Bridge River Project Water Use Plan

Downton Reservoir Fish Habitat and Population Monitoring

Implementation Year 4

Reference: BRGMON-7

BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 4 (2016) Results

Study Period: April 1 2016 to March 31 2017

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Executive Summary

Data collection for Year 4 of this proposed 10-year study was completed in 2016. 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. Eight methods were employed in Year 4 (2016) to document the biological characteristics of the rainbow trout population, generate an annual abundance index, characterize available fish habitats, and assess the effects of modified reservoir operations implemented for the first time this year.

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 (September). Year 4 (2016) was the first year that the reservoir was operated to the new modified maximum elevation (i.e., 734 m). Lowest reservoir elevation in 2016 was very similar to 2013 and 2015, and 10.4 m higher than 2014. Maximum reservoir elevation in 2016 was 740.0 m at the beginning of January as the reservoir was drawing down from 2015 elevations; it filled to just below the modified maximum elevation (733.9 m) by the beginning of September.

The shoreline habitat mapping in 2016 documented a 7.8 km (30%) decrease in reservoir length and 19.4 km (32%) decrease in shoreline length at the 722 m reservoir elevation surveyed, compared to the 745 m (near full pool) elevation surveyed in Year 3 (2015). There was a substantial reduction in steep shoreline habitat (by 21.1 km or almost 50%) and an increase in shallow habitat length despite the reduced wetted extent of the reservoir. Fan habitat decreased in total length, but only slightly (-0.4 km), and actually increased in percent contribution (by 6%) to the total at the low pool elevation. The number and % contribution of creek mouth habitats also increased in the low pool survey 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 22 sites in the reservoir drawdown zone (n= 18) and in select tributary streams (n= 4) during 2016. Overall, fines and small gravels were the most abundant substrate classes; however, the relative proportions did 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%, 40% and 52% at 722 m, 734 m and 747 m, respectively. Interstitial space availability was generally low at all sites, but were highest (and exhibited a gradient with elevation) at creek mouths and in tributaries.

Stream walks were conducted in four tributaries where spawning use has been documented in past years. Based on the Year 4 (2016) results, peak spawn timing for Downton Reservoir rainbow trout occurred between the middle and the end of June, which was at least a week earlier than in 2015, but on par with the median timing for years 1 to 4 combined. Overall, peak counts in the surveyed creeks were in between the highest and lowest numbers observed in previous years. These surveys will help us track any changes in spawn timing or relative magnitude across the 10-year monitoring period.

PIT arrays installed on Trib. #13 and Tram Creek during the rainbow trout spawning period (May to July) detected 21 rainbow trout in Trib. #13 and 11 in Tram Creek. For both creeks, spawning primarily occurred within the drawdown zone (81%), matching visual survey results and indicating the majority rainbow trout redds would be susceptible to inundation if reservoir elevations increased during the incubation period (June and July)

Tributary fish sampling has been conducted in spring and fall by backpack electrofishing in a set of streams accessible to fish from the reservoir to document seasonal rearing use. Catch-per-unit-effort (CPUE) for rainbow trout was 6.1 fish/100 m in spring and 4.4 fish/100 m in fall, though half of the sites had no fish. Captured fish ranged in age from 0+ to 4, but the majority (50% and 29%) were Age 0+ and 1, respectively. While it is clear that the tributaries are important for providing spawning habitats and, likely, food supply to the reservoir (e.g., in the form of drifting invertebrates), these results suggested that use of the creeks for rearing during these seasons is low, relative to the reservoir.

Approximately 13 km of shoreline was sampled by boat electrofishing over 7 nights from late May to early June. In total, 1,028 rainbow trout were captured from 49 sites, as well as 1 bridgelip sucker. Of these fish, 959 were marked with PIT tags and another 19 rainbow trout captured by angling were also PIT tagged and released alive.

Total CPUE in the reservoir was 7.9 fish/100 m of shoreline compared to 7.5 fish/100 m in Year 3 (2015). Highest CPUEs by age were recorded for Age-1 and Age-3 rainbow trout (4.6 and 1.1 fish/100 m, respectively). Highest CPUEs by habitat type were at Creek Mouths (14.4 fish/100 m) and then fans (11.3 fish/100 m), followed by shallow and then steep slopes (7.3 and 6.2 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 Mid zone in 2016; although this has varied among years to-date, reflecting that rainbow trout are generally distributed throughout the reservoir.

Scales from 196 rainbow trout were collected for ageing analysis in 2016. Fish ranged from Age 0+ to Age 7 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) complete a reservoir habitat survey at the modified maximum level (734 m) and elevations <722 m to facilitate comparison of the proportional amount and distribution of habitat types across the range of reservoir operating conditions; 2) Conduct gill net sampling at a range of depths in the pelagic zone of the reservoir to document relative abundance and use of off-shore habitats to provide additional context for the shoreline-based population index survey; 3) Repeat the population indexing survey by boat electrofishing annually, employing the same timing, methods, and effort to establish comparable catch statistics (CPUEs) for monitoring trends associated with reservoir operations in all remaining study years going forward; and 4) Continue seasonal tributary fish sampling to document relative rearing use in the creeks among seasons, which informs the risk of impact to rearing habitats from changing reservoir elevations.

The status of responses to the Management Questions and Study Hypotheses based on results up to, and including, Year 4 (2016) 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 4

Primary Objectives	Management Questions and Study Hypotheses	Year 4 (2016) 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 this year). • The rainbow trout population spawns between late May and late July (peak in mid 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 alluvial fans. Lower numbers are sampled from steep or shallow shorelines not associated with creeks. • In the nearshore areas of the reservoir, the rainbow trout are distributed fairly evenly across the longitudinal zones (i.e., West, Mid, and East). • Sampling in offshore habitats (i.e., by gill netting) is being proposed for Year 5 (2017) to assess relative use of deeper, pelagic habitats for comparison with the nearshore results. • 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-P) result in positive, negative or neutral impact on abundance and diversity of fish populations?	• Overall CPUE values for rainbow trout between 2015 and 2016 (the two years available to-date when sampling methods and effort were consistent) were very similar: 7.5 and 7.9 fish/100 m of shoreline, respectively. • CPUEs *by age class* were also fairly similar across these two years, except for Age 2 fish. Age 2 CPUE dropped across all habitat types by almost two-thirds from 1.7 fish/100 m (2015) to 0.6 fish/100 m (2016), suggesting a possible recruitment anomaly for this age class between those years. • Min. reservoir elevations were very similar between 2015 and 2016, whereas max. fill elevations differed by ~13 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-P 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-P 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 4 (2016) 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 2 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 4 (2016), 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. • Relative to the normal full pool elevation in summer, the amount of creek mouth habitat was actually higher at the low pool elevation surveyed (~722 m) because 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 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 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 reduced the portion of stream length inundated by the reservoir. **H_{4a}:** tentatively rejected; more data needed. While some tributaries are not used at all, the drawdown zone of Tribs. #13 and #19 are used extensively**. See Sections 3.4 and 3.6 for more information**. **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 4 (2016) 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 or <722 m) and substrate characteristics are planned for subsequent monitoring years to characterize these differences.

Primary Objectives	Management Questions and Study Hypotheses	Year 4 (2016) 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 4 (2016) 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 3.17 (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 3.17 (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 2021. Data collection for Year 4 of this proposed 10-year study was completed in 2016.

1.2. Sampling Design

As in previous monitoring years, Year 4 (2016) 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.

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.

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, planned modifications to Downton Reservoir operations (related to seismic risk mitigation at La Joie Dam) also necessitated revision to the original approach.

Under the *modified* operations, the target fill elevation for Downton Reservoir will be 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 is an operational mitigation strategy to reduce seismic risk until physical works at the dam can be completed to address the issue. 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.

In light of these operational changes and in the course of discussions about the program with the monitoring committee, including the BC Hydro Fish & Aquatic Issues Specialist, 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. Since the Year 3 (2015) report, the discussion of results has focussed on the revised study hypotheses as presented in this addendum. 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.

1.3. 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 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-P) 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.

1.4. 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).

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.

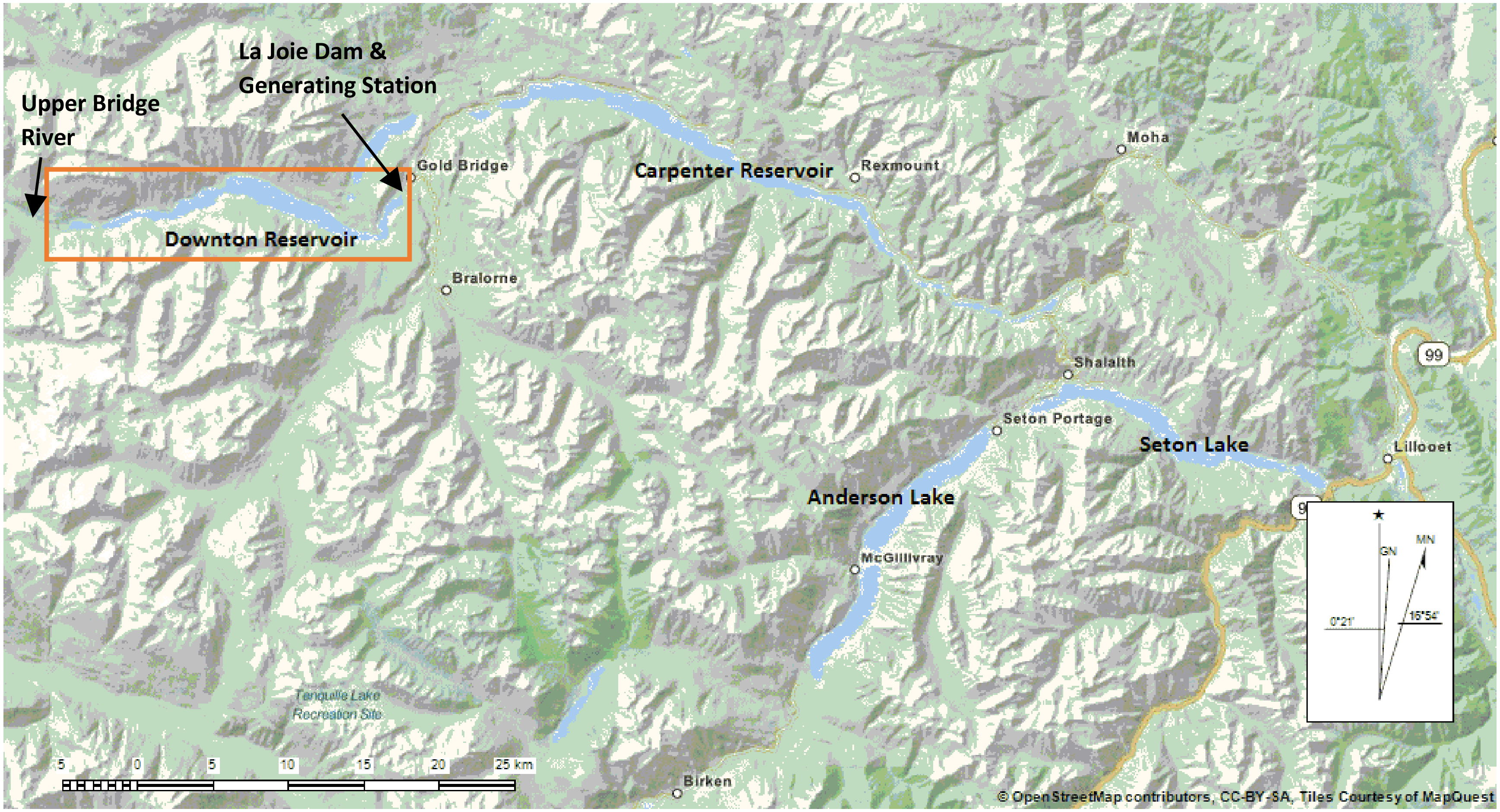


Figure 1.1 Bridge River and Seton River watersheds. The extent of the BRGMON-7 study area, which includes all of Downton Reservoir and tributaries between the Upper Bridge River inflow and La Joie Dam, is outlined by the orange rectangle.

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.

2.1. Sampling Schedule

As per the original ToR, the activities associated with this monitoring program were recommended by the BRG WUP Consultative Committee for a total of 10 years. The study year covered by this report (2016) represents monitoring year 4. The general schedule of field sampling activities is presented in Table 2.1.

Table 2.1 Schedule of Field Sampling Sessions and Activities.

Field Studies	Dates (Year 4 - 2016)
Temperature logger deployment & retrieval	27 April; 4 August; 31 October
Tributary fish sampling (spring)	11, 12, 17, 19 May
Tributary Spawner Surveys and PIT array maintenance	12, 19, 26 May 1, 9, 15, 23, 30 June 7, 13, 20 July; 4 August
Tributary Access Surveys	16 May; 18 May
Supplementary Rainbow Trout Tagging	17 May
Substrate characterization at reservoir & tributary sites	16 to 19, 25 May
Habitat Mapping	24 to 25 May
Fish Population Index Survey	30 May to 5 June

2.2. 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 was initiated as part of the BRGMON-7 program in Year 3 (2015) and continued in Year 4 (2016). As such, temperature data for this context are 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 27 April, checked and downloaded on 4 August, and retrieved on 31 October, 2016. 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, 5 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, and 16.0 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.

2.3. Habitat Surveys

As in Year 3 (2015), habitat surveys were conducted to document habitat availability 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. The plan is to conduct the various habitat survey components across years to document the habitat conditions across the range of observed reservoir levels (i.e., minimum, maximum, and *modified* maximum elevations) and build a larger dataset than what is possible within the budget for a single year. 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 the 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 2016 the habitat mapping was conducted at ~722 m elevation in late May, which corresponded to conditions during the fish population index survey and near low-pool elevation (719.38 m) that year. 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°, or steep slope >15°); habitat sub-type (colluvium or bedrock) for steep habitats only; UTM coordinates for the start and end of each unit; boat track; and presence/absence of adjacent terrestrial vegetation. The collection of these data allowed for calculation of total shoreline length, the length and number of units for each habitat type and sub-type, as well as the proportion of shoreline that interfaces with adjacent terrestrial vegetation. 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). A previous survey at ~745 m reservoir elevation was conducted in Year 3 (2015).

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. The conception 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 4 (2016): ~747 m and ~722 m for the reservoir, representing *normal* maximum and minimum levels; and upland (>749 m) and drawdown (~722 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. Data for the 734 m elevation were collected in June 2015 (Year 3) when the reservoir surface was at that level. 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. As such, the substrate measurement data collected in Year 4 (2016) supplemented the data collected in Year 3 (2015; Figure 2.1).

Substrate measurement locations were selected from the list of fish sampling sites in the reservoir (2016 *n*=18), as well as in tributaries that are generally accessible to fish from the reservoir (2016 *n*=4). At each site, a tape measure was laid out for 30 m parallel to a selected elevation (i.e., ~747 m near full pool or ~722 m near minimum level) 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.

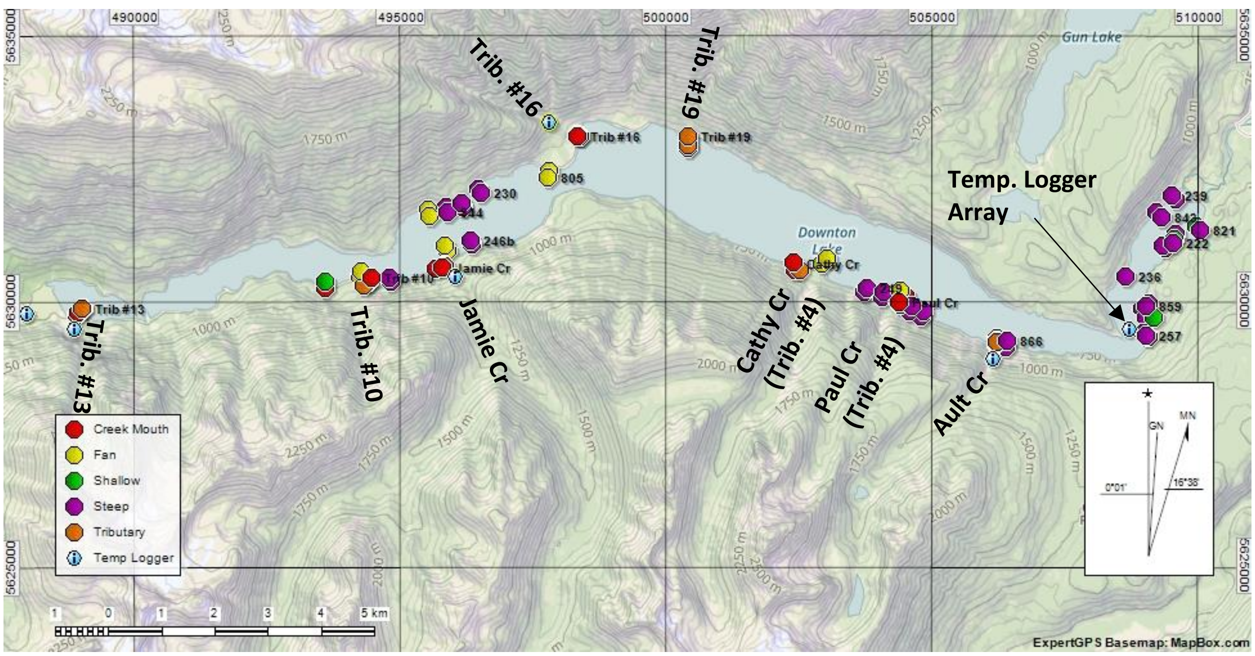


Figure 2.1 All substrate measurement locations to-date as of Year 4 (2016). Multiple dots at each location refer to measurement transects at 747 m (near maximum reservoir level), 734 m (*modified* maximum level), and 722 m (fish sampling level). Surveyed tributaries are labelled and the locations of temperature logger deployments are shown.

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 2.2).

Table 2.2 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

2.4. Tributary Spawner Surveys

Tributary spawner surveys were conducted to maintain an annual index of the relative abundance, timing and distribution of fish spawning in select tributaries of Downton Reservoir. The surveys focussed on rainbow trout, as this is the sole target species for the monitoring program and eggs deposited within the drawdown zone by this species may be impacted by backwatering effects of the reservoir as it fills. Additionally, the distribution of spawners among reservoir tributaries may be affected by the modified operations of the reservoir (i.e., altered drawdown and filling schedule) starting in Year 4 (see Section 2.5 for targeted monitoring component for assessing this).

Spawner surveys were conducted (or at least attempted) on a weekly basis during the rainbow trout spawning period (generally May to July in Downton Reservoir) to get a relative weekly count. Access to known spawning tributaries can be hampered at this time of year by slides and avalanches or low reservoir levels, which precluded some surveys. Flow levels and turbidity also tend to increase across the monitoring period at this time of year. These parameters were subjectively assessed for each survey as follows:

Visibility:	Good	(can see to the bottom throughout survey area)
	Fair	(can see to bottom except in deep pools)
	Poor	(cannot see to bottom in mid channel)

Discharge:	Low	(flow is at or below bottom of the banks)
	Moderate	(channel is approximately half full; average flow for stream)
	High	(flow is near bankfull width or flooded)

To-date, the primary rainbow trout spawning tributaries identified by the program include: Tributary (Trib.) #13, Trib. #16, Trib. #19, and Tram Creek (Figure 2.2). At the start of Year 2 (2014), the road to the north side of the reservoir was blocked by heavy windfall and a large slide, which has continued to preclude land access to Trib. #16 and Trib. #19 since that time. In Year 4 (2016), access to these north side tributaries for the weekly surveys was attempted by boat. Despite the more involved logistics, access by this method was successful on many of the survey dates. However, access was precluded on three surveys around the peak spawning period (23 June, 30 June and 7 July) due to low reservoir levels.

Rainbow trout spawners in each surveyed stream were enumerated by two technicians: one at the top of each bank starting at the creek mouth and walking upstream until either reaching a fish migration boundary or until no further fish had been observed (for several hundred meters). Downton Reservoir sits in a fairly steep-sided valley, so the accessible length of most tributary streams is relatively short (i.e., less than 1 km). Each crew member wore a hat and polarized sunglasses to minimize glare and ambient light interference. Numbers of fish observed in each tributary, and their relative location (upstream or downstream of 749 m full pool elevation), were reconciled between the two observers in the field and recorded on standardized data sheets for each survey. The other recorded parameters included: date, time of day, water temperature, and any comments pertaining to the conditions of the survey.

As indicated in previous reports, it’s important to emphasize that the results of these surveys were uncalibrated by methods such as mark-recapture so observer efficiency was not quantified and the numbers didn’t take into account the variable effects on “sight-ability” of the fish among surveys. As such, it was not possible to estimate total spawner escapements from these data; rather they represent a rough index of spawner timing and abundance in a few key tributaries.

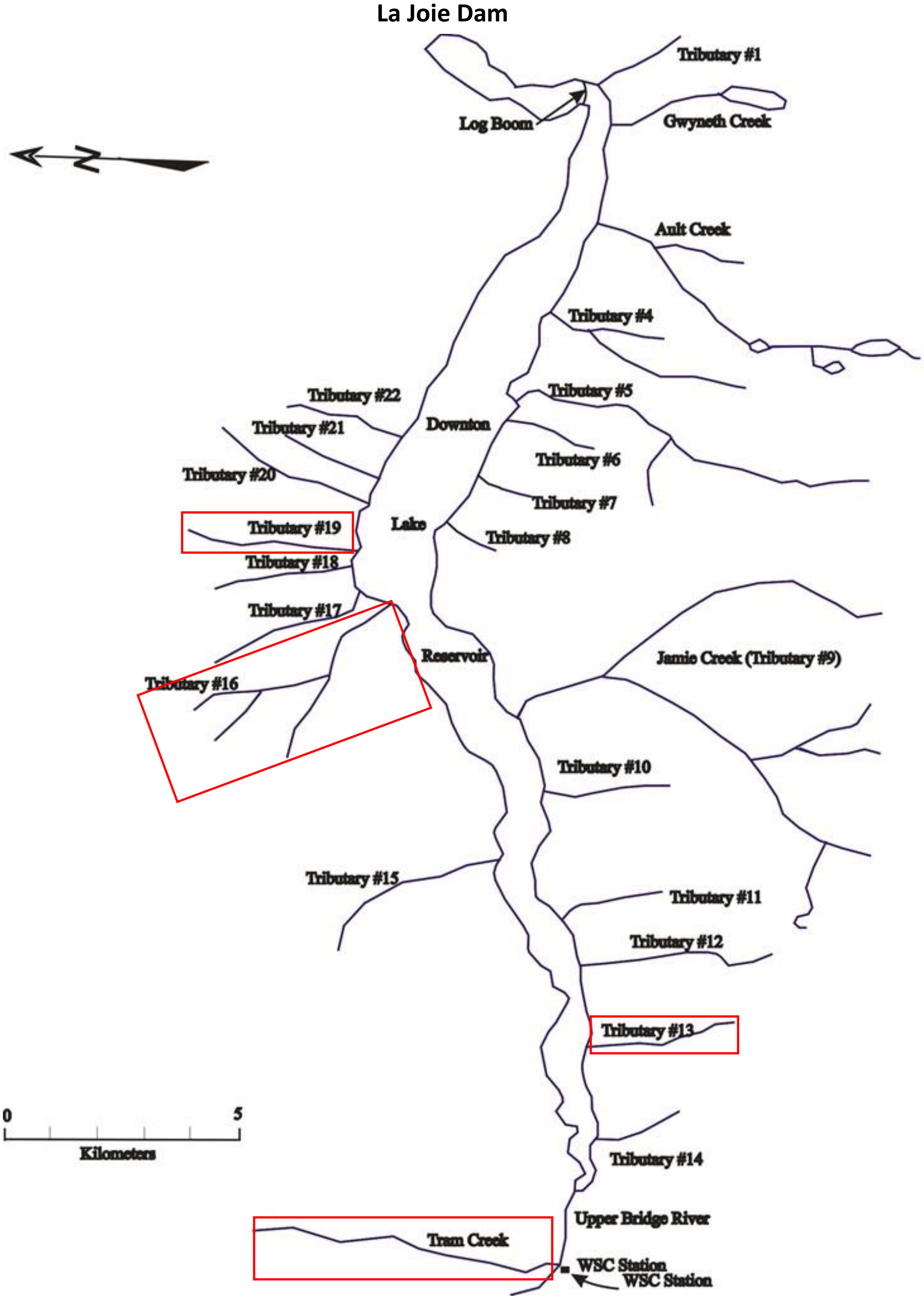


Figure 2.2 Downton Reservoir and the relative location of tributaries. Streams that consistently support rainbow trout spawning, and are monitored for this program, are outlined in red.

2.5. 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 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.

Tributary access surveys were initiated in Year 3 (2015) and repeated again in Year 4 (2016). 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.

2.6. PIT Array Monitoring

As a part of the annual fish sampling on Downton Reservoir, captured rainbow trout of sufficient size and condition are routinely implanted with Passive Integrated Transponder (PIT) tags to document their movement, growth, and rate of recapture between sampling events. As in Year 3 (2015), movement of PIT tagged rainbow trout into spawning tributaries was assessed using fixed PIT reader arrays. Two known spawning tributaries were assessed with PIT installations in Year 4 (2016): Tributary #13 and Tram Creek (Figure 2.3).

In Tram Creek, a single antenna reader was installed to assess the migration of tagged individuals from the reservoir. All habitats in this creek are above 749 m elevation, and therefore outside the zone of influence of the reservoir. In Trib. #13, which flows into the reservoir basin, two multi-antenna PIT readers were installed: One deployed near the mouth of the creek (confluence with the Upper Bridge River channel when the reservoir is drawn down) and one at the interface between the top of the drawdown zone and the upland (i.e., 749 m reservoir full pool elevation). This set up was designed to detect movement of tagged fish into this creek, as well as the proportional distribution of those fish within versus above the drawdown zone. The arrays were operated from 6 May to 27 July 2016.

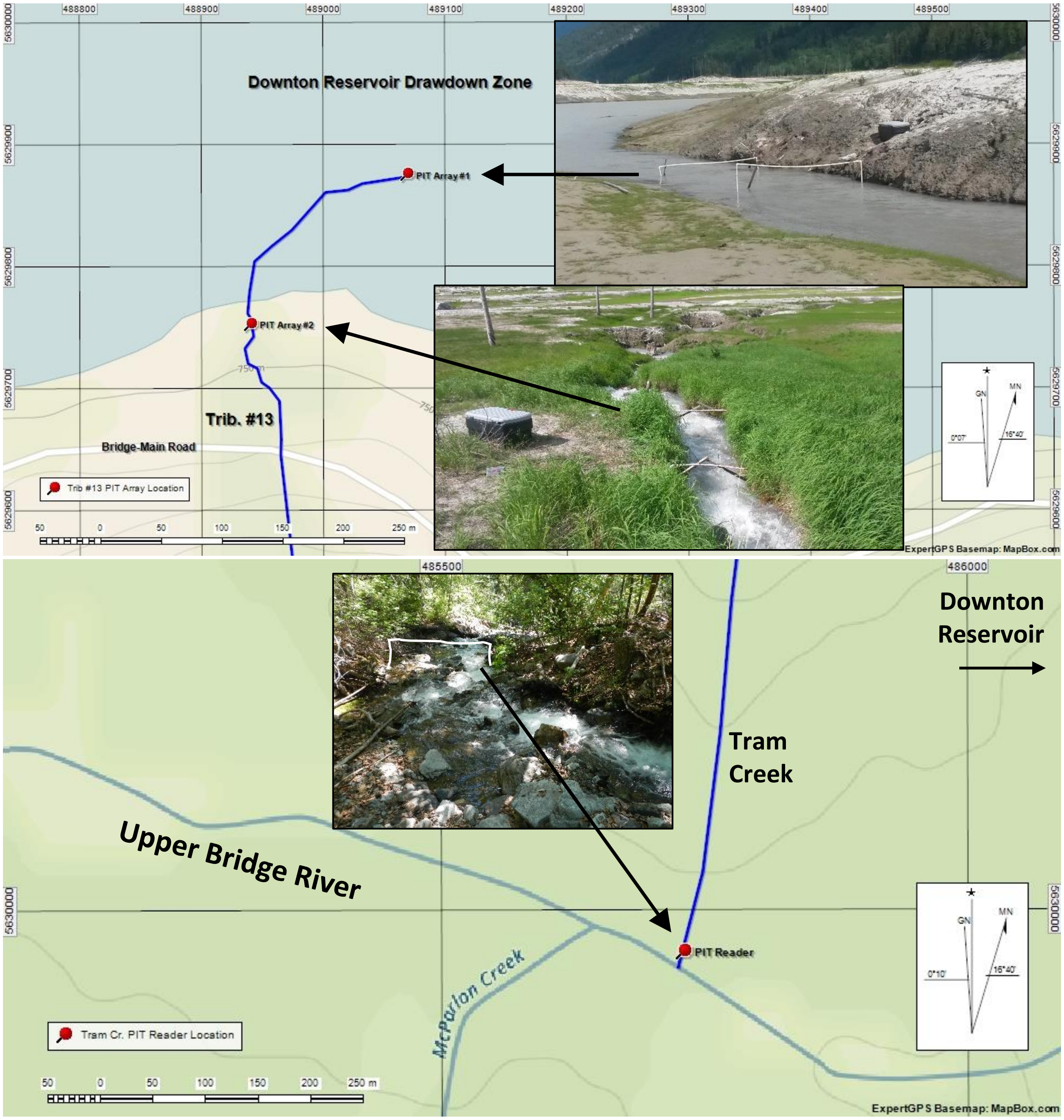


Figure 2.3 Locations of PIT reader arrays (outfitted with swim-through loop antennas) deployed in Trib. #13 (top) and Tram Creek (bottom) during Year 4 (2016).

The PIT tags and array infrastructure were manufactured by Oregon RFID, based in Portland, Oregon. An Oregon RFID reader is a self-contained monitoring station that records detections of half duplex (HDX) PIT tags that pass within range of the antenna(s). The readers are designed for long term unattended operation (within the limits of battery charge) and tag detections are stored on an SD flash memory card. Each array was powered by sets of three 12V deep cycle batteries connected in parallel which were replaced with fully charged sets weekly. The readers and batteries were contained in rugged cargo boxes for protection from the elements in the exposed drawdown zone.

The antennas were designed as vertically-mounted loops that span the channel cross-section, and each reader was outfitted with two of them (one installed upstream of the other). The antennas were constructed using 12 AWG stranded wire coiled inside of a rectangular frame made with 1-inch PVC pipe. Tagged fish are detected as they swim through the antennas, and the PIT tag number, antenna number and time of detection are logged. During post-processing of the logged detections, these parameters can allow determination of arrival date, direction of fish travel past the antennas, departure date, and residence time for each tagged fish that enters and exits the stream during the spawning period.

2.7. 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 spring and fall. Sampled tributaries included: Ault Creek, Cathy Creek (aka Trib. #5), Trib. #13, Trib. #16, Trib. #19, Tram Creek, and the Upper Bridge River. For each 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 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. Fall sampling was completed on 22 October 2015 in Year 3. Spring sampling was completed from 12 to 19 May 2016 in Year 4.

A total of 11 tributary sites were sampled in spring 2016 (drawdown zone *n*= 5; upland *n*= 6) and 3 in fall 2015 (drawdown zone *n*= 1; upland *n*= 2). 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 in the creeks, and as far into the thalweg from one bank as safely possible for the Upper Bridge River channel. 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.

2.8. 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 4 (2016) was completed as one extended survey in the spring (late May to 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 4 (2016) followed a stratified design as described in previous monitoring reports for Year 1 (Sneep 2015) and Year 3 (Sneep 2018). The strata were the four main habitat types identified during the shoreline habitat mapping survey (i.e., creek mouth, fan, shallow slope, and steep slope). 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 2.4). 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 4 (2016) was late May to early June. 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.

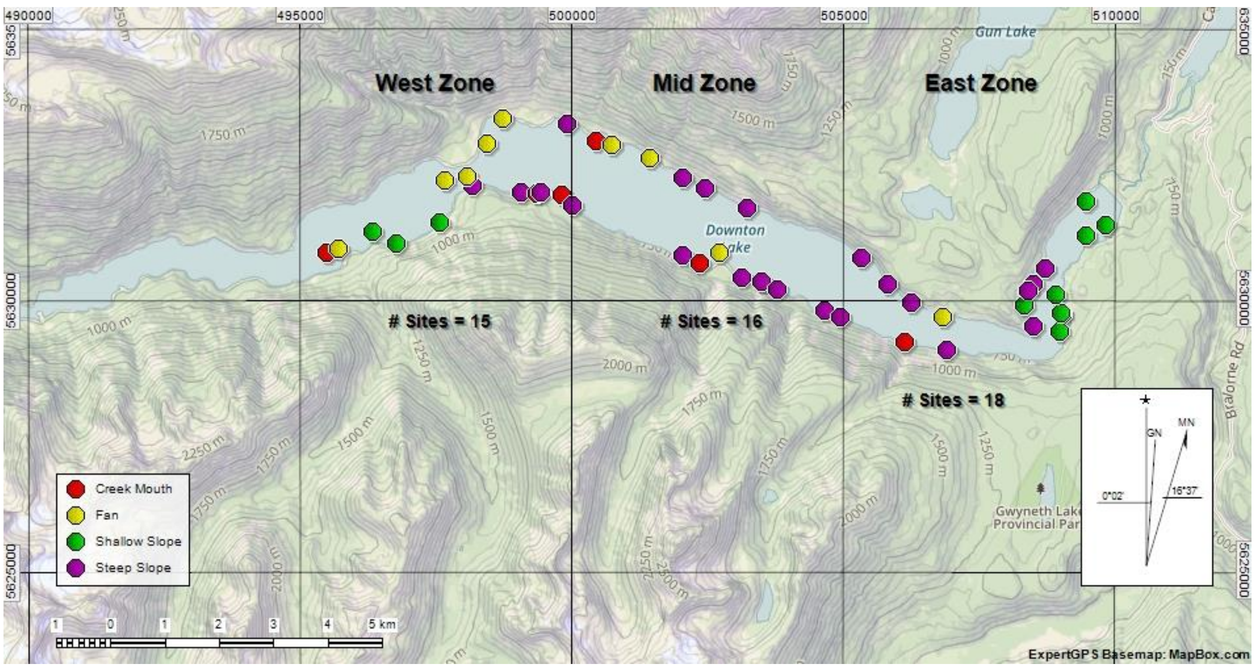


Figure 2.4 The three longitudinal zones (west, mid, and east) and the distribution of sites for the fish population index survey conducted from 30 May to 5 June 2016 (at 723 m reservoir elevation).

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 50%; Output = ca. 3 to 5 amps; DC Current Mode; Frequency = 60 DC pulses/sec. A total of 49 sites were sampled (Creek Mouth *n*= 6; Fan *n*= 9; Shallow *n*= 12; Steep *n*= 22) covering 13,010 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.

2.9. 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. Additionally, PIT tagged fish were required for the PIT array monitoring to describe spawner movement into and back out of two known spawning tributaries (described in Section 2.4). While it was understood that the majority of fish available for tagging would be captured during the boat EF surveys, 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 4 (2016), a total of 4.4 person-hours of angling effort was directed at the Ault Creek confluence area on 17 May, 2016. For each captured fish, length was measured (forklength to nearest mm), sex and maturity were assessed, ageing structures were collected, and a PIT tag was applied.

2.10. Laboratory Analysis

Laboratory analysis (scale reading to determine fish ages) was conducted on 196 scale samples by Marylise Lefevre, M.Sc. of Instream Fisheries Research. After a period of air-drying, scales were pressed under heat to transfer precise images onto soft plastic strips. The images were magnified using a microfiche reader following the methods of Mackay et al. (1990). 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 average 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).

2.11. Data Management

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

All entered data were compiled into an active Microsoft Excel (2013) database that already includes the data from years 1 to 3 of this monitoring program. As this program proceeds, this database will: facilitate data sharing between monitoring programs; continue to be updated each year as new data are collected and entered; and be stored in multiple locations (i.e., office computer, external hard drive, and online storage such as “Dropbox”). All data and document files have been backed up to ensure data security and integrity.

3. Results

3.1. Reservoir Elevations

Records of Downton Reservoir surface elevations were provided by BC Hydro for the period 1 January to 31 December 2016, which are illustrated in Figure 3.1. Daily surface elevations for monitoring years 1 to 3 (2013 to 2015) 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. 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.

At the start of 2016, reservoir elevation was 740.0 m as it was drawing down from 2015 levels. This was also the maximum level for the year since the *modified* maximum target fill elevation

(734 m) was implemented in 2016 for the first time. The mean drawdown and fill rates for the reservoir were -14 cm/day and +12 cm/day, respectively (Table 3.1). Lowest reservoir elevation (i.e., 719.4 m) occurred from 1 to 3 May, and summer full pool elevations occurred from 25 August to 11 September 2016 (max. = 733.9 m on 2 September).

The total differential between minimum and maximum elevations was 20.6 m in 2016, which was the lowest of the study years to-date. In fact, the difference between low pool and the summer full pool elevation in 2016 was only 14.6 m, due to the implementation of the *modified* maximum level. The reservoir had been drawn down to 728.2 m by the end of December.

The 2016 minimum elevation (719.4 m) and mean drawdown rate (-14 cm/day) were similar to the values for years 1 and 3 (2013 and 2015). To date, the lowest reservoir level of 709.0 m (10.4 to 11.4 m lower than other study years) and highest mean drawdown rates (-20 cm/day) have occurred in 2014. As a result of the modified operations, the reservoir was filled to its lowest maximum level (733.9 m) at the lowest mean fill rate (+12 cm/day), and resulting in the lowest minimum-to-maximum elevation differential of any year to-date. These inter-annual differences in how the reservoir is operated provide some ample contrast for analyzing the fish abundance index information across the monitoring years.

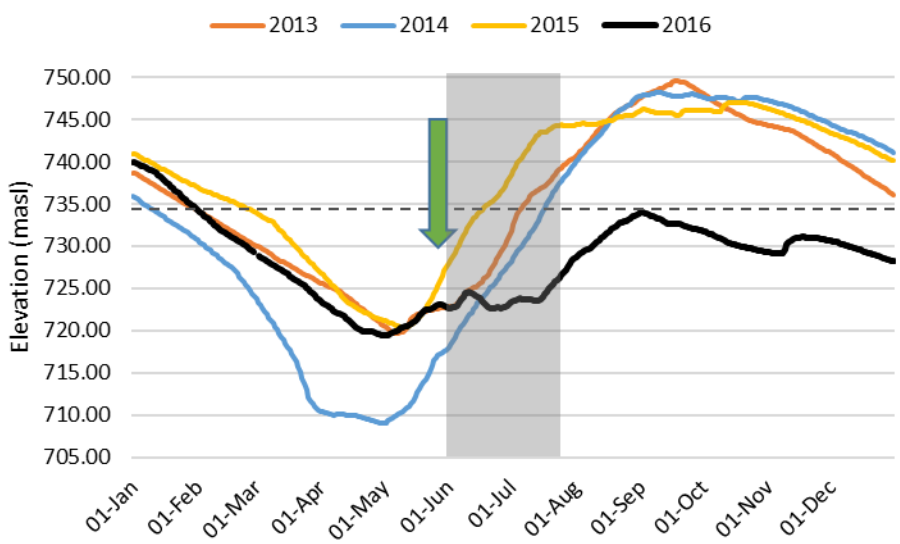


Figure 3.1 Daily surface elevations in Downton Reservoir, 2013 to 2016. For reference, the shaded area represents the observed rainbow trout spawning period and the green arrow indicates the timing of the annual population index survey. The horizontal dashed line indicates the target modified maximum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

Table 3.1 Minimum and maximum reservoir elevations, and mean and maximum drawdown and fill rates for Downton Reservoir during study years 1 to 4 (2013 to 2016).

Study Year	Reservoir Elevations (m)			Drawdown Rates (cm/day)[a]		Fill Rates (cm/day)[b]	
	Min.	Max.	Diff.	Mean	Maximum	Mean	Maximum
1 (2013)	719.7	749.5	29.8	-15	-21	+23	+73
2 (2014)	709.0	748.2	39.2	-20	-80	+31	+81
3 (2015)	720.4	747.0	26.6	-14	-30	+33	+58
4 (2016)	719.4	740.0	20.6	-14	-28	+12	+55

[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.

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.

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 2015 and 2016) and extends until mid October. The reservoir becomes isothermic (consistent temperature from surface to bottom) from late fall to early spring, though temperature loggers were not deployed across all of this period as described in Section 2.2.

In Year 3 (2015), mean daily surface temperatures increased from 14.7°C in mid May to 21.6°C in early July, 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. In 2016, mean daily surface temperatures increased from 15.9°C in mid May to 20.8°C by the end of July, remained between 18.0°C and 21.8°C until the end of August, and then cooled to 8.9°C by the end of October. From 16 m and below, temperatures at each depth interval remained within a narrow range, between 8.0°C and 10.0°C, throughout the monitored period. In 2015 and 2016, there was a gradient of temperatures between the surface and 12 m, which corresponded to the depth of the thermocline in both years.

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.

Relative to the reservoir, temperatures in the tributaries tended to be much cooler, and were variable among streams. Maximum daily mean temperatures ranged from 8.0°C (in the Upper Bridge River) to 13.6°C (in Ault Creek). 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 both years 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.

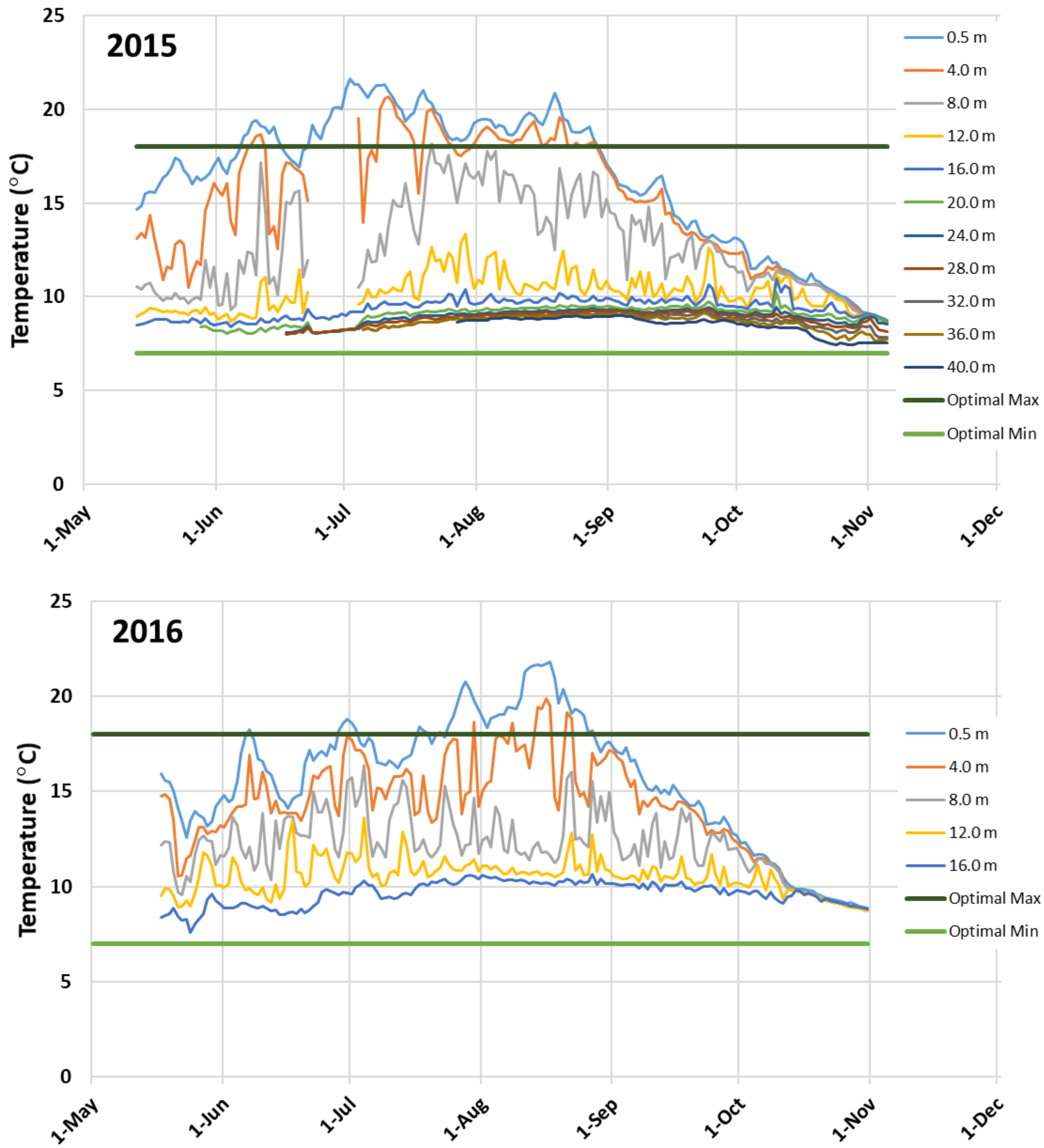


Figure 3.2 Mean daily water temperatures by depth from the Downton Reservoir log boom array, May to November 2015 (upper) and 2016 (lower). The light and dark green horizontal lines bracket the preferred temperature range of rainbow trout (McPhail 2007).

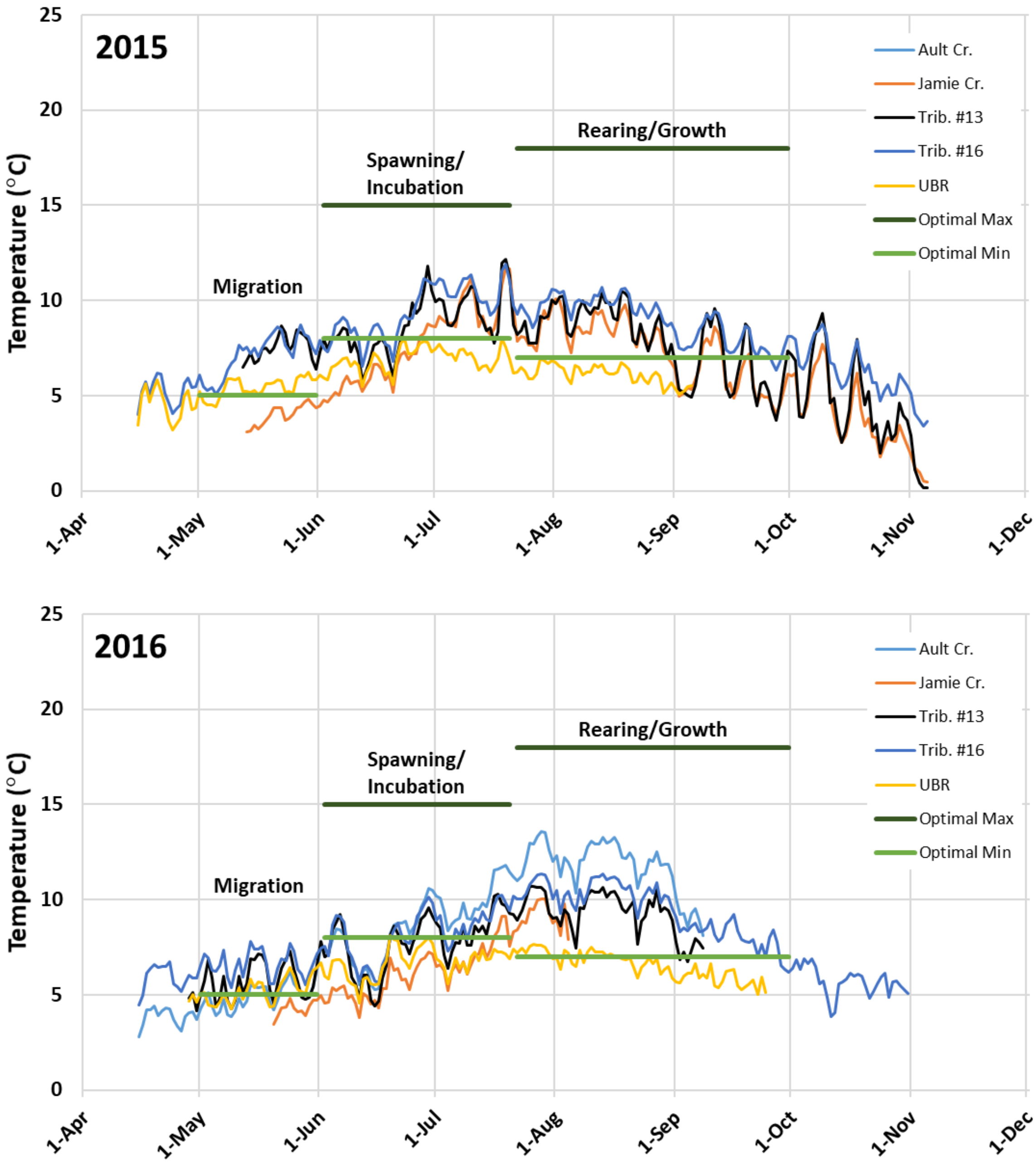


Figure 3.3 Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to November 2015 (upper) and 2016 (lower). The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of rainbow trout (McPhail 2007).

Differences in thermal regime by context are also supported by comparison of mean temperatures according to seasonal or life history period (Table 3.2). Again, creeks with higher values are the ones that coincide with the highest observed fish use for spawning and feeding. 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. Though somewhat limited at this point, these data suggest 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.

The values in the table also offer a comparison of relative thermal trends between years for each context. Between the two years available to-date, 2015 had warmer mean temperatures in the spawning creeks (e.g., tribs. #13 and #16) during the Pre-Spawn/Migration and Spawning/Incubation periods by 1.0 to 1.6°C. Despite these differences, mean temperatures were within optimal ranges for most of that period in both years, and peak spawn timing was similar (i.e., the end of June). Temperatures during the Rearing/Growth period tended to be warmer in 2016 by approximately 0.5°C on average.

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

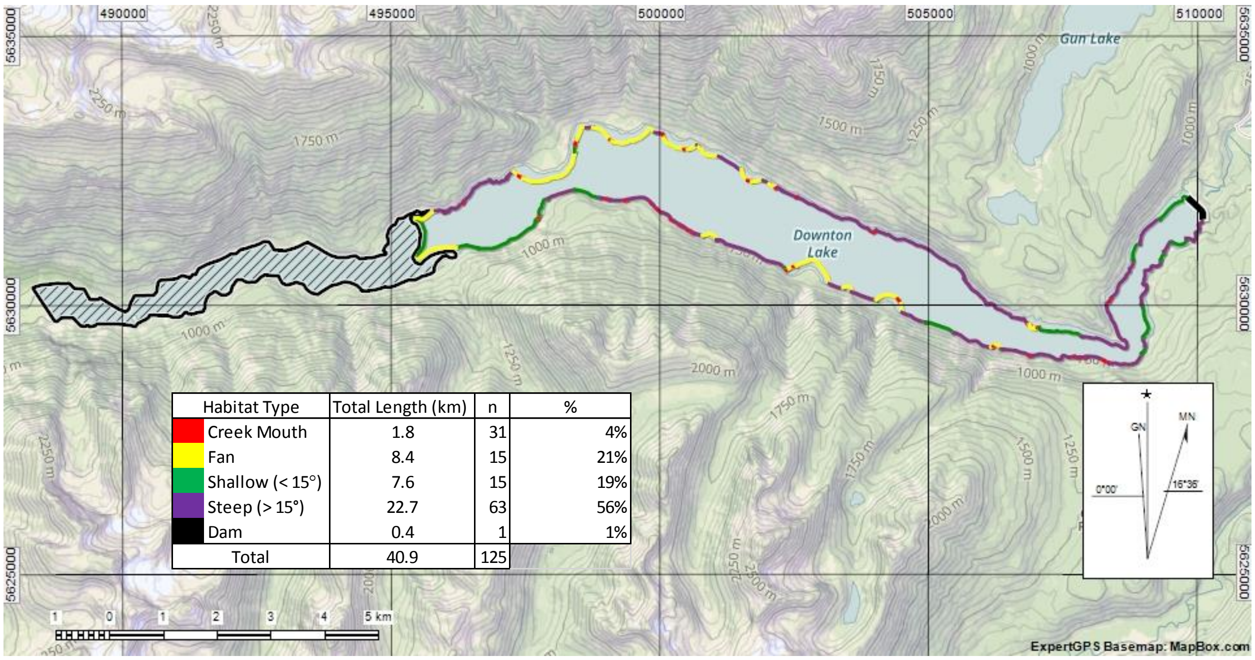
Location	Year	Mean Temperatures by Season / Life History Period			
		Pre-Spawn/ Migration (15 to 31 May)	Spawning/ Incubation (1 Jun to 21 Jul)	Rearing/ Growth (22 Jul to 30 Sep)	Total
Upper Bridge River	2015	5.6	6.9	6.0	6.3
	2016	5.5	6.7	6.5	6.5
Jamie Cr.	2015	4.1	7.6	7.4	7.1
	2016	4.3	6.2		
Trib. #13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

3.3. Habitat Surveys

Habitat Mapping

The shoreline habitat mapping in 2016 documented the proportional availability and distribution of habitat types around the entire perimeter of Downton Reservoir at ~722 m elevation, the typical level for the fish population index sampling (see Section 3.8) in late May to early June (Figure 3.4). At this elevation, the length of the reservoir was 17.8 km, and the total shoreline length was 40.9 km (Table 3.3), which were ~70% of the full pool values. The surveyed extent represented the entire wetted perimeter of the reservoir at this elevation. 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).

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 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). 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.



Habitat Type	Total Length (km)	n	%
Creek Mouth	1.8	31	4%
Fan	8.4	15	21%
Shallow (< 15°)	7.6	15	19%
Steep (> 15°)	22.7	63	56%
Dam	0.4	1	1%
Total	40.9	125	

Figure 3.4 Results of a shoreline habitat mapping survey conducted at the typical reservoir elevation for the fish population index sampling (~722 m) in May 2016. Note: The hashed out area represents the dewatered portion of the reservoir basin at this elevation.

For the Year 4 (2016) habitat mapping survey at 722 m reservoir elevation, steep shorelines (slope > 15°; *n*= 63 units) were the most prevalent type, contributing 22.7 km (56%) to the total perimeter length. The vast majority (20.0 km or 88%) of this steep terrain was made up of alluvial or colluvial material (rocks, boulders and other loose sediment particles), and a smaller portion (2.7 km or 12%) was bedrock. Fans (*n*= 15 units) were the next most prevalent habitat type in the reservoir, contributing 8.4 km (21%) 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*= 15) and creek mouths (*n*= 31), which contributed 7.6 km (19%) and 1.8 km (4%) to the total perimeter distance, respectively. At the east end of the reservoir, the wetted portion of the La Joie Dam face was 0.4 km long, comprising 1% of the reservoir shoreline. The length of the dam-reservoir interface was substantially reduced at the low pool elevation (722 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.

Table 3.3 Summary and comparison of habitat strata contributions to total shoreline length in Downton Reservoir based on the Year 3 (2015) full pool (745 m elevation) and Year 4 (2016) low pool (722 m elevation) habitat mapping.

Habitat Type	Habitat Sub-type	Total Length (km) and % Contribution				Difference between surveys
		~ Full Pool Elevation (745 m)		Fish Index Survey Elevation (722 m)		
Creek Mouth		0.8	**1%**	1.8	**4%**	**+111%** (0.9 km)
Fan		8.8	**15%**	8.4	**21%**	**-4%** (0.4 km)
Shallow (< 15°)		5.7	**9%**	7.6	**19%**	**+32.9%** (1.9 km)
Steep (> 15°)	Bedrock	10.5	17%	2.7	7%	**-74.4%** (7.8 km)
	Colluvium	33.4	55%	20.0	49%	**-39.9%** (13.3 km)
	Total Steep	43.8	**73%**	22.7	**56%**	**-48.2%** (21.1 km)
Dam		1.1	**2%**	0.4	**1%**	**-64.2%** (0.7 km)
Totals		**60.3**		**40.9**		**-32.1% (19.4 km)**

Lake Length (km)	25.6	**100%**	17.8	**70%**	**-30% (7.8 km)**
Terrestrial Veg. (km)	21.3	**35%**	0.0	**0%**	**-35% (21.3 km)**

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 722 m (low pool) survey conducted in May 2016. There was a significant reduction in steep shoreline habitat (by 21.1 km or almost 50%) and an increase in shallow habitat length despite the reduced wetted extent of the reservoir (~70% of full pool length). Fan habitat decreased in total length, but only slightly (-0.4 km), and actually increased in % contribution to the total at the low pool elevation. The number and % contribution of creek mouth habitats also increased in the low pool (spring) survey 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 survey 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 (low pool) survey, 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.

In upcoming monitoring years, repeat surveys at other key reservoir elevations (i.e., 734 m (modified maximum) and <722 m low pool levels) will further highlight any differences in the availability and distribution of these 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), 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.

Substrate size, interstitial depth, and slope measurements were collected from 22 sites in the reservoir drawdown zone (*n*= 18) and in select tributary streams (*n*= 4) during 2016 (Table 3.4). These data supplement the original data set from 25 sites collected in 2015 (drawdown zone *n*= 20; tributary *n*= 5). In the following figures and tables, all data collected to-date have been analyzed and summarized together. In total, 2,622 individual B-axis and interstitial depth measurements have been collected to-date (2015 *n*= 1,413; 2016 *n*= 1,209).

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	5	150	14.3
	747	8	240	14.0
Fan	722	2	60	6.7
	734	4	120	12.0
	747	6	180	15.9
Shallow	722	1	30	11.0
	734	2	60	11.2
	747	1	30	10.0
Steep	722	11	330	22.2
	734	9	270	22.4
	747	19	570	27.6
Tributary	722	4	120	4.3
	734	5	137	13.3
	>749	4	120	12.8
All	722	22	660	14.5
	734	25	737	16.4
	747	38	1,140	21.8

[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 27.6° (steep slopes at 747 m). In general, for most habitat types, slope increased from the lowest elevational zone in the reservoir to the highest, reflecting the U-shaped cross-section of the reservoir basin. However, shallow sites were the exception, where mean slopes were similar across all elevations.

There were some differences evident in the relative proportions of substrate sizes within the reservoir basin. Data from the reservoir sites sampled in 2015 and 2016 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 2.2 in Methods Section 2.3); however, the relative proportions did vary somewhat by elevation (Figure 3.5 top). Collectively, 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. Beyond these smallest substrate classes, the percent contribution of each substrate category tended to diminish with increasing size. 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%, 40% and 52% at 722 m, 734 m and 747 m, respectively).

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.

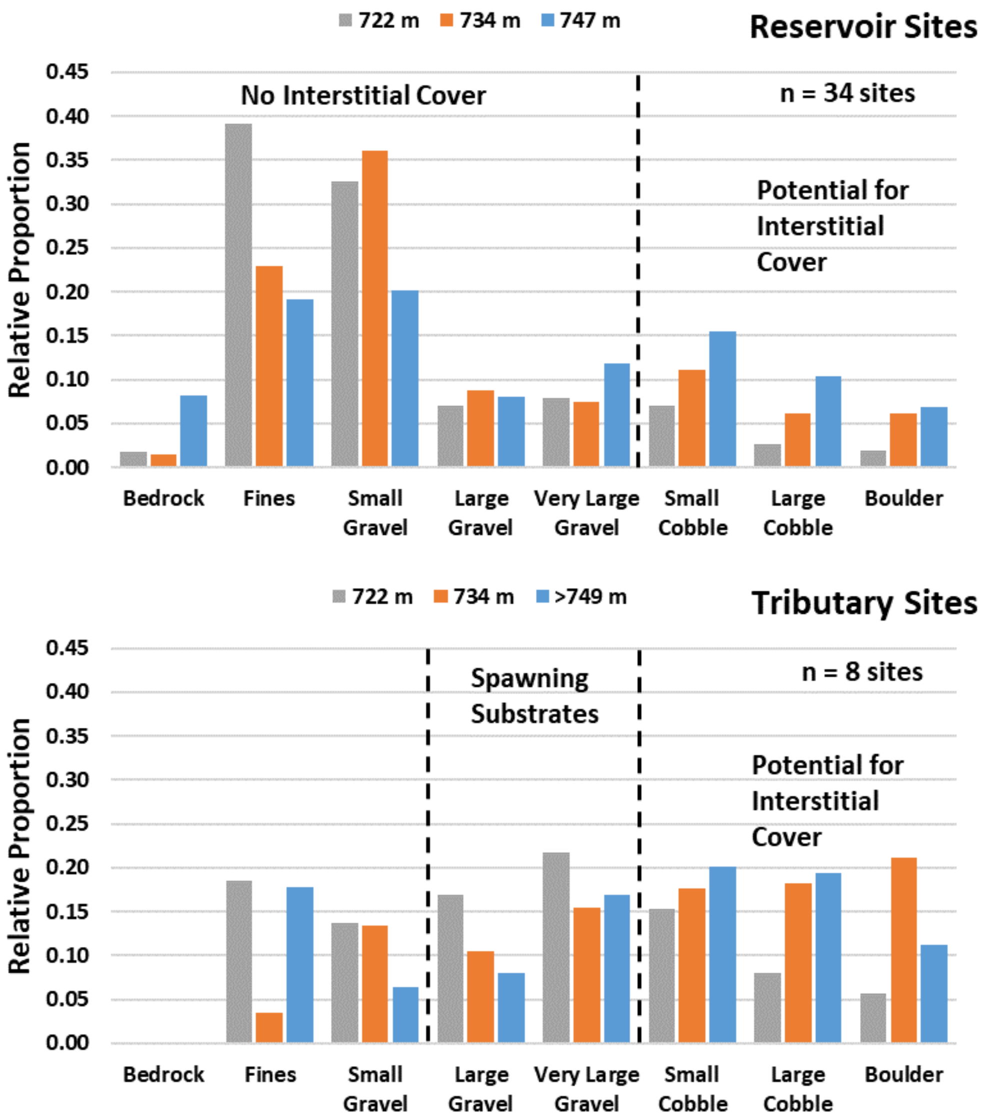


Figure 3.5 Relative proportions of the various substrate categories measured at three elevations within the reservoir drawdown zone (top) and tributaries (bottom). Size categories that can provide interstitial cover (depending on embeddedness) for rainbow trout in reservoir sites, and spawning substrates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

The 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 in the creeks. The smaller substrate classes (i.e., fines and gravels) were again more 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%, 83% and 76% 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.

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 188 to 319+ mm in Downton Reservoir (Age 2 and up; see Table 3.16), this means that substrates between approximately 1.8 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. 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 (8.4 and 6.7 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.

The size distribution of substrates at creek mouths was a little smaller than in the tributaries themselves, but exhibited a similar elevational pattern, likely reflecting the direct influence of sediments from the creeks on this habitat type.

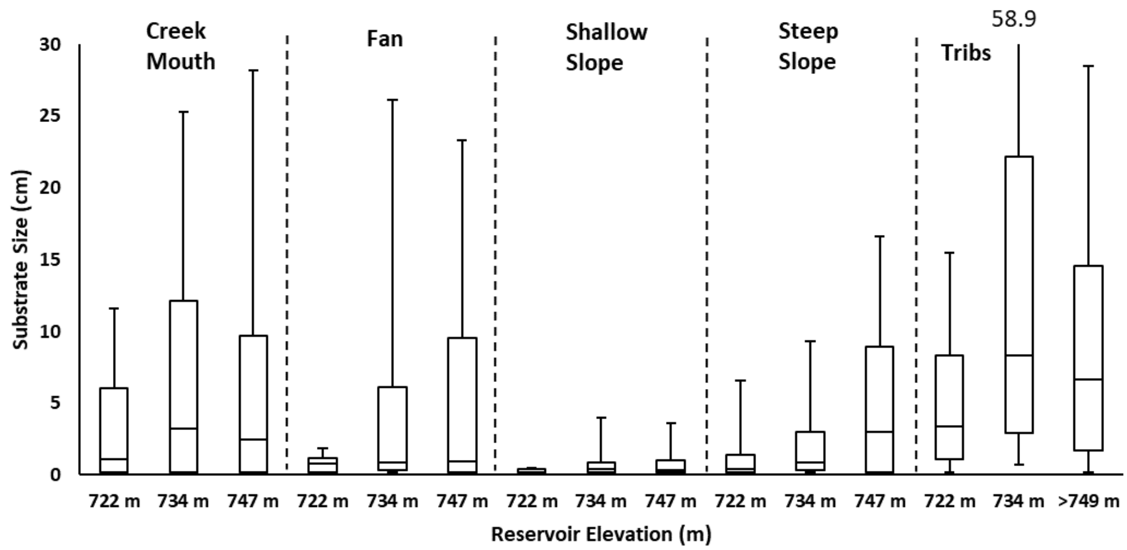


Figure 3.6 "Box-and-whisker" plot representing substrate sizes (B-axis values) for three elevations in each habitat type. The boxes are bounded on the top by the 75th percentile, and on the bottom by the 25th percentile. The median divides each box. The whiskers represent minimum and maximum values.

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

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 [b]
Creek Mouth	1.1 (Small Gravel)	3.2 (Large Gravel)	2.5 (Large Gravel)
Fan	0.8 (Small Gravel)	0.9 (Small Gravel)	1.0 (Small Gravel)
Shallow Slope	0.2 (Fines)	0.4 (Small Gravel)	0.3 (Small Gravel)
Steep Slope	0.4 (Small Gravel)	0.9 (Small Gravel)	3.0 (Large Gravel)
All Reservoir	**0.5 (Small Gravel)**	**1.0 (Small Gravel)**	**2.3 (Large Gravel)**
Tributaries	**3.4 (V. Lg. Gravel)**	**8.4 (Small Cobble)**	**6.7 (Small Cobble)**

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 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 combined effects of substrate recruitment and flushing of fines by the associated streams.

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 except the upland (>749 m) zone of tributaries (median = 0.5 cm). 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 (tributaries) and at the top of the reservoir drawdown zone, and lowest at the bottom. No accessible pore spaces were available in shallow habitats. 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.

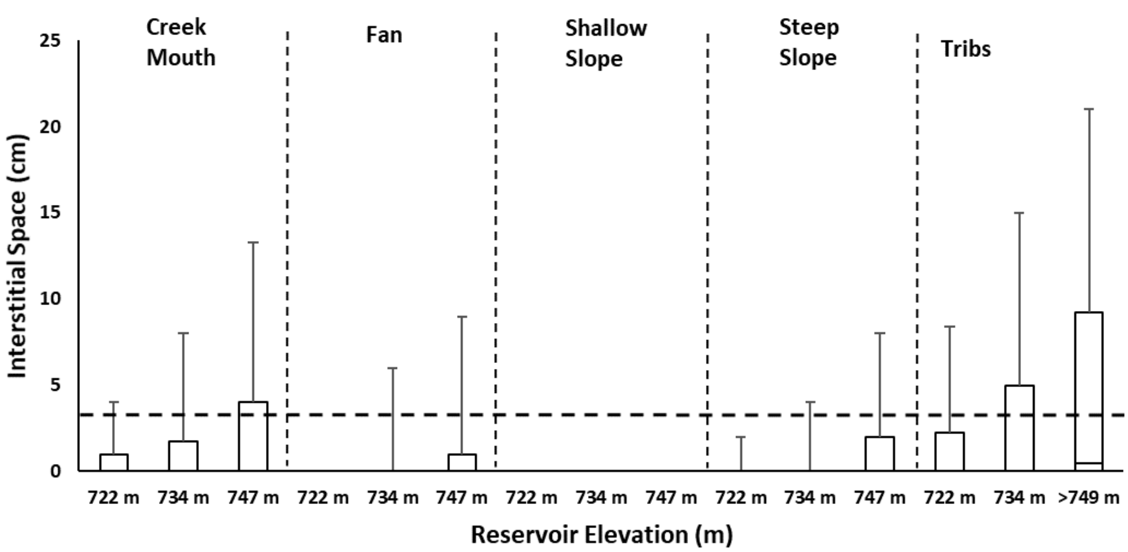


Figure 3.7 “Box-and-whisker” plot (as explained for Figure 3.6, above) representing interstitial space measurements for three elevations in each habitat type. In this case, the minimum, 25th percentile and median values were all zero for each elevation and habitat (except tributary upland habitats >749 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 Spawner Surveys

In Year 4 (2016), weekly spawner surveys were conducted across a 13-week period from 12 May to 4 August. Surveys were conducted in Trib. #13, Trib. #16, Trib. #19 and Tram Creek, which have all had spawning use documented during previous monitoring years. As noted on the data sheets, in-water visibility conditions in 2016 were generally fair or good (see Section 2.4 for definition of these qualitative terms), and discharges increased from low to high across the monitored period. In general, fish in shallow habitats were readily observed on all dates; however, turbidity affected visibility to the bottom of deeper pools during some surveys.

Based on the 2016 weekly counts, spawners first started arriving in a couple of the surveyed tributaries (i.e., Trib. #13 and Trib. #16) around the end of the third week in May (Table 3.6). Peak timing in 2016 was between the middle to the end of June (according to tributary), and spawners were no longer observed after the July 20 survey. This represents a ~9-week migration and spawning period with peak abundance occurring 4 to 6 weeks after the first arrivals. Based on these results, spawn timing in the Downton Reservoir tributaries is approximately two months later than rainbow trout populations lower in the watershed (i.e., Lower Bridge River; Burnett et al. 2016). Delayed spawn-timing in the Downton context is likely an adaptation to the colder temperatures, low stream flows and low reservoir elevations that tend to persist in the study area until at least mid-May.

Across study years, peak spawner count in Trib. #13 was highest in Year 1 (2013), dropped in Years 2 and 3 (2014 and 2015) and then increased again in 2016 (annual max. *n*= 135, 50, 19 and 57, respectively; Figure 3.8). Tributaries #16 and #19 could not be surveyed in 2014 and 2015 due to access issues, so annual trends across all study years could not be assessed for these creeks. Of the two years available, peak counts for Trib. #16 and #19 were greater in 2013 (max. *n*= 116 and 34, respectively) than 2016 (max. *n*= 61 and 2, respectively). However, it must also be noted that access issues precluded several weekly surveys in these creeks around the usual peak timing in 2016, so the reported values for this year may not be representative of the actual peak spawner count. Spawner counts in Tram Creek have generally been lower than the other surveyed creeks, but fairly consistent across study years (max. *n*= 1, 4, 9 and 6 for 2013 to 2016, respectively).

As in previous years, higher numbers of spawners were counted within the reservoir drawdown-portion of each tributary (<749 m) than in the upland (>749 m) on every survey date (except for Tram Creek which is above the drawdown zone for it’s entire length). Assuming that location when observed translates to location of spawning, the proportions suggested a mean of ~78% used the drawdown zone vs. 22% in the upland, overall. Actual proportions for each survey date and totals for each tributary are provided in Table 3.6. As indicated by the substrate measurement results (described in the section above), suitable-sized spawning substrates are available both above and below the maximum reservoir elevation in the tributaries.

Table 3.6 Summary of weekly spawner count data for each surveyed tributary in Year 4 (2016).

Week	Date	Trib. #13			Trib. #16			Trib. #19			Tram Cr. [b]
		n [a]	DS %	US %	*n*	DS %	US %	*n*	DS %	US %	*n*
1	12 May	-			-			-			0
2	19 May	1	100%		1	100%		0			0
3	26 May	0			1	100%		0			0
4	1 Jun	6	100%		0			0			0
5	9 Jun	18	72%	28%	47	89%	11%	-			0
6	15 Jun	14	86%	14%	61	75%	25%	2	100%		0
7	23 Jun	20	65%	35%	-			-			0
8	30 Jun	57	67%	33%	-			-			6
9	7 Jul	26	81%	19%	-			-			0
10	13 Jul	10	90%	10%	0			1	100%		0
11	20 Jul	3	100%		1	100%		0			1
13	4 Aug	0			-			-			0
Peak *n* & Total %		**57**	**75%**	**25%**	**61**	**82%**	**18%**	**2**	**100%**		**6**

[a] "n" = total count for the week; "DS %" and "US %" refer to the proportions of the total count that were observed within the drawdown zone of the reservoir and in the upland (above the max. reservoir elevation), respectively. "-" indicates survey not completed in this tributary for this week.

[b] All habitats in Tram Creek are outside the influence of reservoir operation, so the count for each week represents upland only.

It is important to note that since implementation of the *modified* maximum reservoir elevation (starting in 2016), the reservoir no longer inundates the Trib. #13 channel during the rainbow trout spawning period. As such, eggs deposited in this creek are not at risk of inundation by the reservoir under the modified operations. A portion of the Trib. #16 and #19 channels still becomes inundated at the *modified* maximum level, though far less than at the *normal* maximum level (749.8 m). The differences in length of channel inundated for these creeks among reservoir operations is being assessed and will be available once the habitat mapping survey at 734 m is completed (planned for Year 6 (2018) of the program).

There has been some variation in peak spawner dates across study years (i.e., between mid June in 2013 and 2014, early July in 2015, and later June in 2016). Although, when summarized altogether as cumulative weekly proportions, mid June appears to be the dominant timing of peak counts based on the data from the available creeks and years (Figure 3.9).

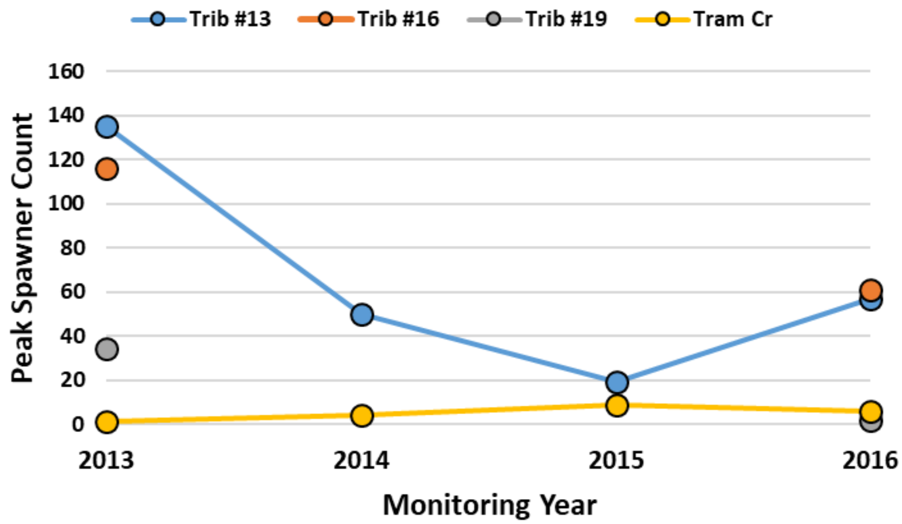


Figure 3.8 Peak spawner counts in each surveyed tributary for BRGMON-7 monitoring years 1 to 4 (2013 to 2016).

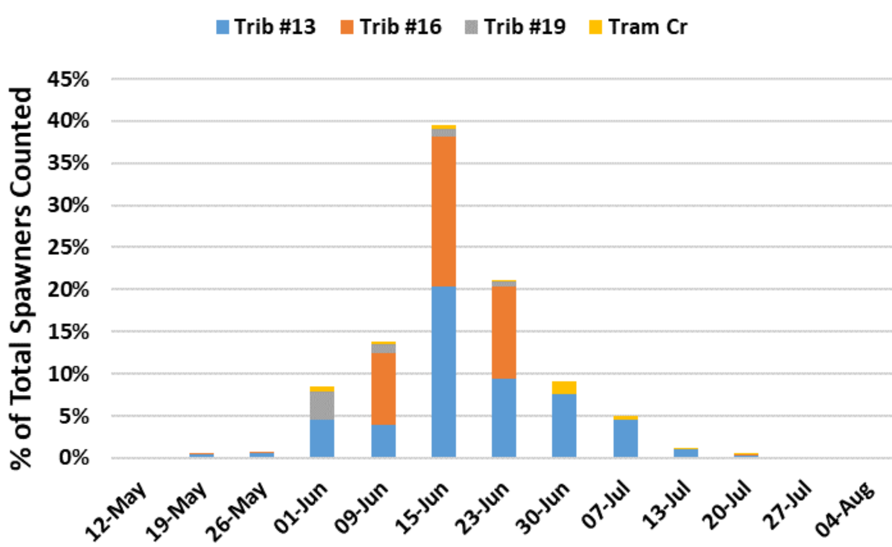


Figure 3.9 % Contribution of weekly spawner counts to the total across the monitoring period, all study years combined. Relative proportions by tributary are included.

Between-year differences in spawning use and distribution among tributaries (e.g., rainbow trout spawners being observed in Jamie Creek for the first time in 2016; Tyler Gray, PGL, pers. comm.) raise the possibility that, to some degree, spawn timing and tributary selection may be somewhat flexible in Downton Reservoir. Factors contributing to the observed variability in spawning distribution could include: reservoir operational characteristics, temperatures, tributary access, flow, fine sediment deposition, etc. in any given year. The ability to opportunistically select a suitable spawning tributary based on conditions would no doubt be a highly selective survival adaptation in this context.

Another potential hypothesis is that other parameters, such as differing gradient or substrate suitability among streams, could also be potential factors driving the observed spawning distribution among zones of the reservoir. However, spawning use of streams to the east of Trib. #19 have not been documented, despite the presence of suitable flows, gradient and substrate in at least some of them (e.g., Trib. #5 aka Cathy Creek, Trib. #4 aka Paul Creek, and Ault Creek). So far, the substrate measurement results have not revealed any significant differences in physical habitat parameters between the seemingly suitable creeks that aren't (currently) being used, from the ones that are.

Both the spawner survey results and PIT array monitoring data have highlighted that rainbow trout spawners do use the portion of tributary streams within the reservoir drawdown zone (i.e., ~80% of the spawners observed or detected in Trib. #13 in Year 4 (2016)), which can subsequently become inundated if the reservoir elevation gets high enough during the incubation period. However, this may also be why the tributaries used for spawning are all concentrated in the Mid and West portions of the reservoir, which inundate later in the year as the reservoir fills, compared with creeks in the East end. In other words, spawning stream selection may already be highly selective for minimizing inundation risk during the incubation period.

3.5. 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 4 (2016) were conducted on 16 and 18 May, to coincide with the early part of the rainbow trout spawning migration period. Reservoir elevations on these dates were 721.2 m and 721.7 m, respectively. Across the duration of the rainbow trout migration and spawning period, the reservoir filled from 721 m in mid-May to 729 m by the end of July. As in Year 3 (2015), the lowest elevations were >10 m higher than those observed in Year 2 (2014) when potential access issues were noted for Ault Creek (though it should be noted that this has not been identified as a spawning tributary to-date).

The creeks visited in Year 4 (2016) 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			
		709 m (8-May-14)	721 m (6-May-15)	722 m (18-May-16)	729 m (4-Jun-15)
Ault Creek	East	FALSE	TRUE	TRUE	TRUE
Trib. #4 (Paul Cr.)	Mid	TRUE	TRUE	TRUE	TRUE
Trib. #5 (Cathy Cr.)	Mid	TRUE	TRUE	TRUE	TRUE
Trib. #19	Mid	TRUE	TRUE	TRUE	TRUE
Trib. #16	West	TRUE	TRUE	TRUE	TRUE
Jamie Creek	West	TRUE	TRUE	TRUE	TRUE
Trib. #10	West	FALSE	TRUE	TRUE	TRUE
Trib. #13	West	TRUE	TRUE	TRUE	TRUE

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

3.6. PIT Array Monitoring

In Year 4, the PIT arrays were operated in Trib. #13 from 11 May to 27 July 2016, and in Tram Creek from 12 May to 25 July 2016, which spanned the entire rainbow trout spawning period (based on the spawner survey results, Section 3.4). Furthermore, due to the reduced filling rate and maximum level of the reservoir under the modified operations in 2016, it was possible to maintain both the upper and lower PIT arrays in Trib. #13 for the entire period.

During the period of operation, 21 PIT tagged fish were detected in Trib. #13 and 11 were detected in Tram Creek (Table 3.8). There was a maximum number of 923 tagged, spawning-age fish available in the reservoir at the start of the PIT array monitoring period in 2016 (not factoring in potential mortality since initial capture). An additional 452 spawning-age fish were tagged during the Year 4 (2016) fish population index survey from late May to early June. Interestingly, 2 spawners (PIT tag IDs: 080932 and 650137) detected by the PIT arrays in Trib. #13 were also detected in Year 3 (2015), which indicated spawning in back-to-back years in the same creek by these fish.

Original capture locations for the detected fish were from all three zones of the reservoir (Figure 3.10), and from all four habitat types: Creek Mouth *n*= 9; Fan *n*= 14; Shallow Slope *n*= 6; Steep Slope *n*= 3. Over 90% (*n*= 29) were PIT tagged during the annual fish indexing surveys; the remainder (*n*= 3) were from the supplementary angling efforts.

Table 3.8 Summary of PIT tagged rainbow trout detected by the PIT reader antennas in Trib. #13 during Year 3 (2015) monitoring, including original capture information.

Detection Location	Tag Code[a]	Original Capture Information					Year 4 (2016) Age[b] (est.)
		Method	Date	Length (mm)	Weight (g)	Age[b] (est.)	
Trib. #13	080932	Angling	25-Jun-13	256		3	6
	086617	Boat EF	8-Jun-13	293	260	3	6
	585083		8-Oct-13	170	64	2	5
	650067		7-Oct-14	242	166	2	4
	650137		7-Oct-14	144	46	1	3
	650745		10-Jun-14	210	103	2	4
	650746		9-Jun-14	202	88	2	4
	650807		13-Jun-15	193	84	2	3
	650890		12-Jun-15	282	252	3	4
	650892		11-Jun-15	238		4	5
	656509		17-Jun-15	309	316	4	5
	656568		16-Jun-15	221	116	2	3
	656580		16-Jun-15	217	124	3	4
	656622		16-Jun-15	242	173	3	4
	656629		17-Jun-15	224	121	2	3
	656644		16-Jun-15	293	279	4	5
	656675		15-Jun-15	290	287	4	5
	656719		15-Jun-15	202	100	2	3
	734662		12-Jun-15	168	74	2	3
	734711	Angling	12-May-15	293		4	5
	889097	Boat EF	31-May-16	305	311	5	5
Tram Cr.	585575	Boat EF	6-Oct-14	180	73	2	4
	585579		6-Oct-14	259	222	3	5
	585630		7-Oct-14	153	48	2	4
	650179		6-Oct-14	239	183	3	5
	650707		9-Jun-14	315	254	4	6
	650914		13-Jun-15	147	63	2	3
	656686		16-Jun-15	222	136	3	4
	656698		17-Jun-15	190	87	2	3
	656703		17-Jun-15	200		2	3
	734607		12-Jun-15	123		1	2
	734797	Angling	4-Jun-15	305		4	5

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

[b] Estimated based on the results of scale ageing for each respective study year.

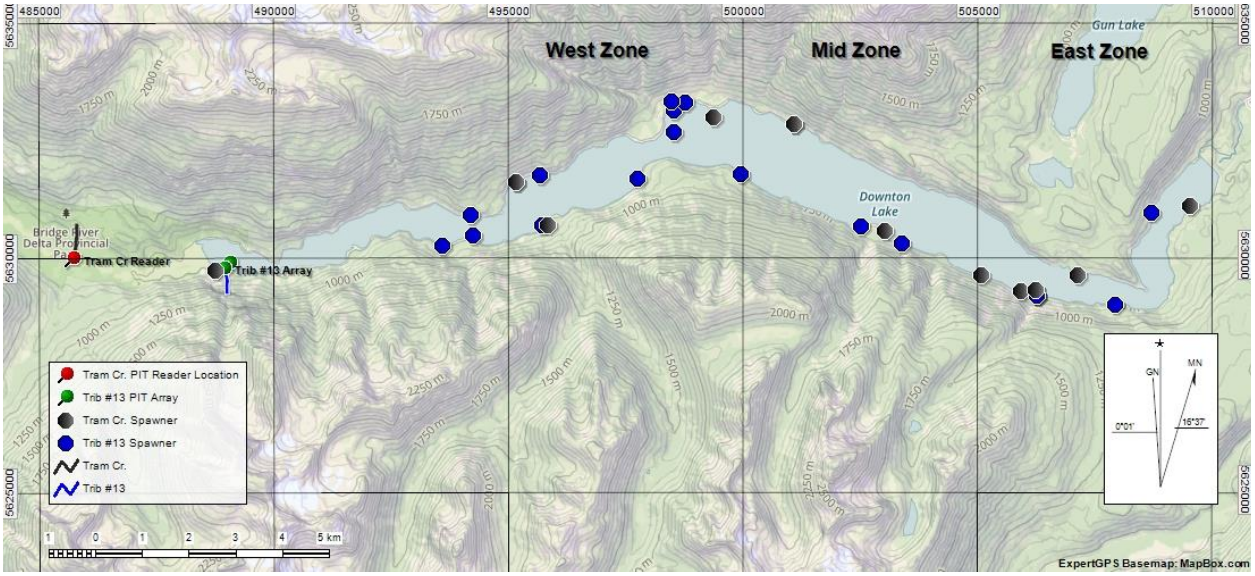


Figure 3.10 Map of the original capture locations for tagged fish detected by the PIT arrays in Trib. #13 (highlighted in blue) and Tram Creek (highlighted in grey) during Year 4 (2016) monitoring.

The dates of initial detection varied among the tagged fish from 14 May to 20 July in Trib. #13 and 18 May to 22 July in Tram Creek, reflecting the arrival of new fish across the spawning period in both creeks. In Trib. #13, 4 of the 21 detected fish (~19%) moved past both antennas at each reader location suggesting they accessed the upland zone (>749 m) during their spawning migration (Figure 3.11). Whereas the remaining 17 tagged fish (~81%) were detected by one or both antennas at the lower reader, but not at the upper reader, suggesting that they remained within the drawdown zone (<749 m) portion of the creek during the detection period in Year 4 (2016). These proportions derived from the PIT detection results corroborate the relative proportions reflected by the visual surveys for the drawdown zone (78%) versus the upland (22%) as well, which reinforces the validity of these results.

The detections of tagged fish by the PIT arrays also allowed for estimation of residence time of spawners in the monitored creeks in 2016. The residence time was estimated by calculating the difference between the dates and times of first and last detections for each tagged fish at the first (i.e., downstream-most) antenna. Differences of <1 day were excluded, since these fish generally remained at or below the lowest antenna so the calculated residence time for these fish was therefore not considered representative. For fish that were only detected by the lower PIT antennas, the estimated mean residence time was 3.1 days in Trib. #13 (n= 7 fish; range = 1.0 to 8.9 days) and 6.0 days in Tram Creek (*n*= 2 fish; range = 4.4 to 7.7 days). For fish that accessed the upland in Trib. #13 (i.e., passed all four antennas), the estimated residence time was 3.6 days (*n*= 4 fish; range = 1.3 to 6.0 days).

These mean residence times suggested by the PIT array monitoring data in both creeks were surprisingly short. In fact, the spawner survey frequency (i.e., every 6 to 8 days) may have been more protracted than the residence time for some fish, such that some proportion of fish could potentially enter, spawn, and leave the creek between survey dates, unobserved. However, for the purposes of tracking any changes in spawn timing or relative use of drawdown versus upland zones among years for this program, the frequency and effort level of the streamwalks is still considered sufficient.

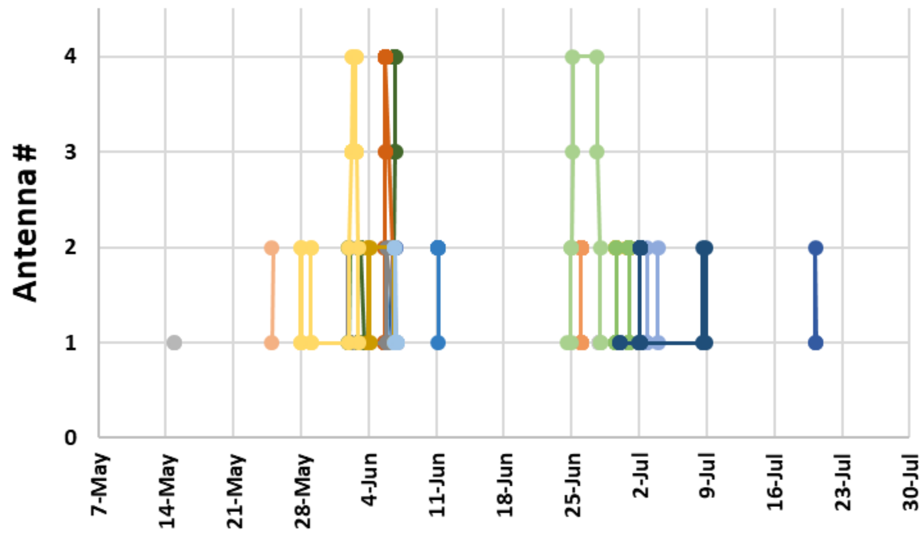


Figure 3.11 Record of detections for PIT tagged fish at the PIT array locations in Trib. #13 during the Year 4 (2016) spawning period. Antennas 1 & 2 are associated with the lower reader near the creek mouth; Antennas 3 & 4 are associated with the upper reader near the reservoir drawdown-upland interface (~747 m).

Interestingly for Tram Creek, the number of PIT tagged fish detected by the PIT reader (*n*= 11) was slightly more than the total number counted during the spawner surveys (*n*= 7) for this creek in 2016. This result reflects that visibility conditions in the tributaries are variable across the spawning period and are often sub-optimal due to turbulence, high flows, and/or turbidity. As a result, an unknown (and variable) proportion of spawners are unobserved during each survey.

3.7. Tributary Fish Sampling

Fish sampling by backpack electrofishing was conducted in three tributaries in fall (22 October 2015) and seven tributaries in spring (11 to 19 May 2016; Table 3.9). Both drawdown and upland zones were targeted where accessible to fish from the reservoir. The full channel width was sampled for each stream, except the Upper Bridge River (UBR) where the sites were oriented along one bank since the greater mid-channel depths and velocities precluded safe wading. Water clarity was good (clear) in the creeks and poor (turbid) in the UBR during both sample periods.

Fish presence and abundance was variable among tributaries, and elevation zones within tributaries, during both seasons. Total catch-per-unit-effort (CPUE) was slightly higher in spring (6.1 fish/100 m) than in fall (4.1 fish/100 m). Of the tributaries sampled, the highest CPUE value in fall was in Tram Creek (10.0 fish/100 m). In spring, highest CPUE was in the drawdown zone of Trib. #19 (33.3 fish/100 m). No fish were captured at 6 of 11 sites (55%) during the spring session, and 1 of 3 (33%) sites in fall.

Table 3.9 Summary of backpack EF effort and catch in Downton Reservoir tributaries during spring (2016) 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
	Mid	Cathy Cr.	Drawdown	30	441	2	6.7
			Upland	30	208		0.0
		Trib. 19	Drawdown	30	165	10	33.3
			Upland	30	165	3	10.0
	West	Trib. 13	Drawdown	30	86		0.0
			Upland	30	63		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
		UBR-2[a]	Upland	30	300		0.0
Spring Totals				**330**	**2,322**	**20**	**6.1**
Fall	West	Trib. 13	Drawdown	30	269	1	3.3
		Tram Cr.	Upland	30	291	3	10.0
		UBR	Upland	30	280		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.

These results indicate that catches of rainbow trout in both of the seasons sampled were highly variable among streams, but lower on average than catch rates for each habitat type in the reservoir based on boat EF sampling (see Section 3.8, below). This was despite the likelihood that capture efficiencies by backpack EF in the tributaries were likely higher than by boat EF in the reservoir. To-date, these results suggest that use of the tributaries for rearing during these seasons is low, relative to use of the reservoir.

Eight fish from the tributary catch were a tag-able size, and were marked with PIT tags. There were no recaptures of previously tagged fish from the reservoir. The ages of captured fish (based on post-field scale analysis) ranged from Age-0+ to Age-4 in spring, 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 (all males; 1

gravid, 3 ripe). The remainder of the fish sampled in both seasons were assessed as sexually immature (Age-0+ to Age-2).

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

Age	Season	n	Forklength (mm)		
			Min.		Max.
0	Spring	9	40	-	63
	Fall	3	42	-	88
1	Spring	6	65	-	116
	Fall	1	97		
2	Spring	2	148	-	189
3	Spring	2	242	-	248
4	Spring	1	285		

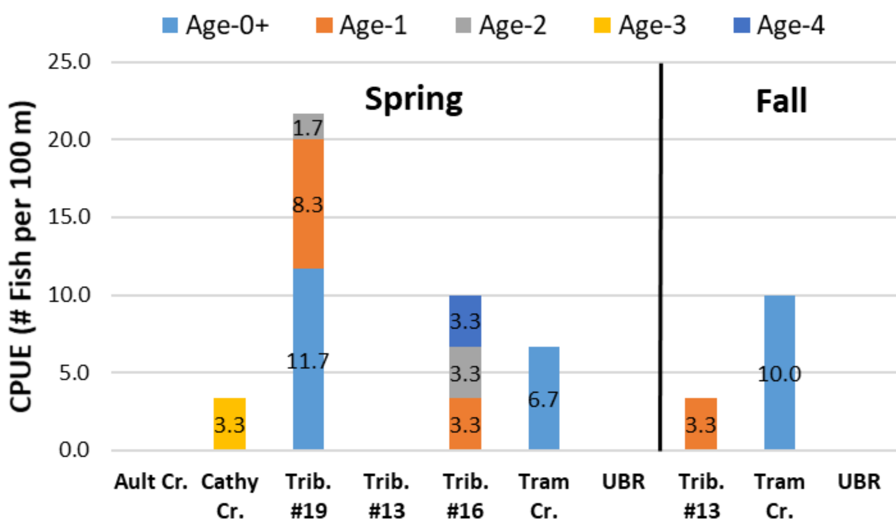


Figure 3.12 Catch-per-unit effort (fish/100 m) by age class for each sampled tributary based on the results of backpack electrofishing surveys in spring (2016) and fall (2015).

3.8. Fish Population Index Survey

A total of 1,028 fish were captured by boat electrofishing during the annual fish index survey in Year 4, conducted between 30 May and 5 June 2016. Forty-nine sites were sampled, including 6 Creek Mouths, 9 Fans, 12 Shallow shorelines, and 22 Steep shorelines (Table 3.11). The total shoreline distance sampled was just over 13 km, or ~32% of the total reservoir perimeter at the survey elevation (~722 m). The catch included 1 bridgelip sucker (forklength = 490 mm) at the mouth of Cathy Creek. All other fish were rainbow trout.

In total, 959 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. Eighteen tagged fish were recaptured during the Boat EF survey in 2016; 10 were within-session recaptures, 1 was a within-year recapture, and 7 were recaptures of fish originally tagged in 2015 (Tables 3.14 and 3.15 in the next sub-section, below).

Table 3.11 Summary of rainbow trout capture results from the Year 4 boat electrofishing index survey in late May and early June 2016.

Metric	Units	Habitat Type			
		Cr. Mouth	Fan	Shallow	Steep
Sites	#	6	9	12	22
Effort	total seconds	1,321	6,253	7,248	13,844
	total meters	570	2,706	3,414	6,320
Catch	# of fish	86	310	252	398
	# of fish marked	81	268	239	371
	# of recaptures	4	3	4	7
CPUE	fish/site	13.7	34.1	20.7	17.8
		21.0			
	(fish/sec)·100	6.2	4.9	3.4	2.8
		3.6			
	(fish/meter)·100	14.4	11.3	7.3	6.2
		7.9			

Catch-per-unit-effort (CPUE) values (by EF seconds and sampled length), were greatest at Creek Mouths, followed by Fan habitats, and then by Shallow shorelines and Steep shorelines; the differences were fairly modest between the latter two types. Mean CPUE values (for all types combined) were: 21.0 fish/site; 3.6 fish/100 sec of electrofishing; or 7.9 fish/100 m of shoreline length. 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 (Table 3.12; 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 Year 3 (2015). CPUE values have been consistently highest at creek mouths every year to-date.

A summary of CPUE values by age class for each monitoring year to-date is provided in Figure 3.13. In Year 4 (2016), the CPUE for Age-1 fish (4.6 fish/100 m) was the highest of any age class, followed by Age-3 fish (1.1 fish/100 m). CPUE values for Age-2, Age-4, and Age-5 were all very similar (0.6, 0.7, and 0.7 fish/100 m, respectively). CPUE for Age-2 fish was lower in Year 4 (2016) than in Year 3 (2015), and conversely, Age-5 CPUE was higher. 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).

As a result of spawn-timing for this population (see Section 3.4), the new year class of Age-0+ fish (i.e., for the current year) likely emerge in July and early August, 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 contributed the smallest proportion to the catch. 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.

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 4.

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

[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.

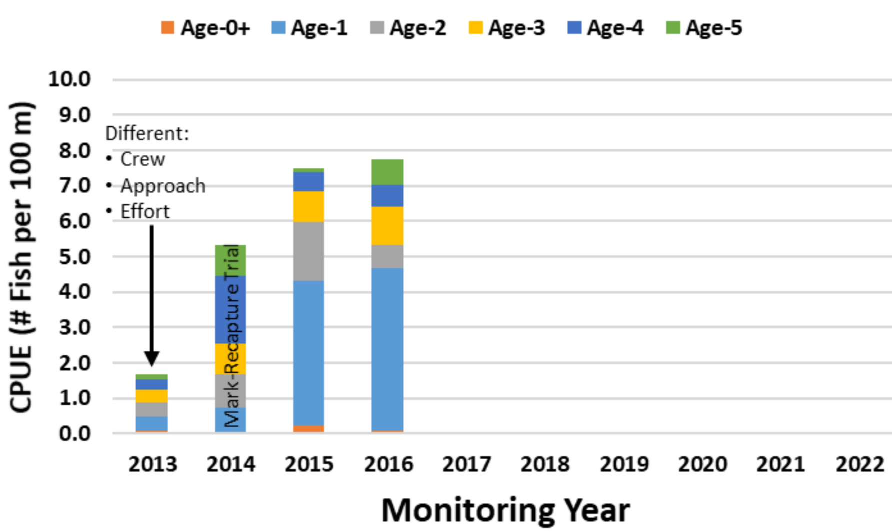


Figure 3.13 Catch-per-unit-effort summary by age class for each monitoring year from 2013 (Year 1) to 2022 (Year 10). Currently only data up to 2016 were available for this report. See important notes about the 2013 and 2014 results, below.

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 4 (2016), the highest CPUE was documented in the Mid zone of the reservoir. Based on the years of monitoring to-date, rainbow trout utilize the entire extent of Downton Reservoir; however, highest catch rates in June have typically been in either the East or Mid zones so far. The West zone has generally had the lowest value of the three. At this point there are still too few annual data points to draw any conclusions, and it would be premature to consider this a trend. The distribution of 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, 30 May to 6 June 2016.

Sample Session	Metric	Longitudinal Zone of the Reservoir [a]		
		West	Mid	East
June	# of Sites	15	16	18
	Catch (# of Fish)	243	372	413
	CPUE (fish/m)·100	**6.6**	**9.1**	**7.9**

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

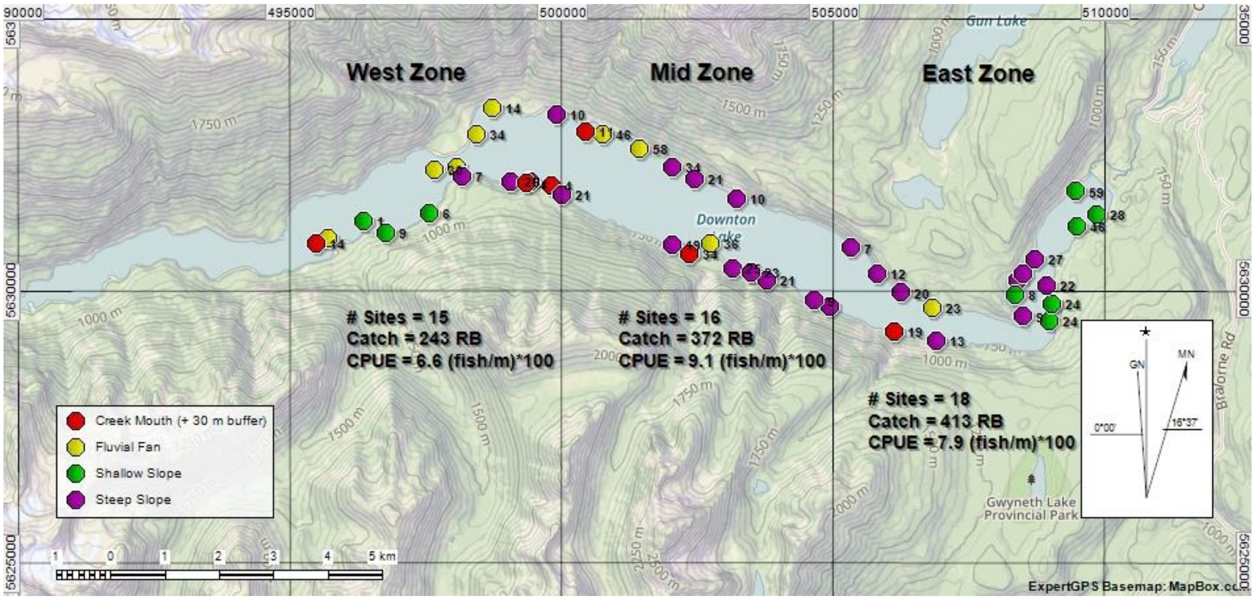


Figure 3.14 The distribution of sites and catches of rainbow trout by habitat type and longitudinal zone of the reservoir, 30 May to 6 June 2016. Catches at individual sites are represented by the numbers next to each coloured dot.

Recaptures of Tagged Fish

A total of ten fish that were marked with PIT tags were recaptured at different sites within the same session in Year 4 (2016; Table 3.14). Six of these fish had moved a short distance (i.e., <1 km), and four had moved more substantial distances (2.2 to 5.4 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 4 (2016).

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)
	Date	Zone	Habitat[b]	Date	Zone	Habitat[b]	
888379	3 June	Mid	ST	3 June	Mid	CM	0.4
889013	30 May	East	ST	5 June	East	SH	0.5
889042	30 May	East	SH	4 June	East	ST	3.7
889065	31 May	West	ST	31 May	West	CM	0.4
889183	30 May	East	ST	5 June	East	ST	2.4
889191	30 May	East	ST	5 June	East	SH	0.7
889240	30 May	East	SH	5 June	East	SH	0.6
889323	2 June	Mid	FN	3 June	Mid	FN	2.2
889461	1 June	West	FN	1 June	West	FN	0.4
889464	1 June	West	FN	2 June	Mid	FN	5.4

[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.

As reported for the Year 3 (2015) data, the number of within-session recaptured fish represented ~1% of the total catch again in Year 4 (2016). Based on the simple Petersen formula for estimating population size for a closed population:

$$\hat{N} = \frac{Kn}{k}$$

Where:

$\hat{N}$ = Number of animals in the population;

K = Number of animals captured

n = Number of animals marked

k = Number of marked animals that were recaptured

the approximate population size for rainbow trout in Downton Reservoir appears to be ~100,000 fish (range = ~75,000 to ~125,000). Granted, this is a fairly simplistic method for population estimation. Other, more robust methods will be explored once the results from additional monitoring years are available.

In addition to the within-session recaptures, there was 1 between-session and 7 between-year recaptures in Year 4 (2016). Original capture and recapture information for these fish is summarized in Table 3.15. All the between-year recaptures were for fish that were initially captured in 2015 (i.e., were at-large for ~1 year). As with the within-session recaptured fish, the locations for each capture event were varying distances apart (i.e., from the same location to two-thirds of the reservoir length). These results further support that rainbow trout move and mix among locations and habitat types throughout Downton Reservoir on both daily and annual time scales.

Table 3.15 Summary of inter-session and inter-year rainbow trout recaptures in Year 4.

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)	Growth (mm/yr)
	Date	Zone	FL (mm)	Date	Zone	FL (mm)		
734749	11-Jun-15	Mid	141	2-Jun-16	Mid	227	1.8	86
650775	12-Jun-15	West	111	30-May-16	East	265	9.1	154
650769	13-Jun-15	Mid	212	31-May-16	West	282	3.9	70
650936	13-Jun-15	Mid	220	2-Jun-16	Mid	293	1.3	73
734681	13-Jun-15	Mid	236	3-Jun-16	Mid	265	0.0	29
656574	15-Jun-15	West	161	31-May-16	West	238	0.1	77
656534	16-Jun-15	Mid	154	3-Jun-16	Mid	286	3.7	132
889046	18-May-16	Mid	114	2-Jun-16	Mid	123	0.1	-

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

Four fish (forklengths = 141, 154, 161 and 236 mm) were assessed as Age-2 based on scale ageing analysis (see section below) when initially captured, and were 227, 286, 238 and 265 mm forklength when recaptured a year later (at Age-3). This represents a growth range of between 29 and 132 mm in one year for this cohort of fish. One fish was 111 mm (Age-1) when initially captured and 265 mm a year later (at Age-2), representing 154 mm of growth. The remaining two recaptured fish grew 70 and 73 mm between Age-3 and Age-4, respectively.

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

A length-frequency histogram for rainbow trout captured by boat electrofishing in Year 4 (2016) 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 196 scale samples spanning the full range of available size classes (broken into 10 mm size increments between 50 and 380 mm). The assigned ages from the scale reading were applied to all of the captured fish according to size. There is typically size overlap (in some cases, extensive) between age classes, particularly for ages >3. This suggests that growth rate diminishes once fish in the reservoir reach this threshold age and size.

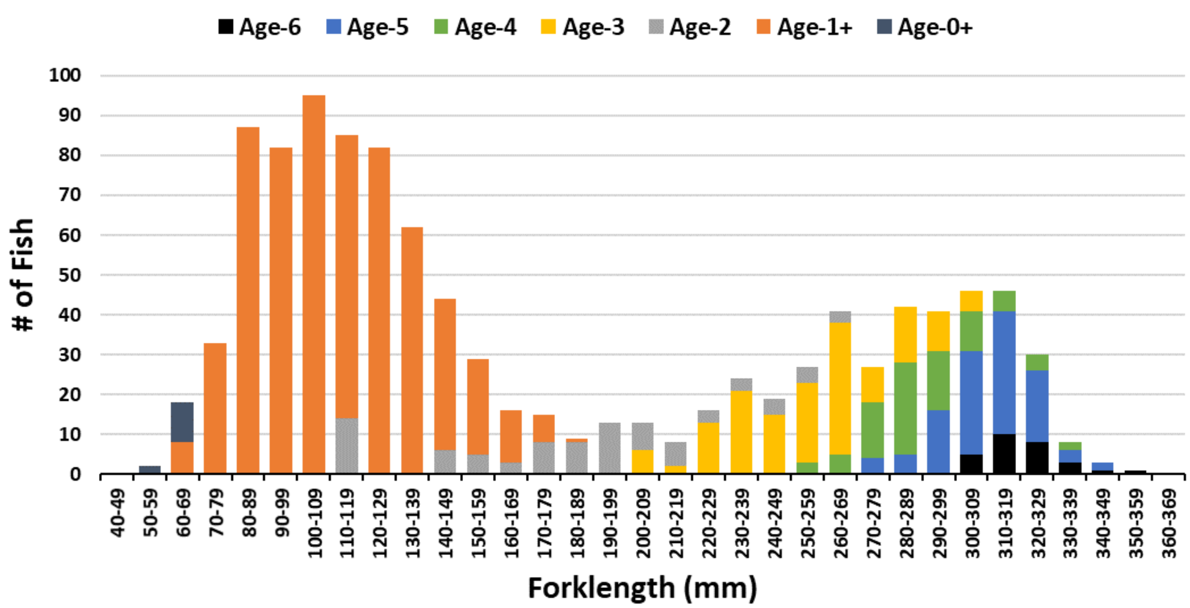


Figure 3.15 Length frequency histogram for rainbow trout captured during the fish population index survey in Downton Reservoir, May to June 2016. Size ranges for each available age class are shown.

According to the median size values for fish aged between 1 and 6 at the time of sampling in 2016, the greatest changes occur for rainbow trout from ages 1 to 3 (i.e., median differences of 79 mm between Age-1 and Age-2; and 70 mm between Age-2 and Age-3; Table 3.16), suggesting highest rates of growth may occur within this age range in the reservoir. 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 and largest fish in the Year 4 (2016) sample was assessed as Age-7 (based on scale ageing; *n*= 1) and was 380 mm. Overall, Age 1 and 3 fish were the most abundant age classes in the 2016 sample.

Table 3.16 Size statistics for the range of ages of rainbow trout captured in Downton Reservoir during Year 4 (2016).

Age	*n* [a]	Forklength (mm)		
		Minimum	Median	Maximum
0+	12	54	**63**	68
1	596	63	**109**	185
2	84	114	**188**	262
3	138	200	**258**	308
4	74	250	**285**	339
5	96	275	**310**	345
6	27	302	**319**	350

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

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*
2013	**76**	4	**113 (+37)**	532	**188 (+75)**	84
2014	**75**	30	**109 (+34)**	596		
2015	**63**	12				

The assignment of ages also allowed for the comparison of CPUE for each age class by habitat type (Figure 3.16). 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). Though overall catch rates differed among habitat types, the age class structure of the catch was very similar for fans, shallow slopes, and steep slopes. The high proportion of Age-1 fish highlighted the use of each of these habitats for rearing. At creek mouths, however, the older age classes (Age-3 and up) tended to dominate, likely reflecting the importance of these habitats for feeding by rainbow trout.

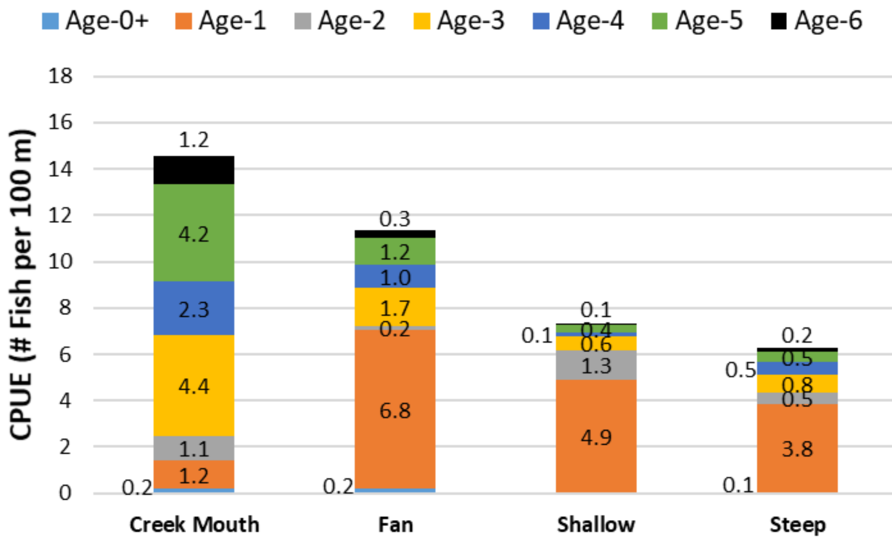


Figure 3.16 Catch-per-unit-effort (fish/100 m) by age class for each habitat type in Downton Reservoir based on the results of the boat electrofishing survey in Year 4, 30 May to 5 June 2016.

In general, the relative contribution of each age class to the catch was similar between 2015 and 2016 (Table 3.18). An exception was the contribution of Age-2 fish, which was reduced in 2016 relative to 2015. The contribution of the older age classes (i.e., Age-3 and up) generally increased in 2016 by between 3 and 8%.

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

Age	CPUE (fish/100 m)	
	2015	2016
0+	0.2 (3%)	0.1 (1%)
1	4.1 (55%)	4.6 (58%)
2	1.7 (22%)	0.6 (8%)
3	0.8 (11%)	1.1 (14%)
4	0.6 (8%)	0.6 (8%)
5	0.1 (1%)	0.7 (9%)
6		0.2 (3%)
All	**7.5**	**8.0**

The reduced contribution of Age-2 fish (i.e., from 1.7 to 0.6 fish/100 m; or 22 to 8% of the sample), may indicate poor survival in the reservoir for this age class between 2015 and 2016 sampling events. This cohort was recruited in 2013, and experienced the low reservoir pool elevation of 709.0 m in their first spring (2014), which was a deeper drawdown than in any other monitoring year to-date. However, they had still been relatively abundant in catches as Age-1 fish during the 2015 survey (Total Age-1 CPUE was 4.1 fish/100 m in 2015 as compared to 4.6 fish/100 m in 2016). Potential causes of the reduced abundance for this cohort in 2016 (as Age-2 fish) are currently unknown. Until more years of data are collected, it is difficult to put the degree of observed change between survey events for this cohort 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 3.17). 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-1*). 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.

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 4 (2016), the Age-0+ rainbow trout were recruited in 2015, the Age-1 fish were recruited in 2014, and the Age-2 fish were recruited in 2013.

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

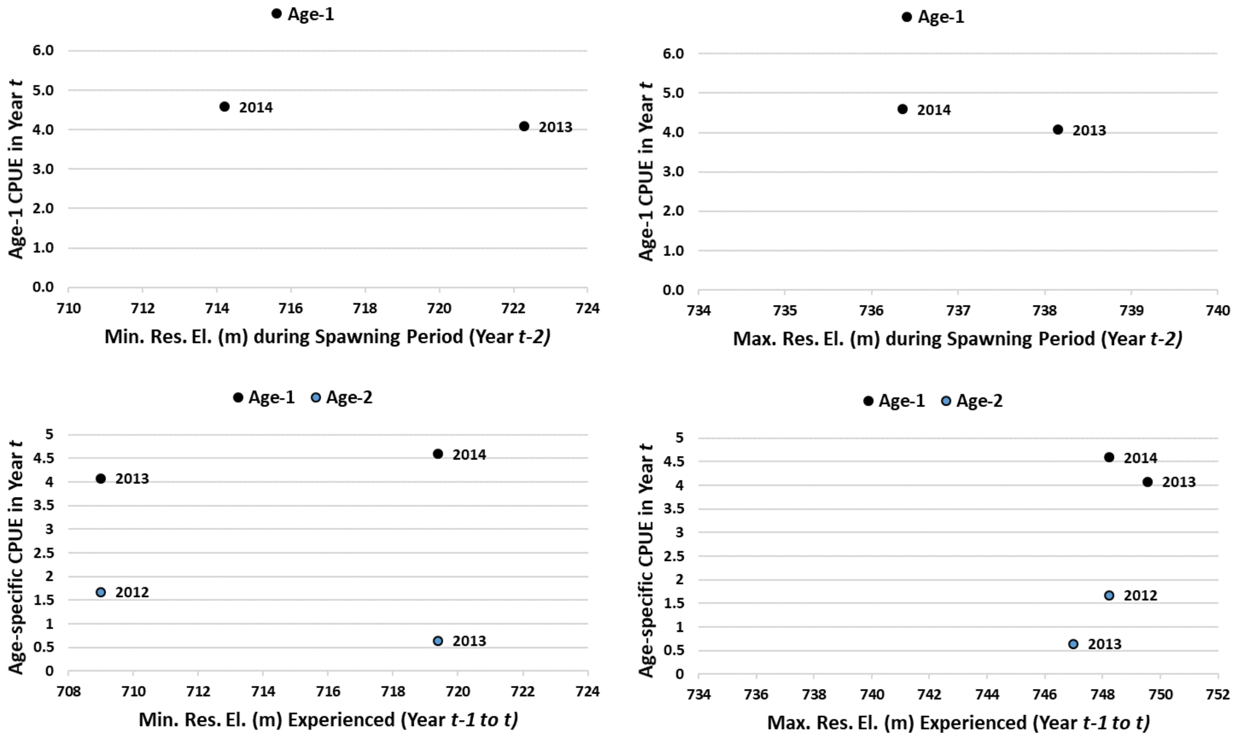


Figure 3.17 Plots of annual age-specific CPUE for Age-1 fish (upper panels) against minimum and maximum reservoir elevations during the spawning period in their recruitment year (*t-2*); and Age-1 and Age-2 CPUEs (lower panels) against the minimum and maximum reservoir levels experienced in the previous year (*t-1* to *t*). Labels next to each data point indicate the recruitment year.

3.9. 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) and one in Year 4 (2016). 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 and 19 rainbow trout were caught by angling in years 1 to 4, respectively, and all fish were a tag-able size (Table 3.20); Sizes ranged from 250 to 335 mm in Year 4 (2016) 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 3.20 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	# 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
Total (to-date)	2,087	261	**2,348**	39

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 4), the Downton Reservoir fish population is almost entirely comprised of rainbow trout (save for 1 bridgelip sucker captured this year). The rainbow trout population spawns between late May and late July (peak in mid 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 be related to earlier reservoir inundation risk at these locations.

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 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 emergence, 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) is provided at the creek mouths, 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 and fan habitats, and lower numbers are sampled from steep or shallow shorelines that are not associated with creeks. Sampling in offshore habitats (i.e., by gill netting) is being proposed for Year 5 (2017) activities to assess relative use of deeper, pelagic habitats for comparison with the nearshore results.

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-P) result in positive, negative or neutral impact on abundance and diversity of fish populations?

Overall CPUE values for rainbow trout between 2015 and 2016 (the two years available to-date when sampling methods and effort were consistent) were very similar: 7.5 and 7.9 fish/100 m of shoreline, respectively. CPUEs *by age class* were also fairly similar across these two years, except for Age 2 fish. Age 2 CPUE dropped across all habitat types by almost two-thirds from 1.7 fish/100 m (2015) to 0.6 fish/100 m (2016), suggesting a possible recruitment anomaly for this age class between those years. Minimum reservoir elevations were very similar between 2015 and 2016, whereas maximum fill elevations differed by ~13 m. There is not currently enough data to draw conclusions about this result 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.

According to the recapture rates for fish marked during the fish population index survey (n= 10 recaptures out of 1,028 captured fish), the estimated population size for Downton Reservoir rainbow trout was roughly 100,000 (± 25,000) individuals in Year 4 (2016). Based on assessment of results to-date, the resolution of the population estimates likely won't be sufficient for detecting change (versus no effect) according to year-to-year effects of operations; however, they may provide some useful information about the relative population size of Downton Reservoir rainbow trout (e.g., 10K vs 100K vs 1000K fish). At this point CPUE will continue to be the primary metric for tracking age-based changes across years.

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-P" 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-P 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-P operation with modified operations due to potential differences in sample size between these operational treatments.

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 2 years of comparable abundance index data points available at this point (refer to sections 2.8 and 3.8). 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 reservoir operation level continued in Year 4 (2016), providing 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 by the flow. However, based on tributary fish sampling results to-date, use of the creeks for rearing by the rainbow trout population appears limited, with abundance of juveniles in the creeks low and declining from spring to fall (Section 3.7). Additional seasonal sampling replication is required in upcoming monitoring years before these results can be considered more definitive. Tributary fish sampling to document summer use is planned for Year 5 (2017) 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 select spawning tributaries tend to reach optimal ranges with 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 some years, temperatures in Jamie Creek have been below the optimal range for much of 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 inconsistent among years. 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 was actually higher at the low pool elevation surveyed (~722 m in 2016) 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 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 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. 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 source 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 3.8).

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 poor due to footprint effects of the reservoir, and the ongoing cycle of drawdown and inundation. If that is the case, then management decisions for the reservoir (e.g., N2-P 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.

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). Accessible tributaries in Mid and East zones (such as Ault, Paul and Cathy creeks) have not been used despite the presence of suitable habitat, and this may be due to inundation risk. Implementation of modified operation in 2016 reduced the portion of stream length inundated by the reservoir due to the reduced fill level relative to normal N2-P 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 are used extensively (refer to sections 3.4 and 3.6)**.**

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, 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 4 (2016) 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 or <722 m) 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 4 (2016) 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 for 2016, 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.

Also, as stated earlier, the modified operations are a departure from the N2-P operations in terms of the maximum fill elevation and potential frequency of deeper drawdowns related to mitigating seismic concerns at La Joie Dam. Unless works are completed at the dam to alleviate these constraints within the monitoring period (2013 to 2022), there will be more years of monitoring the modified operations than the N2-P 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. While total CPUE value for 2016 was consistent with the 2015 value, and trends between habitat types were similar, there were some differences in relative abundance among the age classes between years. 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; The figures 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, 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:

- 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 (approx. normal maximum) and 722 m (fish index sampling) 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.
- Conduct pelagic zone sampling using gill nets to assess relative use of offshore habitats by rainbow trout in the reservoir. Sampling should be conducted throughout the West, Mid, and East zones of the reservoir, and at a variety of depths to characterize the longitudinal and vertical distributions. Sample timing should be similar to the annual fish population index survey (boat EF) so that fish distribution is representative of conditions at that time of year.
- Conduct tributary fish sampling (by backpack EF) in August to assess fish rearing use of tributary habitats during summer, when the reservoir is at or near the modified maximum elevation. 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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