Bridge River Project Water Use Plan

Downton Reservoir Fish Habitat and Population Monitoring

Implementation Year 5

Reference: BRGMON-7

BRGMON-7 Downton Reservoir 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

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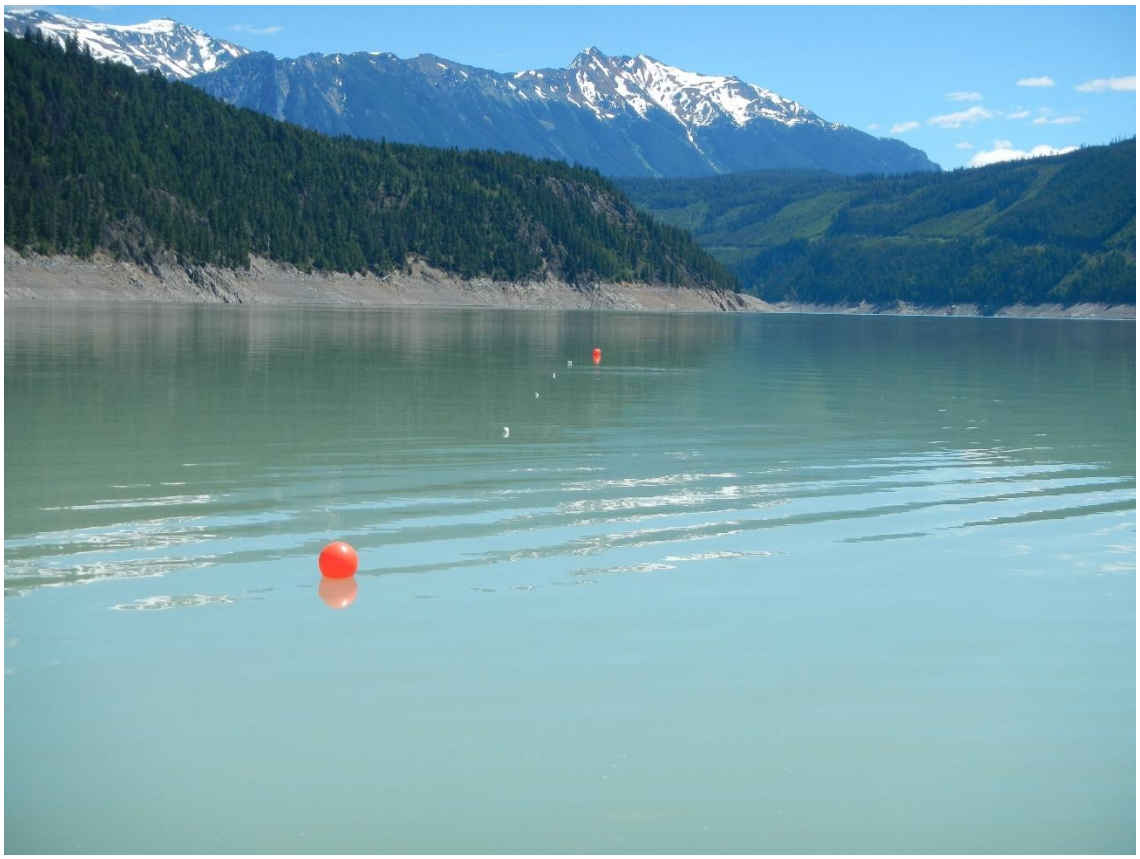
BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 5 (2017) Results



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Executive Summary

Data collection for Year 5 of this proposed 10-year study was completed in 2017. The primary objectives of this monitoring program are: 1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and, 2) To provide information required to link the effects of reservoir operation on fish populations.

To-date, only rainbow trout and a single bridge lip sucker have been captured in the reservoir and its tributaries. Seven methods were employed in Year 5 (2017) to document the biological characteristics of the rainbow trout population, generate an annual abundance index, characterize available fish habitats, and assess the effects of the modified reservoir operations, implemented since Year 4 (2016).

The management of surface elevations in Downton Reservoir follows a seasonal pattern: lowest elevations occur in spring (generally April to May) and highest elevations, or full pool, usually occur in late summer to early fall (August to September). Year 5 (2017) was the second year that the reservoir was operated within the new modified maximum elevation (i.e., 734 m); maximum reservoir elevation in 2017 was 733.5 m. Lowest reservoir elevation in 2017 (711.5 m) was most similar to 2014 (709.0 m), and 8-9 m lower than 2013, 2015, and 2016.

The shoreline habitat mapping in 2017 documented an 11.4 km (45%) decrease in reservoir length and a 25.8 km (43%) decrease in shoreline length at the 716 m reservoir elevation surveyed, compared to the 745 m (near full pool) elevation surveyed in Year 3 (2015). Compared to 722 m elevation (surveyed in Year 4 (2016)), the reservoir and shoreline lengths at 716 m were 3.6 km (20%) and 6.4 km (16%) shorter, respectively, but the percent contributions of each habitat type were very similar. Between the full pool and low pool elevations surveyed, there was a substantial reduction in steep shoreline habitat and an increase in shallow habitat length despite the reduced wetted extent of the reservoir. Fan habitat decreased in total length, but only slightly, and actually increased in percent contribution to the total at the low pool elevation. The number and percent contribution of creek mouths that were receiving flow also increased during the low pool surveys in the spring since all intermittent drainages were flowing at that time (i.e., spring run-off conditions).

Substrate size, interstitial depth, and slope measurements were collected from 25 sites in the reservoir drawdown zone (n= 20) and in select tributary streams (n= 5) during 2017. The collected data focussed on 734 m and 747 m elevation in the reservoir, and upland versus drawdown zone in the tributaries towards the goal of making the sample size equivalent for each targeted elevation across years. The added data did not substantively change conclusions from the results, but bolstered confidence in the observed patterns that are emerging from these data. As was reported previously (Sneep 2018b), fines and small gravels continued to be the most abundant substrate classes; however, the relative proportions vary by elevation. The highest proportions of fines and small gravels were at the lowest surveyed elevation (722 m)

and the lowest proportions were at the top of the drawdown zone. Beyond these smallest substrate classes, the percent contribution of each substrate category tended to diminish with increasing size. Substrates larger than fines and small gravels contributed 27%, 41% and 54% at 722 m, 734 m and 747 m, respectively. Interstitial space availability was generally low at all sites, but were highest (and exhibited a positive correlation with elevation) at creek mouths and in tributaries.

Tributary fish sampling was conducted in summer during Year 5 (2017). Mean CPUE (for all creeks sampled) was 14.7, compared to 6.1 fish/100 m in spring (2016) and 4.4 fish/100 m in fall (2015). Two out of eight sites had no fish and four of the visited tributaries could not be sampled due to steep gradients above the current reservoir level, or because the creeks had gone dry. Captured rainbow trout ranged in age from 0+ to 4, but the majority (i.e., 24 out of 39, or 62%) of the fish captured were the new year class of rainbow trout fry (forklength = 23 to 33 mm) that had recently emerged from the gravel. This data served to generally confirm the predicted emergence timing based on ATUs (late July to early September; peak in third week of August). Other than these Age-0+ fry, the catch rates for the other age classes were as equivalently low as they were in spring and fall.

Approximately 16 km of shoreline was sampled by boat electrofishing over 8 nights from 1 to 8 June. In total, 1,081 rainbow trout were captured from 61 sites. Of these fish, 1,013 were marked with PIT tags and another 21 rainbow trout captured by angling were also PIT tagged and released alive.

Total CPUE in the reservoir was 6.7 fish/100 m of shoreline which was down from 7.5 and 7.9 fish/100 m in Years 3 and 4 (2015 and 2016), respectively. This difference was due to reduced catch of Age-1 fish in 2017, which was down by approx. 50% from previous years. On the other hand, CPUEs for Age-3 to Age-5 fish were higher in 2017, including the Age-2 cohort which had been low in 2016. Highest CPUEs by habitat type were at creek mouths (17.8 fish/100 m) and then shallow slopes (10.8 fish/100 m), followed by fans and then steep slopes (7.1 and 3.9 fish/100 m, respectively). This pattern was generally consistent with the trends among habitat types from previous years. Highest total CPUE by longitudinal zone of the reservoir was recorded in the west zone in 2017; although this has varied among years to-date, reflecting that rainbow trout are generally distributed and move throughout the reservoir.

A gill net survey was conducted in the pelagic zone of Downton Reservoir from 20 to 23 June 2017. A total of 36 rainbow trout was captured from 37 offshore net sets, which were distributed throughout each longitudinal zone of the reservoir. The total sampling effort was 12.1 net-hours, spanning a range of depths from 0 to 17.5 m below the surface. Fish were captured in less than half of the net sets, and all of them were in surface sets. The gill net sample included a lower catch of rainbow trout per unit effort, and represented a narrower and more skewed size and age range (i.e., towards generally larger and older fish) than the boat electrofishing sample from nearshore habitats.

Scales from 192 rainbow trout were collected for ageing analysis in 2017. Fish ranged from Age 0+ to Age 6 with the highest proportion of captured fish Age 1 to Age 3. Older age classes displayed extensive size overlap, suggesting that growth rate decreases above Age 3. Ageing analysis also allowed us to plot the index of abundance for Age 1 and 2 rainbow trout against reservoir elevations (i.e., minimum and maximum during the spawning period for Age 1, and experienced to-date for Age 2). Generating these data across the 10-year monitoring period will enable us to determine if there is a potential causal relationship between reservoir operational characteristics and recruitment.

Recommendations for monitoring in upcoming years of the BRGMON-7 program include: 1) Target installation of the temperature array in Downton Reservoir for mid April and removal by end of October to fully bracket the period of thermal stratification; 2) complete a reservoir habitat survey at the modified maximum level (734 m) to facilitate comparison of the proportional amount and distribution of habitat types across the range of reservoir operating conditions; 3) Collect additional substrate measurement and embeddedness data at 722 m elevation, to make sample sizes more equivalent among selected elevations; 4) Continue spawner count streamwalks and tributary access surveys in widest range of tributaries possible from mid May to end of July; 5) Conduct tributary fish sampling in early October in a range of creeks to re-assess fish rearing use of tributary habitats during fall; 6) Repeat the fish population index sampling by boat electrofishing on the same dates (early June), maintaining the same approach effort, crew, equipment, etc. each year to the extent possible; and, 7) Discontinue pelagic zone sampling using gill nets since boat electrofishing in nearshore habitats has proven the most suitable approach for monitoring this population.

The status of responses to the Management Questions and Study Hypotheses based on results up to, and including, Year 5 (2017) are presented in the summary table that follows.

Management Questions, Study Hypotheses and Interim Status

Status of responses to Management Questions and Study Hypotheses based on results for Years 1 to 5

Primary Objectives	Management Questions and Study Hypotheses	Year 5 (2017) Results To-Date
1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and 2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative on existing reservoir fish populations, and, b) allow better future decisions regarding preferred operation of Downton Reservoir.	1. What are the basic biological characteristics of fish populations in Downton Reservoir and its tributaries?	• The Downton Reservoir fish population is almost entirely comprised of rainbow trout (save for 1 bridgelip sucker captured in 2016). • The rainbow trout population spawns between late May and late July (peak in mid to late June) in accessible tributaries, primarily in the mid and west zones of the reservoir. • Relative to the upland, a higher proportion (70% to 80%) spawn in the drawdown portion of these creeks. • Following emergence, fish use of the tributaries for rearing appears to be low, suggesting that the majority of the fry move into the reservoir where risk of habitat loss from changing reservoir elevations is low. • Highest abundance is at creek mouths where food (likely in the form of drifting invertebrates) is available, followed by shallow slopes and alluvial fans. Lowest catch numbers are routinely associated with steep shorelines. • In the nearshore areas of the reservoir, the rainbow trout are distributed across the longitudinal zones (i.e., west, mid, and east). • Sampling in offshore habitats (i.e., by gill netting) was conducted in Year 5 (2017), which documented that use of pelagic habitats in June was low and limited to within 2.4 m from the reservoir surface. • The age range of sampled fish has spanned from 0+ to 7 years (40 to 437 mm); the majority are between ages 1 to 3. The most rapid growth occurs between ages 0+ and 3, after which growth rate slows. • The population size of rainbow trout in Downton Reservoir is estimated to be approximately 100,000 fish (±25,000). **See Section 3.4, 3.6, 3.7, and 3.8 for more information.**
	2. Will the selected alternative (N2-2P) result in positive, negative or neutral impact on abundance and diversity of fish populations?	• Overall CPUE values for rainbow trout were down slightly in 2017 (6.7 fish/100 m of shoreline) from 7.5 and 7.9 fish/100 m in 2015 and 2016, respectively. • This difference was due to reduced catch of Age-1 fish in 2017, which was down by approx. 50% from previous years. CPUEs for Age-3 to Age-5 fish were higher in 2017, including the Age-2 cohort which had been low in 2016. • Min. reservoir elevation was 8 to 9 m lower in 2017 than in 2015 and 2016, whereas max. fill elevations in 2016 and 2017 were characterized by modified operations (734 m) rather than normal maximum elevations (~749 m). • There is not currently enough data to assess trends at this point. Continued monitoring of each age cohort going forward may shed light on possible interactions between recruitment to Age-1 and Age-2 with specific operational characteristics. **See Section 3.8 for more information.** **Note:** By the end of the current monitoring period in 2022, limited data will be available for typical N2-2P operations (probably 2 years), and the remainder will reflect results associated with *modified* reservoir operation (i.e., target maximum fill elevation 734 m instead of N2-2P normal maximum of 749 m, and possible increased frequency of deeper drawdowns) intended to reduce seismic risk at the La Joie Dam and Generating Station.

Primary Objectives	Management Questions and Study Hypotheses	Year 5 (2017) Results To-Date
1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and 2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative on existing reservoir fish populations, and, b) allow better future decisions regarding preferred operation of Downton Reservoir.	**H_1:** The annual abundance index for rainbow trout in Downton Reservoir is stable over the monitoring period.	**H_1:** not confirmed or rejected; more data needed. It is not possible to address this hypothesis with only the 3 comparable abundance index data points available to-date. While status updates will be provided as more years of results become available, this will ultimately require rainbow trout population index values across the entire monitoring period (to Year 10).
	3. Which are the key habitat factors that contribute to reduced or improved productivity of Downton Reservoir fish populations? **H_4:** Operation of the reservoir restricts the amount of available effective spawning habitat in tributaries limiting the productivity of fish populations. **H_{4a}:** Rainbow trout spawning density in Downton Reservoir drawdown zone is minimal and therefore operations do not limit productivity of fish populations. **H_{4b}:** Operation of the reservoir restricts fish access to tributaries limiting the productivity of fish populations. **H_5:** Habitat availability in Downton Reservoir is independent of reservoir operation, i.e., habitat characteristics are not significantly different between minimum, maximum and modified maximum reservoir elevations.	Specific, targeted habitat data collection linked to reservoir operation level continued in Year 5 (2017), providing additional information for addressing this MQ. **See Section 3.3 for more information**. • The tributaries provide essential spawning habitats and, likely, food supply; however, use for rearing appears limited. • Access to some tributaries by spawners may be impeded when reservoir levels are as low as ~709 m during May. • The majority of rearing appears to occur in the reservoir, and the creek mouths are the most utilized habitat type by the broadest range of age classes. • Temperatures in the reservoir are more broadly spread across the optimal range (according to depth) for growth, relative to the tributaries, which are colder. Temperature may be one of the factors for selecting spawning streams. • Relative to the normal full pool elevation in summer, the total number of flowing creek mouths was actually higher at the low pool elevations surveyed because all intermittent drainages were flowing (start of spring freshet). • Due to the shape of the reservoir basin, only steep shoreline habitats were substantially reduced (by ~50%) at the low pool elevation, which is the habitat type associated with the lowest catch rates of fish during the annual index survey. • In general, the substrate size distribution and embeddedness in the reservoir drawdown zone are positively correlated with elevation (size range, median size and interstitial space tend to increase with the elevation). • Based on the information gathered to-date, it is expected that the main factors limiting population size in Downton Reservoir are food supply, inundation of spawning habitat during the spawning and incubation period (May to July), and possibly overall spawning habitat area available in the tributaries. **H_4:** tentatively confirmed; more data on relationship between reservoir level and accessible spawning habitat availability is needed. Implementation of modified operation (in 2016 and 2017) reduced the portion of stream length inundated by the reservoir. Data to define this relationship for several tributaries is planned for Year 6 (2018). **H_{4a}:** tentatively rejected; more data needed. While some tributaries are not used at all, the drawdown zone of Tribs. #13 and #19 have been used extensively (Sneep 2018b). **H_{4b}:** not confirmed or rejected; more data needed. Some tributaries may lose connectivity when reservoir levels are as low as ~709 m before the onset of freshet, although typical spawning tributaries may not be affected. Requires additional access surveys at the range of reservoir elevations during the rainbow trout spawning period. Surveys for this purpose are planned to continue in future study years. **H_5:** tentatively rejected; more data needed. Efforts in Year 5 (2017) have supplemented data collection initiated in previous study years to define substrate characteristics at 747, 734, and 722 m. Further data collection on temperatures, habitat type distribution (e.g., at 734 m) and substrate characteristics are planned for subsequent monitoring years to characterize these differences.

Primary Objectives	Management Questions and Study Hypotheses	Year 5 (2017) Results To-Date
1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and 2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative on existing reservoir fish populations, and, b) allow better future decisions regarding preferred operation of Downton Reservoir.	4. Is there a relationship between the minimum reservoir elevation and the relative productivity of fish populations? **H_2:** The annual abundance index for rainbow trout is independent of minimum reservoir elevations observed over the period of monitoring. **H_{2a}:** The annual abundance index for Age-1 rainbow trout is independent of a minimum reservoir elevation effect (sampling year minus 1). **H_{2b}:** The annual abundance index for Age-2 rainbow trout is independent of a minimum reservoir elevation effect (sampling year minus 2). **H_3:** The annual abundance index for rainbow trout is independent of maximum reservoir elevations observed over the period of monitoring. **H_{3a}:** The annual abundance index for Age-1 rainbow trout is independent of a maximum reservoir elevation effect (sampling year minus 1). **H_{3b}:** The annual abundance index for Age-2 rainbow trout is independent of a maximum reservoir elevation effect (sampling year minus 2).	• Year 5 (2017) contributed an additional data point to the annual index of abundance, and provided another set of results for documenting the age structure of the rainbow trout population over time. The goal is to address this MQ by correlating abundance of younger ages of fish (recruitment) with various year-specific operational parameters, such as: minimum and maximum reservoir elevations, duration at minimum and maximum levels, and fill and drawdown rates. However, more years of fish population abundance index data collection are required to determine if there is a measurable relationship and reduce uncertainties. **H_2, H_{2a}, H_{2b}:** not confirmed or rejected; more data needed. Requires annual age-specific CPUEs and minimum reservoir elevation values for the entire monitoring period (2013 to 2022). Refer to Figure 3.13 and 3.18 (Section 3.8). **H_3, H_{3a}, H_{3b}:** not confirmed or rejected; more data needed. Requires annual age-specific CPUEs and maximum reservoir elevation values for the entire monitoring period (2013 to 2022). Refer to Figure 3.18 (Section 3.8).
	5. Can refinements be made to the selected alternative to, without significant impact to instream flow conditions in the Middle Bridge River, improve habitat conditions or enhance fish populations in Downton Reservoir?	• The compilation of annual fish abundance index, biological characteristics data, and key habitat factors data for all years of the monitoring program will be required to address this MQ.

Table of Contents

1. Introduction

1.1. Background

As a part of the Water Use Planning (WUP) process completed for BC Hydro's facilities in the Bridge and Seton watersheds (BRG), the Consultative Committee developed aquatic ecosystem objectives for Downton Reservoir in terms of abundance and diversity of fish populations present in the reservoir. However, due to the lack of documented information about fish populations in the reservoir available at the time, it was not possible to develop explicit population-level performance measures that reflected these objectives. Specific gaps in data and understanding were identified in: 1) the species composition, relative abundance, distribution and life history requirements of species of fish in the reservoir and adjacent tributaries, and, 2) the relationship between operating parameters of the reservoir (i.e., maximum/minimum elevation, filling schedule) and the fish population response.

Given the scope of these data gaps and the schedule of the BRG WUP it was not possible to conduct the required studies within the time available before WUP-based operational decisions needed to be made. As such, these decisions were based upon an extensive amount of qualitative judgment about which habitat and operations-related factors were most important in the regulation of fish population abundance and distribution in Downton Reservoir. To resolve these data gaps and better inform reservoir operating strategies, the Consultative Committee recommended a long term monitoring study to obtain more comprehensive information on local habitats and fish populations. 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 Bridge River Power Development Water Use Plan was accepted by the provincial Comptroller of Water Rights in March 2011. Terms of Reference (ToR) for the Downton Reservoir 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.

1.2. Objectives, Management Questions and Study Hypotheses

The primary objectives of this monitoring program are: 1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and, 2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative (referred to as N2-2P in the ToR and ToR Addendum) on existing reservoir fish populations, and, b) allow better future decisions regarding the operation of Downton Reservoir.

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

1. What are the basic biological characteristics of fish populations in Downton Reservoir and its tributaries?

This management question will be evaluated using fish population abundance or index of abundance, fish distribution and biological characteristics data. The target species is rainbow trout.

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

This management question will be evaluated using weight-of-evidence as exhibited by trends in fish population abundance and trends in their biological characteristics in conjunction with trends in reservoir operation over the course of the monitoring program. The underlying operational cause-effect relationship associated with any response may not be evident from this analysis. However, weight-of-evidence will be used to evaluate WUP operations impacts on the reservoir rainbow trout population.

3. Which are the key habitat factors that contribute to reduced or improved productivity of Downton Reservoir fish populations?

This management questions will be evaluated using basic habitat quality and quantity data collected in the reservoir in conjunction with reservoir operations data.

4. Is there a relationship between the minimum reservoir elevation and the relative productivity of fish populations?

This management question will be evaluated using a combination of weight-of-evidence as exhibited by trends in fish population abundance and trends in their biological characteristics in conjunction with trends in reservoir operation.

5. Can refinements be made to the selected alternative to, without significant impact to instream flow conditions in the Middle Bridge River, improve habitat conditions or enhance fish populations in Downton Reservoir?

This management question will be evaluated based on insights gained from results under management questions 1-4.

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

H_1: The annual abundance index for rainbow trout in Downton Reservoir is stable over the monitoring period.

H_2: The annual abundance index for rainbow trout is independent of minimum reservoir elevations observed over the period of monitoring.

- **H_{2a}:** The annual abundance index for Age-1 rainbow trout is independent of a minimum reservoir elevation effect (sampling year minus 1).

H_{2b}: The annual abundance index for Age-2 rainbow trout is independent of a minimum reservoir elevation effect (sampling year minus 2).

H_3: The annual abundance index for rainbow trout is independent of maximum reservoir elevations observed over the period of monitoring.

H_{3a}: The annual abundance index for Age-1 rainbow trout is independent of a maximum reservoir elevation effect (sampling year minus 1).

H_{3b}: The annual abundance index for Age-2 rainbow trout is independent of a maximum reservoir elevation effect (sampling year minus 2).

H_4: Operation of the reservoir restricts the amount of available effective spawning habitat in tributaries limiting the productivity of fish populations.

H_{4a}: Rainbow trout spawning density in Downton Reservoir drawdown zone is minimal and therefore operations do not limit productivity of fish populations.

H_{4b}: Operation of the reservoir restricts fish access to tributaries limiting the productivity of fish populations.

H_5: Habitat availability in Downton Reservoir is independent of reservoir operation, i.e., habitat characteristics are not significantly different between minimum, maximum and *modified* maximum reservoir elevations.

These hypotheses reflect the generalized effects of reservoir operations that were understood to influence habitat suitability and fish population abundance in the Downton context. The goal is to test these hypotheses by analyzing general fish population trends, relative spawning distribution and habitat use, general habitat characteristics in the reservoir, and making inferences based on a weight-of-evidence approach. Also, operations within the WUP-defined ranges were not to be specifically modified for the purposes of the study. Rather, it was understood that operational contrast would naturally be achieved by conducting the study over a 10-year time frame.

Each of these hypotheses could have significant consequences for the predicted impacts of operations on fish; however, they could not be resolved with scientific data during the WUP process. The results of this monitoring program were deemed necessary for informing operating alternatives for Downton Reservoir within the context of the Bridge-Seton generation system.

1.3. Study Area

Field studies for the Downton Reservoir Fish Habitat and Population Monitoring Program (BRGMON-7) were conducted in Downton Reservoir from La Joie dam upstream to the upper extent of the reservoir, including the lower reaches of tributary streams within this section (Figure 1.1).

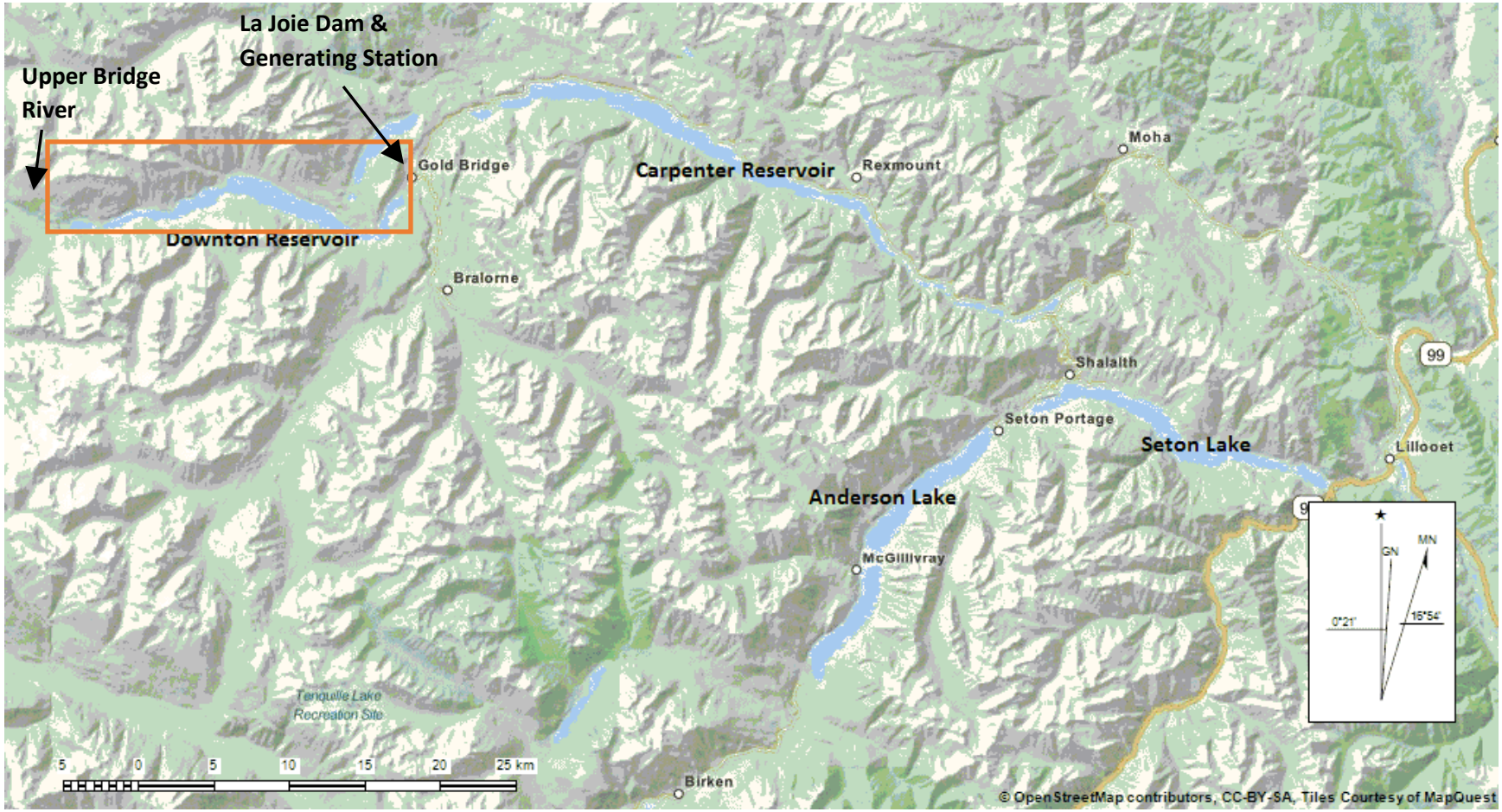


Figure 1.1 Bridge River and Seton River watersheds. The extent of the BRGMON-7 study area, which includes all of Downton Reservoir and tributaries between the Upper Bridge River inflow and La Joie Dam, is outlined by the orange rectangle.

Downton Reservoir elevations and the conveyance of flows into the Middle Bridge River are regulated by BC Hydro's La Joie Dam and Generating Station. 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. Downton Reservoir and the La Joie facility are situated at the upstream end of the Bridge-Seton system.

1.4. Operations Context for Downton Reservoir and La Joie Dam

The context of Downton Reservoir and La Joie Dam N2-2P operations were described succinctly in the Water Use Plan (BC Hydro 2011), as follows:

> *"The reservoir covers ~23.3 km^2 and has an active storage of 705.6 million m^3 between 707.67 and 749.81 m for the purpose of power. Mean annual inflow into Downton Lake reservoir is approximately 42 m^3/s.*
>
> *Subject to appropriate approvals and notification, the reservoir can be drafted to the sill of the hollow cone valves or intakes at 697.38 m for maintenance or dam safety requirements. Water from Downton Lake reservoir is released into Middle Bridge River via two hollow cone valves at the dam or through the La Joie Generating Station through turbine generation or the pressure release valve."*
>
> *"To manage the reservoir for generation, reservoir fish habitat, and Bridge River fish flows, Downton Lake reservoir will be regulated between the conditional minimum of 710.00 m and the weir crest 749.81 m under normal operating conditions.*
>
> *The target minimum elevation of 710.00 m may be relaxed to 697.38 m to maintain minimum flow requirements for Middle Bridge River … [or] to accommodate planned maintenance.*
>
> *The reservoir may exceed 749.81 m to accommodate high inflow events or to help manage other downstream system constraints."*

The drainage area upstream of La Joie Dam is 988 km^2. Inflows to the system are lowest from November to April (typically <10 m^3·s^{-1}), increase in May, peak in June and July (mean = ~100 m^3·s^{-1}), and then decrease across the months of August, September and October back to the winter lows (BC Hydro 2011).

Within the past few years, BC Hydro identified issues with the La Joie Dam pertaining to conformance with current seismic withstand standards. In order to mitigate the seismic risk at this facility (at least in the interim until the necessary physical works at the dam can be completed), the target maximum fill elevation for Downton Reservoir has been lowered to ~734.00 meters above sea level (masl), instead of the normal maximum operating level of 749.81 masl; a reduction of ~15 meters. This difference will reduce the total storage volume of

the reservoir by about 50% and represents a departure from typical N2-2P (i.e., post-Water Use Plan) operations. In the context of the BRGMON-7 monitoring program, this revised management strategy is referred to as *modified* operations, which may be implemented for the remainder of this program.

Under the modified operations, normal minimum reservoir levels will be unchanged although deeper drawdowns may be somewhat more frequent than in the past. Year 4 of the monitoring program (2016) was the first year that modified reservoir operations were implemented, and they occurred again in Year 5 (2017). A summary of Downton Reservoir operating parameters (i.e., minimum and maximum elevations, mean fill and drawdown rates) for each monitoring year are provided in the Results (Section 3.2, Table 3.1).

1.5. Sampling Design and Implementation To-Date

As in previous monitoring years, Year 5 (2017) field activities were focussed on providing data to meet the following sampling design included in the original study ToR (BC Hydro 2012):

a) Collecting time series information on the abundance and biological characteristics of resident fish populations and reservoir habitat conditions;

b) Correlating abundance of younger ages of fish (recruitment) with reservoir operating parameters.

c) Implementing a "stock synthesis" approach to estimating recruitment anomalies associated with operating impacts, which combines age composition and relative trend data collected during monitoring to better define recruitment changes;

d) Examining trends in growth or distribution changes with operations implemented over the course of the study period.

During the initial years of monitoring, a great deal of learning occurred about site access; sampling conditions; and fish distribution, densities, and catchability. This learning helped inform the approach and strategy for this program going forward, but also highlighted issues with the testability of some of the study hypotheses included in the original ToR (BC Hydro 2012). In addition, the modified operations of Downton Reservoir (as described in Section 1.4) also necessitated revision to the original approach. As a result, some specific changes to the study hypotheses were proposed (though the management questions remained the same). These revisions were incorporated into a ToR addendum (BC Hydro 2015) submitted to the provincial Comptroller of Water Rights in January 2015. While further changes of this magnitude are not expected, the sampling design will continue to be reviewed annually to account for new learning in this relatively untested context.

A summary of the sampling methods employed across the years (to-date) for accomplishing the goals and objectives of the BRGMON-7 program are provided in Table 1.1, for reference. For

more information about the methods employed during past years, and the rationale behind them, please refer to the annual monitoring reports produced for those years.

Table 1.1 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	■	■	■	■	■
Temperature Monitoring (Continuous)					
• Tributaries			■	■	■
• In-reservoir profile array			■	■	■
Habitat Surveys					
• Habitat Mapping			■	■	■
• Substrate Measurements			■	■	■
Tributary Spawner Surveys	■	■	■	■	
Tributary Access Surveys			■	■	■
PIT Array Monitoring			■	■	
Tributary Fish Sampling (Backpack EF) -- Seasonal			■ (Fall)	■ (Spring)	■ (Summer)
Fish Population Index Survey (Boat EF)					
• 2 short sessions (spring/fall)	■	■			
• 1 extended session (spring)			■	■	■
Pelagic Fish Survey (Gill Netting)					■
Supplementary Angling	■	■	■	■	■
Fish Ageing Analysis (Scale Reading)			■	■	■

[a] The specific dates that each of the Year 5 (2017) activities were completed are provided in Section 1.6, Table 1.2.

The pelagic fish survey was a new monitoring component added to the program for the first time in Year 5 (2017). Since the annual fish population index survey is conducted around the reservoir perimeter only (by boat electrofishing), this mid-reservoir sampling component was added to address uncertainties about fish distribution between nearshore and offshore habitats. In other words, we wanted to understand the relative proportion of the rainbow trout population that uses mid-reservoir areas that are not sampled by the boat electrofishing method at the time of the spring survey. Tributary spawner surveys and PIT Array monitoring activities were not conducted in Year 5 (2017) in order to make budget room available for adding the pelagic fish survey.

1.6. Year 5 (2017) 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 1.2.

Table 1.2 Year 5 (2017) Schedule of Field Sampling Sessions and Activities.

Field Sampling Activities	Dates (2017)
Temperature logger deployment & retrieval	18 May; 30 May; 23 Jun; 12 Jul; 28 Aug; 18 Oct
Habitat Mapping Survey (717 m elev.)	30 to 31 May
Substrate characterization at reservoir & tributary sites (~734 m elev.)	28 to 31 Aug
Tributary Access Surveys	30 May; 23 Jun
Tributary fish sampling (summer)	29 to 31 Aug
Fish Population Index Survey	1 to 8 Jun
Pelagic Gill Net Sampling	20 to 23 Jun
Supplementary Rainbow Trout Tagging	18 May; 22 Jun

2. Methods

The general approach to this monitoring program is to collect a long-term data set on the fish population and habitat conditions in Downton Reservoir in order to resolve data gaps and better inform the trade-off decisions made during the WUP process. Collection of information on reservoir operating parameters, 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. Trends in these changes over time can be used to test hypotheses (presented in Section 1.2) about the relationship between reservoir operations and fish population response.

Sampling to-date indicates that rainbow trout dominate the species assemblage in the reservoir, and seem to be the only salmonid species present. It is expected that rainbow trout are sensitive to habitat impacts caused by Downton Reservoir operations. For these reasons, rainbow trout will be the sole target species for monitoring in this program based on their ecological and social value, and the ability to consistently sample them.

2.1. Temperature Monitoring

Temperature monitoring was conducted to document the thermal profile in the reservoir and temperature conditions in the tributaries across the rainbow trout spawning and growth periods (May to October). Temperature loggers were removed from late fall to early spring due to adverse conditions during this period that can cause damage or loss of gear, particularly during the winter months. Temperature monitoring has been conducted as part of the

BRGMON-7 program every year since Year 3 (2015). Temperature data for this context were not available for the first two monitoring years in 2013 and 2014.

A vertical temperature logger array was suspended from the log boom at the east end of Downton Reservoir. Individual temperature loggers were also deployed in five tributary streams: Ault Creek, Trib. #13, Trib. #16, Jamie Creek, and the Upper Bridge River (UBR). The loggers were installed on 18 and 30 May, checked and downloaded on 23 June, 12 July, and 28 August, and retrieved for the end of the monitoring period on 18 October, 2017. The locations of the temperature array and other loggers in the study area are provided in Figure 2.1.

The temperature loggers were TidbiT v2 loggers (model UTBI-001) manufactured by Onset Computer Corporation. For the log boom array, 7 loggers were attached to a chain suspended vertically near the midway (i.e., deepest) point at the following intervals: 0.5, 4.0, 8.0, 12.0, 16.0, 20.0, and 24.0 m from the surface. This arrangement was intended to span the thermal layers when the water column is stratified. Water column depth at the log boom location varies from ~6 m at 710 m reservoir elevation to ~30 m at the 734 m *modified* maximum elevation and ~45 m at the 749 m maximum. Loggers deployed in the tributaries were fixed to a weight (i.e., a brick) that was connected to an anchor point on shore using a length of cable. This was necessary to keep the loggers submerged and facilitate retrieval.

Data stored by the loggers were downloaded onto a waterproof shuttle in the field and then transferred to a computer using HOBOware® Pro software upon return to the office.

Predicted emergence dates were calculated for each monitoring year that included temperature data collection during the rainbow trout spawning and incubation period (late May to mid July). Hourly temperature data collected by loggers (summarized as weekly means) were run through the model WinSIRP version 2.0 (Microsoft Windows®-based Salmonid Incubation and Rearing Programs, designed for Microsoft Excel®; Jensen et al. 2009). This model includes an incubation module that predicts embryonic development, for various (selectable) salmonid species, in response to temperature and associated metabolic responses (i.e., oxygen consumption and ammonia excretion). The predicted range of emergence dates was generated by running the weekly mean temperatures from the start, peak, and end of the rainbow trout spawning period (Year 5 (2017) estimates were based on the median timing from previous years since spawner surveys were not conducted that year – see Section 1.5).

2.2. Habitat Surveys

As in Years 3 and 4 (2015 and 2016), habitat surveys were conducted to document habitat characteristics in the reservoir and tributaries to supplement the fish sampling data. Habitat survey activities included: a) habitat mapping; b) quantifying substrate sizes, interstitial depth, and bank slope among each of the identified habitat types; and c) characterizing habitat areas above and within the drawdown zone in four known spawning tributaries. These activities in Year 5 (2017) represented the third year of habitat data collection and specifically targeted

reservoir elevations, sites and tributaries that were not yet assessed in the previous two years in order to supplement and expand the existing data set. Understanding how the selected habitat variables vary according to reservoir elevation may prove useful for interpreting the effects of various reservoir operating scenarios on fish population response.

Habitat Mapping

Habitat mapping involved characterizing and mapping the entire shoreline of Downton Reservoir by boat. Due to high turbidity, the habitat type observed at the water-shoreline interface was considered representative of the habitat ~5 to 10 m offshore where the fish sampling typically occurs. In 2017 the habitat mapping was conducted at ~716 m elevation in late May, which corresponded to the lowest reservoir elevation surveyed to-date. Minimum reservoir elevation in Year 5 (2017) was 711.5 m; however, the reservoir was not accessible by boat at elevations lower than 716 m due to limitations of the boat launch. 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 coordinates 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°, steep slope >15°, dam face); 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. Representative photographs of the reservoir shoreline habitat types (and sub-types), as well as tributary habitats, are provided in Appendix A (Photos A1 to A9). 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. These values are important for evaluating differences in these parameters across the range of reservoir operating levels and for determining the relative proportion of sites for each habitat type to be sampled during the annual fish abundance index survey (Section 2.6, below). Previous surveys at ~745 m and ~722 m reservoir elevations were conducted in Year 3 (2015) and Year 4 (2016), respectively.

Substrate Measurements

Substrate can provide an important form of cover for fish, particularly for juvenile life stages. Other than the turbidity of the water, substrate and its associated interstitial spaces are among the few sources of cover available to rearing fish in the reservoir and drawdown-portion of tributaries. The concept is that cover, in the form of interstitial space, is positively correlated with substrate size. With the ongoing settlement of fine sediments in the reservoir, we predicted that elevations lower in the reservoir drawdown (which are inundated more of the time) will be characterized by finer substrate materials and less interstitial cover than

elevations higher in the reservoir (which have a lower inundation frequency and more direct recruitment of courser substrates from the valley sides).

Data were recorded for two elevations in both the reservoir and tributary sites during Year 5 (2017): ~747 m and ~734 m for the reservoir, representing *normal* maximum and *modified* maximum levels; and upland (>749 m) and drawdown (<747 m) areas for the tributaries, representing habitats outside versus inside of the reservoir zone of influence. The 2 m band of elevation between 747 m and full pool (749 m) couldn't be surveyed at any site due to the extensive deposition of large woody debris within this zone. We have hypothesized that relative substrate size and embeddedness may vary with elevation and habitat type, but do not substantially change with time for the study area as a whole across the period of this monitoring program. As such, a cumulative data set can be collected across years, and the substrate measurement data collected in Year 5 (2017) directly supplement and expand on the data collected in Years 3 and 4 (2015 and 2016; Figure 2.1).

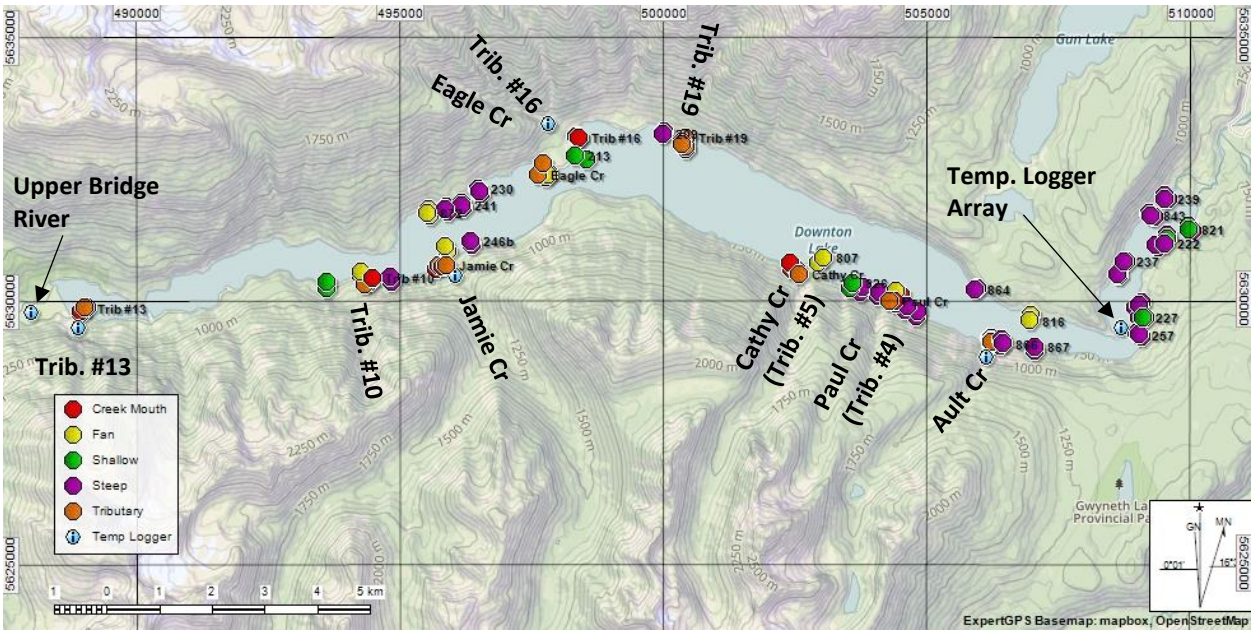


Figure 2.1 All substrate measurement locations to-date as of Year 5 (2017). Multiple dots at each location refer to measurement transects at 747 m (near maximum reservoir level), 734 m (*modified* maximum level), and 722 m (fish sampling level). Surveyed tributaries are labelled and the locations of temperature logger deployments are shown.

Substrate measurement locations were selected from the list of fish sampling sites in the reservoir (2017 *n*=20), as well as in tributaries that are generally accessible to fish from the reservoir (2017 *n*=5). At each site, a tape measure was laid out for 30 m parallel to a selected elevation for reservoir sites, or along the stream axis for tributary sites. As such, vertical elevation varied by 1 to 6 m (depending on the slope) across the 30 m distance in the creeks, but this was not considered significant to the analysis relative to the total vertical difference

among selected survey elevations. The piece of substrate directly under each 1 m marker (from 0 to 30 m) was measured for the length of its intermediate axis (neither the longest nor shortest of the three mutually perpendicular sides of each particle – also known as the b-axis) as well as the interstitial space associated with the substrate. As such, 31 measurements were recorded for each elevational zone at each site.

The b-axis of individual substrate pieces was measured using a large field caliper (manufactured by Haglöf Sweden) which was graduated in millimetres. Plastic tubing (13 mm outside diameter, graduated in centimetres) was used to measure the depth of interstitial spaces accessible from the substrate surface before it was disturbed (as per Finstad et al. 2007). Attempts were made in each case to find the opening under each piece of substrate with the deepest interstitial space measurement, and this value was recorded (to the nearest 0.5 cm). Care was taken to ensure that the substrate was not moved while this measurement was being taken.

Any particles finer than sand were assigned a b-axis value of 0.2 cm, which was the minimum measurable value in the field. For the analysis of these data, bedrock was also assigned a b-axis value of 0.2 cm, since it was considered to function similarly to fines in terms of cover provision for fish (i.e., smooth surface with no interstitial spaces). Where particles were completely embedded, or if the interstitial opening was narrower than the diameter of the tubing, an interstitial depth value of 0 cm was assigned. For analysis, substrate b-axis measurements were compiled as the proportion of total substrate count by substrate category. The substrate categories were adapted from those defined by Wentworth (1922; Table 2.1).

Table 2.1 Substrate size categories used to group the b-axis measurement data adapted from the scale developed by Wentworth (1922).

Substrate Size Category	Size Range (cm)
Fines or Bedrock	<0.2
Small Gravel	0.3 – 1.6
Large Gravel	1.7 – 3.2
Very Large Gravel	3.3 – 6.4
Small Cobble	6.5 – 12.8
Large Cobble	12.9 – 25.6
Boulder	>25.7

2.3. Tributary Access Surveys

Under the *modified* operations initiated in Year 4 (2016) and going forward, the target fill elevation for Downton Reservoir has been reduced, which decreases the total storage volume of the reservoir significantly. In order to maximize the available storage, BC Hydro may need to draw the reservoir down to lower elevations (within the licensed range) on a more frequent basis than in past. Since the period of lowest elevations typically overlaps with at least some

portion of the rainbow trout migration and spawning period, concern was raised about the potential impact of these operations on fish access to spawning tributaries.

To assess this impact and characterize potential reservoir elevations of concern, tributary access surveys were conducted on a couple of dates during the rainbow trout migration and spawning period to identify and document areas where access may be blocked or obstructed. This was noted for Ault Creek in May 2014 (Year 2) when reservoir elevations were <710 m and creek flows were low (i.e., pre-freshet; Refer to Sneep 2015 for more information and photos). In this case stream flows went to ground before reaching the reservoir edge. Some tributaries have also been noted to run dry (e.g., Trib. #10, Trib. #19); however, this usually occurs in mid-summer, after the spawning period is over.

Tributary access surveys were initiated in Year 3 (2015) and repeated again in Years 4 (2016) and 5 (2017). They were timed to target the conditions at the start of the rainbow trout migration and spawning period when the tributaries are typically still in pre-freshet condition and the reservoir is beginning to fill from its lowest elevation. The surveys involved a field crew visiting creek mouths (on foot or by boat) to assess connectivity and continuity between the creeks and the reservoir pool or the section of the Upper Bridge River channel that winds through the reservoir basin under drawdown conditions. Each creek was assigned an access score of TRUE (continuously connected with no apparent access issues) or FALSE (not connected or blocked). Crews recorded notes about any observations in the field book and took photos.

2.4. Tributary Fish Sampling

Seasonal use of Downton Reservoir tributaries for rearing by rainbow trout was assessed by backpack electrofishing (backpack EF) in select creeks during summer. The summer survey in 2017 was intended to complement the information on seasonal rearing use previously collected in fall (2015) and spring (2016), which were documented in the Year 4 report. Sampled tributaries included: Paul Creek (aka Trib. #4), Cathy Creek (aka Trib. #5), Jamie Creek, and Eagle Creek (Figure 2.1). Summer sampling was completed from 29 to 31 August 2017.

A few of the tributaries that were visited could not be sampled because they were either dry at the time of the survey (Tribs. #10 and #19), or the accessible habitat was too steep above the current (~734 m) reservoir elevation (Ault Creek and Trib. #16). For each sampled creek, the surveys targeted a site within the drawdown zone (<747 m elevation) and the upland zone (>749 m elevation). As with the substrate measurements, it was not possible to include the 2 m extent between 747 m and 749 m elevation in the sites for the selected creeks due to the deposition of large woody debris from the reservoir within this range.

A total of 8 tributary sites were sampled in summer 2017 (drawdown zone *n*= 4; upland *n*= 4). Sites were 30 m long and were sampled during the day by a two-person crew using a Smith-Root Model 12B electrofisher (settings: 400 V, frequency and pulse J4). One crew member

operated the electrofisher and the other netted fish stunned by the electrical field. Each site was sampled by methodically wading the site in an upstream direction and capturing all fish that were observed. Sites were not enclosed, and sampling was conducted from bank to bank (i.e., spanned the full stream width) in the creeks. Each site was completed by a single upstream pass.

Following completion of the sampling at a site, fish were anesthetized using clove oil, identified to species, and measured (fork length to the nearest mm and weight to the nearest gram). Fish of a suitable size (>100 mm FL) were marked with a PIT tag. These data were recorded into a field notebook, as well as the following parameters for each site: Date, site name, elevation zone, UTM coordinates, sampled length, electrofishing effort (seconds), and water temperature. Following a short recovery period, all fish were released back into the site.

2.5. Fish Population Index Survey

The fish population index surveys are intended to provide information on the inter-annual variation in the relative abundance, distribution and growth rate of rainbow trout in the reservoir. The index survey data is collected in near shore areas of the littoral zone by a standardized boat electrofishing (boat EF) method, which is generally most effective within the ~0.5 to 3.0 m range of water depths. The index survey in Year 5 (2017) was completed as one extended survey in the spring (early June). Based on the results from previous monitoring years, it was clear that maximizing the effort in terms of length of shoreline sampled (within the constraints of the available budget) was important for establishing a representative population index.

Site selection in Year 5 (2017) followed a stratified design as described in previous monitoring reports for Year 1 (Sneep 2015), Year 3 (Sneep 2018a), and Year 4 (Sneep 2018b). The strata were the five main habitat types identified during the shoreline habitat mapping survey (i.e., creek mouth, fan, shallow slope, steep slope, and dam face – see representative photos in Appendix A). The number of sites selected for each strata was based on two main objectives: 1) generally assign the number of sites to each strata according to the contribution of each type to the total shoreline length of the reservoir at the sampled elevation; and 2) ensure each habitat type is adequately represented by a sufficient sample size of sites to facilitate comparison of results between types. The specific locations of the sites were based on GPS coordinates that were randomly selected along the shoreline within each of the pre-determined habitat strata to avoid the potential for high-grading the sampled sections in the field.

Sites were also distributed throughout the basin so that each of the longitudinal zones (i.e., west end, mid-reservoir, and east end) were represented (Figure 2.2). For the purposes of the data analyses, the west end has been arbitrarily defined as the 5+ km portion of the reservoir (and drawdown zone) west of the UTM easting line 500000 (which lies just east of Trib. #20);

the mid-reservoir has been defined as the ~5 km section between the UTM easting lines 500000 and 505000; and the east end is ~5 km between easting line 505000 and the dam (at ~510000).

The sample timing for the fish index survey in Year 5 (2017) was early June. As in previous years, the reason for this timing was to optimally align the following survey conditions: a) adequate reservoir level to be able to use the only boat launch for accessing the reservoir; b) appropriate water temperatures to facilitate electrofishing effectiveness, and c) prior to the bulk of the rainbow trout spawning migration into the tributaries, which affects a portion of the fish ages 3 and up. While all available age classes are sampled, the main ones of interest for tracking an annual recruitment index (Age 1 and 2 fish) primarily reside in the reservoir year-round, so catches for these fish should not be affected by migrations or potential changes in spawn timing across the study period.

Boat EF is conducted by running an electrical current through the water between a set of boom-mounted anodes extended off the front of the boat and a cathode array, while propelling the boat forward at slow speed (~1 to 2 km/h). Within the electrical field that this generates, fish are stunned and drawn up to the surface where they can be netted by crew members standing on a bow platform and transferred to an on-board fish holding tank. Not all stunned fish are observed by the netters, and not all of the observed fish are successfully netted. Therefore, catches represent an annual index which is standardized by ensuring that methods and effort are consistently applied across years.

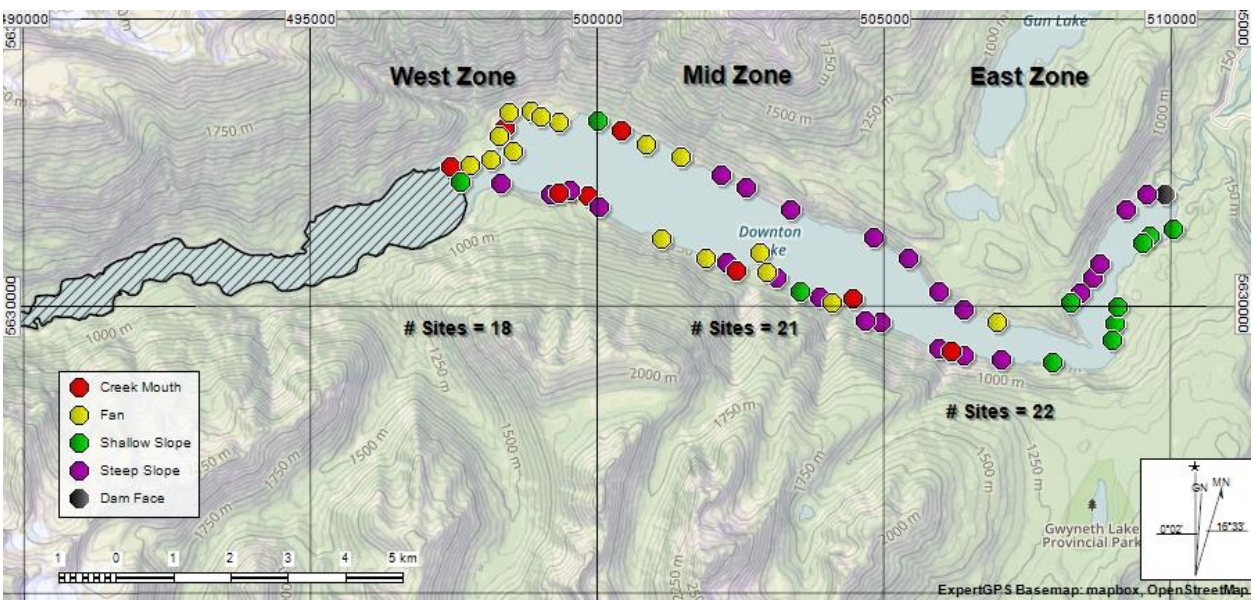


Figure 2.2 The three longitudinal zones (west, mid, and east) and the distribution of sites for the fish population index survey conducted from 1 to 8 June 2017 (at 718 m to 720 m reservoir elevation). Note: The hashed-out area represents the dewatered portion of the reservoir basin at the time of the survey.

Boat electrofishing was conducted at night. At each site, the boat was maneuvered to a pre-designated starting point (GPS coordinate) along the reservoir perimeter from which a section

of edge habitat was electrofished. The following boat EF settings were used: Electrofisher = Smith-Root 5.0 GPP; Voltage Range = High (50 – 1000 V); % of Power = 20% to 80%; Output = ca. 3 to 5 amps; DC Current Mode; Frequency = 60 DC pulses/sec. A total of 61 sites were sampled (creek mouth *n*= 8; fan *n*= 16; shallow *n*= 11; steep *n*= 26) covering 16,118 m of shoreline length. Sampling effort was based on a target site length of 300 m for steep, shallow, and fan habitat types. Site length for creek mouths was targeted to extend ~50 m on either side of the tributary inflow. Each site spanned only one habitat type and was sampled in a single pass.

All fish collection efforts were accompanied by detailed sampling of the biological characteristics of the captured fish, as well as measurement of general sampling conditions (i.e., temperature and secchi depth). Fish were measured for length and weight, evaluated for sex and sexual maturity (as possible), and aging structures were collected. Individual coded (PIT) tags were applied to all captured fish of appropriate size and condition to provide information on within-session and inter-annual recapture rates, as well as movement and growth patterns.

To assist in developing an understanding of the recruitment, life history, growth characteristics and age class structure of the rainbow trout population in Downton Reservoir, fish sampling included collection of age structures (i.e., scales) from captured fish. Approximately five to ten scales were collected from selected fish from the preferred area above the lateral line and immediately behind the dorsal fin. Samples were placed in coin envelopes marked with appropriate data for cross-reference. Scale samples were taken from a target of 8 to 10 fish for each 10 mm size range between 50 mm and 360 mm forklength in order to determine the size distribution for each age class and allow assignment of ages to fish that were not scale sampled. To assign ages to the rest of the fish, the proportions of each age class for fish that were *aged* were then applied to the fish that were *not aged*, such that the proportions within each 10 mm size bin were maintained.

Upon release, a sample of processed fish were placed in a floating holding tank that was deployed in the reservoir, in order to assess mortality and tag loss approx. 24-hours post-capture (Photo 2.1). The holding tank was constructed of 2” x 8” lumber bolted together to form a square frame, which supported four 80L lidded containers. The containers were perforated below the water line to allow for continuous water exchange with the surrounding reservoir water. Each container was covered with a lid, which was secured by an elastic cord. The floating frame was anchored approx. 10 to 15 m offshore in a sheltered location, and equipped with 2 large orange floats for visibility. To ensure the containers were not overloaded, only fish from 1 site per night were held (i.e., up to 50 fish maximum). Fish were generally divided amongst the containers according to size in order to minimize the risk of predation in the tank: Two of the containers were generally reserved for larger fish (e.g., >250 mm), and two containers were for smaller fish (e.g., <250 mm).

Each fish that was placed in the holding tank was noted on the data sheet. The next evening (i.e., approx. 24-hours post-capture and processing), the floating raft was retrieved and each fish was re-assessed for condition (live, moribund, or dead) and scanned for PIT tag number. This information was recorded on the data sheet. The cumulative set of this information for fish sampled from each night and habitat type allowed for analysis of fish condition after a more extended period post-capture, assessment of the incidence of tag loss post-release, and identification of any PIT tag number recording errors.

Photo 2.1 Floating fish-holding tank used during the 2017 Downton Reservoir fish population index survey to assess the incidence of fish mortality and tag loss 24-hours post-capture.

As part of the analyses of the fish population index survey data, we also calculated annual growth curves based on the median size (from the forklength data) of each age class (determined by scale ageing – see Section 2.8) using the von Bertalanffy growth equation:

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

Where:

L_t is Length at Age $_t$;
L_∞ is the "asymptotic length";
K is the "curvature parameter"; and
t_0 is the "initial condition parameter".

2.6. Pelagic Fish Survey

A pelagic fish sampling survey was conducted in Year 5 (2017) to address uncertainties about relative fish distribution between nearshore and offshore habitats in Downton Reservoir at the time of the spring fish population indexing survey. Since the boat electrofishing method can only sample nearshore habitats around the perimeter of the reservoir, there was uncertainty about the relative proportion of the rainbow trout population that may use mid-reservoir areas that are not sampled by this method. For this reason, offshore habitats were sampled by a standardized gill netting method from 20 to 23 June, adjacent to the timing of the annual boat electrofishing survey.

Since nearshore areas are extensively sampled by the boat electrofishing method, gill netting was conducted in offshore (i.e., greater than 50 m horizontal distance from shore) habitats only. Gill nets were deployed in each longitudinal zone of the reservoir, and sampled a range of depths from 0 to 17.5 m from the water surface (i.e., spanning the epilimnion, metalimnion, and hypolimnion thermal layers determined from the temperature array data at the log boom). The maximum depth of the reservoir was ~32 m at the east end (nearest the dam) at the time of the survey. Nets were not deployed along the bottom of the reservoir due to the potential snagging hazard caused by stumps and submerged debris in the reservoir. In this case, the high risk of gear damage or loss outweighed the benefit of collecting information for the reservoir bottom, especially since fish densities at those depths were expected to be low (based on professional judgement).

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 2.2), 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 2.2 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 37 sites distributed across the wetted length of Downton Reservoir at the time of the survey (west *n*= 10; mid *n*= 13; east *n*= 14; Figure 2.3). To mitigate the rate of mortality associated with long duration sets (i.e., overnight), the nets were set for a short duration (target = 15 to 30 minutes) throughout the day so that the fish could be removed from the nets and processed much more quickly. This also meant that a larger number of locations could be sampled within the timeframe available.

A six-panel RIC gill net was deployed at each site location, set at a selected sampling depth from the surface to below the thermocline (i.e., 0, 5, 10, or 15 m to the top of the net). 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 reservoir and was connected by an adequate length of rope to a large orange buoy at the surface. For sets at depth, a sinking net was 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. A floating net was used for surface sets, without dropper lines. Another concrete anchor with buoy was deployed at the end of each net set.

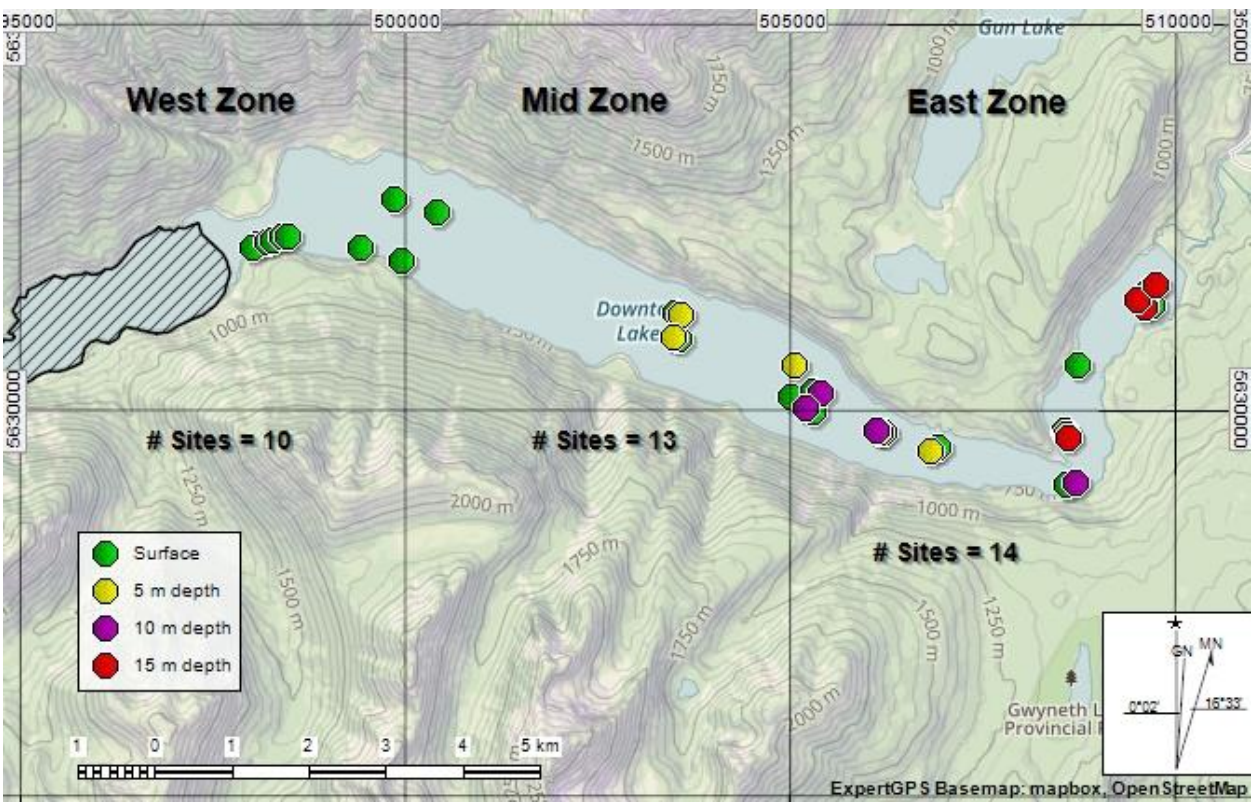


Figure 2.3 BRGMON-7 study area showing longitudinal sections and the locations of the offshore gill net sets, according to depth, during Year 5 (2017). Note: The hashed-out area represents the dewatered portion of the reservoir basin at the time of the survey.

The 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). 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.

All captured fish were identified to species, measured for length and weight, and evaluated for sex and sexual maturity (as possible). Ageing structures were collected from any fish that could supplement the size ranges sampled by the boat electrofishing survey (as needed to reach minimum sample sizes). Fish that were in good condition were marked with PIT tags prior to release to facilitate identification of any recaptures during the survey (or future fish sampling surveys). Additional data recorded at each sampling location included set and retrieval times for the nets, UTM coordinates, water temperature and secchi depth.

2.7. Supplementary Rainbow Trout Tagging

Based on the proposed approach, the recapture of tagged fish is important for defining growth rates and movement patterns between study years. While it was understood that the majority of fish available for tagging would be captured by the boat EF and gill net methods, it was recognized that this could also be supplemented at low cost by angling. Therefore, some supplemental tagging for rainbow trout was also proposed. However, in the interest of dedicating as much effort to the annual abundance index surveys as possible, these supplementary tagging surveys have been conducted on an opportunistic basis (i.e., when other activities in the study area are being conducted) and limited to a few dates per year.

For these supplemental tagging surveys, fish were captured by angling using hooks baited with cured salmon roe. To improve capture efficiency, angling effort was focussed on reservoir areas with the highest fish densities, which was generally adjacent to tributary mouths. In Year 5 (2017), angling was conducted on the Upper Bridge River (near the Tram Creek confluence) on 18 May, and at the Ault Creek and Cathy Creek confluence areas on 22 June, for a total of 6.2 person-hours of effort. For each captured fish, length was measured (forklength to nearest mm), sex and maturity were assessed, ageing structures were collected (as needed), and a PIT tag was applied.

2.8. Laboratory Analysis

Following a period of air drying, 192 rainbow trout scale samples were mounted by Ed Serroul, a St'at'imc Eco-Resources technician, in preparation for ageing. Mounting involved pressing the scales onto plastic strips, which were softened by heat, to transfer precise images that could be viewed and magnified using a microfiche reader following the methods of Mackay et al. (1990). Scale reading to determine fish ages was conducted on 182 of the mounted samples (10 were noted as un-readable due to regeneration) by staff at Instream Fisheries Research. First, second and third scale readings to determine fish ages were conducted by Marylise Lefevre, Jennifer Buchanan, and Dani Ramos-Espinoza (all from IFR), respectively.

These data will allow analysis of trends in the abundance index of specific age classes and how this index correlates with reservoir operation (i.e., annual minimum and maximum elevations). In addition, this will allow estimation of annual growth rates of the different year classes of rainbow trout in the reservoir which will contribute to an understanding of how different operating strategies influence fish condition (size-at-age).

2.9. 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 (Ed Serroul and Ron James). Data quality assurance (QA) checks were completed by the Project Manager (Jeff Sneep).

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. Reservoir Elevations

Records of Downton Reservoir surface elevations were provided by BC Hydro for the period 1 January to 31 December 2017, which are illustrated in Figure 3.1. Daily surface elevations for monitoring years 1 to 4 (2013 to 2016) are also included for reference.

The management of surface elevation in Downton Reservoir follows a seasonal pattern: lowest elevations occur in spring (generally April to May) and highest elevations, or full pool, occur in late summer to early fall (August and September). The timing, duration and magnitude of low pool and full pool elevations vary from year-to-year, as well as the rates of drawdown and fill between these periods and across the rainbow trout spawning window (Figure 3.1). We are tracking these statistics for each study year as they may prove to be informative variables related to fish recruitment, survival and growth, which will ultimately be evaluated at the end of the monitoring period.

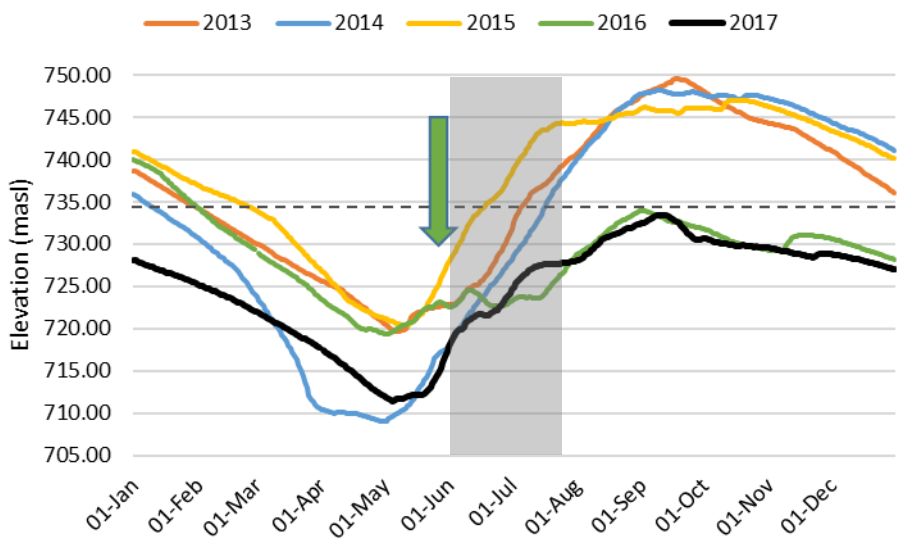


Figure 3.1 Daily surface elevations in Downton Reservoir, 2013 to 2017. For reference, the shaded area represents the observed rainbow trout spawning period and the green arrow indicates the timing of the annual population index survey. The horizontal dashed line indicates the target modified maximum fill elevation (734 m), which was implemented in Years 4 and 5 (2016 and 2017).

The modified maximum elevation target (i.e., 734 m) was implemented for the first time in Year 4 (2016) and again in Year 5 (2017). At the start of 2017, reservoir elevation was 728.1 m as it was drawing down from the 2016 maximum fill level of 733.9 m. The mean drawdown and fill rates for the reservoir were -9 cm/day and +17 cm/day, respectively (Table 3.1). Lowest reservoir elevation (i.e., 711.5 m) occurred from 4 to 6 May, and summer full pool elevations occurred from 6 to 16 September 2017 (max. = 733.5 m on 9 September). The reservoir had been drawn down to 727.0 m by the end of December.

Table 3.1 Minimum and maximum reservoir elevations, and mean and maximum drawdown and fill rates for Downton Reservoir during study years 1 to 5 (2013 to 2017).

Study Year	Reservoir Elevations (m)			Drawdown Rates (cm/day)[a]		Fill Rates (cm/day)[b]	
	Min.	Max.	Diff.	Mean	Maximum	Mean	Maximum
1 (2013)	719.69	749.53	29.84	-15	-21	+23	+73
2 (2014)	709.00	748.23	39.23	-20	-80	+31	+81
3 (2015)	720.40	746.98	26.58	-14	-30	+33	+58
4 (2016)	719.38	739.99	20.62	-14	-28	+12	+55
5 (2017)	711.47	733.46	21.99	-9	-29	+17	+69

[a] Calculated between the end of the full pool period and the start of the low pool period.
[b] Calculated between the end of the low pool period and the start of the full pool period.

The total differential between minimum and maximum elevations was ~22.0 m in 2017, which was similar to 2016 (the only other year of modified operations to-date), and between 4.5 m

and 17.2 m less than the differentials during previous study years of normal (i.e., N2-2P) operations from 2013 to 2015. The 2017 minimum elevation (711.5 m) was most similar to 2014 (709.0 m) and ~8 to 9 m lower than the other study years. The mean drawdown rate (-9 cm/day) was the lowest value to-date; whereas the mean fill rate was in-between the values for N2-2P and modified operation years so far.

The change from normal maximum fill elevation of 749.81 m to 734.00 m under modified operations, represented a ~16 m reduction in fill level; however, maximum fill levels within those two operational treatments (N2-2P vs. *modified*) have been fairly consistent. In addition to that change, the minimum drawdown elevation has been variable across all study years to-date (±11.4 m from year-to-year). As such, the total differential varies both within and among operational treatments (according to both minimum and maximum levels in any given year), which should provide ample contrast for assessing the fish population response across the period of monitoring, but may complicate comparison of the broader operational strategies (i.e., N2-2P to modified operations).

3.2. Temperature Monitoring

Monthly water temperatures for the May to October period at the reservoir log boom array and in the monitored tributaries are displayed in Figures 3.2 and 3.3, respectively. Comparable figures for study years 3 and 4 (2015 and 2016) are provided in Appendix B (Figures B1 and B2).

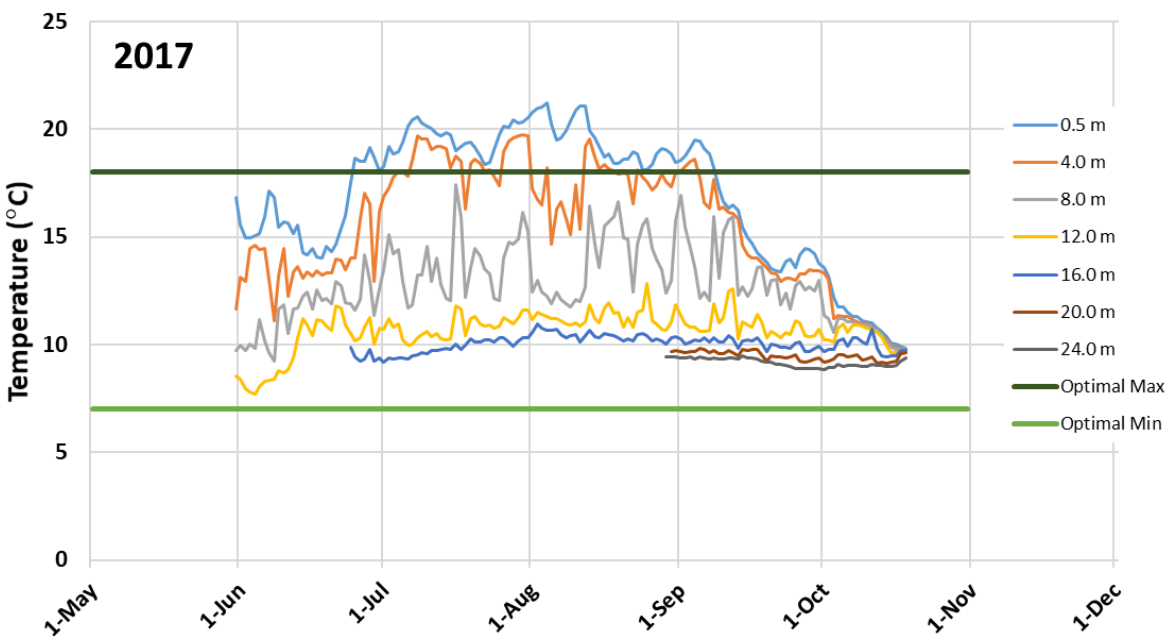


Figure 3.2 Mean daily water temperatures by depth from the Downton Reservoir log boom array, May to October 2017. The light and dark green horizontal lines bracket the preferred temperature range of rainbow trout (McPhail 2007).

Based on the log boom array data, thermal stratification in the reservoir begins sometime in late April or early May (i.e., sometime shortly before loggers were deployed in 2017) and extends until mid October. The plan for Year 6 (2018) monitoring, and going forward, is to deploy the temperature array by mid April with the intent of better capturing the start of the stratification period. The reservoir becomes isothermic (consistent temperature from surface to bottom) from mid October to mid April, though temperature loggers were not deployed across all of this period as described in Section 2.2.

In Year 5 (2017), mean daily surface temperatures initially dropped from 16.8°C to 14.0°C across the first 2 weeks of June, and then increased to 20.6°C by the second week of July. Surface temperatures remained between 18.0°C and 21.0°C until the end of August, and then cooled to 9.0°C by the end of October. There was a gradient of temperatures between the surface and 12 m, which corresponded to the depth of the thermocline in both years (within the limits of precision available from the depth intervals of the loggers). From 16 m and below, temperatures at each depth interval remained within a narrow range, between 8.9°C and 10.9°C, throughout the monitored period. These temperatures and patterns were very similar to those reported for previous years (Sneep 2018b), with only minor (≤ 1°C) differences in maximum or minimum temperatures across the monitored period.

The light and dark green lines in Figure 3.2 bracket the preferred temperature range of rainbow trout (McPhail 2007). Based on this range, temperatures in Downton Reservoir are suitable for this species across a broad range of depths throughout the year. However, temperatures from the reservoir surface down to ~4 m depth tend to exceed the optimal range during the warmest summer months (i.e., July and August). Cooler temperatures from the tributary inflows (i.e., at creek mouths) likely provide important thermal refuge for this generally surface-oriented species.

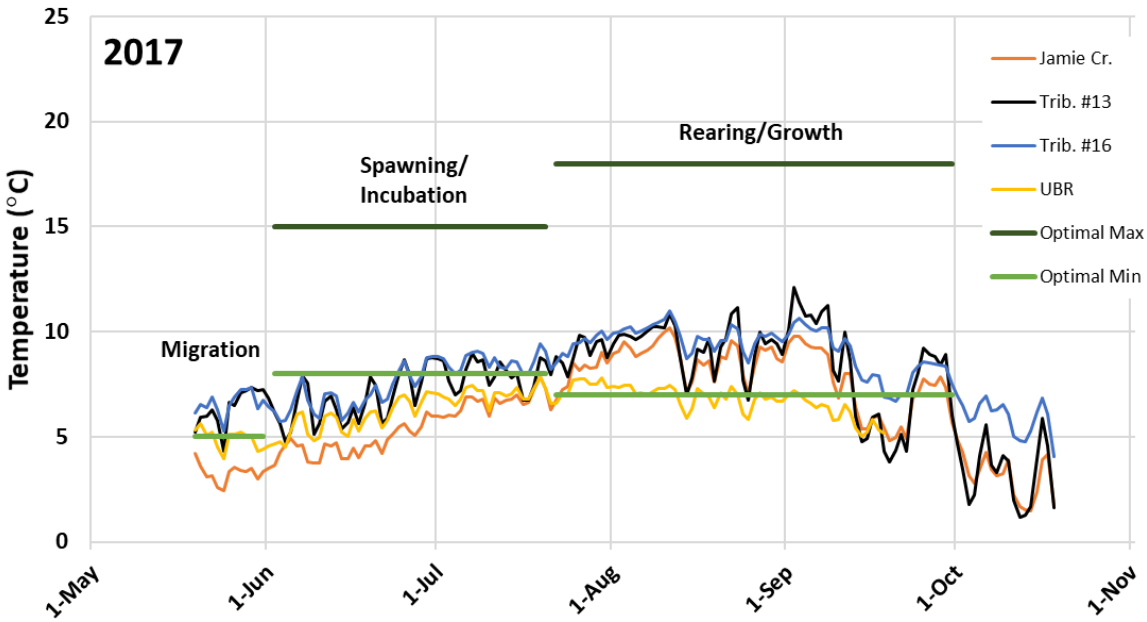


Figure 3.3 Mean daily water temperatures in a set of Downton Reservoir tributaries, May to October 2017. The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of rainbow trout (McPhail 2007).

Relative to the reservoir, temperatures in the tributaries tended to be much cooler, and were variable among streams. Maximum daily mean temperatures ranged from 7.9°C (in the Upper Bridge River) to 12.1°C (in Trib. #13). Based on the preferred temperature ranges as displayed in Figure 3.3, the tributaries known to consistently support spawning (i.e. Tribs. #13 and #16) and fish congregating at the mouth (Ault Cr.) tended to have warmer temperatures (and within preferred ranges by life history period), relative to Jamie Creek and the Upper Bridge River. Temperatures in Jamie Creek were generally below optimal thresholds for the spawning and incubation period, and the Upper Bridge River was generally below optimal thresholds for most of the monitored period in every year to-date. These differences in thermal regimes among tributaries could be one of the factors that influences stream selection for spawning, and explains why fish use of the Upper Bridge River (in particular) may be low.

The differences in the thermal regimes among tributaries and the reservoir context, described above, are also supported by comparison of mean temperatures according to seasonal or life history period for rainbow trout (Table 3.2). Again, creeks with higher values are the ones that coincide with the highest observed fish use for spawning and feeding (Trib. #13, Trib. #16 and Ault Cr.). By comparison, mean temperature values at the reservoir surface tended to be higher (by a factor of 2) than the values from any of the creeks. As in previous monitoring years, the temperature data collected in Year 5 (2017) further support that temperatures may be a factor that contributes to observed patterns of fish use and distribution among creeks, and between creeks and the reservoir, in the study area.

Table 3.2 Mean Water Temperatures by Season/Life History Period, Context (Tributaries, Reservoir), and Study Year.

Location	Year	Mean Temperatures by Season / Life History Period			
		Pre-Spawn/ Migration (15 to 31 May)	Spawning/ Incubation (1 Jun to 21 Jul)	Rearing/ Growth (22 Jul to 30 Sep)	Overall Mean
Upper Bridge River	2015	5.6	6.9	6.0	6.3
	2016	5.5	6.7	6.5	6.5
	2017	4.9	6.3	6.8	6.4
Jamie Cr.	2015	4.1	7.6	7.4	7.1
	2016	4.3	6.2	-[a]	-
	2017	3.3	5.4	8.1	6.6
Trib. #13	2015	7.6	8.8	7.9	8.2
	2016	6.0	7.8	8.4	7.9
	2017	6.4	7.2	8.7	7.9
Trib. #16	2015	7.8	9.4	9.0	9.0
	2016	6.7	8.3	9.4	8.7
	2017	6.6	7.6	9.3	8.4
Ault. Cr.	2015	-	-	-	-
	2016	5.3	8.7	11.0	9.5
	2017	-	-	-	-
Reservoir Surface	2015	16.4	19.3	17.2	17.9
	2016	14.2	16.7	17.5	16.9
	2017	-[b]	17.4	18.0	17.7

[a] Temperature data not available for this period because logger was found out of the water or lost following a period of high flows.

[b] Temperature data were not available for the reservoir during this period (log boom array installed on 31 May in 2017).

The values in Table 3.2 also offer a comparison of relative thermal trends between years for each season/life history period. Among the three years available to-date, 2015 had warmer mean temperatures in the spawning creeks (e.g., Tribs. #13 and #16) during both the Pre-Spawn/Migration and Spawning/Incubation periods by 1.0 to 1.8°C. Despite these differences, mean temperatures were within optimal ranges for most of that period in each year, and peak spawn timing was similar (i.e., the end of June), as reported previously (Sneep 2018b). Notably, this observed spawn timing for the Downton Reservoir population coincided with the period when the mean temperatures reached and exceeded the optimal minimum temperature threshold (i.e., 8°C). Temperatures during the Rearing/Growth period tended to be warmest in 2017 so far, by approximately 0.3°C to 0.8°C on average.

Collection of temperature data in the tributaries during the spawning period allowed for the prediction of emergence timing based on modelling the accumulated thermal units (ATUs) using WinSIRP version 2.0 (Table 3.3; Jensen et al. 2009). Based on the model outputs,

emergence timing has not varied significantly across the years available to-date (2015 to 2017). In general, emergence begins at the end of July or early August, peaks in the third week of August, and is complete by the end of August or early September. These predictions were corroborated by the capture of recently emerged fry (23 to 33 mm forklength) in several tributaries sampled by backpack electrofishing at the end of August 2017 (see Section 3.5). The incubation period ranged from a minimum of 47 days to a maximum of 64 days for eggs fertilized late versus early in the spawning period, respectively (median incubation= ~50 days). Based on the model estimates, the emergence timing has been quite consistent, with peak timing varying by only 4 or 5 days between years.

Due to the late spawn-timing for the Downton Reservoir population, as noted in past reports, the new year class of fry also emerge from the substrate much later in the growing season relative to rainbow trout populations lower in the watershed (i.e., Lower Bridge River). As a result, the available rearing/growth period in their first season may only be ~3 to 7 weeks long (depending on emergence timing) before tributary temperatures drop below optimal levels in the latter part of September.

Table 3.3 Predicted range of emergence dates by monitoring year for two known spawning tributaries based on weekly mean temperatures from the start, peak and end of the rainbow trout spawning period.

Tributary	Year [a]	Predicted Emergence Dates (# of Incubation days)		
		Start	Peak	End
Trib. #13	2015	29 Jul (55)	25 Aug (52)	31 Aug (53)
	2016	31 Jul (60)	21 Aug (52)	10 Sep (52)
	2017	01 Aug (64)	20 Aug (56)	02 Sep (53)
Trib. #16	2015	25 Jul (51)	21 Aug (48)	26 Aug (48)
	2016	28 Jul (57)	18 Aug (49)	05 Sep (47)
	2017	30 Jul (62)	17 Aug (53)	31 Aug (51)

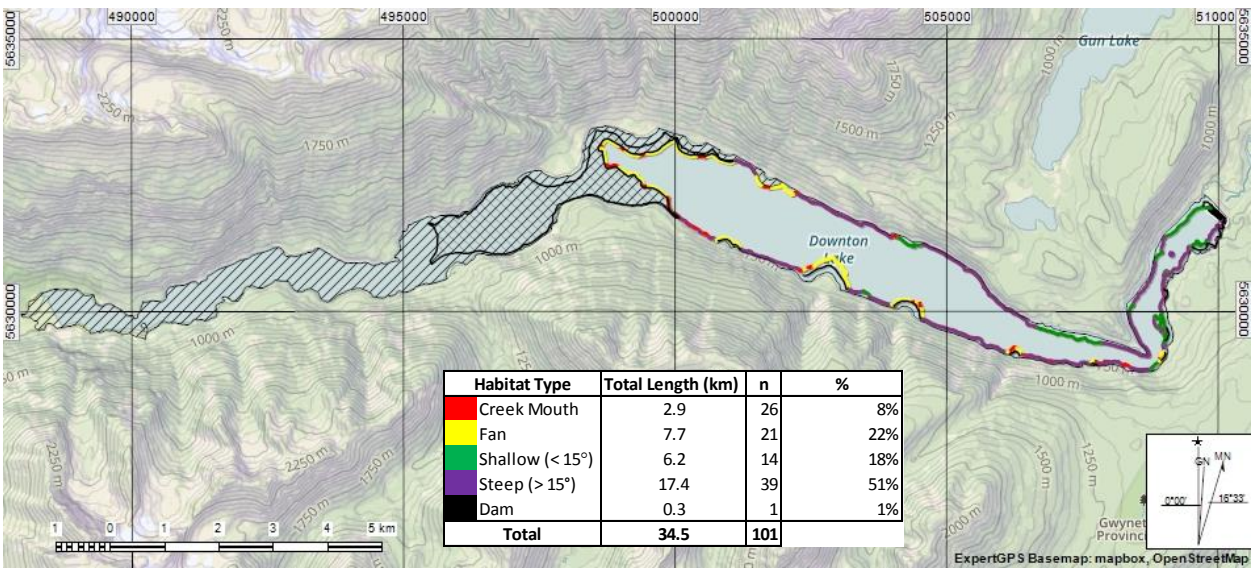
[a] Continuous temperature monitoring (using loggers) was initiated in 2015. As such, emergence timing predictions are not available for Years 1 and 2 (2013 and 2014).

This emergence timing might explain why the majority of the population appears to rear in the reservoir where temperatures remain warmer longer into the fall (i.e., longer growing season), and provide some additional clues about why certain accessible tributaries with seemingly suitable habitat available in the spring are not selected for spawning: a) some have been observed to go dry by August (e.g., Trib. #10, Trib. #19), which would desiccate eggs before the fry hatch or emerge, and b) the temperatures in some creeks (e.g., Jamie Creek) tend to be colder across the incubation and growth periods, such that fry would emerge even later. Given the already limited duration of the first growth period for Age-0+ trout fry in this context, later emergence would likely not be sustainable.

3.3. Habitat Surveys

Habitat Mapping

The habitat mapping in 2017 documented the proportional availability and distribution of shoreline habitat types around the entire wetted perimeter of Downton Reservoir at ~716 m elevation, representing low pool conditions. These data were intended to supplement the existing survey data collected at 745 m (near full pool) in August 2015, and the 722 m survey (representing the typical fish population index sampling level) conducted in May 2016 (Figure 3.4). At the 716 m elevation assessed in Year 5 (2017), the length of the reservoir was 14.2 km, and the total shoreline length was 34.5 km (Table 3.3), which were 57% and 56% of the full pool values, respectively. The habitat to the west of the surveyed perimeter represented the drawdown (i.e., non-inundated) portion of the reservoir basin (i.e., hashed out area on Figure 3.4).



Habitat Type	Total Length (km)	n	%
Creek Mouth	2.9	26	8%
Fan	7.7	21	22%
Shallow (< 15°)	6.2	14	18%
Steep (> 15°)	17.4	39	51%
Dam	0.3	1	1%
Total	**34.5**	**101**	

Figure 3.4 Results of a shoreline habitat mapping survey conducted at low pool in May 2017 (~716 m elevation). Note: The hashed out areas represent the wetted perimeter of the reservoir at the typical elevation for the fish population index sampling (i.e., ~722 m; cross-hatched area), and the 745 m near normal-maximum reservoir elevation (i.e., diagonal hashed area).

Due to the effects of inundation and drawdown from reservoir operations on vegetation colonization, there was no direct interaction between the wetted edge of the reservoir and adjacent terrestrial vegetation at the surveyed low pool level. This parameter is documented for each survey because terrestrial vegetation can be an important source of allochthonous nutrients to littoral food webs in aquatic systems (Perrin et al. 2016). Depending on the primary food sources for the rainbow trout in Downton Reservoir, documenting differences in the availability of overhanging vegetation among the different reservoir elevations may provide relevant information for supporting the fish size-at-age analysis at the conclusion of the

monitor. Also, terrestrial vegetation will likely begin to colonize the non-undated portion of the drawdown zone between the normal maximum fill level (749.81 m) and the modified maximum level (734 m) during the period of this monitoring program. Evidence of this succession was observed in it's very initial stages in Year 5 (2017), the second year of modified operation implementation.

Table 3.3 Summary of habitat strata contributions to total shoreline length in Downton Reservoir based on the near full-pool (745 m elevation), fish sampling elevation (722 m), and low pool (716 m) habitat mapping.

Habitat Type	Habitat Sub-type	Total Length (km) and % Contribution					
		~ Full Pool Elevation (745 m)		Fish Index Survey Elevation (722 m)		~ Low Pool Elevation (716 m)	
Creek Mouth		0.8	**1%**	1.8	**4%**	2.9	**8%**
Fan		8.8	**15%**	8.4	**21%**	7.7	**22%**
Shallow (< 15°)		5.7	**9%**	7.6	**19%**	6.2	**18%**
Steep (> 15°)	Bedrock	10.5	17%	2.7	7%	1.6	**5%**
	Colluvium	33.4	55%	20.0	49%	15.8	**46%**
	Total Steep	43.8	**73%**	22.7	**56%**	17.4	**51%**
Dam		1.1	**2%**	0.4	**1%**	0.3	**1%**
Totals		**60.3**		**40.9**		**34.5**	
Reservoir Length (km)		25.6	**100%**	17.8	**70%**	14.2	**56%**
Terrestrial Veg. (km)		21.3	**35%**	0.0	**0%**	0.0	**0%**

For the Year 5 (2017) habitat mapping survey at 716 m reservoir elevation, steep shorelines (slope > 15°; *n*= 39 units) were the most prevalent type, contributing 17.4 km (51%) to the total perimeter length. The vast majority (15.8 km or 91%) of this steep terrain was made up of alluvial or colluvial material (rocks, boulders and other loose sediment particles), and a smaller portion (1.6 km or 9%) was bedrock. Fans (*n*= 21 units) were the next most prevalent habitat type in the reservoir, contributing 7.7 km (22%) to the total shoreline length. Fans, which are generally shallow, are formed by alluvial processes associated with streams and intermittent drainages in the valley.

The remaining habitats were shallow shorelines (slope <15°; *n*= 14) and creek mouths (*n*= 26), which contributed 6.2 km (18%) and 2.9 km (8%) to the total perimeter distance, respectively. At the east end of the reservoir, the wetted portion of the La Joie Dam face was 0.3 km long, comprising 1% of the reservoir shoreline. The length of the dam-reservoir interface was substantially reduced at the lower reservoir elevations (722 m and 716 m) because the reduced footprint of the reservoir exposed shallow and steep shorelines adjacent to the toe of the dam on the north and south shores, respectively (see Appendix A, Photos A6 and A7).

There were some interesting differences in the contributions of the various habitat types between the 745 m (near full pool) survey conducted in August 2015 and the lower elevation surveys (722 m and 716 m) conducted in May 2016 and May 2017. There was a significant reduction in steep shoreline habitat (by 21.1 km (or ~50%) at 722 m, and 26.4 km (or ~60%) at 716 m), and an increase in shallow habitat length despite the reduced wetted extent of the reservoir (70% and 56% of full pool length at 722 m and 716 m elevations, respectively). Fan habitat decreased in total length, but only slightly (-0.4 km at 722 m and -1.1 km at 716 m), and actually increased in percent contribution to the total at the lower elevations. The number and percent contribution of creek mouth habitats also increased in the lower (spring) surveys relative to the full pool (mid summer) survey. These changes can be attributed to the shape and morphology of the reservoir basin, and to the seasonal timing of each of the surveys.

At full pool, the majority of the reservoir edge interfaces with the valley sides, which tend to be steep. At low pool, the reservoir edge is nearer the bottom of the valley sides where gradients tend to be lower, resulting in the observed increase in shallow habitats (and the corresponding decrease in steep habitats). Among the steep shorelines, many of the bedrock outcrops tend to be perched nearer the top of the drawdown zone. When the reservoir has dropped, colluvial materials deposited at the base of the bedrock become exposed, thereby decreasing the proportion of bedrock (or conversely increasing the proportion of colluvium) that interfaces with the wetted edge of the reservoir at low pool.

Fan habitats are the shape of an inverted cone, since the accumulation of alluvial materials deposited by creeks and drainages spreads out from high to low elevation within the reservoir drawdown zone. As a result of this shape, even though there are more individual fan units when the reservoir is full (since it extends further up the valley), the length of shoreline for each fan unit increases as the water level drops.

At first glance, the increased number and length contribution of creek mouth habitats during the low pool surveys seemed a bit counter-intuitive given the reduced length of the reservoir. However, the changes were due to the differences in seasonal timing, rather than morphological characteristics of the reservoir basin, between the two surveys. During the spring (lower elevation) surveys, snow melt was occurring, creeks were in pre-freshet condition and all intermittent drainages were flowing. By contrast, during the full pool survey in August 2015, creeks were in summer low flow condition and the intermittent drainages were dry.

Overall, the results of the 716 m low pool survey in Year 5 (2017) were very similar to the 722 m fish population indexing elevation survey conducted in Year 4 (2016), with the main difference being the reduction in total reservoir length and available shoreline length (-3.6 km and -6.4 km, respectively). The differences in the relative contribution of the various habitat types was generally minor between these elevations. Based on the 716 m survey results (relative to the 722 m results): steep shorelines were reduced by 5%, shallow shorelines were reduced by 1%, fan habitats increased by 1%, and creek mouths increased by 4%. Based on the available data

for the elevations surveyed to-date, it appears that the contribution of shallow slope and fan habitats (both length and %) were highest at the 722 m elevation. Steep shorelines were most abundant at the 745 m elevation, and creek mouth habitat was most prevalent at 722 m and 716 m (in spring, during freshet).

In the next monitoring year (Year 6 – 2018), a habitat mapping survey is planned for the 734 m modified maximum reservoir elevation. This survey will provide data for another key reservoir elevation that will supplement the results of the surveys conducted at other key reservoir elevations to-date (i.e., 745 m, 722 m, and 716 m levels). These data will also further flesh-out the differences in the availability and distribution of the identified habitat types across the range of operations during the study period. This information has been used to inform sample site distribution for the fish population index survey, and could be a potential explanatory variable for changes in the fish abundance index across different reservoir operations among years.

Substrate Measurements

Starting in Year 3 (2015), and continuing in Year 4 (2016) and Year 5 (2017), we set out to assess whether substrate size and interstitial space, as a proxy for rearing or spawning habitat suitability (according to habitat type), varied among elevations and habitat types within the reservoir drawdown, or the upland vs. drawdown zone for tributaries. Substrate size by habitat type and elevation was incorporated as a monitoring component for BRGMON-7 because substrates have the potential to provide a form of cover for fish, spawning habitat (in the tributaries), and potentially different food production capacity (e.g., invertebrates) according to size and embeddedness.

The selected elevations for this monitoring component represented the maximum (747 m), *modified* maximum (734 m), and fish index sampling (~722 m) levels. For the tributaries, the upper elevation was >749 m (instead of 747 m) to characterize the accessible *upland* portion of the creeks, relative to the elevations within the drawdown portion. Ultimately, the goal of this data collection is to characterize the sediment composition and embeddedness for each habitat type according to it's contribution to the reservoir shoreline (from the habitat mapping data), and based on an equivalent number of measurements for each selected elevation. Planned for Year 6 (2018), more data will be collected at 722 m so the sample size will be more equivalent to those currently accumulated for the 734 m and 747 m elevations. While it is not expected that the additional data will dramatically alter conclusions as reported here, having equivalent and substantial enough sample sizes for each elevation and habitat type will bolster confidence in the results.

Substrate size, interstitial depth, and slope measurements were collected from 25 sites in the reservoir drawdown zone (n= 20) and in select tributary streams (n= 5) during 2017 (Table 3.4). These data supplement the original data set from 42 sites collected in 2015 and 2016 (drawdown zone n= 34; tributary n= 8). In the following figures and tables, all data collected to-

date have been analyzed and summarized together. In total, 3,639 individual b-axis and interstitial depth measurements have been collected to-date (2015 *n*= 1,413; 2016 *n*= 1,209; 2017 *n*= 1,017).

Table 3.4 Number of sites, sampled distance, and mean slope for substrate measurements in each habitat type at the fish index sampling (722 m), *modified* maximum (734 m), and maximum (747 m) reservoir elevations.

Habitat Type	Elevation [a]	# of Sites	Sampled Distance (m)	Mean Slope (°)
Creek Mouth	722	4	120	8.3
	734	7	210	15.3
	747	8	240	14.0
Fan	722	2	60	6.7
	734	8	240	11.6
	747	8	240	16.2
Shallow	722	1	30	11.0
	734	5	150	13.9
	747	1	30	10.0
Steep	722	11	330	22.2
	734	20	600	29.7
	747	24	720	28.4
Tributary	722	4	120	4.3
	734	7	197	11.8
	>749	8	240	9.7
All	722	22	660	14.5
	734	47	1,397	20.1
	747	49	1,470	22.8

[a] 722 m = Fish index sampling elevation; 734 m = *modified* maximum elevation; 747 m = near maximum elevation; >749 m (for tributary sites only) = upland.

Gradients within the study area ranged broadly from a minimum of 4.3° (tributaries at 722 m elevation) to 29.7° (steep slopes at 734 m). In general, for most habitat types, slope increased from the lowest elevational zone in the reservoir to the 734 m (modified maximum) elevation, and then decreased slightly at the highest elevation (i.e., 747 m in the reservoir, or >749 m upland in the tributaries). This pattern reflects the general U-shaped cross-section of the reservoir basin.

There were some differences evident in the relative proportions of substrate sizes within the reservoir basin, and the inclusion of the data collected in Year 5 (2017) did not substantially change the interpretation of the results described in the last report (Sneep 2018b). Data from the reservoir sites sampled from 2015 to 2017 indicate that, overall, fines (≤ 0.2 cm) and small gravels (0.3 to 1.6 cm) were the most abundant substrate classes (according to the Wentworth size categories; see Table 2.1 in Methods Section 2.2); however, the relative proportions did

vary somewhat by elevation (Figure 3.5 top). The highest proportions of fines and small gravels were at the lowest reservoir elevation (722 m) and the lowest proportions were at the top of the drawdown zone. Conversely, coarse substrates (i.e., those larger than fines and small gravels) contributed an increasing proportion from the lowest elevation to the highest (i.e., a combined total of 27%, 41% and 54% at 722 m, 734 m and 747 m, respectively).

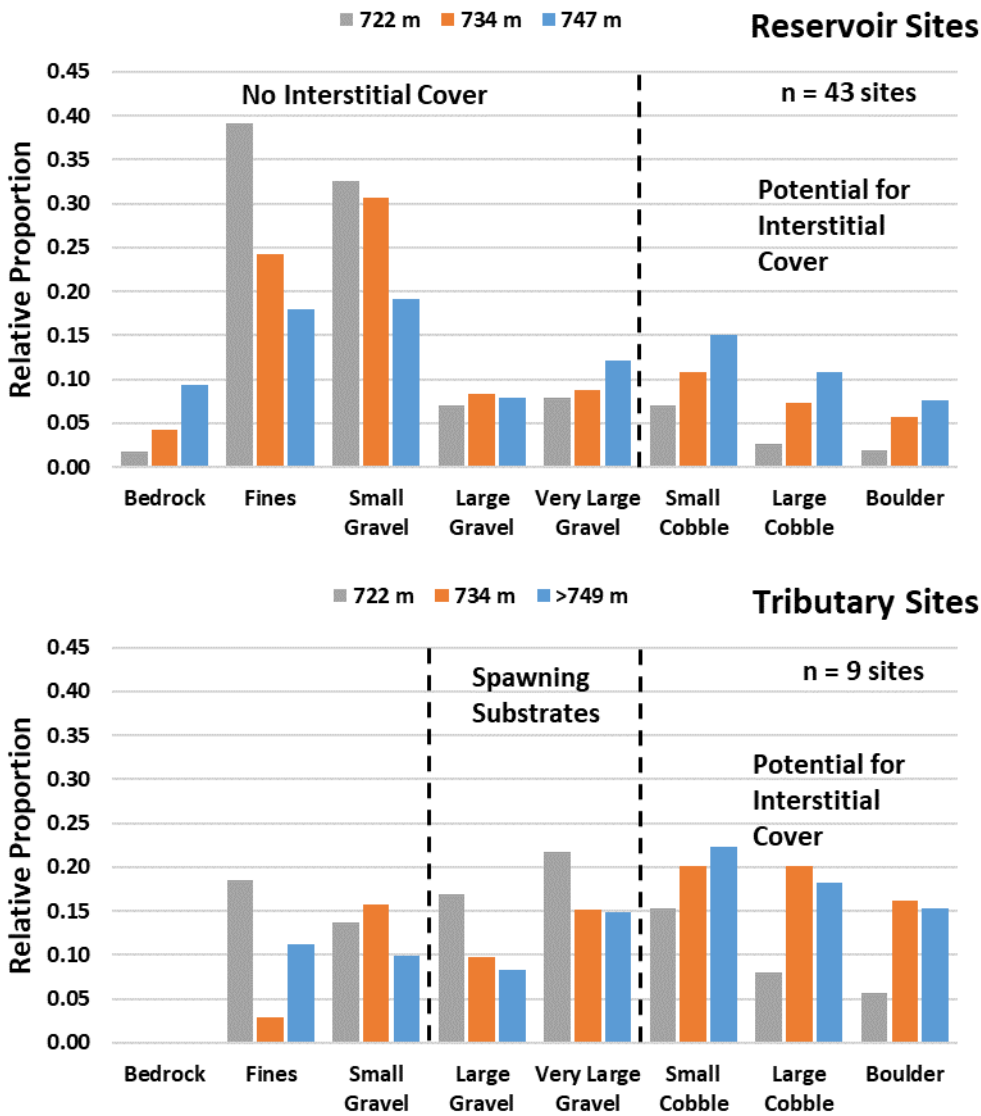


Figure 3.5 Relative proportions of the various substrate categories measured at three elevations within the reservoir drawdown zone (top) and tributaries (bottom). Size categories that can provide interstitial cover (depending on embeddedness) for rainbow trout in reservoir sites, and spawning substrates in the tributaries, are noted.

The general size range of substrates that have the potential to provide interstitial cover for rainbow trout fry are denoted on Figure 3.5. These are the range of sizes categorized as cobbles and boulders (i.e., 6.5 cm and up), though it must be added that the degree of potential cover

available also depends on the degree of embeddedness and the body size of the fish. In general, cobbles and boulders are among the least abundant substrate classes in the reservoir drawdown zone, but proportional availability is positively correlated with elevation: availability is lowest at low pool elevations and highest at the normal maximum level.

The relative contribution of substrate size classes was a bit different for the tributary sites (Figure 3.5 bottom) compared to the reservoir sites. While fines and small gravels still contributed, the proportions were smaller relative to the reservoir habitats, and the larger substrate sizes were more abundant due to the combination of flushing effects and substrate recruitment associated with the creek flows. In other words, the distribution of substrates was more broadly spread across the range of sizes. Differences among elevations were generally more modest and variable in the creeks. The smaller substrate classes (i.e., fines and gravels) were collectively most dominant at the lowest elevation (722 m), relative to the other surveyed elevations in the tributaries. Coarse substrates (i.e., those larger than fines and small gravels) contributed 68%, 81% and 79% at 722 m, 734 m and >749 m, respectively. In general, the distributions by size category were quite similar between the modified maximum (734 m) and upland (>749 m) elevations. Gravels suitable for rainbow trout spawning were available at each surveyed elevation, but were most prevalent at 722 m.

The useable size of spawning substrates, available in the tributaries, can generally be characterized as approximately 10% of fish body length (Kondolf and Wolman 1993). Given that median body size for spawning-age rainbow trout ranges from approx. 160 to 319+ mm in Downton Reservoir (Age 2 and up), this means that substrates between approximately 1.6 and 3.2+ cm would be appropriate for spawning by this population. These sizes fall within the Large Gravel to Very Large Gravel categories (denoted on Figure 3.5), based on the Wentworth scale.

Analysis of the substrate size distributions was also conducted by generating five-number summaries (i.e., minimum, 25th percentile, median, 75th percentile, and maximum values) for each habitat type and surveyed elevation, and updating as each new year of data becomes available. The box-and-whisker plots based on these summaries provided a clear picture of the range and central tendency of the size distributions and revealed some differences among types (Figure 3.6).

As expected, substrate size (median and range) was generally largest in tributary habitats for each surveyed elevation, relative to the other habitat types. Within the tributaries, the highest median values were at 734 m and in the upland >749 m (8.1 and 7.8 cm, respectively), which were in the small cobble size range (Table 3.5). The median at 722 m was 3.4 cm (very large gravel). This analysis further demonstrates that fines are less dominant in the tributaries, and the most abundant substrates included gravels of appropriate size for rainbow trout spawning at each elevation.

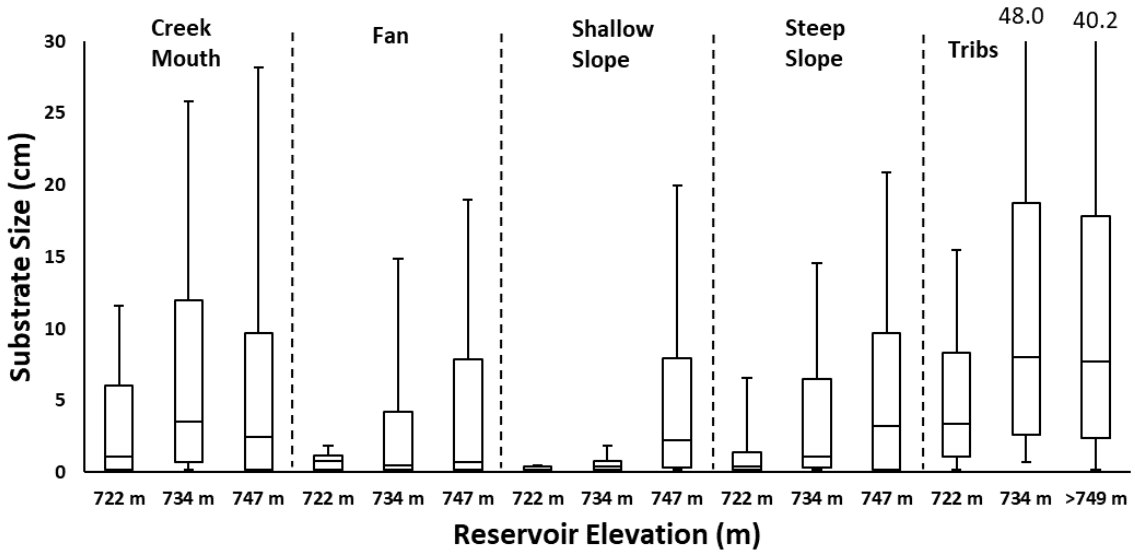


Figure 3.6 "Box-and-whisker" plot representing substrate sizes (b-axis values) for three elevations in each habitat type. The boxes are bounded on the top by the 75th percentile, and on the bottom by the 25th percentile. The median divides each box. The whiskers represent the 10th and 90th percentiles.

Table 3.5 Median substrate sizes (i.e., D50 in cm) by elevation for each habitat type in the reservoir as well as tributaries.

Habitat Type	Elevation (above sea level) [a]		
	722 m	**734 m**	**747 m**
Creek Mouth	1.1 (Small Gravel)	3.5 (V. Lg. Gravel)	2.5 (Large Gravel)
Fan	0.8 (Small Gravel)	0.5 (Small Gravel)	0.7 (Small Gravel)
Shallow Slope	0.2 (Fines)	0.4 (Small Gravel)	2.3 (Large Gravel)
Steep Slope	0.4 (Small Gravel)	1.1 (Small Gravel)	3.2 (Large Gravel)
All Reservoir	**0.5 (Small Gravel)**	**0.9 (Small Gravel)**	**2.5 (Large Gravel)**
Tributaries	**3.4 (V. Lg. Gravel)**	**8.1 (Small Cobble)**	**7.8 (Small Cobble)**

[a] 722 m = Fish index sampling elevation; 734 m = *modified* maximum elevation; 747 m = near maximum elevation (for reservoir sites) or upland (>749 m) for tributary sites.

The substrate measurement results at creek mouths reflected the influence of the tributaries on this habitat type. Median substrate sizes and ranges were smaller than in the creeks themselves, but the trend among elevations was generally similar. Also, substrates at the creek mouths were generally larger than in the other reservoir habitat types, likely due to two effects of the tributary inflows on this habitat type: 1) recruitment of larger substrates from those drainages, and 2) flushing of fines by the creek flows, particularly prior to inundation by the reservoir as it refills each year.

Among the other habitats in the reservoir drawdown zone, the substrate sizes were generally smaller than in the tributaries and varied by elevation according to habitat type. In fan and shallow slope habitats, the median sizes were very small (in the range of fines to large gravels)

at each elevation. The higher elevations on fans had a broader distribution of sizes available, whereas the range was very small at both 722 m and 734 m on shallow slopes. This result suggests that below 747 m, shallow slopes may be the most susceptible to the deposition or retention of fines (related to reservoir operation) of all the surveyed habitat types.

On steep slopes, there was a gradient according to elevation: median size and distribution were smallest at the lowest elevation and highest at the top of the reservoir drawdown zone. This variable size distribution could be due to the gradient of slope that characterizes this habitat type (causing finer depositional material to slough and settle down the slope), combined with recruitment of coarser colluvial materials from the valley sides.

The same analysis and plot was generated for the interstitial space data (Figure 3.7). Overall, interstitial spaces were limited in most habitats. In fact, the minimum, 25th percentile, and median values were *zeros* for all habitats and elevations surveyed. For tributaries, creek mouths, fans and steep slopes, the tail-length of the size distributions were correlated with elevation. 75th percentile and maximum values were highest in the upland of the tributaries and at the top of the reservoir drawdown zone, and lowest at the bottom. In shallow habitats, pore spaces were only available at the highest elevation (747 m). This information indicates that the availability of interstitial spaces for fish are not overly abundant in much of the study area (reflecting the high proportion of fines and embeddedness of larger substrates), but are generally more available at the highest elevations and diminish with decreasing elevation within the drawdown zone.

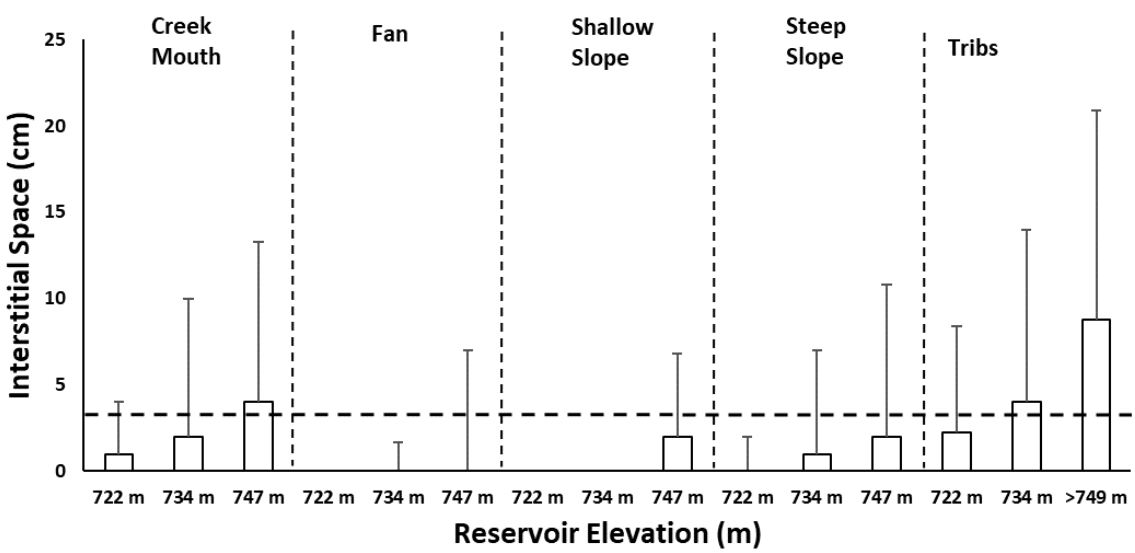


Figure 3.7 "Box-and-whisker" plot (as explained for Figure 3.6, above) representing interstitial space measurements for three elevations in each habitat type. In this case, the minimum, 25th percentile and median values were all zero for each elevation and habitat (except tributary upland habitats >749 m). The horizontal dashed line approximates the minimum interstitial space size (~3 cm) required to accommodate a rainbow trout fry.

Assuming a minimum space size of 3 cm (depicted as a horizontal dashed line on Figure 3.7) is required to provide interstitial cover for rainbow trout fry (minimum forklength = ~25 mm), only a small proportion of measurement results exceeded this threshold. The top quartile (or 75th percentile) exceeded the threshold at only 3 of the habitat-type-and-elevation combinations surveyed: Creek mouths at the full pool elevation (747 m), and tributaries at the modified maximum (734 m) and upland (>749 m) elevations. Median values were below the threshold for all habitats and elevations.

3.4. Tributary Access Surveys

At the start of this program, it was anticipated that reservoir operations would have the potential to impact the reservoir fish population, including rainbow trout spawning success. Rainbow trout access the lower reaches of reservoir tributaries to spawn during the late spring to early summer (i.e., mid-May to late July), which corresponds with the time when Downton Reservoir is generally starting to fill from its lowest elevation.

The tributary access surveys in Year 5 (2017) were conducted on 30 May and 23 June, to coincide with the early part of the rainbow trout migration and peak spawning periods, respectively. Reservoir elevations on these dates were 716.6 m and 722.1 m. Across the duration of the rainbow trout migration and spawning period, the reservoir filled from 712 m in mid-May to 728 m by the end of July. The Year 5 (2017) minimum elevation of 711.5 m (on 5 May) was only 2.5 m higher than those observed in Year 2 (2014) when Ault Creek was observed flowing to ground before reaching the reservoir edge. However, Ault Creek has not been identified as a spawning tributary to-date, and the date when potential access issues were observed (8 May 2014) was prior to the typical start of the rainbow trout migration and spawning period for this population.

The creeks visited in Year 5 (2017) included: Ault Creek, Paul Creek, Cathy Creek, Jamie Creek, Trib. #10, Trib. #13, Trib. #16 and Trib. #19. Access issues were not identified on either of the survey dates at any of the surveyed tributaries during this monitoring year (Table 3.7).

Table 3.7 Tributary-Reservoir surface flow connectivity scores as assessed during the tributary access surveys (TRUE = connected; FALSE = disconnected).

Tributary	Reservoir Zone[a]	Reservoir Elevation Observed (m) and Date(s)				
		709 m (8-May-14)	717 m (30-May-17)	721 m (6-May-15)	722 m (18-May-16, 23-Jun-17)	729 m (4-Jun-15)
Ault Creek	East	FALSE	TRUE	TRUE	TRUE	TRUE
Trib. #4 (Paul Cr.)	Mid	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #5 (Cathy Cr.)	Mid	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #19	Mid	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #16	West	TRUE	TRUE	TRUE	TRUE	TRUE
Jamie Creek	West	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #10	West	FALSE	TRUE	TRUE	TRUE	TRUE
Trib. #13	West	TRUE	TRUE	TRUE	TRUE	TRUE

[a] Reservoir longitudinal zone as described in Section 2.6.

3.5. Tributary Fish Sampling

Fish sampling by backpack electrofishing was conducted in the drawdown and upland portions of four tributaries in summer 2017 (29 to 31 August). Four other tributaries were also visited but were not sampled because the accessible section above the reservoir elevation was either too steep (Ault Creek and Trib. #16) or was dry during the survey period (Tribs. # 10 and #19). These data supplemented fall and spring seasonal tributary data that was previously collected in Year 3 (2015) and Year 4 (2016), respectively (Table 3.9). Water clarity during the summer sampling period was noted as good (clear) in all of the tributaries except Jamie Creek, which was considered poor due to chronic high turbidity.

As noted for the other seasons, fish presence and abundance were variable among tributaries, and elevation zones within tributaries, during both seasons. Total catch-per-unit-effort (CPUE) in summer (14.7 fish/100 m) was more than double the values for spring and fall (6.1 and 4.1 fish/100 m, respectively). Of the tributaries sampled, the highest CPUE value in summer was in the drawdown zone of Eagle Creek (40.0 fish/100 m). In spring and fall, highest CPUEs were in the drawdown zone of Trib. #19 (33.3 fish/100 m) and Tram Creek (10.0 fish/100 m), respectively. These are each documented spawning tributaries for Downton Reservoir rainbow trout. No fish were captured at 6 of 11 sites (55%) during the spring session, 2 of 8 sites (25%) during summer, and 1 of 3 (33%) sites in fall. In almost all cases, catches in the drawdown-portion of the sampled creeks were higher than the upland catches.

Table 3.9 Summary of backpack EF effort and catch in Downton Reservoir tributaries during spring (2016), summer (2017) and fall (2015). All captured fish were rainbow trout.

Season	Reservoir Zone	Tributary	Elevation Zone	Site Ln (m)	EF Effort (sec)	Catch (# fish)	CPUE (fish/m)·100
Spring	East	Ault Cr.	Drawdown	30	296	0	0.0
	Mid	Cathy Cr.	Drawdown	30	441	2	6.7
			Upland	30	208	0	0.0
		Trib. 19	Drawdown	30	165	10	33.3
			Upland	30	165	3	10.0
	West	Trib. 13	Drawdown	30	86	0	0.0
			Upland	30	63	0	0.0
		Trib. 16	Drawdown	30	90	3	10.0
		Tram Cr.	Upland	30	257	2	6.7
		UBR-1[a]	Upland	30	251	0	0.0
		UBR-2[a]	Upland	30	300	0	0.0
Spring Totals				**330**	**2,322**	**20**	**6.1**
Summer	East	Ault Cr.	Drawdown	-[b]	-	-	-
	Mid	Paul Cr.	Drawdown	30	250	7	23.3
			Upland	30	160	0	0.0
		Cathy Cr.	Drawdown	30	289	0	0.0
			Upland	30	241	2	6.7
	West	Eagle Cr.	Drawdown	45	311	18	40.0
			Upland	26	251	4	15.4
		Jamie Cr.	Drawdown	44	758	5	11.4
			Upland	30	336	3	10.0
Summer Totals				**265**	**2,596**	**39**	**14.7**
Fall	West	Trib. 13	Drawdown	30	269	1	3.3
		Tram Cr.	Upland	30	291	3	10.0
		UBR-1	Upland	30	280	0	0.0
Fall Totals				**90**	**840**	**4**	**4.4**

[a] UBR-1 located on the Upper Bridge River at the Water Survey of Canada tram crossing; UBR-2 located further upstream at the Bridge-Main road bridge.

[b] Ault Creek could not be sampled in Summer since the accessible section of channel was too steep above the reservoir surface elevation at the time of the 2017 survey.

Thirteen fish from the tributary catch were a tag-able size: two were recaptures in Jamie Creek that were originally caught in the east zone of the reservoir in 2016, and eleven were newly marked with PIT tags. The ages of captured fish (based on post-field scale analysis) ranged from Age-0+ to Age-4 in both spring and summer, and from Age-0+ to Age-1 in fall (Table 3.10; Figure 3.12). Two fish in Cathy Creek (both Age-3) and two fish in Trib. #16 (Age-2 and Age-4) captured during the spring sampling were sexually mature and in some stage of pre-spawning

condition (all males; 1 gravid, 3 ripe). The remainder of the fish sampled in each season were assessed as either sexually immature (*n*= 56) or mature (*n*= 6) based on size or age, but were not in spawn-ready condition at the time of sampling.

Table 3.10 The size range of rainbow trout by age class and season for tributaries sampled by backpack electrofishing in spring (2016), summer (2017), and fall (2015).

Age	Season	n	Forklength (mm)			CPUE (fish/m)·100
			Min.		Max.	
0	Spring	9	40	-	63	2.7
	Summer	24	23	-	33 [a]	9.1
	Fall	3	42	-	88	1.3
1	Spring	6	65	-	116	1.8
	Summer	10	65	-	105	3.8
	Fall	1	97			0.4
2	Spring	2	148	-	189	0.6
	Summer	2	110	-	159	0.8
3	Spring	2	242	-	248	0.6
	Summer	3	180	-	235	1.1
4	Spring	1	285			0.3
	Summer	3	275	-	282	1.1

[a] New year-class present.

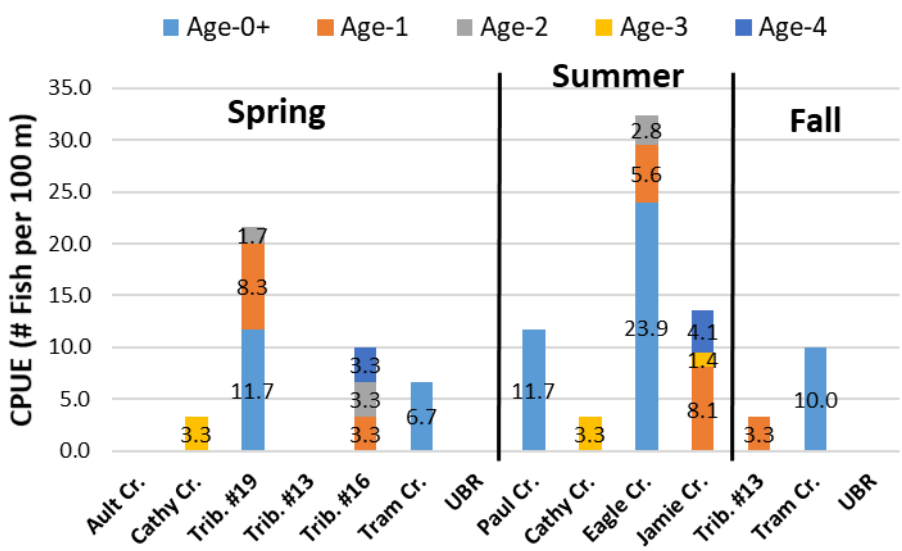


Figure 3.12 Catch-per-unit effort (fish/100 m) by age class for each sampled tributary based on the results of backpack electrofishing surveys in spring (2016), summer (2017) and fall (2015).

These results highlight that the highest catches of fish in the creeks generally correspond with the known spawning tributaries (i.e., Eagle Creek, Trib. #16, Trib. #19, Tram Creek), suggesting that these creeks are selected (to some degree) for rearing use in addition to spawning use. However, other than the contribution of the new year-class of Age-0+ fish, the CPUE values were lower on average than most of the habitat types in the reservoir based on boat EF (see Section 3.6, below). This was despite the likelihood that capture efficiencies by backpack EF in the tributaries were higher than by boat EF in the reservoir.

The higher catch rates in summer, relative to spring and fall, reflected the prevalence of recently emerged rainbow trout fry (23 to 33 mm) during this period, which contributed the highest proportion of any age class to the catch. The catches of these fish during the end-of-August sampling period also serves to generally confirm the emergence timing predicted by the ATU calculations (see Section 3.2; Table 3.3). Tributary sampling planned for fall in Year 6 (2018) will target a broader range of tributaries than what was sampled during that season in Year 3 (2015). This will provide more information about the condition of these streams during that season, and confirm whether catch rates change reflecting a shift in rearing use to the reservoir.

3.6. Fish Population Index Survey

A total of 1,081 fish were captured by boat electrofishing during the annual fish index survey in Year 5, conducted between 1 and 8 June 2017. Sixty-one sites were sampled, including 8 creek mouths, 16 fans, 11 shallow shorelines, and 26 steep shorelines (Table 3.11). The total shoreline distance sampled was just over 16 km, or ~40% of the total reservoir perimeter at the survey elevation (~719 m). All captured fish were rainbow trout.

In total, 1,013 rainbow trout were newly marked with PIT tags. Fish that were too small (< 80 mm fork length) or in poor condition when processed, were not tagged. Twenty-one tagged fish were recaptured during the Boat EF survey in 2017; 11 were within-session recaptures and 7 were recaptures of fish originally tagged in 2015 and 2016 (Tables 3.14 and 3.15 in the next sub-section, below).

Table 3.11 Summary of rainbow trout capture results from the Year 5 boat electrofishing index survey in early June 2017.

Metric	Units	Habitat Type			
		Cr. Mouth	Fan	Shallow	Steep
Sites	#	8	16	11	26
Effort	total seconds	2,798	10,959	6,355	13,620
	total meters	808	4,915	2,699	7,696
Catch	# of fish	144	349	291	297
	# of fish marked	133	335	280	271
	# of recaptures	5	3	0	7
CPUE	fish/site	18.0	21.8	26.5	11.4
		17.7			
	(fish/sec)·100	5.1	3.2	4.6	2.2
		3.2			
	(fish/meter)·100	17.8	7.1	10.8	3.9
		6.7			

Catch-per-unit-effort (CPUE) values (by EF seconds and sampled length), were greatest at creek mouths, followed by Shallow shorelines, and then by Fan habitats and Steep shorelines. Mean CPUE values (for all types combined) were: 17.7 fish/site; 3.2 fish/100 sec of electrofishing; or 6.7 fish/100 m of shoreline length. These values were down slightly from results in Years 3 and 4 (2015 and 2016) (Table 3.12). Going forward, these CPUE metric values (pooled by habitat type and total for the reservoir) will continue to be generated annually and compared as a reflection of trends in population index between monitoring years (Figure 3.13). Trends in CPUE values among habitat types was generally consistent with previous monitoring years, except the value for fans was higher than for shallow slopes in Years 2 and 4 (2014 and 2016); whereas the opposite was true in Years 3 and 5 (2015 and 2017). CPUE values have been consistently highest at creek mouths in every year to-date.

Table 3.12 Summary of catch-per-unit-effort values (fish per 100 m of shoreline) by habitat type from the fish population indexing survey, monitoring years 1 to 5.

Habitat Type	**CPUE values (fish/meter)·100**				
	Year 1 (2013)[a]	**Year 2 (2014)**	**Year 3 (2015)**	**Year 4 (2016)**	**Year 5 (2017)**
Creek Mouth	5.1	14.3	15.9	14.4	17.8
Fan	1.6	3.8	7.0	11.3	7.1
Shallow Slope	ns[b]	1.3	8.0	7.3	10.8
Steep Slope	0.8	2.6	6.2	6.2	3.9
All	**1.7**	**5.3**	**7.5**	**7.9**	**6.7**

[a] Note: Data for Year 1 was collected by a different consultant and capture efficiencies were anomalously low relative to each year since. As such, results for this first year should be viewed with caution.

[b] Shallow slope habitats were not sampled in June 2013.

A summary of CPUE values by age class for each monitoring year to-date is provided in Figure 3.13. In Year 5 (2017), the CPUE for Age-1 fish (2.2 fish/100 m) was again the highest of any age class in the sample; however, this value was much lower than Age-1 CPUEs in 2015 and 2016 (4.1 and 4.6 fish/100 m, respectively). CPUE values for Age-2, Age-3, and Age-4 fish were all similar (1.6, 1.4, and 1.2 fish/100 m, respectively) and higher than values documented for these age classes in 2015 and 2016. There are not yet enough years of data to sort out potential causes or reasons for some of these age-specific differences among years (e.g., cause-induced changes vs. inherent variability in the results among years).

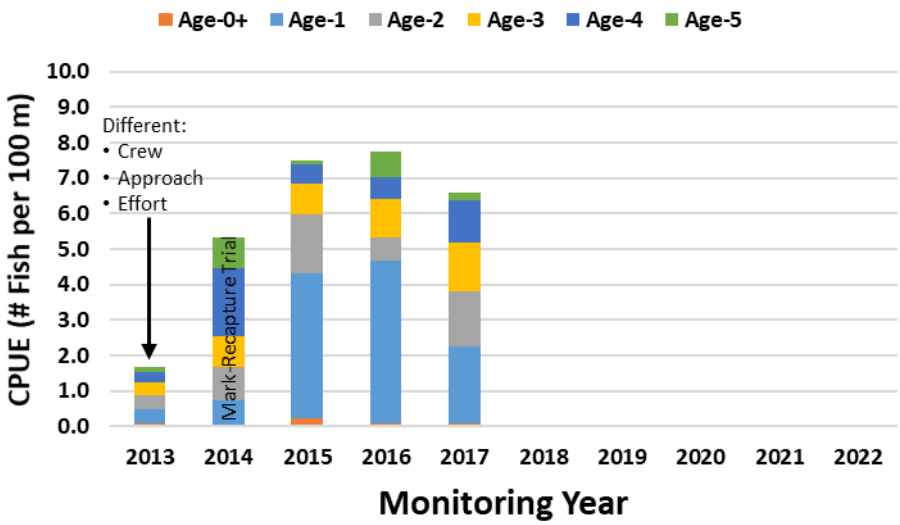


Figure 3.13 Catch-per-unit-effort summary by age class for each monitoring year from 2013 (Year 1) to 2022 (Year 10). Currently only data up to 2017 were available for this report. See important notes about the 2013 and 2014 results, below.

As a result of spawn-timing for this population, the new year class of Age-0+ fish (i.e., for the current year) likely emerge from late July to early September (see Table 3.3 in Section 3.2), and are therefore not available for the population survey until the subsequent year. Age-0+ fish (i.e., recruited the previous year but not yet a full-year old) have consistently comprised a small proportion of the catch in the reservoir. Based on seasonal tributary sampling to-date, it appears that the rainbow trout fry spend very little time rearing in the tributaries post-emergence, and that rearing likely occurs in the reservoir from a young age for this population. The consistently low catches of this age class during the annual population indexing survey likely has more to do with low catchability of this age class by boat electrofishing related to small body size (i.e., <60 mm) and habitat use (e.g., ≤0.5 m from shore), not a reflection of low abundance in the reservoir.

Due to the poor capture efficiency for the Age-0+ fish, focus remains on the Age-1 and Age-2 classes for monitoring trends and the effects of operations by this program. However, it must also be noted that using Age-1 and Age-2 fish as the indicator for monitoring the effects of

operations also incorporates the effects across more than one year, which adds additional uncertainty to the interpretation of results. Fish condition (i.e., Fulton's condition factor, K) is another suitable metric for assessing the quality of conditions where fish reside on an annual basis. Assessment of condition factor, and comparison of this metric among years, will begin with the Year 6 (2018) reporting.

There are some important things to note about the Year 1 and 2 (2013 and 2014) results: During those first two years, fish sampling effort was split across two seasons (spring and fall) such that effort in June was significantly less than in subsequent study years. Furthermore, sampling in Year 1 was conducted by a different consultant with different boat EF gear and capture efficiencies were anomalously low for this first year without adequate explanation (refer to Year 1 and 2 monitoring report; Sneep 2015). During Year 2 (2014), the sampling design was based on a mark-recapture approach, such that fewer sites were sampled (since each site needed to be visited twice for mark and recapture passes) and more effort tended to be concentrated on habitats with larger fish (i.e., older age classes).

As such, in the context of trend monitoring across the period of the study, the CPUE results for these first two years must be viewed with caution. For the reasons highlighted here, the differences likely preclude comparison of age-specific and total CPUE values with subsequent monitoring years (i.e., Year 3 (2015) onward). Since 2015, the crew, gear, sampling approach, effort, and methods have been standardized by the current researchers to ensure the consistency and comparability of the results for all other study years.

A summary of the distribution of effort (# of sites), catch, and CPUE by longitudinal zone of the reservoir (as defined in Section 2.2) is provided in Table 3.13. In Year 5 (2017), the highest mean CPUE was documented in the west zone of the reservoir. However, based on the years of monitoring to-date, rainbow trout utilize the entire extent of Downton Reservoir; highest catch rates have been recorded in each of the three zones among years. The distribution of site-based catches according to habitat type and zone of the reservoir are illustrated in Figure 3.14.

Table 3.13 Summary of the seasonal fish distribution according to longitudinal zone of Downton Reservoir, 1 to 8 June 2017.

Sample Session	Metric	Longitudinal Zone of the Reservoir [a]		
		West	Mid	East
June	# of Sites	18	21	22
	Catch (# of Fish)	334	317	430
	CPUE (fish/m)·100	**8.0**	**5.9**	**6.5**

[a] As defined in Section 2.5; west is furthest from the dam and east is closest to the dam.

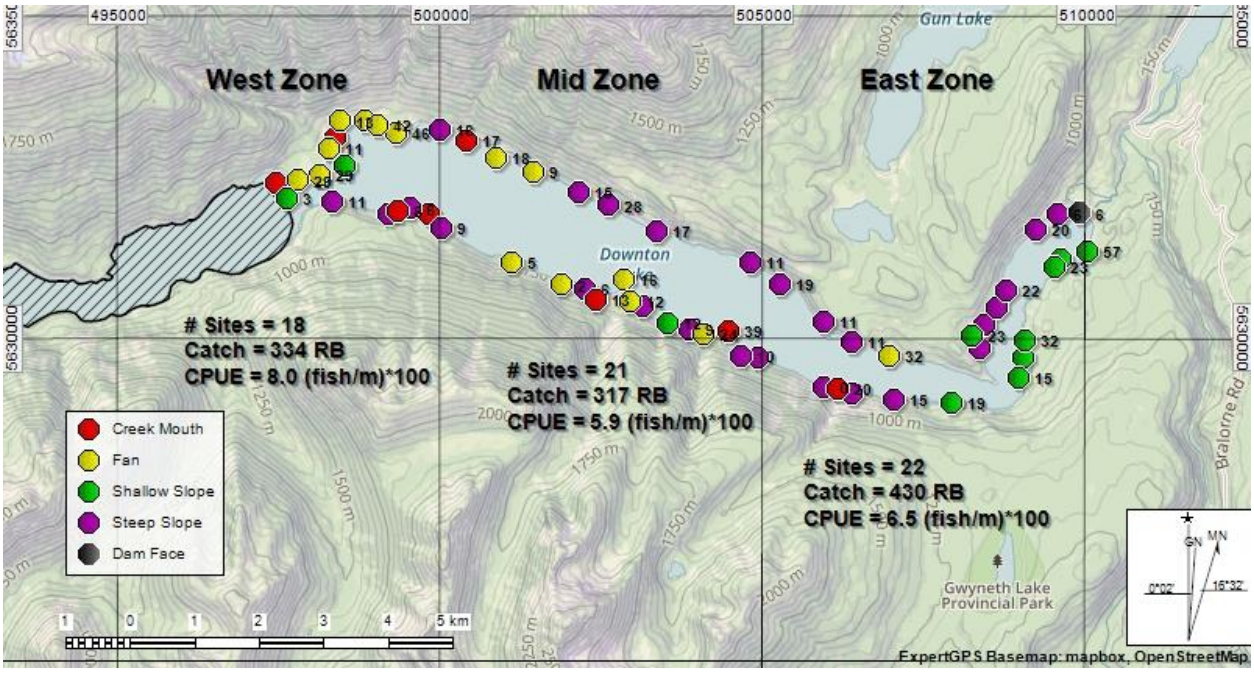


Figure 3.14 The distribution of sites and catches of rainbow trout by habitat type and longitudinal zone of the reservoir, 1 to 8 June 2017. Catches at individual sites are represented by the numbers next to each coloured dot. The hashed-out area represents the dewatered portion of the reservoir basin at the time of the survey.

A total of 5 of the 1,081 captured fish (or <0.5%) in Year 5 (2017) were noted as mortalities upon release after processing (i.e., sampling-induced mortality). This low incidence of immediate mortality was considered a success, but there was uncertainty about the potential incidence of mortality after a longer period post-release. As a means of testing the post-capture and processing survival of fish, a sample of 127 fish (~12% of the catch) were held for approx. 24 hours after sampling, then re-evaluated for condition and tag loss, and then released. 100% of the held fish were alive after 24 hours and were noted to be in vigorous condition upon release (i.e., 0% delayed mortality based on this sample). Tag loss was noted for 1 of the held individuals (0.8%). Going forward, a sample of fish will be held in a similar manner each year to build a larger sample size of fish assessed, so we can better understand the incidence of latent mortality and tag loss for fish captured by boat-electrofishing in this context.

Recaptures of Tagged Fish

A total of eleven fish that were marked with PIT tags were recaptured at different sites within the same session in Year 5 (2017; Table 3.14). Six of these fish had moved a short distance (i.e., <1 km), and five had moved more substantial distances (1.5 to 2.4 km) within a few days between capture and recapture events. As indicated in past reports, these data reveal that rainbow trout can exhibit significant movements within the reservoir, even on a daily basis.

Table 3.14 Summary of within-session rainbow trout recaptures during monitoring Year 5 (2017).

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)
	Date	Zone	Habitat[b]	Date	Zone	Habitat[b]	
888510	1-Jun-17	Mid	ST	6-Jun-17	Mid	ST	2.4
888685	1-Jun-17	Mid	ST	3-Jun-17	Mid	ST	1.6
975862	2-Jun-17	Mid	ST	3-Jun-17	Mid	ST	0.9
888413	3-Jun-17	Mid	FN	3-Jun-17	Mid	CM	0.4
976137	4-Jun-17	West	FN	4-Jun-17	West	CM	0.3
976208	4-Jun-17	West	FN	5-Jun-17	West	FN	1.5
976240	5-Jun-17	West	FN	5-Jun-17	West	ST	1.5
975003	6-Jun-17	East	SH	8-Jun-17	East	ST	0.6
975080	6-Jun-17	East	SH	8-Jun-17	East	ST	0.6
975226	7-Jun-17	East	ST	7-Jun-17	East	ST	2.4
975384	8-Jun-17	East	SH	8-Jun-17	East	SH	0.4

[a] The prefix to each of these tag codes is: 900 226000
[b] CM = Creek Mouth; FN = Fluvial Fan; SH = Shallow Slope; ST = Steep Slope.

In addition to the within-session recaptures, there were 10 between-year recaptures in Year 5 (2017). Original capture and recapture information for these fish is summarized in Table 3.15. Nine of the ten between-year recaptures were for fish that were initially captured in 2016 (i.e., were at-large for ~1 year). One of the between-year recaptures was originally tagged in 2015 (~2 years at large). As with the within-session recaptured fish, the locations for each capture event were varying distances apart (i.e., ranging from 0.2 to 13.0 km). Two tagged fish originally captured in Steep habitats near the dam in June 2016 were recaptured in Jamie Creek (1 in the upland; 1 in the drawdown portion) during the summer tributary sampling in August 2017. These results further support that rainbow trout move and mix among locations, habitat types, and longitudinal zones throughout Downton Reservoir on both daily and annual time scales.

Six fish (forklengths = 89, 91, 103, 104, 105 and 152 mm) were assessed as Age-1 based on scale ageing analysis (see section below) when initially captured, and were 172, 180, 192, 204, 202 and 250 mm forklength when recaptured a year later (at Age-2). This represents a growth range of between 72 and 99 mm in one year for this cohort of fish. One fish was 176 mm (Age-2) when initially captured and 295 mm a year later (at Age-3), representing 60 mm of annual growth. One fish was 273 mm (Age-3) when initially captured and 275 mm a year later (at Age-4), representing only 2 mm of growth across that year. The remaining two recaptured fish grew 4 and 6 mm between Ages 4 and 5, respectively. These results provide evidence of dramatic changes in annual growth for Downton Reservoir rainbow trout as they age (i.e., particularly after Age-3).

Table 3.15 Summary of inter-session and inter-year rainbow trout recaptures in Year 5.

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)	Growth (mm/yr)
	Date	Zone	FL (mm)	Date	Zone	FL (mm)		
656582	16-Jun-15	Mid	176	5-Jun-17	West	295	2.3	60
889107	30-May-16	East	152	6-Jun-17	East	250	3.4	96
889234	30-May-16	East	273	29-Aug-17	West	275	13.0	2
889032	31-May-16	West	103	4-Jun-17	West	192	1.6	88
889225	31-May-16	West	311	6-Jun-17	West	315	0.2	4
889393	31-May-16	West	105	7-Jun-17	East	202	9.0	95
889411	1-Jun-16	West	104	5-Jun-17	West	204	1.4	99
888413	3-Jun-16	Mid	294	3-Jun-17	Mid	300	1.0	6
888393	4-Jun-16	Mid	89	6-Jun-17	West	172	3.8	83
888463	4-Jun-16	East	91	30-Aug-17	West	180	10.7	72

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

Length-Frequency, Size-at-Age, and Age-specific trends

A length-frequency histogram for rainbow trout captured by boat electrofishing in Year 5 (2017) is presented in Figure 3.15. The coloured bars in this figure represent the contribution of the different age classes as determined by analysis of 182 scale samples spanning the full range of available size classes (broken into 10 mm size increments between 50 and 335 mm). The assigned ages from the scale reading were applied to all of the captured fish according to size. As has been reported previously, there was extensive size overlap (in some cases, complete) between certain age classes, particularly for ages >3. This suggests that growth rate diminishes once fish in the reservoir reach this threshold age and size. Length-frequency histograms for each study year are provided in Appendix C (Figure C1) to allow for comparison of results among years.

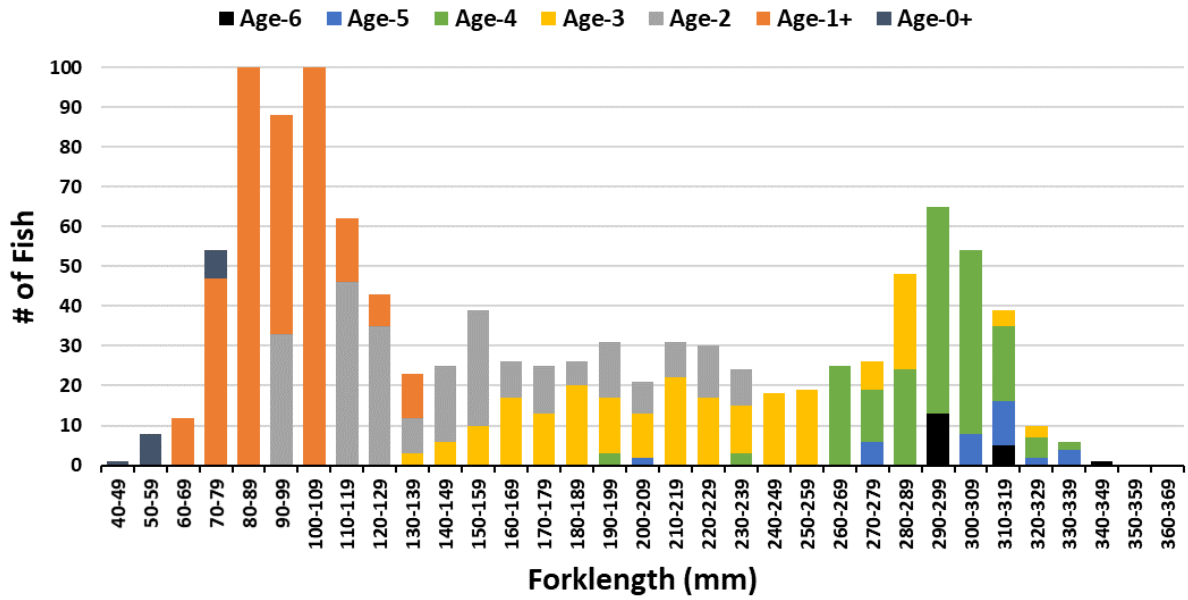


Figure 3.15 Length frequency histogram for rainbow trout captured during the fish population index survey in Downton Reservoir, 1 to 8 June 2017. Size ranges for each available age class are shown.

According to the median size values for fish aged between 1 and 6 at the time of sampling in 2017, the greatest size differences were apparent between ages 2 and 4 (i.e., median differences of 77 mm between Age-2 and Age-3; and 78 mm between Age-3 and Age-4; Table 3.16). In previous years, the greatest size differences were between ages 1 and 3 (Sneep 2018b). The reason for this change was lower median sizes for Age-2 and Age-3 fish in 2017.

Table 3.16 Size statistics for the range of ages of rainbow trout captured in Downton Reservoir during Year 5 (2017).

Age	*n* [a]	Forklength (mm)		
		Minimum	Median	Maximum
0+	16	42	**58**	75
1	349	63	**92**	136
2	251	90	**140**	237
3	220	136	**217**	325
4	192	192	**295**	335
5	33	202	**310**	335
6	19	290	**297**	344

[a] Sample sizes for Age-0+, Age-5 and Age-6 fish were small so size characterizations may not be representative for these cohorts.

We also computed von Bertalanffy growth curves based on the median size values for each age class for the 2015 to 2017 data sets to assess differences in growth among years based on this standardized method (Figure 3.16). The differences in the estimated growth curves are not dramatic to-date, but the differences in median values for particular age classes among years is apparent. The median sizes of Age-1, Age-2, and Age-3 fish were all lower in 2017 than the values in 2015 and 2016, suggesting reduced growth for these age classes occurred within the 12-month period prior to sampling (i.e., June 2016 to May 2017).

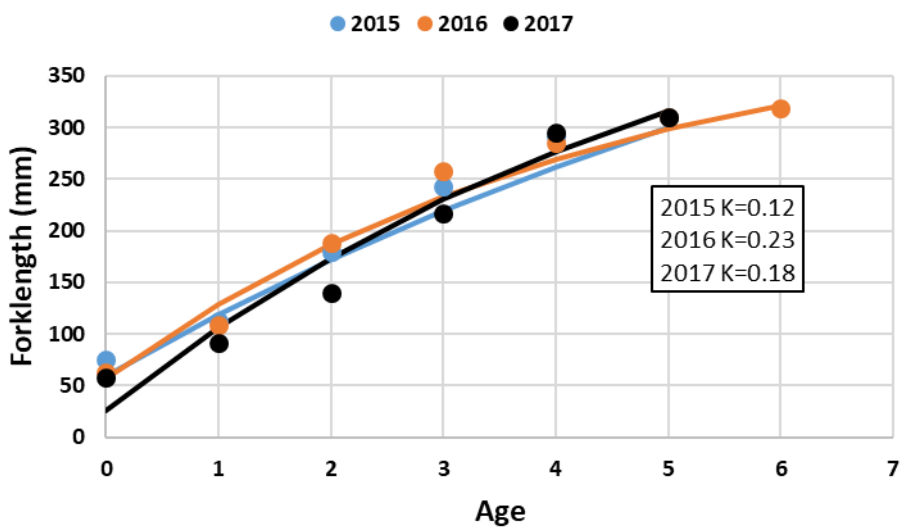


Figure 3.16 Size-at-age plot for rainbow trout captured during the annual fish population index survey, Years 3 to 5 (2015 to 2017). The lines represent the year-specific von Bertalanffy growth curves based on the median size values for each available age class in Downton Reservoir. "K" value is the curvature parameter.

In order to assess these year-to-year changes a bit better, the growth rates for individual cohorts (by recruitment year) are also being tracked (Table 3.17). However, there are still too few annual data points to draw comparisons between cohorts at this point. The oldest fish in the Year 5 (2017) sample were assessed as Age-6 (based on scale ageing; *n*= 2). The largest fish captured was 335 mm. Overall, Age 1 and 3 fish were the most abundant age classes in the 2017 sample.

Table 3.17 Median size for each cohort of rainbow trout by recruitment year across the available years of monitoring to-date (Age-0+ = Recruit Year + 1; Age-1 = Recruit Year + 2, etc.) during the annual population index survey. Growth (i.e., difference in median size between years) is shown in brackets.

Recruitment Year	Median Size (mm)							
	Age-0+	*n*	Age-1	*n*	Age-2	*n*	Age-3	*n*
2013	**76**	4	**113 (+37)**	532	**188 (+75)**	84	**217 (+29)**	220
2014	**75**	30	**109 (+34)**	596	**140 (+31)**	251		
2015	**63**	12	**92 (+29)**	349				
2016	**58**	16						

The assignment of ages also allowed for the comparison of CPUE for each age class by habitat type (Figure 3.17). The range of available age classes were represented in each habitat type (except Age-0+ fish were very poorly sampled regardless of habitat type, as has been the case in each previous monitoring year). In Year 5 (2017), Age-1 fish were equivalently abundant at creek mouths, shallow slopes, and fan habitats. Age-2 fish were most prevalent in shallow habitats followed by creek mouths. As in past years, older fish (Age-3 and up) were most prevalent at creek mouths. The contributions of the youngest age classes were generally the lowest in steep slope habitats. These results suggest that, to varying degrees, each habitat type is used by rainbow trout for rearing, and that creek mouths are likely significant feeding areas for the broadest distribution of age classes, as well as potential staging areas for spawning by mature fish.

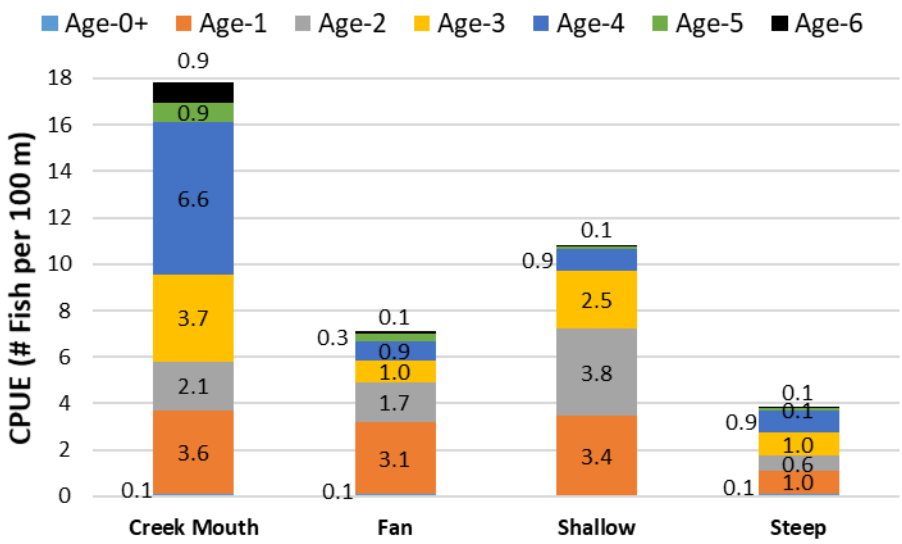


Figure 3.17 Catch-per-unit-effort (fish/100 m) by age class for each habitat type in Downton Reservoir based on the results of the boat electrofishing survey in Year 5, 1 to 8 June 2017.

There were some differences in the relative contribution of each age class to the catch in 2017, compared to 2015 and 2016 (Table 3.18). The CPUE for Age-1 fish was reduced by about 50%, whereas the value for Age-2 fish returned to the 2015 value after dropping in 2016. The contributions of Age-3 and Age-4 fish both increased in 2017, whereas Age-5 fish were equivalent to 2015 levels.

Table 3.18 Comparison of catch-per-unit-effort (fish/100 m) by age class for monitoring years 3 (2015), 4 (2016), and 5 (2017). The percent contribution of each age class to the yearly total is provided in brackets.

Age	CPUE – fish/100 m (% contribution)		
	2015	**2016**	**2017**
0+	0.2 (3%)	0.1 (1%)	0.1 (1%)
1	4.1 (55%)	4.6 (58%)	2.2 (32%)
2	1.7 (22%)	0.6 (8%)	1.6 (23%)
3	0.8 (11%)	1.1 (14%)	1.4 (20%)
4	0.6 (8%)	0.6 (8%)	1.2 (18%)
5	0.1 (1%)	0.7 (9%)	0.2 (3%)
6		0.2 (3%)	0.1 (2%)
All	**7.5**	**8.0**	**6.7**

The reduced contribution of Age-1 fish (i.e., from 4.6 to 2.2 fish/100 m; or 58 to 32% of the sample), may indicate poor recruitment or reduced survival in the reservoir for this age class between 2016 and 2017 sampling events. This cohort was recruited in 2015, the year with the highest reservoir elevations during the spawning period (i.e., up to 744.1 m), which may have impacted spawning success or incubation conditions. On the other hand, the Age-2 fish that had a reduced contribution to the catch in 2016, rebounded as Age-3 fish in 2017, suggesting good rearing conditions for this cohort between 2016 and 2017 (the first full year of modified operations in the reservoir). However, the specific causes of these changes in abundance by age class and cohort, and the degree to which they are linked to reservoir operation, are still uncertain. Until more years of data are collected, it is difficult to put the degree of observed change between survey events in context. Tracking these kinds of age-specific changes are a key component of the analysis for this program that will continue to develop our understanding as more years of data are collected.

Year-specific CPUEs for Age 1 and Age 2 fish were also compared according to reservoir operating levels among years (Figure 3.18). Total CPUE for Age-1 fish (in Year *t*) was plotted against minimum and maximum levels experienced during the spawning period (i.e., ~21 May to ~21 July) in the year of recruitment (i.e., Year *t-2*). For Age-2 fish, total CPUE (in Year *t*) was plotted against the minimum and maximum levels experienced by this cohort in the past year

(Year *t-1* to Year *t*). While there are still too few data points to reliably fit regression lines to the points, these figures will continue to be populated as each new year of data becomes available such that any potential trends can be determined by the end of the monitor.

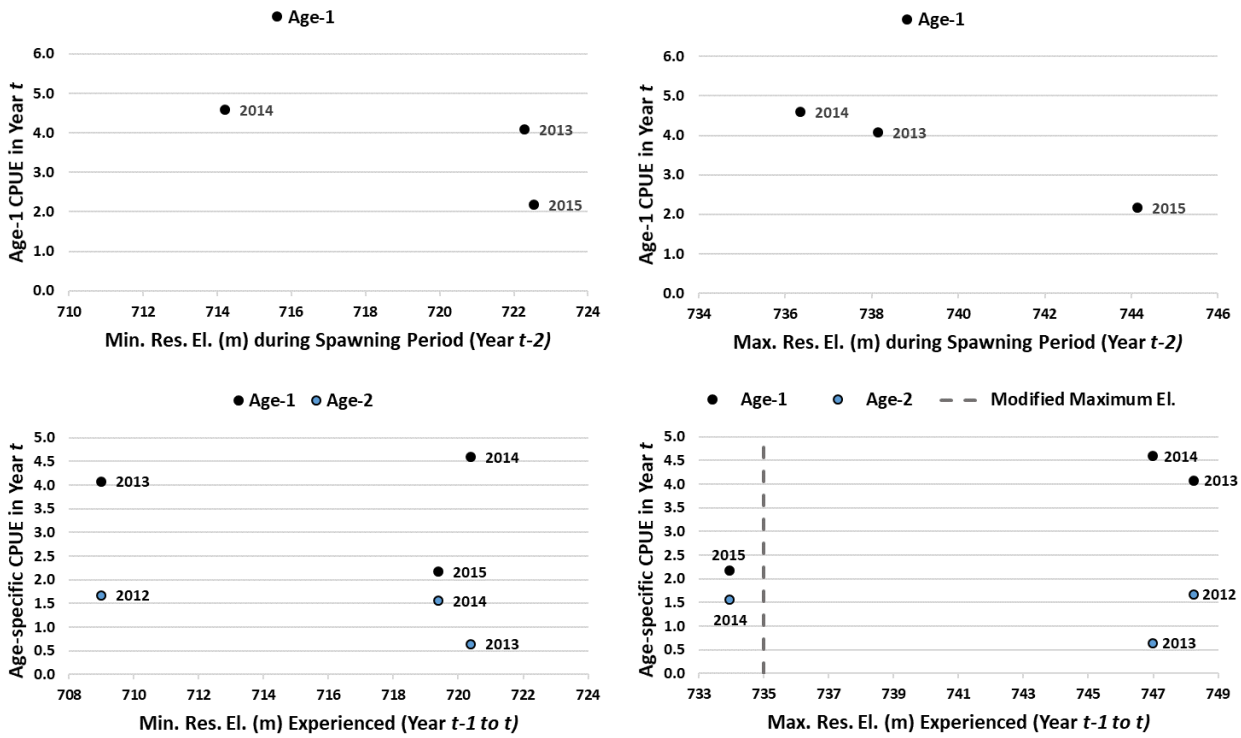


Figure 3.18 Plots of annual age-specific CPUE for Age-1 fish (upper panels) against minimum and maximum reservoir elevations during the spawning period in their recruitment year (*t-2*); and Age-1 and Age-2 CPUEs (lower panels) against the minimum and maximum reservoir levels experienced in the previous year (*t-1* to *t*). Labels next to each data point indicate the recruitment year.

For clarity, the monitoring year that each age class between Age-0+ and Age-2 are sampled in the reservoir, based on recruitment year, is provided in Table 3.19. In Year 5 (2017), the Age-0+ rainbow trout were recruited in 2016, the Age-1 fish were recruited in 2015, and the Age-2 fish were recruited in 2014.

Table 3.19 Sampling years for the Age-0+, Age-1 and Age-2 classes according to recruitment year.

Recruitment Year	Year Sampled		
	Age-0+	Age-1	Age-2
2013	2014	2015	2016
2014	2015	2016	2017
2015	2016	2017	2018
2016	2017	2018	2019
2017	2018	2019	2020

3.7. Pelagic Fish Survey

A pelagic fish survey was conducted in Downton Reservoir from 20 to 23 June by gill netting. A total of 36 rainbow trout was captured from 37 offshore net sets, which were distributed throughout each longitudinal zone of the reservoir (see Figure 2.3). The total sampling effort was 12.1 net-hours (east zone = 5.1 net-hours; mid zone = 3.5 net-hours; west zone = 3.5 net-hours), spanning a range of depths from 0 to 17.5 m below the surface. Fish were captured in less than half of the net sets (i.e., 15 out of 37), and all of them were in surface sets (i.e., between 0 and 2.4 m from the water surface). PIT tags were applied to 31 of the captured rainbow trout. Only fish that were alive and in robust condition were tagged. No fish that had been previously tagged were recaptured by gill netting in Year 5 (2017).

Catches of rainbow trout in offshore habitats were quite consistent among the three longitudinal sections (Table 3.20). The CPUE in the mid section (3.7 fish/hr) was highest, followed by the east section (3.4 fish/hr), and the west section was lowest (2.2 fish/hr). By comparison, the catch rates in nearshore habitats by boat electrofishing were 126.3, 93.7, and 129.3 fish/hr for the east, mid, and west sections, respectively. Though catch rates between the two methods are not directly comparable (e.g., one is a passive method and the other is an active method), it was clear that the number of fish captured per duration of effort expended was substantially lower in the pelagic zone. While these results may not provide an exact proportional comparison, they are likely reflective of *relative* differences in use of nearshore versus offshore habitats by rainbow trout in this context. It also highlights that the nearshore boat electrofishing is the better method for capturing a larger sample of fish for establishing the annual population abundance index for the purposes of this program.

The fish captured by gill netting ranged in size from 117 to 335 mm (or Age 2 to 6), documenting the presence of a range of age classes in the pelagic zone (near the surface). However, 83% of them were between Age-3 and Age-5 (186 to 328 mm), which represented a narrower and more skewed size and age range than the boat electrofishing sample from nearshore habitats (Table 3.21). The absence of fish <117 mm in the gill net catch may reflect that the youngest age classes of fish tend to rear more exclusively in nearshore habitats in the

reservoir, or simply that fish of that size may have been too small to be effectively captured by the range of mesh sizes of the gill nets (see Table 2.2).

Table 3.20 Summary of the gill net catch distribution according to longitudinal zone of Downton Reservoir, 20 to 23 June 2017. All captured fish were rainbow trout.

Sample Session	Metric	Longitudinal Zone of the Reservoir [a]			Totals
		West	Mid	East	
June	# of Sites	14	13	10	37
	Catch (# of Fish)	11	13	12	36
	CPUE (fish/hr)	**2.2**	**3.7**	**3.4**	**3.0**

[a] As defined in Section 2.5; west is furthest from the dam and east is closest to the dam.

Table 3.21 Comparison of percent contribution to the catch by age class for rainbow trout captured by pelagic gill netting versus nearshore boat electrofishing in Year 5 (2017).

Age	% Contribution to the Catch	
	Pelagic (Gill Net)	Nearshore (Boat EF)
0+	-	1%
1	-	32%
2	8%	23%
3	28%	20%
4	39%	18%
5	17%	3%
6	3%	2%

3.8. Supplemental Rainbow Trout Tagging

Supplemental tagging surveys were conducted on four dates in Year 1 (2013), three in Year 2 (2014), two in Year 3 (2015), one in Year 4 (2016), and two in Year 5 (2017). More effort was initially focussed on angling in the first study year which has since shifted more to boat EF (and other program components) in recent years. In addition to the number of fish tagged by boat EF sampling during the fish indexing surveys (described in Section 3.8), totals of 182, 31, 29, 19, and 21 rainbow trout were caught by angling in years 1 to 5, respectively, and all fish were a tag-able size (Table 3.22); Sizes ranged from 234 to 342 mm in Year 5 (2017) and 192 to 437 mm across years.

Across the years of monitoring to-date, four of the fish recaptured during the boat EF surveys were originally caught by angling during these supplemental tagging events. These angling surveys have also provided additional scale samples for ageing purposes.

Table 3.22 Total numbers of PIT tags applied by sampling method during each sampling year to-date. Note: the numbers applied to fish captured by boat EF are included for comparison purposes.

Year	Capture Method		Total PIT tags	# of Recaptures
	Boat EF	Angling		
2013	205	182	387	5
2014	309	31	340	7
2015	614	29	643	9
2016	959	19	978	18
2017	1,013	21	1,034	21
Totals (to-date)	**3,100**	**282**	**3,382**	**60**

4. Discussion

4.1. What are the basic biological characteristics of fish populations in Downton Reservoir and its tributaries?

Based on the results of monitoring to-date (up to and including Year 5), the Downton Reservoir fish population is almost entirely comprised of rainbow trout (save for 1 bridgelip sucker captured in 2016). The rainbow trout population spawns between late May and mid July (peak in mid to late June) in accessible tributaries, primarily in the mid and west zones of the reservoir, which inundate later in the year as the reservoir fills. The absence of observed spawning in some creeks in the mid and east zones of the reservoir (e.g., Ault, Paul and Cathy creeks) which provide suitable habitats for rainbow trout spawning (based on flow, gradient, and substrate composition), may reflect local adaptation by this population to earlier reservoir inundation risk at these locations. Differences in temperature may also play a role, as creeks selected for spawning tend to have temperatures that reach the optimal range for rainbow trout during the spawning period, whereas other tributaries (e.g., Jamie Creek and the Upper Bridge River) are generally colder.

A higher proportion (70% to 80%) spawn in the drawdown portion of these creeks (i.e., relative to the upland), which can be susceptible to inundation depending on how high, how quickly, and how early the reservoir fills during the incubation period (i.e., June and July). Further data collection on accessible stream-length according to reservoir elevation for the known spawning tributaries in upcoming monitoring years (planned for Year 6 – 2018) will provide more information on this reservoir level vs. available spawning habitat relationship. This may contribute a useful input for reservoir operation management decisions.

Following spawning and incubation in the selected tributaries, fry emergence is predicted to occur between the end of July and the beginning of September, with the peak in approx. the third week of August, based on ATU calculations using the available temperature data. This

timing was also generally confirmed by the sampling of recently emerged fry (forklength range = 23 to 33 mm) at the end of August in several creeks.

Beyond this post-emergence period, fish use of the tributaries for rearing appears to be low, suggesting that the majority of the fry move into the reservoir where a range of suitable temperatures for growth are available (according to depth), food (likely in the form of drifting invertebrates at the creek mouths or amphipods in the reservoir – see Photo A10 in Appendix A) is provided, the year-round turbidity provides cover, and the risk of habitat loss from changing reservoir elevations is low (as opposed to within the drawdown zone of the tributaries). In the nearshore areas of the reservoir, the rainbow trout are distributed fairly evenly across the longitudinal zones (i.e., west, mid, and east; shown on Figure 2.4). The highest densities occur at the creek mouths, followed by fan and shallow slope habitats. The lowest numbers are consistently associated with steep shorelines. Offshore sampling (i.e., by gill netting) in Year 5 (2017) suggested that use of pelagic habitats by rainbow trout in Downton Reservoir is low during the spring sample period, and fish were only captured within 2.4 m of the surface, despite sampling at a range of depths between the surface and the near-bottom.

Creek mouths have also consistently been the habitat type where the greatest capture success by angling has occurred throughout the year, and where CPUEs were similarly highest when an additional boat electrofishing session was conducted in October during Years 1 and 2 (Sneep 2015). Together, these results indicate that the more abundant catch at creek mouths reflects not just pre-spawning aggregations of the older, mature fish in these habitats in June, but also greater use by every age class in general throughout the year.

Across the years to-date, the age range of the sample has spanned from 0+ to 7 years (40 to 437 mm); the majority of sampled fish are between ages 1 to 3. The most rapid growth occurs between ages 0+ and 3, after which growth rate slows and there is considerable size overlap among these older age classes. The population size of rainbow trout in Downton Reservoir is estimated to be approximately 100,000 fish (±25,000).

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

Overall CPUE values for rainbow trout were down slightly in 2017 (6.7 fish/100 m of shoreline) from 7.5 and 7.9 fish/100 m in 2015 and 2016, respectively (the other two years available to-date when sampling methods and effort were consistent). This difference was due to reduced catch of Age-1 fish in 2017, which was down by approx. 50% from previous years. On the other hand, CPUEs for Age-3 to Age-5 fish were higher in 2017, including the Age-2 cohort which had been low in 2016. It's possible that the Age-1 cohort was smaller in 2017 due to the high reservoir elevations that occurred during the spawning period of their recruitment year (2015), affecting spawning success or incubation conditions that year. The improved contribution of

older fish (Age-3 and up) may be related to the modified operation of the reservoir (reduced maximum fill elevation), which was implemented for the first full year between 2016 and 2017. However, there is not currently enough data to draw firm conclusions about these results at this point. Continued monitoring, applying consistent approach, methods and effort, for each age cohort going forward may shed light on possible interactions between recruitment to Age-1 and Age-2 with specific operational characteristics.

It is also important to note that by the end of the current monitoring period in 2022, limited data will be available for typical "N2-2P" operations (i.e., possibly only 2 years), and the remainder will reflect results associated with *modified* reservoir operation (i.e., target maximum fill elevation 734 m instead of N2-2P normal maximum of 749 m, and possible increased frequency of deeper drawdowns) intended to reduce seismic risk at the La Joie Dam and Generating Station. The discrepancy in number of years for each treatment within the study period may constrain comparison of N2-2P operation with modified operations due to substantial differences in sample size between these operational treatments.

However, by the end of Year 10, monitoring results should be able to inform whether the operations implemented have had a positive, neutral, or negative effect on rainbow trout abundance in the reservoir, across the monitored period. Also, since the range of modified operations for Downton Reservoir (i.e., 710 m to 734 m elevations) are a subset of the range of N2-2P operations (i.e., 710 m to 749 m elevations), the relationships between operations and fish production informed by the results of this program for modified operations should apply to that portion of the N2-2P range as well. There will likely be a higher degree of uncertainty about the effects of the higher end of the N2-2P range due to a more limited number of data points at those elevations (i.e., >734 m).

The null hypothesis that pertains to this management question (H_1), which states: "*The annual abundance index for rainbow trout in Downton Reservoir is stable over the monitoring period*," cannot be confirmed or rejected at this stage of the program – more years of data are needed. While the program has established a method for tracking this information (Fish Population Index Survey) that is being successfully implemented, there are currently 3 years of comparable abundance index data points available at this point (refer to sections 2.5 and 3.6). While status updates will continue to be provided as more years of results become available, this will ultimately require rainbow trout population index values across the entire monitoring period (to Year 10) to provide a more definitive response to this management question and confirmation or rejection of the H_1 hypothesis.

4.3. Which are the key habitat factors that contribute to reduced or improved productivity of Downton Reservoir fish populations?

Specific, targeted habitat data collection linked to key reservoir operation elevations in Year 5 (2017), provided additional information for addressing this MQ (refer to Section 3.3 for specific habitat survey results).

The tributaries provide essential spawning habitats and, likely, food supply in the form of invertebrates that are produced in the creeks and drift into the reservoir at the creek mouths. However, based on tributary fish sampling results to-date, use of the creeks for rearing by the rainbow trout population appears limited. In select creeks (i.e., those associated with spawning use), highest abundance occurs in summer (i.e., August) related to the presence of newly emerged fry at that time of year. However, the abundance of fish in the creeks diminishes by fall and only modestly increases in spring (Section 3.5). Due to low inflows, some creeks have been observed to go dry in the summer (e.g., Trib. #19, Trib. #10), or may freeze solid in winter. Additional seasonal sampling replication is required in upcoming monitoring years before these results can be considered more definitive. Tributary fish sampling to document use of the range of available tributaries in the fall is planned as a part of Year 6 (2018) activities.

Access to some tributaries by spawners may be impeded when reservoir levels are as low as ~709 m (observed in 2014) during May before the onset of freshet flows in the creeks. To-date, access issues at other elevations or periods during the spawning window have not been observed (Table 3.7). The majority of rearing appears to occur in the reservoir (with all age classes represented in the reservoir sample, and particularly Age-1 and Age-2 fish), and the creek mouths are the most utilized habitat type by the broadest range of age classes.

Temperatures in the reservoir are more broadly spread across the optimal range (according to depth) for growth, relative to the tributaries, which are colder. Temperatures in the monitored spawning tributaries tend to reach optimal ranges within the observed migration, spawning and incubation periods (Figure 3.3). The Upper Bridge River tends to be colder than any other tributary throughout the year, with a maximum mean daily temperature of only 8°C. In 2 of the 3 years of available data, temperatures in Jamie Creek have been below the optimal range for the rainbow trout spawning and incubation period (mid May to end of July), which may be at least partly why spawning use of this tributary has been very infrequent. Later onset of optimal temperatures in each of the monitored tributaries at this time of year, relative to lower down in the watershed (i.e., Lower Bridge River; Sneep and Hall 2012), likely contributes to the later spawn-timing for the Downton Reservoir population.

Relative to the normal full pool elevation in summer (i.e., ~749 m, which fully inundates the reservoir basin), the total habitat length of creek mouths (that were receiving flow) was actually higher at the low pool elevations surveyed (722 m in 2016; 716 m in 2017) because the creeks were in pre-freshet condition and all intermittent drainages were flowing. Due to the shape of the reservoir basin, only steep shoreline habitats were substantially reduced (by ~50%) at the low pool elevations, which is the habitat type associated with the lowest catch rates of fish during the annual index survey. The percent contributions of each habitat type for the two low-pool surveys (i.e., 722 m and 716 m) were very similar. The main differences between these surveys were the length of the reservoir (17.8 km vs. 14.2 km) and the length of the available shoreline habitat (40.9 km vs. 34.5 km), which were 70% and 56% of the normal full pool values, respectively.

In general, the substrate size distribution and embeddedness in the reservoir drawdown zone are positively correlated with elevation (size range, median size and interstitial space each increase with the elevation), although there are not enough fish abundance index data points to correlate access to different maximum elevations with recruitment or size-at-age metrics at this point. The substrate composition and embeddedness data collected in Year 5 (2017) supplemented the sample size (particularly for the 734 m modified maximum elevation and the upland of tributaries), but did not significantly alter the results or conclusions at this point. Based on the information gathered to-date, it is expected that the main factors limiting population size in Downton Reservoir are food supply, inundation of spawning habitat during the spawning and incubation period (May to July), and possibly overall spawning habitat area available in the tributaries.

Overall highest catch rates for rainbow trout in the reservoir during the annual fish population index survey have consistently been at the creek mouths, where all age classes are represented. Given the important food sources that the tributaries likely provide, it is not surprising that the highest fish densities tend to be concentrated around creek mouths and their adjacent habitats. Similar to the results of a productivity assessment in Carpenter Reservoir in 2000, high natural turbidity and large seasonal fluctuation in surface elevation may limit food production within most of the reservoir drawdown zone (Josh Korman, pers. comm.). These factors, combined with other physical habitat characteristics (e.g., the high proportion of steep shorelines, predominance of fines in bottom sediments, limited interaction with terrestrial sources of nutrients, and colder temperatures in the tributaries) are also likely drivers behind the observed patterns in habitat-stratified fish distribution (see Section 3.6).

If the concentration of rainbow trout at creek mouths reflects the source of their food supply, then it's possible that reservoir operation may not directly impact that existing food supply (unless reservoir operations affect food production within the lower extent of the tributaries, which is unknown). Food production in the reservoir itself may be comparatively poor due to footprint effects of the reservoir, and the ongoing cycle of drawdown and inundation, which may also be reflected by the much lower relative use of pelagic habitats by rainbow trout in the reservoir (refer to pelagic sampling results in Section 3.7). If that is the case, then management decisions for the reservoir (e.g., N2-2P vs. modified operations) may not directly affect the current food supply for rainbow trout in the reservoir; however, a more targeted study on the specific sources of the rainbow trout food supply would be required to address uncertainties around this. Amphipods (a form of zooplankton) were anecdotally observed in the reservoir in spring 2017 (see photo A10 in Appendix A). These invertebrates would serve as a sizable food item for a fish and would likely be part of the rainbow trout diet. However, within the current scope of this program it is not known how abundant these amphipods are in the reservoir (i.e., as a food source relative to drift from the creeks), or how various reservoir operations may impact them.

The primary null hypothesis that pertains to this management question (H_4), which states: "*Operation of the reservoir restricts the amount of available effective spawning habitat in tributaries limiting the productivity of fish populations,*" is tentatively confirmed; however, more data are needed. Evidence suggests that rainbow trout primarily use tributaries in the western portion of the reservoir basin for spawning since habitats in these streams inundate later in the year (i.e., after the incubation period). Use of accessible tributaries in mid and east zones (such as Ault, Paul and Cathy creeks) has not been observed despite the presence of suitable habitat, and this may be due to inundation risk. Implementation of modified operations (starting in 2016) reduced the portion of stream length inundated by the reservoir due to the reduced fill level relative to normal N2-2P operations. Monitoring in upcoming years will document whether spawning distribution expands or shifts to include these tributaries under modified operations.

The secondary null hypothesis (H_{4a}), which states**:** "*Rainbow trout spawning density in Downton Reservoir drawdown zone is minimal and therefore operations do not limit productivity of fish populations*" is tentatively rejected; however, more data are needed to define the relationship between operations (e.g., min. and max. reservoir elevations and drawdown and fill rates) and rainbow trout recruitment and survival. While some tributaries are not used at all (see above), the drawdown zone of Tribs. #13 and #19 have been used extensively (Sneep 2018b)**.**

The secondary null hypothesis (H_{4b}), which states**:** "*Operation of the reservoir restricts fish access to tributaries limiting the productivity of fish populations*" cannot be confirmed or rejected at this point; more data from the tributary access surveys for the range of low reservoir elevations during the spawning period are needed. Evidence to-date suggests that connectivity of some tributaries may be cut off when reservoir levels are as low as ~709 m during May before the onset of freshet (due to creeks flowing to ground), although effects on the typical spawning tributaries have not yet been observed (or at least not during the spawning period). Requires additional access surveys at the range of reservoir elevations during the rainbow trout spawning period. Surveys for this purpose are planned to continue in future study years, such that access scores in Table 3.7 can be populated for the full range of reservoir operations.

An additional primary null hypothesis that pertains to this management question (H_5), which states: "*Habitat availability in Downton Reservoir is independent of reservoir operation, i.e., habitat characteristics are not significantly different between minimum, maximum and modified maximum reservoir elevations*" is tentatively rejected based on current findings (see Section 3.3); however, more data are needed to fully characterize or solidify differences in selected attributes among the key elevations. Efforts in Year 5 (2017) supplemented data collection initiated in previous study years to define substrate characteristics at 747, 734, and 722 m. Further data collection on temperatures, habitat type distribution (e.g., at the 734 m modified maximum level) and substrate characteristics are planned for subsequent monitoring years to characterize these differences. Towards completion of this monitoring program in

2022, the collection of data characterizing physical habitat attributes in Downton Reservoir and its tributaries is intended to provide relevant inputs for interpreting potential trends in the fish abundance results according to different reservoir operations among years based on a weight-of-evidence approach.

4.4. Is there a relationship between the minimum reservoir elevation and the relative productivity of fish populations?

There are not yet enough annual fish abundance index data points to evaluate a potential relationship between operational parameters (such as minimum reservoir elevation) and fish population response at this point in the monitoring program schedule. Year 5 (2017) contributed an additional data point to the annual index of abundance, and provided another set of results for documenting the age structure of the rainbow trout population over time. In addition to a potential relationship between minimum reservoir elevation and the relative productivity of fish populations, it is our intent to look for evidence of effects according to other year-specific operational parameters as well, such as: magnitude of maximum elevations, duration (# of days) at maximum and minimum elevations, fill rate, and drawdown rate.

At this point, none of the primary or secondary hypotheses that pertain to this management question (i.e., H_2, H_{2a}, H_{2b}, H_3, H_{3a}, or H_{3b}) can be confirmed or rejected as more annual abundance estimates coupled with year-specific operational parameters (as described above) are needed. The years monitored to-date have provided an ample degree of operational contrast (i.e., varying minimum and maximum levels, and fill and drawdown rates), but in order to fully define the potential relationships and reduce uncertainty, values for all monitoring years (to 2022) will be required.

4.5. Can refinements be made to the selected alternative, without significant impact to instream flow conditions in the Middle Bridge River, to improve habitat conditions or enhance fish populations in Downton Reservoir?

Based on the reservoir elevation and fill rate information provided by BC Hydro (see Figure 3.1 and Table 3.1), the modified operation of La Joie Dam (i.e., reduced full pool elevation and slower fill rate) may provide benefits in terms of a reduced proportion of eggs at risk of inundation by the reservoir and an increase in useable stream length above the *modified* maximum reservoir level. However, it is still too early in the monitoring program to reliably answer this management question in terms of all the informative metrics being compiled by this study. Evaluation of the annual fish abundance index, biological characteristics data, and key habitat factors data for all years of the monitoring program will be required to provide sufficient weight-of-evidence inferences to inform operational management decisions and reduce uncertainties.

Determining the effects of various operational scenarios for the management of Downton Reservoir on Middle Bridge River flows could only be determined based on BC Hydro flow modelling that is outside the scope of this monitoring program. However, this would be a useful exercise for BC Hydro to undertake, with relevant inputs from this program, during the period of monitoring to inform operating decisions and the final report (in Year 10). Potentially relevant inputs from this program could include identification of Downton Reservoir elevation ranges and associated date ranges that are important for spawning use and protecting the most significant amount of rainbow trout spawning habitat in reservoir tributaries, as observed under modified operations.

Also, as stated earlier, the modified operations are a departure from the N2-2P operations in terms of the maximum fill elevation and potential frequency of deeper drawdowns related to mitigating seismic concerns at La Joie Dam. According to BC Hydro's current capital schedule, the modified operations will continue until at least the end of the BRGMON-7 monitoring period (i.e., 2022) (Matt Casselman, BC Hydro NRS, pers. comm.). As such, there will be more years of monitoring the modified operations than the N2-2P operations. The modified operations *do* have a significant impact to instream flow conditions in the Middle Bridge River (and elsewhere in the Bridge-Seton hydroelectric complex) due to lost storage in Downton Reservoir caused by the lower maximum fill target (i.e., 734 m instead of 749 m). These changes may require changes in how this question is interpreted and addressed relative to its original intent, at the end of the BRGMON-7 program.

5. Recommendations

Going forward, the CPUE metric values provided in this report will continue to be generated annually and compared as a reflection of trends in population index between monitoring years. To-date, there has been some variation in total CPUE values, trends between habitat types, and relative abundance among the age classes in Years 3 to 5 (2015, 2016 and 2017). However, there were still too few data points to reliably fit a regression line to the CPUE vs reservoir operation (minimum or maximum levels) relationship, or fully understand the significance of these differences or changes in context. The figures and tables generated for this report will continue to be populated as each new year of data becomes available such that any potential trends can be determined by the end of the monitor.

Other operational parameters which may affect rainbow trout recruitment and survival may also include: duration (# of days) at maximum or minimum elevations; or reservoir drawdown and fill rates. Once a sufficient sample size of fish population abundance index data is available, analyses can include examination of potential relationships between these factors and age-specific CPUE.

For comparative purposes, the assessment of abundance trends across the years of monitoring will continue to focus primarily on the younger age classes (i.e., Age 1 and 2 fish). Fish from

these age classes are adequately represented in the sample to-date, primarily occupy the reservoir throughout the year, and are the most appropriate ages for potentially linking the effects of reservoir operations with recruitment. Differences in the abundance of the older age classes (i.e., ages 4 and up) across years may be noted, but won't necessarily be relied upon for drawing conclusions about reservoir operations effects. A wider array of additional factors may be involved in determining the number of older-age fish in the sample from year-to-year (e.g., changes in spawn timing or migrations, etc.).

The sample size of fish from the current monitoring effort should be sufficient for monitoring trends in the *relative* abundance of each age class according to CPUE, particularly focussing on Age 1s and 2s, for linking with annual differences in reservoir operation (i.e., minimum and maximum reservoir elevations) by the end of the study period.

In addition to the CPUE-based tracking of population trends for each year of the monitor, we intend to continue the mark-recapture component (using PIT tags) as well. The mark-recapture component provides the opportunity to estimate population size, growth of individuals between capture and recapture events, and potential catchability assessment of the boat EF method in this context. While the resolution of the population estimates alone may not be high enough to track changes with specific operations among years, it can be helpful to have multiple lines of evidence to provide context or support to population trends assessed by CPUE, by the end of the monitor.

Recommendations pertaining to specific monitoring components or methods for upcoming years of field data collection for the program are as follows:

- Target installation of the temperature array in Downton Reservoir for mid April and removal by end of October to fully bracket the period of thermal stratification in this context, such that changes in the timing of thermal stratification development or collapse can be assessed among years in addition to the specific temperature profiles.
- Conduct habitat mapping at 734 m modified operation maximum level to collect a comparable data set on habitat availability and distribution as for the 747 m (approx. normal maximum), 722 m (fish index sampling), and 716 m (low pool) elevations. Having data across this range of key elevations will facilitate analysis of the relationship between reservoir elevation and habitat type availability that could inform differences or changes in fish population trends.
- Collect additional substrate measurement and embeddedness data at 722 m elevation, to make sample sizes more equivalent among selected elevations.
- Conduct spawner count streamwalks and tributary access surveys in widest range of tributaries possible (e.g., Tram Cr., Trib. #13, Jamie Cr., Eagle Cr., Cathy Cr., and Ault Cr.) from mid May to end of July to document start, peak, and end of spawn timing as well as relative abundance among creeks.

- Repeat the fish population index sampling by boat electrofishing on the same dates (early June), maintaining the same approach effort, crew, equipment, etc. each year to the extent possible.
- Discontinue pelagic zone sampling using gill nets. Offshore gill net sampling documented low use of pelagic habitats in Downton Reservoir, and confirmed that boat electrofishing in nearshore habitats is the most suitable approach for monitoring this population.
- Conduct tributary fish sampling (by backpack EF) in early October in a range of creeks (e.g., Ault Cr., Paul Cr., Cathy Cr. Eagle Cr., Jamie Cr., Trib. #13, Tram Cr., and Upper Bridge River) to assess fish rearing use of tributary habitats during fall, when the reservoir is drawing down from the modified maximum elevation and temperatures are cooling. As for seasonal sampling in past years, spatial distribution of sites should include the drawdown zone and the upland zone (where accessible to fish from the reservoir) in the selected creeks.

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Appendix A – Representative Photos of Reservoir and Tributary Habitats

Photo A1 Reservoir Habitat Type 1: **Creek Mouth**

Photo A2 Reservoir Habitat Type 2: **Fan**

Photo A3 Reservoir Habitat Type 3: **Shallow Slope**

Photo A4 Reservoir Habitat Type 4: **Steep Slope** (Sub-type Colluvium)

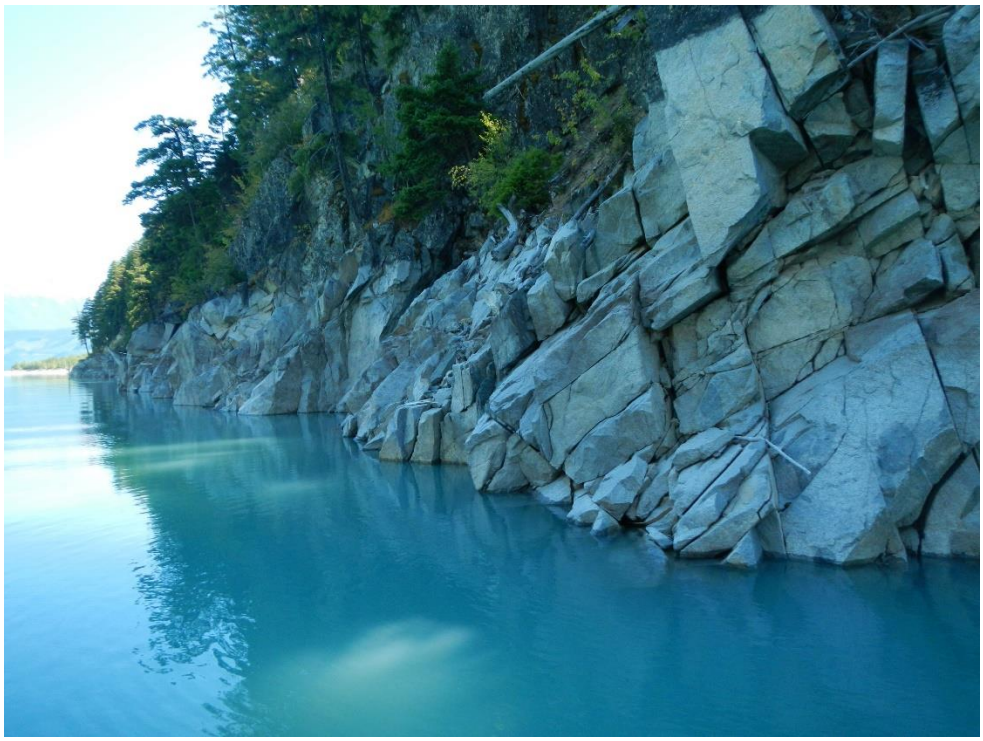

Photo A5 Reservoir Habitat Type 4: **Steep Slope** (Sub-type Bedrock)

Photo A6 Reservoir Habitat Type 5: **Dam Face** (at approx. 734 m elevation)

Photo A7 Reservoir Habitat Type 5: **Dam Face** (at approx. 722 m elevation). Note the reduced reservoir-dam interface (and exposure of natural substrate materials at the toe of the dam) at lower elevations relative to Photo A6.

Photo A8 Tributary Habitat – Upland

Photo A9 Tributary Habitat – Drawdown

Photo A10 A couple of amphipods opportunistically collected near the surface in a nearshore habitat of Downton Reservoir. These are a likely food source for rainbow trout in the reservoir (Chris Perrin, pers. comm.). Scale shown is in millimeters.

Appendix B – Temperature Figures from Past Study Years

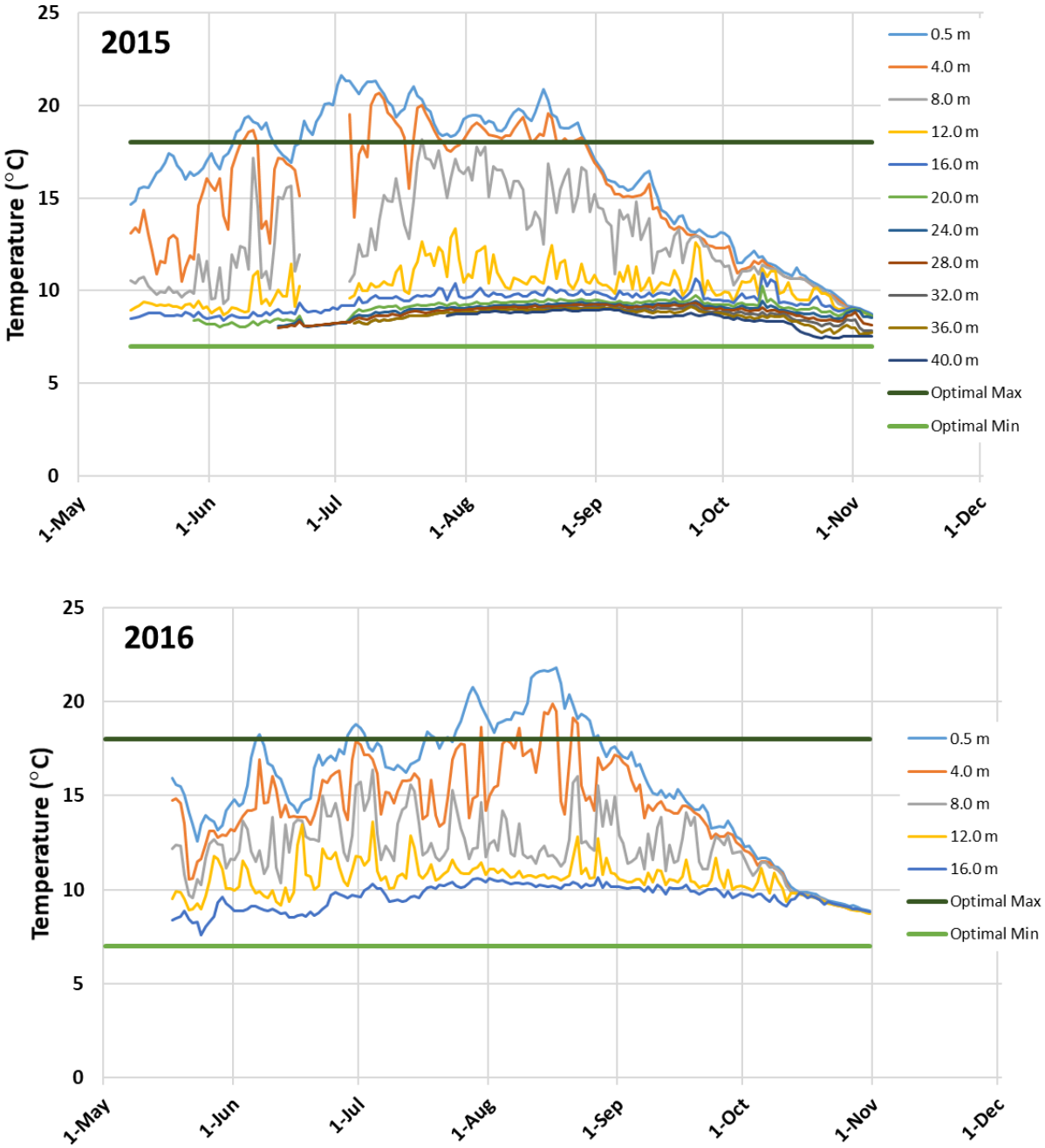

Figure B1 Mean daily water temperatures by depth from the Downton Reservoir log boom array, May to November 2015 (upper) and 2016 (lower). The light and dark green horizontal lines bracket the preferred temperature range of rainbow trout (McPhail 2007).

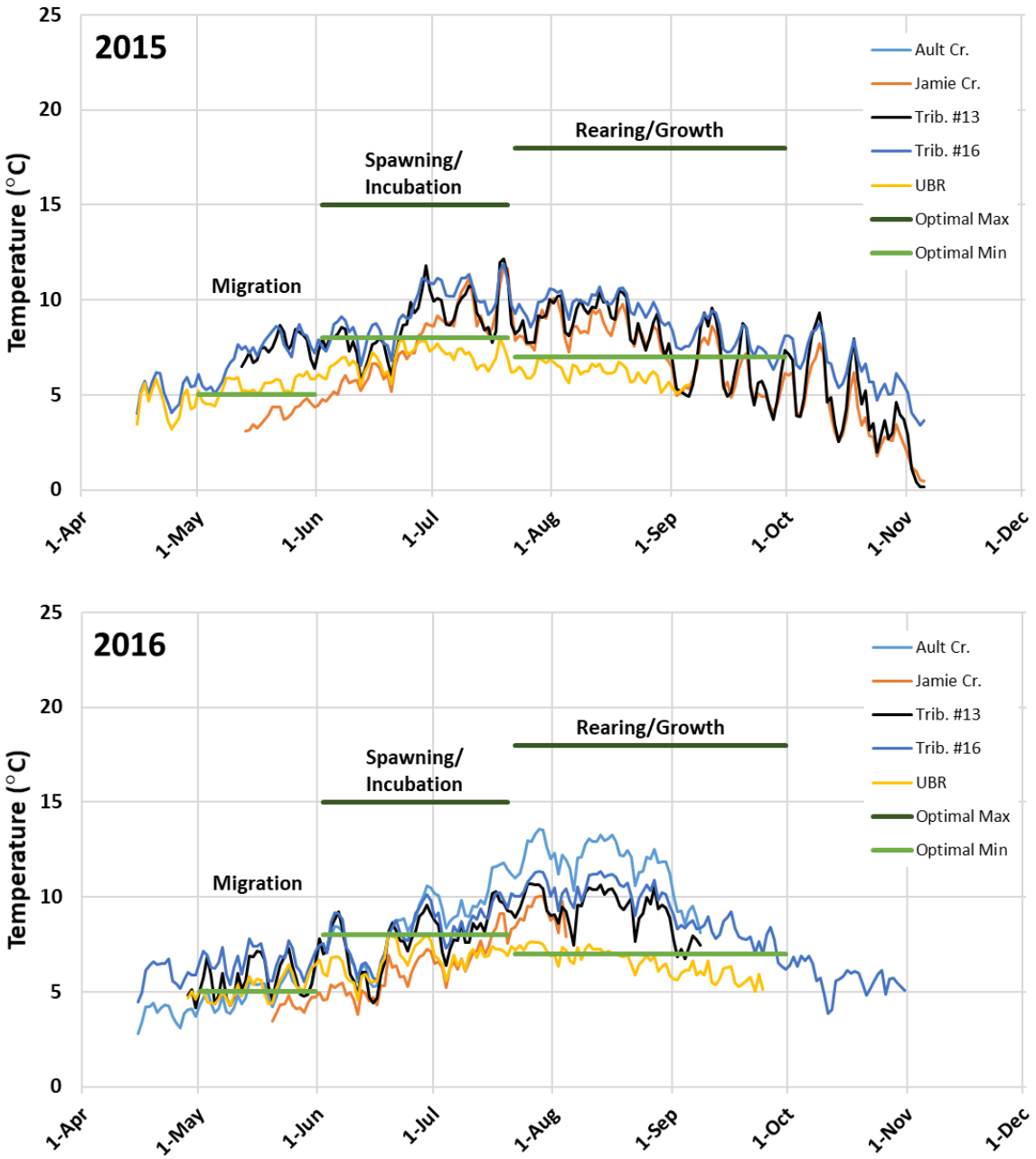

Figure B2 Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to November 2015 (upper) and 2016 (lower). The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of rainbow trout (McPhail 2007).

Appendix C – Length-Frequency Figures by Study Year

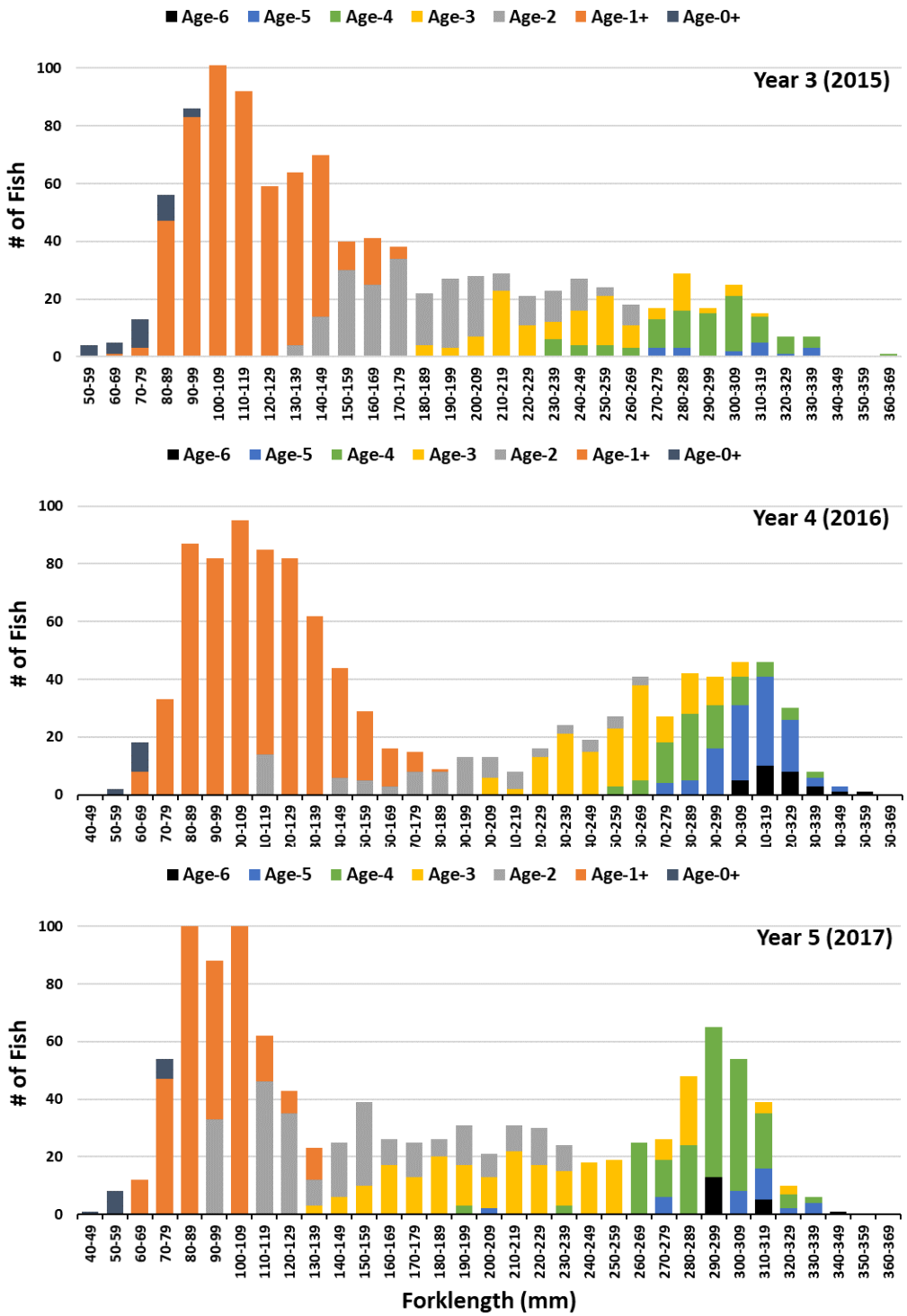

Figure C1 **Length-frequency histograms for each study year showing the distribution of age classes for rainbow trout in Downton Reservoir in late May to early June. Note: results for years 1 and 2 are not included due to different sampling approach in those years.**