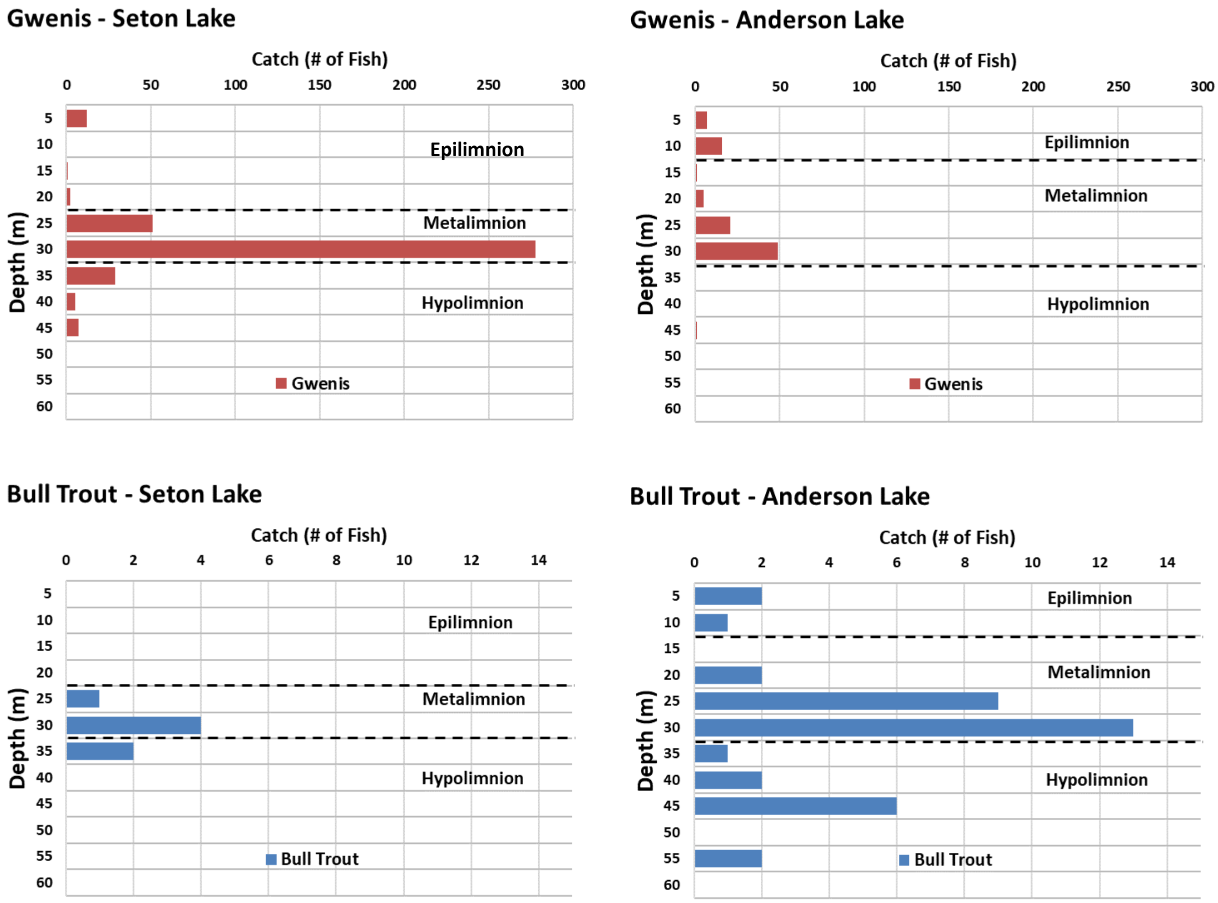


Figure 3.12 Numbers of gwenis (upper plots) and bull trout (lower plots) by capture depth in Seton Lake (left) and Anderson Lake (right) during the annual population indexing survey in Year 5 (2017). Note the different x-axis scales between upper and lower plots.

In terms of horizontal distribution from shore, the majority (98%) of gwenis in Seton Lake tended to be >60 m from the lake edge (Figure 3.13). This pattern was also evidenced in the distance from shore distribution for bull trout, which reflected that the bull trout tended to be found in panels that also captured gwenis (despite dramatically different body size). 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).

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 or the very end panel of nearshore nets (i.e., >75 m horizontal distance from shore). As in Seton Lake, the *O. nerka* caught in <10 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 widely distributed across the range of sampled distance from shore, though a higher proportion (i.e., 61%) were at distances between 45 m and 90 m from the lake edge. The catch rate tended to diminish with increasing distance beyond that (i.e., in offshore sets) and, notably, the distance from shore pattern reflected that the spatial distribution of bull trout and gwenis barely overlapped in this lake.

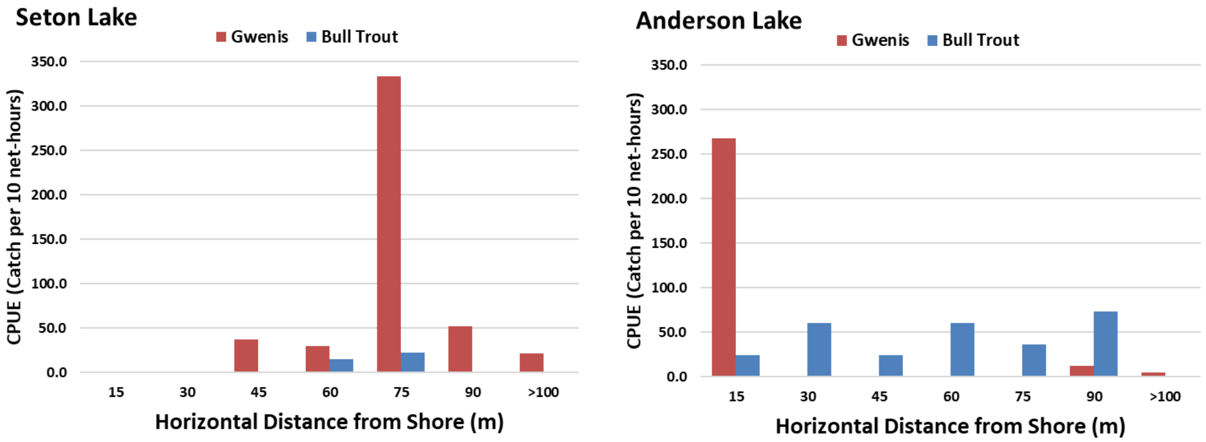


Figure 3.13 CPUE for gwenis (red columns) and bull trout (blue columns) by horizontal distance from shore in Seton Lake (left) and Anderson Lake (right) during the annual population indexing survey in Year 5 (2017). Note: Distances less than 100 m are from nearshore sets; offshore sets are represented 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 3.14). Minimum sizes in the sample (across years) have been 95 mm and 106 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. Median forklengths for Age 1 gwenis were 107 mm in Seton Lake; Age 1 fish were not captured in Anderson Lake. Median Age 2 forklengths were 130 mm (Seton) and 135 mm (Anderson). In Seton Lake, all of the mature gwenis were Age 3, the same as what was reported for the Year 3 and 4 (2015 and 2016) results, as well as the BRGMON-6 ageing results (Limnotek 2015), and ranged narrowly in size from 158 to 220 mm (median = 191 mm).

In Anderson Lake, the mature gwenis were up to 4 years old and larger than the Seton Lake fish, ranging in size from 142 to 342 mm (median = 232 mm and 302 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 (22 September to 6 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). The Seton Lake fish may also benefit from shallower daytime habitat use afforded by the turbidity, and lower predation risk (due to lower predator abundance), which may also contribute to the higher growth rates observed for the early age classes of *O. nerka*. 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 the lower fish densities coupled with 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 3.14).

For the bull trout sampled in Seton Lake (*n*= 7) in 2017, one was Age 3 (268 mm in length), four were Age 6 (383 to 683 mm), and two were Age 7 (436 & 434 mm) (Figure 3.15). More age classes were represented by the bull trout captured in Anderson Lake (i.e., Age 3 to Age 9), and they spanned a size distribution from 300 to 760 mm. By accruing size-at-age data across monitoring years, we were able to fit growth curves to the median values for bull trout from both Seton and Anderson Lakes 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 median size values of 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), and the predicted growth curve based on the available data is also lower. Bull trout may be larger in Seton Lake due to lower density of this species, resulting in less competition for food resources relative to Anderson Lake where bull trout abundance is higher. There is a trade-off with foraging opportunity, however, since predation efficiency in Seton Lake may be limited by the turbidity resulting from the diversion inflows (Limnotek 2016). In addition, we speculate that the inclusion of mature gwenis in the diet of the Seton Lake bull trout (due to appropriate prey body size) may lend itself to better growth since the gwenis are relatively abundant in that lake. The larger body size of most mature gwenis in Anderson Lake (which are also less abundant) may preclude them as a prey item for bull trout. Some evidence of bull trout movements (Seton Entrainment Study; BRGMON-8 Year 4 results) also suggests that Seton Lake bull trout may be more migratory – opportunistically moving into and out of Seton Lake to and from the Seton River corridor, Fraser River, or adjacent watersheds (e.g., Bridge River, Yalakom River) to capitalize on the best feeding locations wherever they occur at different times of year (Burnett and Parkinson 2018; Sneep 2018b). 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 curves to further support any conclusions about differences in growth rates between the lakes.

Figure 3.14 **Size-at-age box plot based on scale ageing data from randomly selected gwenis captured during the annual gill net survey in Seton and Anderson lakes from late September to early October, 2015 to 2017. The boxes are bounded by the 75th and 25th percentiles. The median divides each box and the whiskers represent the 10th and 90th percentiles. Sample sizes for some age groups are still relatively small.**

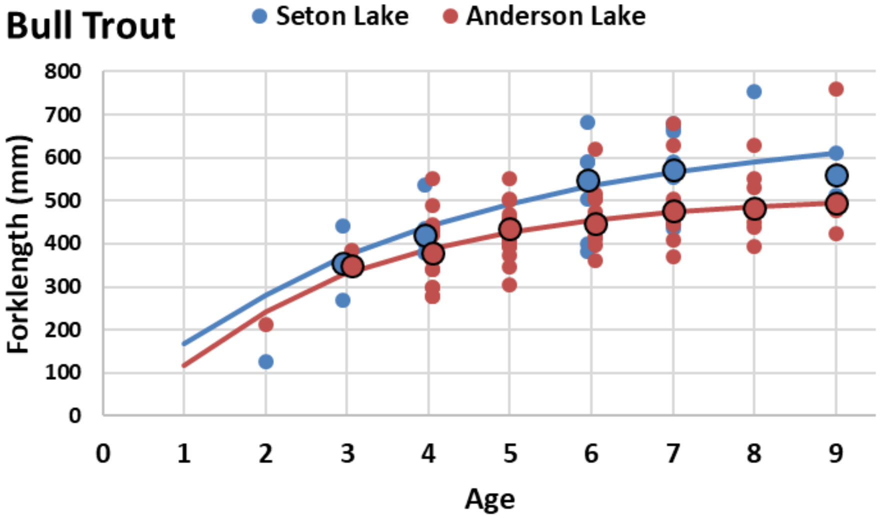


Figure 3.15 Size-at-age plot based on fin ray and otolith ageing data from bull trout captured during the annual gill net surveys in Seton and Anderson lakes from late September to early October, 2015 to 2017. The lines represent the von Bertalanffy growth curves based on median size values for each lake.

A total of eighteen rainbow trout were captured in Year 5 (2017), and the majority of them (*n*= 17) were in Anderson Lake. They ranged in size from 117 to 348 mm. Scales were collected from 8 fish, but age was not readable from 1 of those due to poor scale condition. Of the seven fish that were aged, two were Age 2 (117 and 188 mm), four were Age 3 (130, 187, 203, and 222 mm), and one was Age 4 (220 mm).

Bull trout stomach contents

Stomach contents were assessed in the field for 13 bull trout that had succumbed to the sampling in Year 5 (2017); 3 were from Seton Lake and 10 were from Anderson Lake (Table 3.7). 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). As has been noted in previous reports, the bull trout in Seton Lake had been feeding on gwenis, which were between approximately 160 mm and 200 mm in length. The Anderson Lake bull trout had been feeding on juvenile gwenis (size range: approx. 100 to 130 mm). In four cases the stomachs were completely empty or the contents had been so digested that there was no identifiable matter remaining.

Table 3.7 **Summary of stomach contents assessed for bull trout from Seton and Anderson lakes during the annual gill netting survey, 22 September to 6 October 2017.**

Lake	Bull Trout Size		Stomach Contents			
	Fork length (mm)	Weight (g)	Species	#	Approx. Prey Size (mm)	Comments
Seton	268	203	Stomach contents digested			
	436	1134	GW	3	160 - 200	2 mostly digested
	444	1147	GW	1	na	Partially digested
Anderson	300	249	Unid.	1	na	Mostly digested
	395	573	Stomach contents fully digested (empty)			
	417	663	O. nerka	1	100 - 130	Juvenile
	424	711	O. nerka	1	100 - 130	Juvenile
	429	800	O. nerka	5	100 - 130	Juveniles
	451	892	Stomach contents fully digested (empty)			
	460	944	O. nerka	6	100 - 130	Juveniles
	570	1850	O. nerka	2	100 - 130	Juveniles
	628	2450	Stomach contents fully digested (empty)			
	680	3590	O. nerka	1	100 - 130	Juvenile

4. Discussion

Data were collected and analysed in 2017 (Year 5) 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 5 (2017) 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?

Gwenis

As in Years 3 and 4 (2015 and 2016), gwenis were the most abundant species in the annual resident fish sampling in Year 5 (2017), 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.

Since the timing of sampling coincides with the start of spawning for this species in Seton Lake, this apparent gradient of abundance along the longitudinal axis of the lake appears to reflect differential spawning use among the inflow, mid and outflow sections. This could be related to the varying degrees of fine sediment deposition according to proximity to the diversion inflows, as described by the sedimentation results (Section 3.1). Other factors contributing to the observed distribution could also include differential food base availability or foraging opportunities among the sections. However, these results are still considered uncertain at this point due to limited replication. Data from the remaining monitoring years will contribute to the weight of evidence.

As in previous years, the Seton Lake gwenis were noticeably smaller than the Anderson Lake gwenis, particularly after Age 2 (median sizes at Age 3 = 191 mm vs. 232 mm, respectively, as of Year 5 (2017)). 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 5 (2017), 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 between 30 to 90 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 in Anderson Lake were almost exclusively either <15 m from shore (i.e., juveniles) or in offshore habitats (i.e., >100 m from shore), and either near the surface (0 to 10 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 or early rearing as juveniles, 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. 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 both Seton and Anderson lakes spawn approx. 1.5 months earlier than Portage Creek sockeye that apparently rear only in Seton Lake (Limnotek 2016).

On the other hand, it’s also possible that the spawn timing difference reflects localized adaptations to differing habitat conditions among the two lakes. Studies in other systems have shown that *O. nerka* spawning habitat use or ecotypes (e.g., stream versus in-lake spawning), as well as spawn timing, are highly adaptive according to conditions, and sympatric populations with different ecotypes and run timings can be found within the same systems (Whitlock et al. 2018). The results of a study on *O. nerka* in Lake Washington suggested that rapid differentiation in these traits among population groups was the result of local adaptation to particular spawning and incubation environments (Hendry et al. 1998).

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 the populations are no longer connected. 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 budget and is not within the scope of 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 (2017 *n*= 13 among both lakes). Across all monitoring years to-date, it has been noted that all of the identifiable prey items in the bull trout stomachs at the time of the surveys have been various lifestages of the species *O. nerka* (i.e., sockeye or gwenis; eggs, juveniles and adults). In some cases, several (up to 5 or 6) adult gwenis have been noted in the stomachs of some of the larger bull trout in Seton Lake. This capacity to forage on adult gwenis as a primary food item may contribute to the larger mean size-at-age and growth rate for Seton Lake bull trout relative to the Anderson Lake fish. 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, whereas gwenis were most abundant at the outflow end and less so in the mid and inflow sections. As noted here and in previous reports, 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), as well as Spider Creek and Whitecap Creek (which are both tributaries of Portage Creek); 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 during Year 4 (2016), bull trout movements in Seton Lake tended to have a downstream orientation during the monitored period (27 July to 12 October, 2016), 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, reflecting possible spawning movements and/or foraging opportunities associated with the Gates Creek sockeye returns. 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).

Recaptures of PIT tagged bull trout can also shed light on their movements within or among sample sessions. Three PIT tagged bull trout have been recaptured by the program to-date (two in Anderson Lake; one in Seton Lake). Each of these fish were recaptured in the same lake where they were originally captured, further suggesting some degree of lake-based fidelity. This is a small sample size to-date, but capture and recapture locations for PIT tagged fish will continue to be monitored to build on this dataset of bull trout movement information within the Seton-Anderson watershed.

Rainbow Trout

Rainbow trout have only been sampled in very low numbers during all five years of this monitoring program to-date. One rainbow trout was captured in Seton Lake in 2017. The other seventeen individuals captured in Year 5 (2017) were predominantly captured within the epilimnion layer in the mid and outflow sections of Anderson Lake. In 2016 the highest catch rates were in the inflow section of Anderson Lake. Across years, the sizes of these fish have ranged from 117 mm to 440 mm, and the aged individuals (*n*= 15) have ranged from Age 2 to Age 8 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. The summary of life history information that follows for these species was based on the information available from the BRGMON-8 sampling results, supplemented by information referenced from "The Freshwater Fishes of British Columbia" (McPhail 2007), which incorporates information from other watersheds in BC.

Across years, northern pikeminnow have been the most abundant of this group (*n*= 234) and contributed fairly equally to the sample from each lake. They ranged in size from 102 to 446 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*= 199), but were more prevalent in the Seton Lake catch than the Anderson Lake catch. They ranged in size from 105 to 290 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).

Redside shiner (*n*= 82) and bridgelip sucker (*n*= 51) were more abundant in Seton Lake, and ranged in size from 79 to 122 mm, and 97 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.

Mountain whitefish (*n*= 16) were captured in equally low numbers in each lake. They ranged in size from 120 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).

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, 4 and 5 (2015 to 2017) 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 three years to-date, it is not possible to determine whether the selected alternative has an effect on the abundance and diversity of fish populations in Seton Lake at this point.

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 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. Three bull trout that had been captured and tagged in Year 4 (2016) were recaptured in Year 5 (2017), but each of these fish were in the same lake as their original capture event, and 2 of them were recaptured in the exact same locations. Nonetheless, 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 3 years of replicate fish sampling (using the gill netting method) and less than 3 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 was high in spring of 2016 and 2017 relative to the previous monitoring years. These high inflow seasons and years may provide a signal that is unique to the conditions in prior or subsequent years, and may be detectable in the various parameters being monitored for this program. However, because we don’t yet have enough replicate data for years with higher or lower diversion inflows to compare the 2016 and

2017 results 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 two years 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 in the summer were higher than fall/winter in the mid section of Seton Lake, but were relatively equal across those seasons at the outflow end of both lakes.

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, 4 and 5 (2015 to 2017) 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.
- 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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