Bridge River Project Water Use Plan

Downton Reservoir Fish Habitat and Population Monitoring

Implementation Year 6

Reference: BRGMON-7

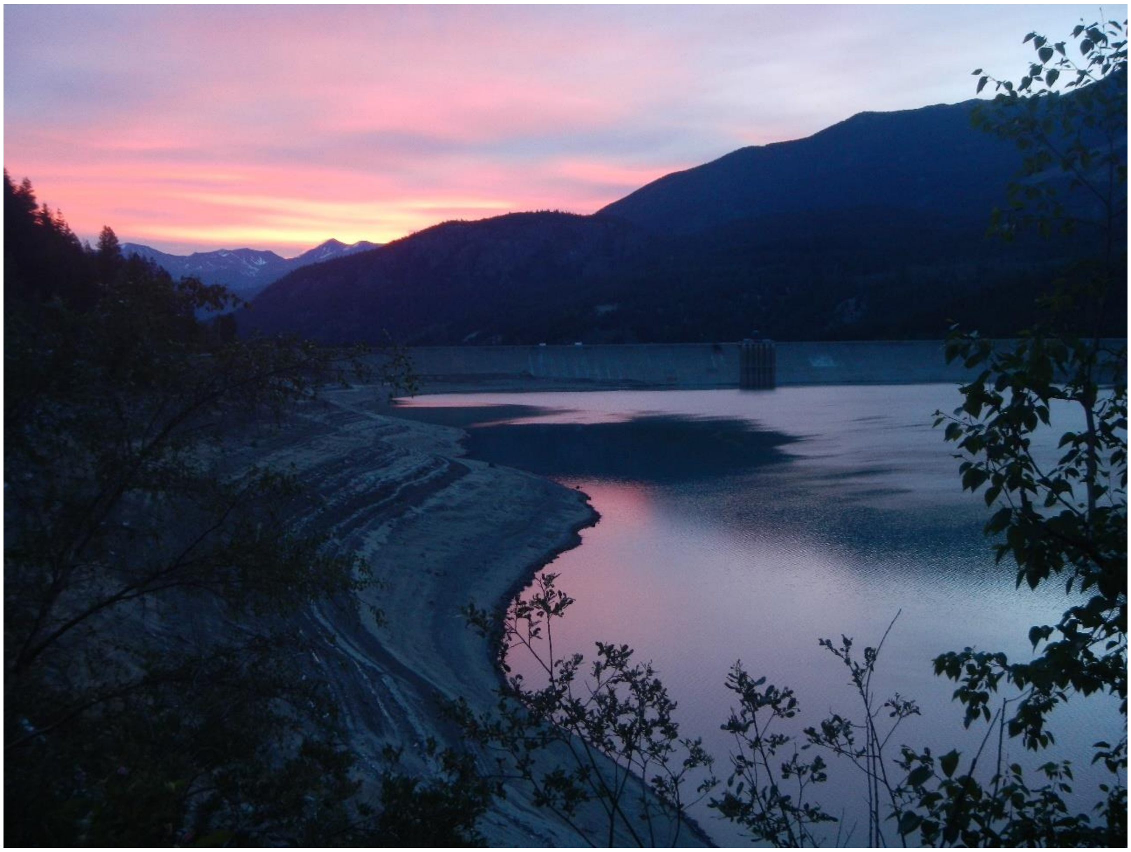
BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 6 (2018) Results

Study Period: April 1 2018 to March 31 2019

Jeff Sneep and St'at'imc Eco-Resources

December 20, 2019

BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 6 (2018) Results



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Executive Summary

Data collection for Year 6 of this proposed 10-year study was completed in 2018. The primary objectives of this monitoring program are: 1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and, 2) To provide information required to link the effects of reservoir operation on fish populations.

To-date, only rainbow trout and a single bridge lip sucker have been captured in the reservoir and its tributaries. Seven methods were employed in Year 6 (2018) to document the biological characteristics of the rainbow trout population, generate an annual abundance index, characterize available fish habitats, and assess the effects of the modified reservoir operations, implemented since Year 4 (2016).

The management of surface elevations in Downton Reservoir follows a seasonal pattern: lowest elevations occur in spring (generally April to May) and highest elevations, or full pool, usually occur in late summer to early fall (August to September). Year 6 (2018) was the third year that the reservoir was operated within the new modified maximum elevation (i.e., 734 m); maximum reservoir elevation in 2018 was 733.0 m. Lowest reservoir elevation in 2018 (711.3 m) was most similar to 2017 (711.5 m) and 2014 (709.0 m), and 8-9 m lower than 2013, 2015, and 2016 (i.e., 719.7 m, 720.4 m, and 719.4 m, respectively).

The shoreline habitat mapping in 2018 documented a 3.1 km (12%) decrease in reservoir length and a 6.6 km (11%) decrease in shoreline length at 733 m (near the 734 m *modified* maximum elevation), compared to the 745 m (near normal full pool) elevation surveyed in Year 3 (2015). Compared to the 722 m and 716 m elevations (surveyed in Years 4 and 5), the reservoir length at 733 m was 4.7 km (21%) and 8.3 km (37%) longer, respectively; and shoreline lengths were 12.8 km (24%) and 19.2 km (36%) longer, respectively.

The percent contributions of each habitat type were very similar among full pool elevations (i.e., 745 m and 734 m) and among the low pool elevations surveyed (i.e., 722 m and 716 m). However, there were differences between full pool and low pool elevations: there was a substantial reduction in steep shoreline habitat and an increase in shallow habitat length at both low pool elevations despite the reduced wetted extent of the reservoir. Fan habitat decreased in total length at lower elevations, but percent contribution to the total was actually maintained across each surveyed elevation for this habitat type. The number and percent contribution of creek mouths that were receiving flow also increased during the low pool surveys in the spring since all intermittent drainages were flowing at that time (i.e., spring run-off conditions). Several creeks were dry or very low during the full pool surveys (i.e., at 734 m and 745 m) in summer.

Substrate size, interstitial depth, and slope measurements were collected from 26 sites in the reservoir drawdown zone (n= 22) and in select tributary streams (n= 4) during 2018. The collected data focussed on 722 m elevation in the reservoir, and the drawdown zone in the tributaries,

towards the goal of making the sample size equivalent for each targeted elevation across years. The added data did not substantively change conclusions from the results, but bolstered confidence in the observed patterns that have emerged from these data. As was reported previously (Sneep 2019), fines and small gravels continued to be the most abundant substrate classes; however, the relative proportions vary by elevation. The highest proportions of fines (38%) and small gravels (30%) were at the lowest surveyed elevation (722 m) and the lowest proportions were at the top of the drawdown zone (19% and 19%, respectively). 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 31%, 41% and 52% (combined) at 722 m, 734 m and 747 m, respectively. Interstitial space availability was generally low at all sites, but was highest (and exhibited a positive correlation with elevation) at creek mouths and in tributaries.

Stream walks were conducted in four tributaries where spawning use has been consistently documented in past years (i.e., Tram Creek, Trib. #13, Eagle Creek and Trib. #19), as well as three additional tributaries where spawning has not been, or only minimally, confirmed (i.e., Jamie Creek, Cathy Creek and Ault Creek). Based on the Year 6 (2018) 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 Year 3 (2015), but consistent with the median timing for every other study year to-date. Spawning was again confirmed in 3 of the 4 known spawning tributaries (Trib. #19 went dry during the spawning period so was not used). Peak counts in the known spawning creeks were lower than the highest counts observed in Year 1 (2013), but were in the same range as every other year since then. Small numbers of spawners were documented in Jamie, Cathy and Ault creeks (peak counts = 3, 2 and 3, respectively) in 2018. While the spawner numbers documented can only be considered a relative index, the results of these surveys are useful for tracking changes in spawn timing, distribution and relative magnitude across the 10-year monitoring period.

Tributary fish sampling was conducted in fall during Year 6 (10-12 October 2018). Mean CPUE (for all creeks sampled) was 20.2 fish/100 m, compared to 6.1 fish/100 m in spring (2016) and 14.7 fish/100 m in summer (2017). Catches were zero in three out of fifteen sites. Captured rainbow trout ranged in age from 0+ to 2, but the majority (i.e., 75 out of 91, or 83%) of the fish captured were the new year class of rainbow trout fry (forklength = 20 to 58 mm) that had recently emerged from the gravel. This data served to further support the predicted emergence timing based on ATUs (late July to early September) and suggests that at least some of the newly emerged fish remain in the creeks until fall. Other than these Age-0+ fry, the catch rates for the other age classes were as equivalently low as they were in spring and fall.

Approximately 17 km of shoreline was sampled by boat electrofishing over 8 nights from 1 to 8 June 2018, at a reservoir elevation of approx. 721 m. This reservoir elevation was within the typical range observed during sampling in most years to-date (i.e., ~719 to ~723 m), except in 2015 when elevation was higher during the annual survey (~730 m). In total, 1,658 rainbow trout were captured from 61 sites, which was the highest catch to-date. Of these fish, 1,317 were newly marked with PIT tags and 15 marked fish were recaptured (6 that were marked within this sampling session, and 9 from previous years).

Total CPUE in the reservoir was 12.2 (SE 1.4) fish/100 m of shoreline which was up from 8.9 (SE 1.0), 8.7 (SE 0.8) and 8.1 (SE 1.0) fish/100 m in Years 3, 4 and 5 (2015, 2016 and 2017), respectively. This difference was primarily due to increased catches of Age-1 and Age-4 fish in 2018, which more than doubled the catch rates for those age classes from 2017. CPUEs for Age-2 and Age-3 fish were also slightly higher in 2018, further improving on an increase in these age classes between 2016 and 2017. Highest CPUEs by habitat type were at creek mouths (23.5 (SE 3.8) fish/100 m) and then shallow slopes (17.0 (SE 5.1) fish/100 m), followed by steep slopes and then fans (10.3 (SE 1.8) and 6.9 (SE 0.9) fish/100 m, respectively). This was the first year that CPUEs in steep shorelines were higher than fans, which was due to a substantial increase in Age-1 fish in this habitat type (as well as in shallow habitats) relative to past years. Highest total CPUE by longitudinal zone of the reservoir was recorded in the east zone in 2018; although this has varied among years to-date, reflecting that rainbow trout are generally distributed and move throughout the reservoir.

Data reporting in Year 6 (2018) also included analysis of length-at-age (von Bertalanffy growth curves), log-length-to-log-weight relationships, and condition factor (Fulton's K) assessment by age and study year. Based on the growth curves, rainbow trout growth was slightly lower in 2017 and 2018 relative to 2015 and 2016, particularly for fish aged 1-3, which coincided with the period of modified operations. Median sizes for the other age classes were more similar among years. The regression of log-transformed lengths and weights showed that this relationship has not demonstrably changed among any of the years to-date. Slope values for each year were very similar and R^2 values were all very high (≥0.98).

The assessment of condition factor showed some similarities to the length-at-age analysis: differences among consecutive years were small although there was a general trend of reduced condition factor across the sampling years for some age classes (i.e., Age-2, Age-3 and Age-4). Interestingly, a reduction in condition factor has been noted for rainbow trout in Carpenter Reservoir as well (since 2014; Putt et al. 2018). This may be coincidental, or may point to a general change in food base, physical conditions (e.g., temperature) or productivity affecting both reservoirs in the system. However, mean condition factor of rainbow trout appeared to be higher in Downton Reservoir than in Carpenter Reservoir for the available study years to-date, and lowest observed growth and condition coincided with the study years (2017 and 2018) when surface temperatures in Downton Reservoir were slightly warmer on average during the growing season (i.e., Jul to Sep; see Table 3.2 in Section 3.2).

Scales from 192 rainbow trout were collected for ageing analysis in 2018. Fish ranged from Age 0+ to Age-5 with the highest proportion of captured fish Age-1 to Age-3. Once again, the older age classes displayed extensive size overlap, confirming 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). With the years of data available, there is no clear indication that the recruitment of rainbow trout to Age-1 or Age-2 in the reservoir are correlated with the range of minimum or full pool elevations observed to-date (i.e., current results may be consistent with no effect). However, maximum reservoir elevation during the rainbow trout spawning period appears to be negatively correlated with recruitment to Age-1 ($R^2 = 0.68$). Additional data points from the remaining study years will be important for further defining any potential causal relationships and confirming these results.

Recommendations for monitoring in upcoming years of the BRGMON-7 program include: 1) Target installation of the temperature array in Downton Reservoir for mid April and removal by end of October to fully bracket the period of thermal stratification; 2) discontinue habitat mapping and substrate measurement activities (now that a reasonably complete set for target elevations has been acquired) to make budget room available for completing recommendations 3 and 4; 3) Continue spawner count streamwalks and tributary access surveys in widest range of tributaries possible from mid May to end of July, and include more specific documentation of spawner locations (and any redds) to better characterize spawning distribution within the drawdown zone; 4) Conduct tributary fish sampling in three seasons within a year (spring, summer and fall) at the same range of creeks as previous to re-assess seasonal rearing use of tributary habitats and reduce the inherent variability associated with sampling one different season each year; and 5) Repeat the fish population index sampling by boat electrofishing on the same dates (early June), maintaining the same approach effort, crew, equipment, etc. each year to the extent possible.

The status of responses to the Management Questions and Study Hypotheses based on results up to, and including, Year 6 (2018) 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 6

Primary Objectives	Management Questions and Study Hypotheses	Year 6 (2018) Results To-Date
1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and 2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative on existing reservoir fish populations, and, b) allow better future decisions regarding preferred operation of Downton Reservoir.	1. What are the basic biological characteristics of fish populations in Downton Reservoir and its tributaries?	• The Downton Reservoir fish population is almost entirely comprised of rainbow trout (save for 1 bridgelip sucker captured in 2016). • The rainbow trout population spawns between late May and late July (peak in mid to late June) in accessible tributaries, primarily in the mid and west zones of the reservoir. • Relative to the upland, a higher proportion (70% to 80%) spawn in the drawdown portion of these creeks. • Beyond the post-emergence period within their first growing season, fish use of the tributaries for rearing appears to be low, suggesting that the majority of the fry move into the reservoir prior to their first spring where risk of habitat loss from changing reservoir elevations is low. • Highest abundance is at creek mouths where food (likely in the form of drifting invertebrates) is available, followed by shallow slopes, alluvial fans, and steep shorelines. Catches in steep habitats were higher than fans in 2018. • In the nearshore areas of the reservoir, the rainbow trout are distributed across the longitudinal zones (i.e., west, mid, and east). • Sampling in offshore habitats (i.e., by gill netting) was conducted in Year 5 (2017), which documented that use of pelagic habitats in June was low and limited to within 2.4 m from the reservoir surface. • The age range of sampled fish has spanned from 0+ to 7 years (40 to 437 mm); the majority are between ages 1 to 3. The most rapid growth occurs between ages 1 and 3, after which growth rate slows. **See Section 3.5, 3.6, and 3.7 for more information.**
	2. Will the selected alternative (N2-2P) result in positive, negative or neutral impact on abundance and diversity of fish populations?	• Overall CPUE values for rainbow trout increased significantly in 2018 (to 12.2 fish/100 m of shoreline) from 8.1 to 8.9 fish/100 m between 2015 and 2017. • This difference was primarily due to increased catches of Age-1 fish in 2018, which improved by more than 2-fold from 2017 catches. CPUEs for Age-2 to Age-4 fish have increased (albeit more modestly) each year since 2016. • 2018 min. reservoir elevation was very similar to 2017, and 8-9 m lower than in 2015 and 2016, whereas max. fill elevations since 2016 have been characterized by modified operations (734 m) rather than normal max. elevations. • These results suggest that the modified operations may be improving recruitment conditions, reservoir rearing conditions, or both. However, this inference must still be considered tenuous at this point, and will be further informed by results from the remaining years of monitoring. **See Section 3.7 for more information.** **Note:** By the end of the current monitoring period in 2022, limited data will be available for typical N2-2P operations (probably 2 years), and the remainder will reflect results associated with *modified* reservoir operation. However, the results will speak to the operational range tested, which is a sub-set of the normal operating range (i.e., lower maximum, but similar minimum elevations).

Primary Objectives	Management Questions and Study Hypotheses	Year 6 (2018) 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 at this point; more data needed. The 2018 results suggested that the annual abundance index increased for fish that recruited under modified operations (since 2016) relative to those that recruited before. Status updates will continue to be provided as more years of results become available, but confirmation/rejection 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 6 (2018), providing additional information for addressing this MQ. **See Section 3.2, 3.3, 3.4, and 3.5 for more information**. • The tributaries provide essential spawning habitats and, likely, food supply; however, use for rearing beyond the initial growing season post-emergence appears limited. • Access to some tributaries by spawners may be impeded when reservoir levels are <713 m and inflows are low. • The majority of rearing appears to occur in the reservoir, and the creek mouths are the most utilized habitat type by the broadest range of age classes. • Temperatures in the reservoir are more broadly spread across the optimal range (according to depth) for growth, relative to the tributaries, which are colder. Temperature may be one of the factors for selecting spawning streams. • Relative to the full pool elevations in summer (normal or modified maximum), the total number of flowing creek mouths was actually higher at the low pool elevations surveyed because all intermittent drainages were flowing (start of spring freshet). • Due to the shape of the reservoir basin, only steep shoreline habitats were substantially reduced (by ~50%) at the low pool elevation, which is the habitat type associated with the lowest catch rates of fish during the annual index survey. • In general, the substrate size distribution and embeddedness in the reservoir drawdown zone are positively correlated with elevation (size range, median size and interstitial space tend to increase with the elevation). • Based on the information gathered to-date, it is expected that the main factors limiting population size in Downton Reservoir are food supply, inundation of spawning habitat during the spawning and incubation period (May to July), and possibly overall spawning habitat area available in the tributaries. **H_4:** tentatively confirmed; more data on relationship between reservoir level and accessible spawning habitat availability is needed. Implementation of modified operation (in 2016 and 2017) reduced the portion of stream length inundated by the reservoir. Data to define this relationship for several tributaries was collected in Year 6 (2018). **H_{4a}:** tentatively rejected; more data needed. While some tributaries are not used at all, the drawdown zone of Tribs. #13 and #19 have been used extensively. More spawning distribution data to be collected in 2019. **H_{4b}:** not confirmed or rejected; more data needed. Some tributaries may lose connectivity when reservoir levels are <713 m before the onset of freshet, although primary spawning tributaries have not been 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 based on current findings. Efforts in Year 6 (2018) supplemented the data set for defining habitat type distribution and substrate characteristics at 747, 734, and 722 m. We propose to put further data collection for these parameters on hold to make budget room for additional tributary fish sampling sessions.

Primary Objectives	Management Questions and Study Hypotheses	Year 6 (2018) 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).	• 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. Year 6 (2018) contributed an additional data point to the annual index of abundance, and provided another set of results for documenting the age structure and condition of the rainbow trout population over time. Regressions were included on Figure 3.18. • There are not yet any clear relationships between minimum (absolute or during spawning period) or absolute maximum reservoir levels and the abundance index for Age-1 or Age-2 fish that can be differentiated from "*no effect*" at this point (see Figure 3.18). • One emerging relationship is a potential negative correlation between maximum reservoir elevation *during the spawning period* and the subsequent abundance of Age-1 fish that recruited under those conditions (Figure 3.18). • Any inferences about relationships made from the available results must still be considered tenuous at this point and will be further supported (one way or other) by inclusion of data points from the remaining monitoring years. **H_2, H_{2a}, H_{2b}:** not confirmed or rejected; more data needed. Requires annual age-specific CPUEs coupled with minimum reservoir elevation values for the entire monitoring period (2013 to 2022). Refer to Figure 3.12 and 3.18 (Section 3.7). **H_3, H_{3a}, H_{3b}:** not confirmed or rejected; more data needed. Requires annual age-specific CPUEs coupled with maximum reservoir elevation values for the entire monitoring period (2013 to 2022). Refer to Figure 3.18 (Section 3.8).
	5. Can refinements be made to the selected alternative to, without significant impact to instream flow conditions in the Middle Bridge River, improve habitat conditions or enhance fish populations in Downton Reservoir?	• Based on the reservoir elevation and fill rate information provided by BC Hydro, the modified operation of Downton Reservoir (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. • The increased abundance of Age-1 fish documented in 2018 (i.e., the first cohort that recruited under the lower modified operations levels) seems to support this. Observed increases in Age-2 to Age-4 fish abundance during the modified operations years also suggests good, or even potentially improved, survival to those age classes in the reservoir under those operations. • Similarly, refinements to the selected alternative (N2-2P) that can include a reduced maximum fill elevation and slower fill rate, particularly during the rainbow trout spawning period (Jun-Jul), would likely improve spawning habitat conditions and enhance recruitment for the Downton Reservoir fish population. • Depending on inflows in a given year, a*ny* operation that reduces the maximum fill elevation in Downton Reservoir is likely to impact instream flow conditions in the Middle Bridge River as more flow must be passed through La Joie Dam to offset the reduced storage in the reservoir. The lost storage from a reduced maximum elevation cannot be fully offset

Primary Objectives	Management Questions and Study Hypotheses	Year 6 (2018) Results To-Date
		by a lower minimum elevation. This effect (reduced storage and higher flow conveyance in the Middle Bridge River and elsewhere in the system downstream) has been observed under modified operations. • 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, as well as BC Hydro flow modelling. These will ultimately be evaluated for the preparation of the end-of-monitoring synthesis report.

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 fish population responses to the selected WUP operations were also defined to provide direction for the study.

The Bridge River Power Development Water Use Plan was accepted by the provincial Comptroller of Water Rights in March 2011. Terms of Reference (ToR) for the Downton Reservoir Fish Habitat and Population Monitoring program were developed and approved by late 2012, and field data collection activities were initiated in 2013. Under the WUP, monitoring for this program is scheduled to continue annually until 2022. Data collection for Year 6 of this proposed 10-year study was completed in 2018.

1.2. Objectives, Management Questions and Study Hypotheses

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.3. Study Area

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

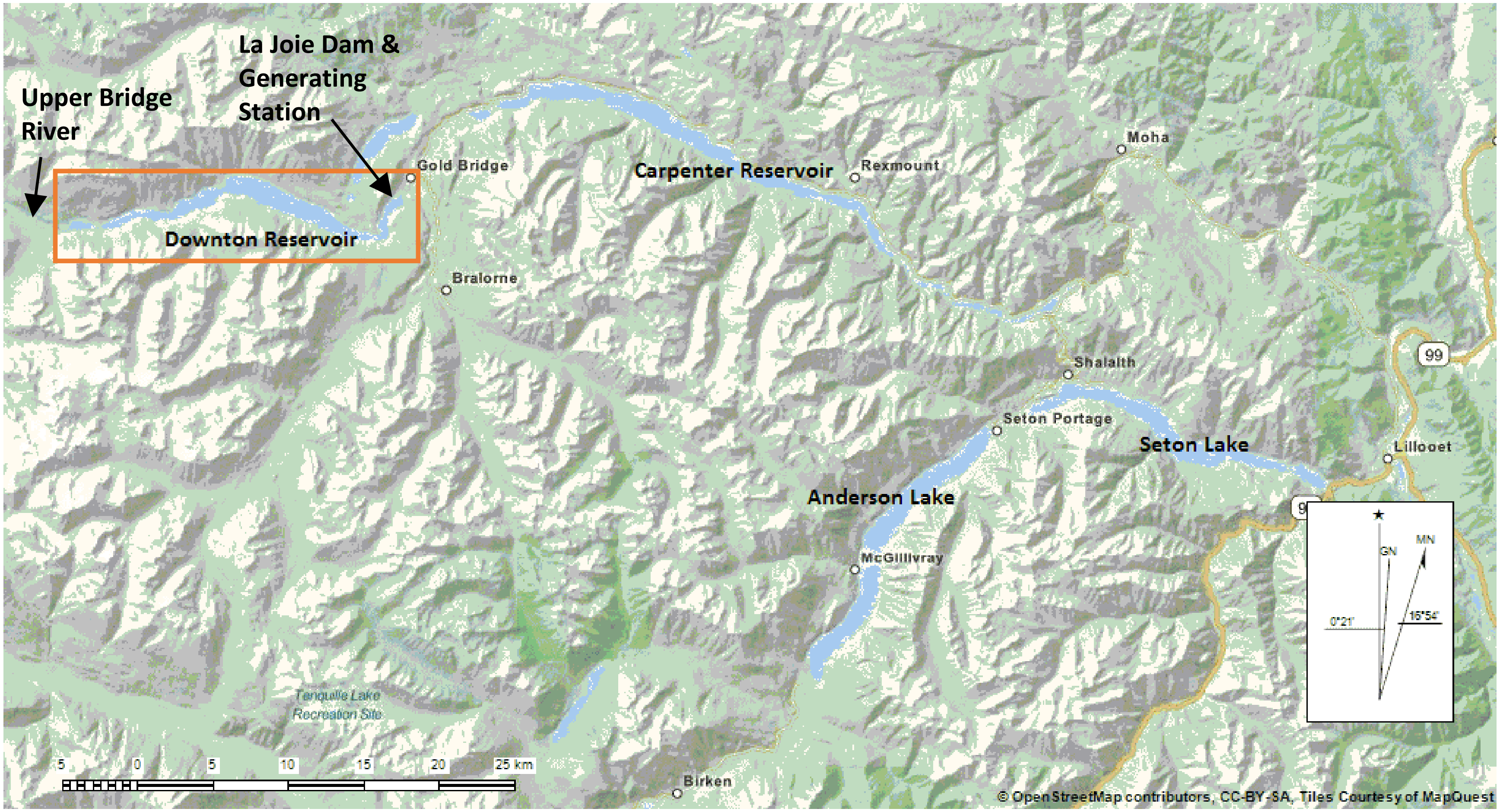

Figure 1.1 Bridge River and Seton River watersheds. The extent of the BRGMON-7 study area, which includes all of Downton Reservoir and tributaries between the Upper Bridge River inflow and La Joie Dam, is outlined by the orange rectangle.

Downton Reservoir elevations and the conveyance of flows into the Middle Bridge River are regulated by BC Hydro's La Joie Dam and Generating Station. The entire Bridge-Seton hydroelectric complex is integrated and the operations of each reservoir and facility are managed based on storage, conveyance, and generation decisions that account for water management priorities, electricity demands, plant maintenance requirements, fisheries impacts, as well as other values. Downton Reservoir and the La Joie facility are situated at the upstream end of the Bridge-Seton system.

1.4. Operations Context for Downton Reservoir and La Joie Dam

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

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

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

Within the past few years, BC Hydro identified issues with the La Joie Dam pertaining to conformance with current seismic withstand standards. In order to mitigate the seismic risk at this facility (at least in the interim until the necessary physical works at the dam can be completed), the target maximum fill elevation for Downton Reservoir has been lowered to ~734.00 meters above sea level (masl), instead of the normal maximum operating level of 749.81 masl; a reduction of ~16 meters. This difference will reduce the total storage volume of the reservoir by about 50% and represents a departure from typical N2-2P (i.e., post-Water Use Plan) operations. In the context of the BRGMON-7 monitoring program, this revised management strategy is referred to as *modified operations*, which may be implemented for the remainder of this program.

Under the modified operations, normal minimum reservoir levels will be unchanged although deeper drawdowns may be somewhat more frequent than in the past. Year 4 of the monitoring program (2016) was the first year that modified reservoir operations were implemented, and they occurred again in Year 5 (2017) and Year 6 (2018). A summary of Downton Reservoir operating parameters (i.e., minimum and maximum elevations, mean fill and drawdown rates) for each monitoring year are provided in the Results (Section 3.1, Table 3.1).

1.5. Sampling Design and Implementation To-Date

As in previous monitoring years, Year 6 (2018) field activities were focussed on providing data to meet the following sampling design included in the original study ToR (BC Hydro 2012):

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

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

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

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

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

A summary of the sampling methods employed across the years (to-date) for accomplishing the goals and objectives of the BRGMON-7 program are provided in Table 1.1, for reference. For more information about the methods employed during past years, and the rationale behind them, please refer to the annual monitoring reports produced for those years.

Table 1.1 Methods Implementation by Study Year To-date. For more details on the specific methods employed, refer to the annual monitoring report for each year.

Monitoring Method	Study Year					
	1 (2013)	2 (2014)	3 (2015)	4 (2016)	5 (2017)	6 (2018)[a]
BC Hydro Operations	■	■	■	■	■	■
Temperature Monitoring (Continuous)						
• Tributaries			■	■	■	■
• In-reservoir profile array			■	■	■	■
Habitat Surveys						
• Habitat Mapping			■	■	■	■
• Substrate Measurements			■	■	■	■
Tributary Spawner Surveys	■	■	■	■		■
Tributary Access Surveys			■	■	■	■
PIT Array Monitoring			■	■		
Tributary Fish Sampling (Backpack EF) -- Seasonal			■ (Fall)	■ (Spring)	■ (Summer)	■ (Fall)
Fish Population Index Survey (Boat EF)						
• 2 short sessions (spring/fall)	■	■				
• 1 extended session (spring)			■	■	■	■
Pelagic Fish Survey (Gill Netting)					■	
Supplementary Angling	■	■	■	■	■	
Fish Ageing Analysis (Scale Reading)			■	■	■	■

[a] The specific dates that each of the Year 6 (2018) activities were completed are provided in Section 1.6, Table 1.2.

The tributary spawner surveys were resumed in Year 6 (2018) after a 1-year hiatus to accommodate a one-time pelagic fish survey of the reservoir using gill nets in Year 5 (2017). Catch rates of fish at a variety of depths in the pelagic zone of the reservoir were very low relative to the nearshore sampling (by boat electrofishing) and the results provided minimal added benefit for monitoring the reservoir fish population so it was discontinued (Sneep 2019). It remains clear that, in this context, boat electrofishing in nearshore habitats is the most suitable approach for monitoring the rainbow trout population. Also, it is our intent to continue the tributary spawner surveys in each of the remaining years of the program to maintain a continuity of information on the start, peak and end of spawning as well as relative spawning use among creeks.

One other minor component that was discontinued in Year 6 (2018) was the supplementary angling in order to focus adequate effort on each of the primary monitoring components. The angling has always been opportunistic, supplemental, and very non-essential to the objectives of the program. A much higher number of fish, across a broader range of sizes and age classes, are sampled and marked during the boat electrofishing survey each year.

1.6. Year 6 (2018) 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 (2018) represents monitoring year 6. The general schedule of field sampling activities is presented in Table 1.2.

Table 1.2 Year 6 (2018) Schedule of Field Sampling Sessions and Activities.

Field Sampling Activities	Dates (2018)
Temperature logger deployment & retrieval	19 Apr; 7 Jun; 13 Jun; 1 Aug; 6 Sep; 11 Oct
Habitat Mapping Survey (734 m elev.)	6, 7 Sep
Substrate characterization at reservoir & tributary sites (~722 m elev.)	13 to 15 Jun
Tributary Access Surveys	19 Apr; 24,29 May
Tributary Spawner Surveys	17 May to 1 Aug (weekly)
Tributary Fish Sampling (fall)	10 to 12 Oct
Fish Population Index Survey	1 to 8 Jun

2. Methods

The general approach to this monitoring program is to collect a long-term data set on the fish population and habitat conditions in Downton Reservoir in order to resolve data gaps and better inform the trade-off decisions made during the WUP process. Collection of information on reservoir operating parameters, habitat conditions, and the resident fish population (including life history information, age structure, biological characteristics, and an index of abundance) is intended to allow identification of potential broad scale changes. Trends in these changes over time can be used to test hypotheses (presented in Section 1.2) about the relationship between reservoir operations and fish population response.

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

2.1. Temperature Monitoring

Temperature monitoring was conducted to document the thermal profile in the reservoir during the period of stratification, and temperature conditions in the tributaries across the rainbow trout migration, spawning, incubation and growth periods (April to October). Temperature loggers were removed from late fall to early spring (November to March) due to adverse conditions during this period that can cause damage or loss of gear, and preclude access to sites. Water temperatures tend to be the lowest and most consistent across sites and reservoir depths (i.e., isothermic conditions) across these months, which is also when biological activity slows or ceases (i.e., fish stop growing), so the lack of data for this period of the year was not considered significant for answering the management questions. Temperature monitoring has been conducted as part of the BRGMON-7 program every year since Year 3 (2015). Temperature data for this context were not available for the first two monitoring years in 2013 and 2014.

A vertical temperature logger array was suspended from the log boom at the east end of Downton Reservoir. Individual temperature loggers were also deployed in five tributary streams: Ault Creek, Trib. #13, Trib. #16, Jamie Creek, and the Upper Bridge River (UBR). The loggers were installed on 19 April, checked and downloaded on 13 June, 1 August, and 6 September, and retrieved for the end of the monitoring period on 11 October, 2018. The locations of the temperature array and other loggers in the study area are shown on Figure 2.1 (in Section 2.2).

The temperature loggers were TidbiT v2 loggers (model UTBI-001) manufactured by Onset Computer Corporation. For the log boom array, 7 loggers were attached to a chain suspended vertically near the midway (i.e., deepest) point at the following intervals: 0.5, 4.0, 8.0, 12.0, 16.0, 20.0, and 24.0 m from the surface. This arrangement was intended to span the thermal layers when the water column is stratified. Water column depth at the log boom location varies from ~8 m at 710 m reservoir elevation to ~32 m at the 734 m *modified* maximum elevation and ~47 m at the 749 m normal maximum. Loggers deployed in the tributaries were fixed to a weight (i.e., a brick) that was connected to an anchor point on shore using a length of cable. This was necessary to keep the loggers submerged and facilitate retrieval.

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

Predicted emergence dates were calculated for each monitoring year that included temperature data collection during the rainbow trout spawning and incubation period (late May to mid July). Hourly tributary temperature data collected by loggers (summarized as weekly means) were run through the model WinSIRP version 2.0 (Microsoft Windows®-based Salmonid Incubation and Rearing Programs, designed for Microsoft Excel®; Jensen et al. 2009). This model includes an incubation module that predicts embryonic development, for various (selectable) salmonid species, in response to temperature and associated metabolic responses (i.e., oxygen consumption and ammonia excretion). The predicted range of emergence dates was generated by running the weekly mean temperatures from the start, peak, and end of the rainbow trout spawning period.

2.2. Habitat Surveys

As in Years 3 and 4 (2015 and 2016), habitat surveys were conducted to document habitat characteristics in the reservoir and tributaries to supplement the fish sampling data. Habitat survey activities included: a) habitat mapping; b) quantifying substrate sizes, interstitial depth, and bank slope among each of the identified habitat types; and c) characterizing habitat areas above and within the drawdown zone in four known spawning tributaries. These activities in Year 6 (2018) represented the fourth year of habitat data collection and specifically targeted reservoir elevations, sites and tributaries that were not yet assessed in the previous three years in order to supplement and expand the existing data set. Understanding how the selected habitat variables vary according to reservoir elevation may prove useful for interpreting the effects of various reservoir operating scenarios on fish population response.

Habitat Mapping

Habitat mapping involved characterizing and mapping the entire shoreline of Downton Reservoir by boat. Due to high turbidity, the habitat type observed at the water-shoreline interface was considered representative of the habitat ~5 to 10 m offshore where the fish sampling typically occurs. In 2018, the habitat mapping was conducted at ~734 m elevation in early September, which corresponded to the *modified* maximum reservoir elevation. To accomplish the survey, the boat was propelled forward at slow speed adjacent to the shoreline. The habitat type was recorded for each unit and breaks between units were marked as waypoints on a GPS device. The GPS unit also recorded the boat track, which conformed to the shape of the shoreline in each unit, enabling more accurate measurement of shoreline length once coordinates were transferred to mapping software in the office.

The parameters recorded for the habitat mapping included: shoreline habitat type (i.e., creek mouth, fan, shallow slope <15°, steep slope >15°, dam face); habitat sub-type (colluvium or bedrock) for steep habitats only; UTM coordinates for the start and end of each unit; boat track; and presence/absence of adjacent terrestrial vegetation on shore. Representative photographs of the reservoir shoreline habitat types (and sub-types), as well as tributary habitats, are provided in Appendix A (Photos A1 to A9). The collection of these data allowed for calculation of total shoreline length, the length and number of units for each habitat type and sub-type, as well as the proportion of shoreline that interfaces with adjacent terrestrial vegetation. These values are important for evaluating differences in these parameters across the range of reservoir operating levels and for determining the relative proportion of sites for each habitat type to be sampled during the annual fish abundance index survey (Section 2.6, below). Previous surveys at ~745 m (near normal maximum), ~722 m (fish sampling level), and ~716 m (low pool) reservoir elevations were conducted using the same methods in Year 3 (2015), Year 4 (2016), and Year 5 (2017), respectively.

Substrate Measurements

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

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 that can be analyzed for trends among elevations and habitat types. During Year 6 (2018), measurements were primarily taken at ~722 m (low pool; fish sampling elevation) in both the reservoir and tributary sites. These data were intended to directly supplement and expand on the substrate measurement data collected during previous years at ~734 m and ~747 m for the reservoir, representing *normal* maximum and *modified* maximum levels; and upland (>749 m) and drawdown (<747 m) areas for the tributaries, representing habitats outside versus inside of the reservoir zone of influence. The goal was to generate a comparable sample size at each selected elevation, and characterize each of the habitat strata sampled for the fish monitoring components (see Sections 2.4 to 2.6).

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; however, the substrate composition between the top and bottom of this narrow band would not likely be significantly different relative to differences among the surveyed elevations (i.e., 747 m vs. 734 m vs. 722 m). Similarly, substrate composition was not considered likely to change further at elevations <722 m, since fines and small gravels were already so dominant at this reservoir level. Therefore, 722 m has been the lowest elevation surveyed.

Substrate measurement locations were selected from the list of fish sampling sites in the reservoir (2018 *n*=22), as well as in tributaries that are generally accessible to fish from the reservoir (2017 *n*=4) (Figure 2.1). At each site, a tape measure was laid out for 30 m parallel to a selected elevation for reservoir sites, or along the stream axis for tributary sites. As such, vertical elevation varied by 1 to 6 m (depending on the slope) across the 30 m distance in the creeks, but this was not considered significant to the analysis relative to the total vertical difference among selected survey elevations. The piece of substrate directly under each 1 m marker (from 0 to 30 m) was measured for the length of its intermediate axis (neither the longest nor shortest of the three mutually perpendicular sides of each particle – also known as the b-axis) as well as the interstitial space associated with the substrate. As such, 31 measurements were recorded for each elevational zone at each site.

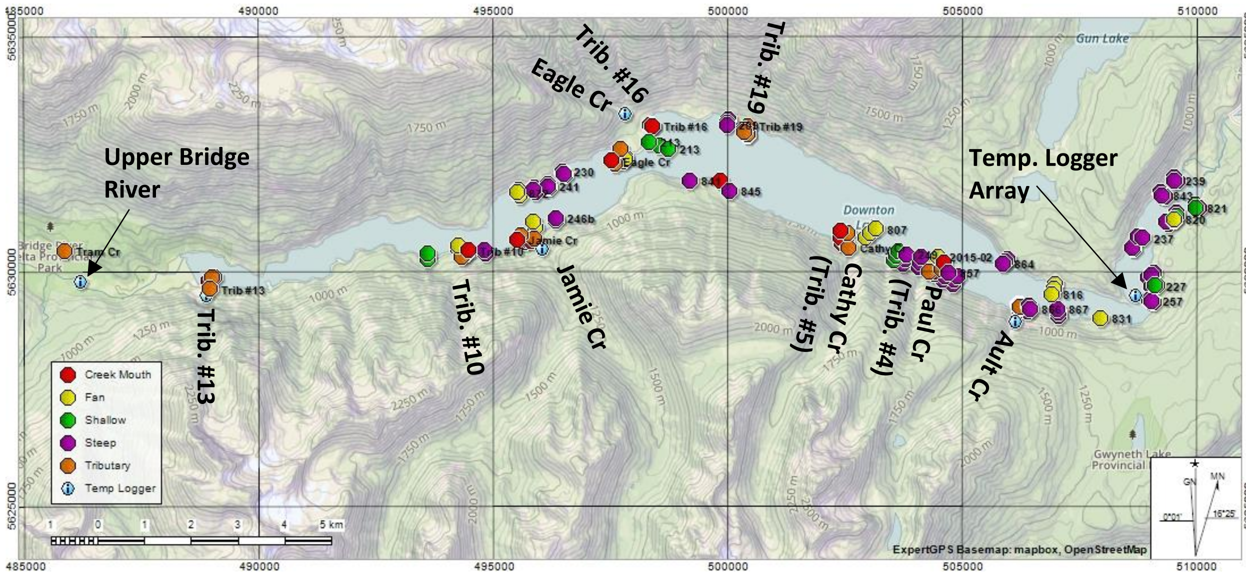

Figure 2.1 All substrate measurement locations to-date as of Year 6 (2018). Multiple dots at each location refer to measurement transects at 747 m (near maximum reservoir level), 734 m (*modified* maximum level), and 722 m (fish sampling level). Surveyed tributaries are labelled and the locations of temperature logger deployments are also shown.

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

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

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

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

2.3. Tributary Access Surveys

Under the *modified* operations initiated in Year 4 (2016) and going forward, the target fill elevation for Downton Reservoir has been reduced, which decreases the total storage volume of the reservoir significantly (see Section 1.4). 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 reservoir elevations of potential concern, tributary access surveys were conducted on a couple of dates during the rainbow trout migration and spawning period to identify and document any areas where access may be blocked or obstructed due to low water levels. This was noted for Ault Creek in May 2014 (Year 2) when reservoir elevations were <710 m and creek flows were low (i.e., pre-freshet; Refer to Sneep 2015 for more information and photos). In this case stream flows went to ground before reaching the reservoir edge. Some tributaries have also been noted to periodically run dry (e.g., Trib. #10, Trib. #19) This usually occurs in mid-summer after the spawning period is over, but potentially during the egg incubation period which can extend until the end of August or beginning of September.

Tributary access surveys were initiated in Year 3 (2015) and repeated again in Years 4 (2016), 5 (2017) and 6 (2018). They were timed to target the conditions at the start of the rainbow trout migration and spawning period when the tributaries are typically still in pre-freshet condition and the reservoir is beginning to fill from its lowest elevation. The surveys involved a field crew visiting creek mouths (on foot or by boat) to assess connectivity and continuity between the creeks and the reservoir pool or the section of the Upper Bridge River channel that winds through the reservoir basin under drawdown conditions. Each creek was assigned an access score of TRUE (continuously connected with no apparent access issues) or FALSE (not connected or blocked). Crews recorded notes about any observations in the field book and took photos.

2.4. Tributary 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) which started in Year 4.

Spawner surveys were conducted (or at least attempted) on a weekly basis during the rainbow trout spawning period (generally mid May to late July in Downton Reservoir) to get a relative weekly count. Access to known spawning tributaries by field crews can be hampered at this time of year by slides and avalanches or low reservoir levels, which precluded some surveys. Flow levels and turbidities in the creeks 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, Eagle Creek (Trib. #16), Trib. #19, and Tram Creek (Figure 2.2). In addition to these tributaries, surveys in Year 6 (2018) were also conducted at Jamie Creek, Cathy Creek and Ault Creek to document potential spawning use of these accessible, but generally under-utilized sites. 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 Eagle Creek and Trib. #19 since that time. Therefore, access to these north side tributaries for the weekly surveys has been attempted by boat. Despite the more involved logistics, access by this method has been successful on many of the survey dates. However, access was precluded for some surveys due to low reservoir levels (i.e., <720 m).

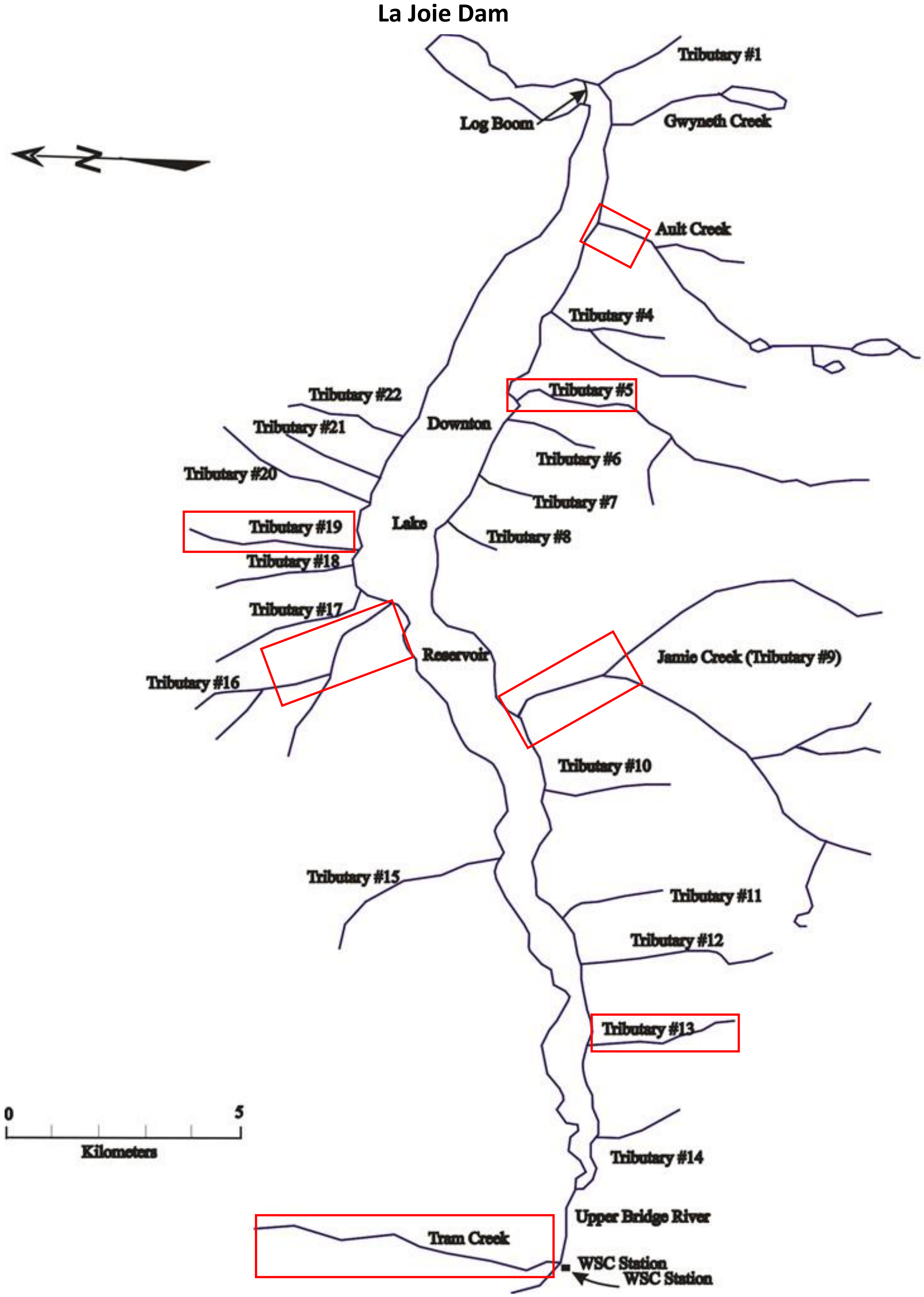

Figure 2.2 Downton Reservoir and the relative location of tributaries. Streams that were monitored for this program in Year 6 (2018) are outlined in red.

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 the 749 m normal maximum 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, visibility & discharge (as described above), 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 peak abundance in a few key tributaries.

For the first time in Year 6 (2018), stream length was also measured for each assessed tributary during the spawner surveys. This provided information on the amount of tributary habitat available to spawners in the selected creeks within the drawdown zone of the reservoir, and how that changes as the reservoir fills across the spawning period. Stream length was measured on each survey date using a hip chain which was tethered to a piece of vegetation at the top of the drawdown zone and along the route as the technician walked downstream along the stream axis to the reservoir edge. This length was recorded on the data sheet in meters. Additionally, lengths of the spawner survey area in the upland zone (i.e., outside the influence of the reservoir) were measured once for each creek.

2.5. Tributary Fish Sampling

Seasonal use of Downton Reservoir tributaries for rearing by rainbow trout was assessed by backpack electrofishing (backpack EF) in a range of creeks. The fall survey completed in 2018 was intended to complement the information on seasonal rearing use previously collected in spring (2016) and summer (2017), which were documented in the Year 5 (2017) report. Sampled tributaries included: Ault Creek, Paul Creek (Trib. #4), Cathy Creek (Trib. #5), Trib. #19, Eagle Creek (Trib. #16), Jamie Creek, Trib. #13, Tram Creek, and the Upper Bridge River (UBR; see Figure 2.2 in Section 2.4). Fall sampling was completed from 10 to 12 October 2018.

For each sampled creek, the surveys targeted a site within the drawdown zone (<747 m elevation) and the upland zone (>749 m elevation). As with the substrate measurements, it was not possible to include the 2 m extent between 747 m and 749 m elevation in the sites for the selected creeks due to the deposition of large woody debris from the reservoir within this range. The upland zone in a couple of the tributaries were not sampled either because the habitat above the current (~731 m) reservoir elevation was far too steep (i.e., Ault Creek), or the stream channel was too overgrown with dense vegetation cover to be sampled effectively (i.e., Paul Creek).

A total of 15 tributary sites were sampled in fall 2018 (drawdown zone *n*= 7; upland *n*= 8). Sites were each 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, but the netter employed both a large bag-style dip net in one hand, which was held immediately downstream of the pass of the anode wand (i.e., to catch stunned fish not seen at the surface), and a smaller dip net in the other hand for more agile dipping of mobile fish. Sampling was conducted from bank to bank (i.e., spanned the full stream width) in the smaller creeks, and was conducted along one shoreline (extending out from the wetted edge to the mid-channel velocity limit for juvenile salmonids) in Jamie Creek and the UBR. 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, scanned for the presence of a PIT tag, and measured (fork length to the nearest mm and weight to the nearest gram). Unmarked fish of a suitable size (≥80 mm FL) were injected with a PIT tag under the skin. Ageing structures (i.e., scales) were also collected from a sub-set of sampled fish according to size. All of these data were recorded into a field notebook, and also included 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.

2.6. 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 biological characteristics 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. As in years 3 to 5 (2015 – 2017), the index survey in Year 6 (2018) was completed as one extended survey in the spring (early June). Based on the results from the first two monitoring years (2013 & 2014), 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 6 (2018) followed a stratified design as described in previous monitoring reports for Year 1 (Sneep 2015), Year 3 (Sneep 2018a), Year 4 (Sneep 2018b), and Year 5 (Sneep 2019). The strata were the five main habitat types identified during the shoreline habitat mapping survey (i.e., creek mouth, fan, shallow slope, steep slope, and dam face – see representative photos in Appendix A). The number of sites selected for each strata was based on two main objectives: 1) generally assign the number of sites to each strata according to the contribution of each type to the total shoreline length of the reservoir at the sampled elevation (based on the habitat mapping results – see Section 3.3); 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 2.3). 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 6 (2018) was 1 to 8 June. As in previous years, the reason for this timing was to optimally align the following survey conditions: a) adequate reservoir level to be able to use the only boat launch for accessing the reservoir; b) appropriate water temperatures to facilitate electrofishing effectiveness, and c) prior to the bulk of the rainbow trout spawning migration into the tributaries, which affects a portion of the fish ages 3 and up. While all available age classes are sampled, the main ones of interest for tracking an annual recruitment index (Age 1 and 2 fish) primarily reside in the reservoir year-round, so catches for these fish should not be affected by migrations or potential changes in spawn timing across the study period.

Boat EF is conducted by running an electrical current through the water between a set of boom-mounted anodes extended off the front of the boat and a cathode array, while propelling the boat forward at slow speed (~1 to 2 km/h). Within the electrical field that this generates, fish are stunned and drawn up to the surface where they can be netted by two 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.

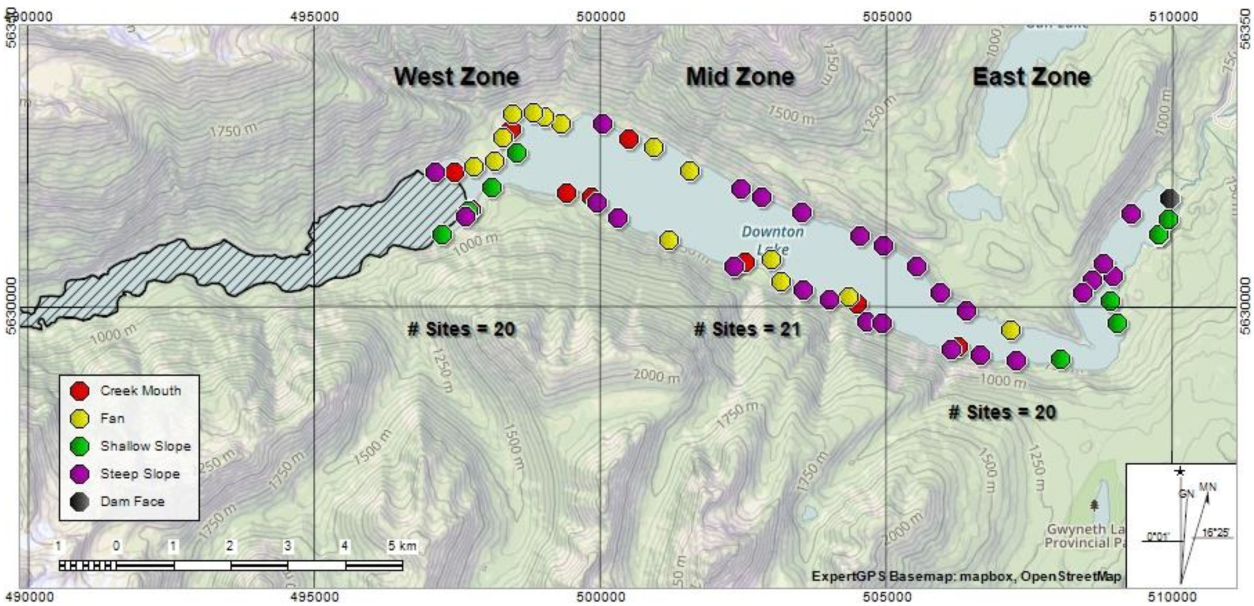

Figure 2.3 The three longitudinal zones (west, mid, and east) and the distribution of sites for the fish population index survey conducted from 1 to 8 June 2018 (at 720 m to 721 m reservoir elevation). Note: The hashed-out area represents the dewatered portion of the reservoir basin at the time of the survey.

Boat electrofishing was conducted at night. At each site, the boat was maneuvered to a pre-designated starting point (GPS coordinate) along the reservoir perimeter from which a section of edge habitat was electrofished. The following boat EF settings were used: Electrofisher = Smith-Root 5.0 GPP; Voltage Range = High (50 – 1000 V); % of Power = 20% to 80%; Output = ca. 3 to 5 amps; DC Current Mode; Frequency = 60 DC pulses/sec. A total of 61 sites were sampled (creek mouth *n*= 9; fan *n*= 16; shallow *n*= 8; steep *n*= 28) covering 17,242 m of shoreline length. Sampling effort was based on a target site length of 300 m for steep, shallow, and fan habitat types. Site length for creek mouths was targeted to extend ~50 m on either side of the tributary inflow. Each site spanned only one habitat type and was sampled in a single pass.

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

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

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

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

Photo 2.1 Floating fish-holding tank used during the 2017 & 2018 Downton Reservoir fish population index survey to assess the incidence of fish mortality and tag loss 24-hours post-capture.

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

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

Where:

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

We also assessed length-weight relationships by plotting the log-transformed lengths versus the log-transformed weights for each study year and comparing the annual regressions to look for changes or differences among years. Fulton's Condition Factor (K) was also calculated to characterize the body condition of each rainbow trout measured for length and weight from Downton Reservoir according to the following equation (Anderson and Neumann 1996):

$$K = \frac{W \times 10^N}{L^3}$$

Where:

W is weight in grams;
L is forklength in millimeters; and
N is an integer that scales the condition factor close to a value of 1 (N=5 for Downton Reservoir).

We calculated the mean condition factor by age class for each study year, as well as the standard deviations and standard error.

2.7. Laboratory Analysis

Following a period of air drying, 200 rainbow trout scale samples were mounted by St'at'imc Eco-Resources technicians in preparation for ageing. Mounting involved pressing the scales onto plastic strips, which were softened by heat, to transfer precise images that could be viewed and magnified using a microfiche reader following the methods of Mackay et al. (1990). Scale reading to determine fish ages was conducted on 185 of the mounted samples (15 were noted as un-readable due to regeneration or other factors) by staff at Instream Fisheries Research (IFR). First, second and final scale readings to determine fish ages were conducted by Jennifer Buchanan and Dani Ramos-Espinoza (both from IFR).

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

2.8. 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 an SER technician (Kelsey Alec). Data quality assurance (QA) checks were completed by the Project Manager (Jeff Sneep).

All entered data were compiled into an active Microsoft Excel (2016) database that already includes the data from years 1 to 5 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 "Google Drive"). 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 2018, which are illustrated in Figure 3.1. Daily surface elevations for monitoring years 1 to 5 (2013 to 2017) are also included for reference.

The management of surface elevation in Downton Reservoir follows a seasonal pattern: lowest elevations occur in spring (generally April to May) and highest elevations, or full pool, occur in late summer to early fall (August and September). The timing, duration and magnitude of low pool and full pool elevations vary from year-to-year, as well as the rates of drawdown and fill between these periods and across the rainbow trout spawning window (Figure 3.1). We are tracking these statistics for each study year as they may prove to be informative variables related to fish recruitment, survival and growth for the reservoir fish population. This will ultimately be evaluated at the end of the monitoring period when all years of data are available for a synthesis using a multivariate statistical analysis approach that incorporates annual fish catch results, size and condition factor with key physical and habitat variables (e.g., minimum and maximum reservoir elevations, drawdown and fill rates, habitat type distribution, substrate size classes available, etc.).

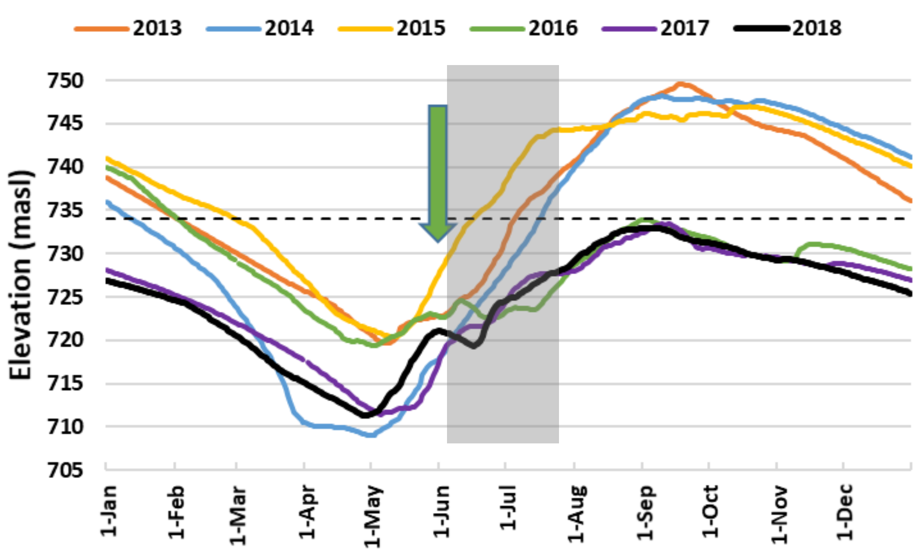

Figure 3.1 Daily surface elevations in Downton Reservoir, 2013 to 2018. For reference, the shaded area represents the observed rainbow trout spawning period and the green arrow indicates the timing of the annual population index survey. The horizontal dashed line indicates the target modified maximum fill elevation (734 m), which was implemented in Years 4 to 6 (2016 to 2018).

The modified maximum elevation target (i.e., 734 m) was implemented for the first time in Year 4 (2016) and again in Years 5 and 6 (2017 and 2018). Reservoir operation in 2018 was nearly identical to 2017 across the year, other than that low pool elevations extended approx. 2 weeks later in May before filling. At the start of 2018, reservoir elevation was 726.9 m as it was drawing down from the 2017 maximum fill level of 733.5 m. The mean drawdown and fill rates for the reservoir were -10 cm/day and +19 cm/day, respectively (Table 3.1). Lowest reservoir elevation (i.e., 711.3 m) occurred from 27 to 29 April, and summer full pool elevations occurred from 21 August to 13 September 2018 (max. = 733.0 m on 3 September). The reservoir had been drawn down to 725.4 m by the end of December.

Table 3.1 Minimum and maximum reservoir elevations, and mean and maximum drawdown and fill rates for Downton Reservoir during study years 1 to 6 (2013 to 2018).

Study Year	Reservoir Elevations (m)			Drawdown Rates (cm/day)[a]		Fill Rates (cm/day)[b]	
	Min.	Max.	Diff.	Mean	Maximum	Mean	Maximum
1 (2013)	719.69	749.53	29.84	-15	-21	+23	+73
2 (2014)	709.00	748.23	39.23	-20	-80	+31	+81
3 (2015)	720.40	746.98	26.58	-14	-30	+33	+58
4 (2016)	719.38	733.94	14.56	-14	-28	+12	+55
5 (2017)	711.47	733.46	21.99	-9	-29	+17	+69
6 (2018)	711.29	732.96	21.67	-10	-22	+19	+67

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

The total differential between minimum and maximum elevations was ~22 m in 2018, which was similar to 2016 and 2017 (the other years of modified operations). The min/max differentials during previous study years of normal (i.e., N2-2P) operations from 2013 to 2015 were between ~27-39 m. The 2018 minimum elevation (711.3 m) was most similar to 2014 (709.0 m) and 2017 (711.5 m), and ~8 to 9 m lower than the other study years. The mean drawdown and fill rates (-10 cm/day and +19 cm/day, respectively) were on par with the other *modified* operations years (i.e., 2016-2018) and generally lower than the normal operations years (2013-2015).

The change from normal maximum fill elevation of 749.81 m to 734.00 m under modified operations, represented a ~16 m reduction in fill level; however, maximum fill levels within each operational treatment (N2-2P vs. *modified*) have been fairly consistent. In addition to that change, the minimum drawdown elevation has been different among groups of years and did not strictly conform to the two operational treatment periods (i.e., ~720 m in 2013, 2015 and 2016; ~710 m in 2014, 2017 and 2018). As such, the total differential varies both within and among operational treatments (according to both minimum and maximum levels in any given year), which should provide ample contrast for assessing the fish population response across the period of monitoring, but the limited number of years of 'standard' N2-2P operations may limit certainty in the comparison of the broader operational strategies (i.e., N2-2P vs. modified operations).

3.2. Temperature Monitoring

Monthly water temperatures for the April to October period at the reservoir log boom array and in the monitored tributaries are displayed in Figures 3.2 and 3.3, respectively. Comparable figures for all available study years to-date (i.e., 2015 to 2018) are provided in Appendix B (Figures B1 and B2).

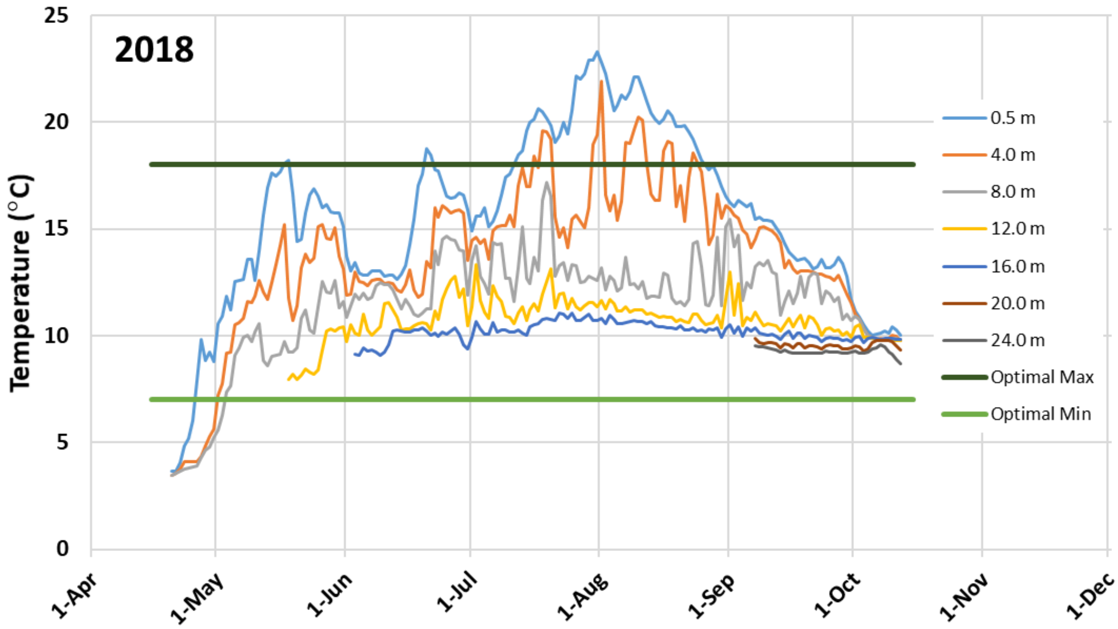

Figure 3.2 Mean daily water temperatures by depth from the Downton Reservoir log boom array, April to October 2018. The light and dark green horizontal lines bracket the preferred temperature range of rainbow trout (McPhail 2007).

Based on the log boom array data, thermal stratification in the reservoir begins sometime in late April or early May and extends until late September to mid October (depending on the year; Appendix B, Figure B1). The reservoir becomes isothermic (consistent temperature from surface to bottom) from mid October to mid April, though temperature loggers were not deployed across this seasonal period as described in Section 2.1.

In Year 6 (2018), mean daily surface temperatures increased from 3.6°C to 18.0°C from mid- April to mid-May, and then decreased to 13.0°C across the first two weeks of June as snow-melt inflows increased into the reservoir at low pool. Temperatures at depth followed a similar trend, but with lower magnitudes across this period. Surface temperatures increased across the month of July, peaked at 23.3°C on 31 July, and then gradually cooled to 10°C by mid-October. Across the period of thermal stratification, there was a gradient of temperatures between the surface and 12 m, which corresponded to the depth of the thermocline (within the limits of precision available from the depth intervals of the loggers). From 16 m and below, temperatures at each depth interval remained within a narrow range, between 8.7°C and 11.1°C, throughout the monitored period. Other than a higher peak temperature in 2018 (23.3°C), relative to past monitored years (2015 to 2017 range = 21.2°C to 21.8°C), the temperatures and patterns were generally similar to those reported for previous years (Sneep 2019).

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

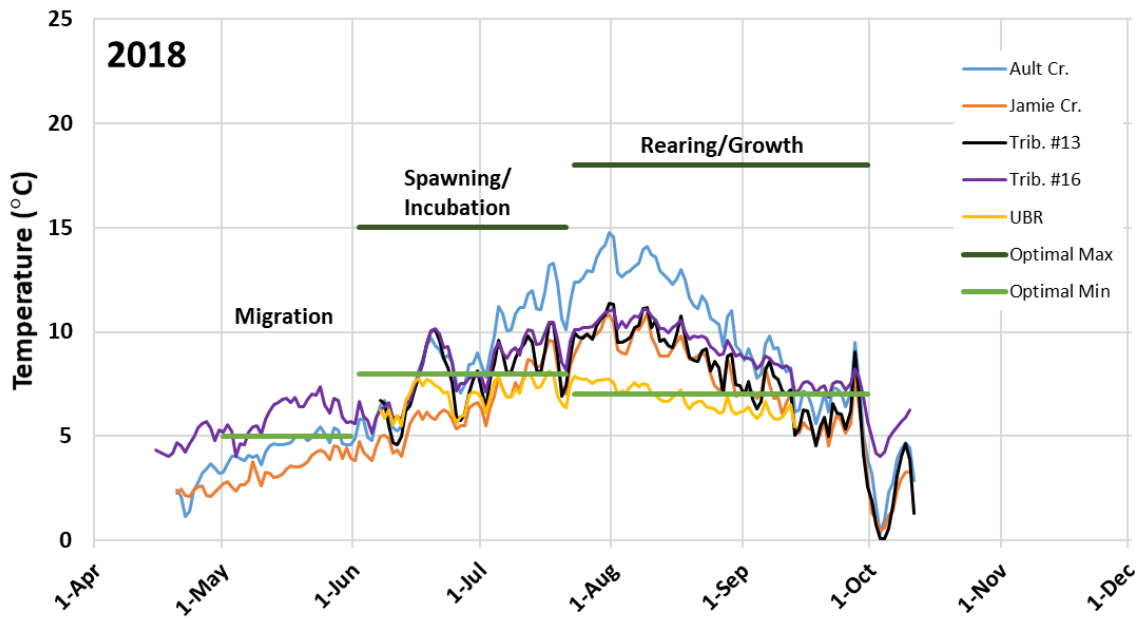

Figure 3.3 Mean daily water temperatures in a set of Downton Reservoir tributaries, April to October 2018. The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of rainbow trout (McPhail 2007).

Relative to the reservoir, temperatures in the tributaries tended to be much cooler, and were variable among streams. Maximum daily mean temperatures ranged from 8.1°C (in the Upper Bridge River) to 14.7°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 Creek) tended to have warmer temperatures (and within preferred ranges by life history period), relative to Jamie Creek and the Upper Bridge River. Temperatures in Jamie Creek were generally below optimal thresholds for the spawning and incubation period, and the Upper Bridge River was generally below optimal thresholds for most of the monitored period in every year to-date. These differences in thermal regimes among tributaries could be one of the factors that influences stream selection for spawning and rearing, and could explain why observed fish use during the spawner streamwalks and tributary fish sampling surveys varies among them (see Sections 3.5 and 3.6).

The differences in the thermal regimes among tributaries and the reservoir context are also supported by comparison of mean temperatures according to seasonal or life history period for rainbow trout (Table 3.2). Again, creeks with higher values are the ones that coincide with the highest observed fish use for spawning and feeding (Trib. #13, Trib. #16 and Ault Creek). By comparison, mean temperature values at the reservoir surface tended to be higher (by a factor of 2) than the values from any of the creeks. As in previous monitoring years, the temperature data collected in Year 6 (2018) further support that temperatures may be a factor that contributes to observed patterns of fish use and distribution among creeks, and between creeks and the reservoir, in the study area.

The values in Table 3.2 also offer a comparison of relative thermal trends between years for each season/life history period. Among the four years available to-date, 2015 had warmer mean temperatures in the spawning creeks (e.g., Tribs. #13 and #16) during both the Pre-Spawn/Migration and Spawning/Incubation periods by 1.0 to 1.8°C. Despite these differences, mean temperatures were within optimal ranges for most of that period in each year, and peak spawn timing was similar (i.e., mid to late June), as reported previously (Sneep 2018b). Notably, this observed spawn timing for the Downton Reservoir population coincided with the period when the mean temperatures reached and exceeded the optimal minimum temperature threshold (i.e., 8°C). Temperatures during the Rearing/Growth period tended to be warmest in Year 5 (2017) so far, but were generally quite similar among years (means varied by only 0.2°C to 0.8°C).

Collection of temperature data in the tributaries during the spawning period allowed for the prediction of emergence timing based on modelling the accumulated thermal units (ATUs) using WinSIRP version 2.0 (Table 3.3; Jensen et al. 2009). Based on the model outputs, emergence timing has not varied significantly across the years available to-date (2015 to 2018). In general, predicted emergence begins at the end of July or early August, peaks in the third week of August, and is complete by the end of August or early September. These predictions were corroborated by the capture of recently emerged fry (23 to 33 mm forklength) in several tributaries sampled by backpack electrofishing at the end of August 2017 (see Section 3.6; Sneep 2019). The incubation period ranged from a minimum of 47 days to a maximum of 64 days for eggs fertilized late versus early in the spawning period, respectively (median incubation= ~50 days). Based on the model estimates, the emergence timing has been quite consistent, with peak timing varying by only 1 to 8 days between years.

Due to the late spawn-timing for the Downton Reservoir population, as noted in past reports, the new year-class of fry also emerge from the substrate much later in the growing season relative to rainbow trout populations lower in the watershed (i.e., Lower Bridge River). As a result, the available rearing/growth period in their first season may only be ~3 to 7 weeks long (depending on emergence timing) before tributary temperatures drop below optimal levels in the latter part of September. The new year-class of rainbow trout sampled in tributary streams during fall 2018 (i.e., 10-12 October) were still relatively abundant in the sampled creeks and ranged from 20 to 58 mm by that time (see Section 3.6).

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

Location	Year	Mean Temperatures by Season / Life History Period			
		Pre-Spawn/ Migration (15 to 31 May)	Spawning/ Incubation (1 Jun to 21 Jul)	Rearing/ Growth (22 Jul to 30 Sep)	Overall Mean
Upper Bridge River	2015	5.6	6.9	6.0	6.3
	2016	5.5	6.7	6.5	6.5
	2017	4.9	6.3	6.8	6.4
	2018	-[a]	7.0	6.8	6.9
Jamie Cr.	2015	4.1	7.6	7.4	7.1
	2016	4.3	6.2	-	-
	2017	3.3	5.4	8.1	6.6
	2018	3.9	6.3	7.8	6.8
Trib. #13	2015	7.6	8.8	7.9	8.2
	2016	6.0	7.8	8.4	7.9
	2017	6.4	7.2	8.7	7.9
	2018	-	7.9	8.2	8.1
Trib. #16	2015	7.8	9.4	9.0	9.0
	2016	6.7	8.3	9.4	8.7
	2017	6.6	7.6	9.3	8.4
	2018	6.5	8.1	9.1	8.4
Ault. Cr.	2015	-	-	-	-
	2016	5.3	8.7	11.0	9.5
	2017	-	-	-	-
	2018	4.9	8.7	10.3	9.0
Reservoir Surface	2015	16.4	19.3	17.2	17.9
	2016	14.2	16.7	17.5	16.9
	2017	-[b]	17.4	18.0	17.7
	2018	16.3	16.1	17.8	17.0

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

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

However, this emergence timing might explain why the majority of the population >Age-0+ appears to rear in the reservoir where temperatures remain warmer longer into the fall (i.e., longer growing season), and provide some additional clues about why certain accessible tributaries with seemingly suitable habitat available in the spring are not selected for spawning:

a) some have been observed to go dry by August or earlier (e.g., Trib. #10, Trib. #19), which would desiccate eggs before the fry hatch or emerge, and b) the temperatures in some creeks (e.g., Jamie Creek) tend to be colder across the incubation and growth periods, such that fry would emerge even later. Given the already limited duration of the first growth period for Age-0+ trout fry in this context, later emergence would likely not be sustainable.

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

Tributary	Year [a]	Predicted Emergence Dates (# of Incubation days)		
		Start	Peak	End
Trib. #13	2015	29 Jul (55)	25 Aug (52)	31 Aug (53)
	2016	31 Jul (60)	21 Aug (52)	10 Sep (52)
	2017	01 Aug (64)	20 Aug (56)	02 Sep (53)
	2018	2 Aug (59)	17 Aug (52)	12 Sep (54)
Trib. #16	2015	25 Jul (51)	21 Aug (48)	26 Aug (48)
	2016	28 Jul (57)	18 Aug (49)	05 Sep (47)
	2017	30 Jul (62)	17 Aug (53)	31 Aug (51)
	2018	30 Jul (56)	15 Aug (50)	7 Sep (49)

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

3.3. Habitat Surveys

Habitat Mapping

The habitat mapping in 2018 documented the proportional availability and distribution of shoreline habitat types around the entire wetted perimeter of Downton Reservoir at ~733 m elevation, representing the *modified* maximum level (i.e., 734 m). These data were intended to supplement the existing survey data collected at 745 m (near normal maximum) in August 2015, 722 m (representing the typical fish population index sampling level) in May 2016, and 716 m (representing low pool conditions) in May 2017 (Figure 3.4). At the 733 m elevation assessed in Year 6 (2018), the length of the reservoir was 22.5 km, and the total length of shoreline habitat was 53.7 km (Table 3.4), which were approx. 12% less than the values for the near normal maximum level (745 m), and approx. 18% and 32% greater than the 722 m and 716 m elevations, respectively. The habitat to the west of each surveyed perimeter shown on Figure 3.4 represented the drawdown (i.e., non-inundated) portion of the reservoir basin at each elevation.

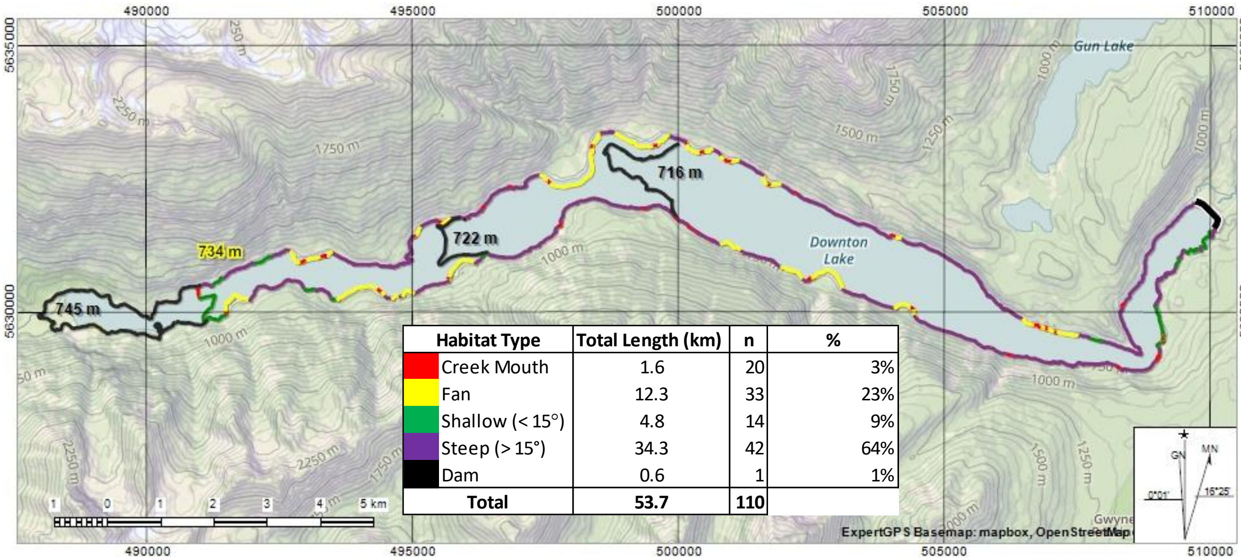

Figure 3.4 Results of a shoreline habitat mapping survey conducted at the *modified* maximum elevation (734 m – coloured perimeter) in September 2018. Note: The dark grey lines represent the wetted extent of the reservoir at low pool (~716 m), the typical elevation for the fish population index sampling (~722 m), and the near normal maximum reservoir elevation (~745 m).

Table 3.4 Summary of habitat strata contributions to total shoreline length in Downton Reservoir based on the near full-pool (745 m elevation), *modified* maximum elevation (734 m), fish sampling elevation (722 m), and low pool (716 m) habitat mapping.

Habitat Type	**Habitat Sub-type**	**Total Length (km) and % Contribution**			
		~ Full Pool Elevation (745 m)	**Modified Maximum Elevation (734 m)**	**Fish Index Survey Elevation (722 m)**	**~ Low Pool Elevation (716 m)**
Creek Mouth		1.2 **2%**	1.6 **3%**	1.8 **4%**	2.9 **8%**
Fan		13.2 **22%**	12.3 **23%**	8.4 **21%**	7.7 **22%**
Shallow (< 15°)		4.1 **7%**	4.8 **9%**	7.6 **19%**	6.2 **18%**
Steep (> 15°)	Bedrock	9.7 16%	6.9 13%	2.7 7%	1.6 5%
	Colluvium	30.9 51%	27.5 51%	20.0 49%	15.8 46%
	Total Steep	40.7 **67%**	34.3 **64%**	22.7 **56%**	17.4 **51%**
Dam		1.1 **2%**	0.6 **1%**	0.4 **1%**	0.3 **1%**
Totals		**60.3 100%**	**53.7 100%**	**40.9 100%**	**34.5 100%**

Reservoir Length (km)	25.6 **100%**	22.5 **88%**	17.8 **70%**	14.2 **56%**
Terrestrial Veg. (km)	21.3 **35%**	5.7 **11%**	0.0 **0%**	0.0 **0%**

The presence/absence of terrestrial vegetation adjacent to the wetted edge of the reservoir is documented for each survey because terrestrial vegetation can be an important source of allochthonous nutrients to littoral food webs in aquatic systems (Perrin et al. 2016). Depending on the primary food sources for the rainbow trout in Downton Reservoir, documenting differences in the availability of overhanging vegetation among the different reservoir elevations may provide relevant information for supporting the fish size-at-age analysis at the conclusion of the monitor.

At the normal maximum level (745 m) there was adjacent vegetation documented for 35% of the shoreline length. 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 716 m and 722 m levels. At the modified maximum level, there was overhanging vegetation along approx. 11% of the shoreline (mostly at the top of steep bedrock outcrops). However, it was also noted that terrestrial vegetation (starting with ground cover species) was beginning to colonize the non-undated portion of the drawdown zone between the normal maximum fill level (749.81 m) and the modified maximum level (734 m). This succession is expected to continue as long as the modified maximum fill target is met, and until normal operations resume at some point in the future.

For the Year 6 (2018) habitat mapping survey at 733 m reservoir elevation, steep shorelines (slope > 15°; *n*= 42 units) were again the most prevalent type, contributing 34.3 km (64%) to the total perimeter length. The majority (27.5 km or 80%) of this steep terrain was made up of alluvial or colluvial material (rocks, boulders and other loose sediment particles), and a smaller portion (6.9 km or 20%) was bedrock. Fans (*n*= 33 units) were the next most prevalent habitat type in the reservoir, contributing 12.3 km (23%) to the total shoreline length. Fans, which generally have a shallow slope, are formed by alluvial processes associated with tributary streams and intermittent drainages in the valley.

The remaining habitats were shallow shorelines (slope <15°; *n*= 14) and creek mouths (*n*= 20), which contributed 4.8 km (9%) and 1.6 km (3%) to the total perimeter distance, respectively. At the east end of the reservoir, the wetted portion of the La Joie Dam face was 0.6 km long, again comprising 1% of the reservoir shoreline. Relative to the normal maximum level, the length of the dam-reservoir interface was progressively reduced at the lower reservoir elevations (733 m, 722 m and 716 m) because the reduced footprint of the reservoir exposed shallow and steep shorelines adjacent to the toe of the dam on the north and south shores (see Appendix A, Photos A6 and A7).

There were some interesting differences in the contributions of the various habitat types among the surveyed elevations. In general, other than the absolute differences in longitudinal and shoreline habitat lengths, the percent contributions of each habitat type were similar between the two maximum elevations (i.e., near-normal and modified), and between the two low pool elevations (722 m and 716 m). But there were some notable differences between the full pool versus low pool levels.

At 733 m, there was an increase in steep shoreline habitat by 11.6 km and 16.9 km (or 50% and 97%) relative to 722 m and 716 m. At 745 m elevation, the amount of steep habitat increased a further 6.4 km (or 16%) compared to the modified maximum level. This difference in steep habitat contribution accounted for ~95% of the difference between normal maximum and modified maximum elevations. Conversely, the length and contribution of shallow habitats was negatively correlated with reservoir elevation. Shallow habitats contributed 4.1 km, 4.8 km, 7.6 km and 6.2 km (or 7%, 9%, 19% and 18%) at 745 m, 733 m, 722 m and 716 m, respectively. Fan habitat decreased in total length, but in proportion to the changes in total shoreline length across elevations, so the percent contribution remained quite consistent (i.e., between 21-23%). The number and percent contribution of creek mouth habitats increased in the lower (spring) surveys relative to the two full pool (mid summer) surveys.

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

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

At first glance, the increased number and length contribution of creek mouth habitats during the low pool surveys seemed a bit counter-intuitive given the reduced length of the reservoir. However, the changes were due to the differences in seasonal timing, rather than morphological characteristics of the reservoir basin, between the two surveys. During the spring (lower elevation) surveys, snow melt was occurring, creeks were in pre-freshet condition and all intermittent drainages were flowing. By contrast, during the two full pool surveys in August 2015 and September 2018, creeks were in summer low flow condition and the intermittent drainages were dry.

Based on the available data for the elevations surveyed, it appears that steep shorelines were most abundant at the 745 m elevation. The percent contribution of fans was highest at the 733 m elevation (although fairly equivalent at all elevations), and shallow slope habitats contributed most (by both length and %) at 722 m. Creek mouth habitat was most prevalent at 722 m and 716 m (in spring, during freshet).

Substrate Measurements

Starting in Year 3 (2015), and continuing in Years 4 to 6 (2016-2018), we set out to assess whether substrate size and interstitial space, as a proxy for rearing or spawning habitat suitability (according to habitat type), varied among elevations and habitat types within the reservoir drawdown, or the upland vs. drawdown zone for tributaries. Substrate size by habitat type and elevation was incorporated as a monitoring component for BRGMON-7 because substrates have the potential to provide a form of cover for fish, spawning habitat (in the tributaries), and potentially different food production capacity (e.g., invertebrates) according to size and embeddedness.

The selected elevations for this monitoring component represented the maximum (747 m), *modified* maximum (734 m), and fish index sampling (~722 m) levels. For the tributaries, the upper elevation was >749 m (instead of 747 m) to characterize the accessible *upland* portion of the creeks, relative to the elevations within the drawdown portion. Ultimately, the goal of this data collection is to characterize the sediment composition and embeddedness for each habitat type according to it's contribution to the reservoir shoreline (from the habitat mapping data), and based on an equivalent number of measurements for each selected elevation. Data collection in Year 6 (2018) targeted additional sites at 722 m to make the sample size at that elevation more equivalent to those accumulated for the 734 m and 747 m levels in previous years. The addition of the 2018 data did not alter conclusions reported previously (Sneep 2019), but having equivalent and substantial enough sample sizes for each elevation and habitat type has further bolstered confidence in the results.

Substrate size, interstitial depth, and slope measurements were collected from 26 sites at 722 m in the reservoir drawdown zone (n= 22) and in select tributary streams (n= 4) during 2018. These data supplemented the original set collected from 2015 to 2017, bringing the sample size for 722 m up to 48 sites (drawdown zone n= 40; tributary n= 8) from 22 in Year 5, and contributed another 840 m to the sampled distance for a total of 4,367 m (Table 3.5). In addition, 1 creek mouth site at 747 m elevation and 1 tributary site in the upland (>749 m) were also completed in 2018. In the following figures and tables, all data collected to-date have been analyzed and summarized together. In total, 4,507 individual b-axis and interstitial depth measurements have been collected to-date (2015 n= 1,413; 2016 n= 1,209; 2017 n= 1,017; and 2018 n= 868).

Mean gradients within the study area ranged broadly from a minimum of 3.9° (tributaries at 722 m elevation) to 29.7° (steep slopes at 734 m). In general, for most habitat types, slope increased from the lowest elevational zone in the reservoir to the 734 m (modified maximum) elevation, and then decreased slightly at the highest elevation (i.e., 747 m in the reservoir, or >749 m upland in the tributaries). This pattern reflects the general trough-shaped cross-section of the reservoir basin.

Table 3.5 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	9	270	7.6
	734	7	210	15.3
	747	9	270	13.6
Fan	722	7	210	7.8
	734	8	240	11.6
	747	8	240	16.2
Shallow	722	4	120	15.4
	734	5	150	13.9
	747	1	30	10.0
Steep	722	20	600	23.6
	734	20	600	29.7
	747	24	720	28.4
Tributary	722	8	240	3.9
	734	7	197	11.8
	>749	9	270	9.3
All	722	48	1,440	14.3
	734	47	1,397	20.1
	747	50	1,530	22.5

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

There were some differences evident in the relative proportions of substrate sizes within the reservoir basin, and the inclusion of the data collected in Year 6 (2018) did not substantially change the interpretation of the results described in the last annual report (Sneep 2019). Data from the reservoir sites sampled from 2015 to 2018 indicate that, overall, fines (≤ 0.2 cm) and small gravels (0.3 to 1.6 cm) were the most abundant substrate classes (according to the Wentworth size categories; see Table 2.1 in Methods Section 2.2); however, the relative proportions did vary somewhat by elevation (Figure 3.5 top). The highest proportions of fines and small gravels were at the lowest reservoir elevation (722 m; 68% combined) and the lowest proportions were at the top of the drawdown zone (55% at 734 m and 38% at 747 m, combined). 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 31%, 41% 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., b-axis ≥6.5 cm), 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.

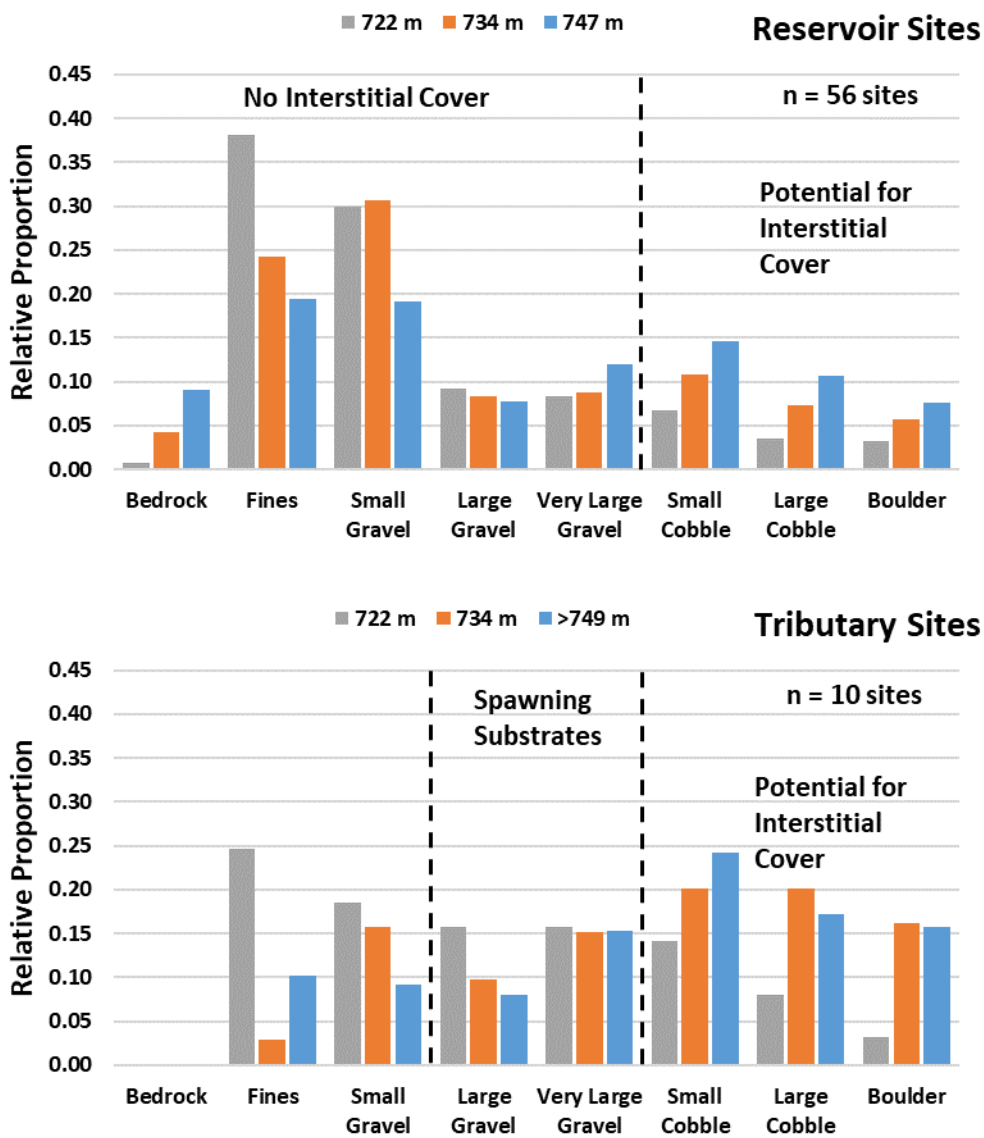

Figure 3.5 Relative proportions of the various substrate categories measured at three elevations within the reservoir drawdown zone (top) and tributaries (bottom). Size categories that can provide interstitial cover (depending on embeddedness) for rainbow trout in reservoir sites, and spawning substrates 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 recruitment of larger substrates from within those drainages. In other words, the distribution of substrates was more broadly spread across the range of sizes. Differences among elevations were generally more modest and variable in the creeks. The smaller substrate classes (i.e., fines and small gravels) were collectively most dominant at the lowest elevation (722 m; 43%), relative to the other surveyed elevations in the tributaries (i.e., 19% at both 734 m and >749 m). Coarse substrates (i.e., those larger than fines and small gravels) contributed 68%, 81% and 79% at 722 m, 734 m and >749 m, respectively. In general, the distributions by size category were quite similar between the modified maximum (734 m) and upland (>749 m) elevations. Gravels suitable for rainbow trout spawning were available at each surveyed elevation, but were slightly more prevalent at 722 m.

The useable size of spawning substrates, available in the tributaries, can generally be characterized as approximately 10% of fish body length (Kondolf and Wolman 1993). Given that median body size for spawning-age rainbow trout ranges from approx. 160 to 319+ mm in Downton Reservoir (Age 2 and up), this means that substrates between approximately 1.6 and 3.2+ cm would be appropriate for spawning by this population. These sizes fall within the Large Gravel to Very Large Gravel categories (denoted on Figure 3.5 bottom), based on the Wentworth scale. Further work is proposed to characterize spawning distribution among elevations within the drawdown zone to determine whether selection of spawning locations by rainbow trout correlates with these spawning gravel distributions (see Section 5 – Recommendations).

Analysis of the substrate size distributions was also conducted by generating five-number summaries (i.e., 10th percentile, 25th percentile, median, 75th percentile, and 90th percentile values) for each habitat type and surveyed elevation, and updating as each new year of data becomes available. The box-and-whisker plots based on these summaries provided a clear picture of the range and central tendency of the size distributions and further characterized the differences among types (Figure 3.6).

As expected, substrate size (median and range) was generally largest in tributary habitats for each surveyed elevation, relative to the other habitat types. Within the tributaries, the highest median values were at 734 m and in the upland >749 m (8.1 and 7.9 cm, respectively), which were in the small cobble size range (Table 3.6). The median at 722 m was 2.2 cm (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 substrate measurement results at creek mouths reflected the influence of the tributaries on this habitat type. Median substrate sizes and ranges were smaller than in the creeks themselves, but the trend among elevations was generally similar. Also, substrates at the creek mouths were generally larger than in the other reservoir habitat types, likely due to two effects of the tributary inflows on this habitat type: 1) recruitment of larger substrates from those drainages, and 2) flushing of fines by the creek flows, particularly prior to inundation by the reservoir as it refills each year.

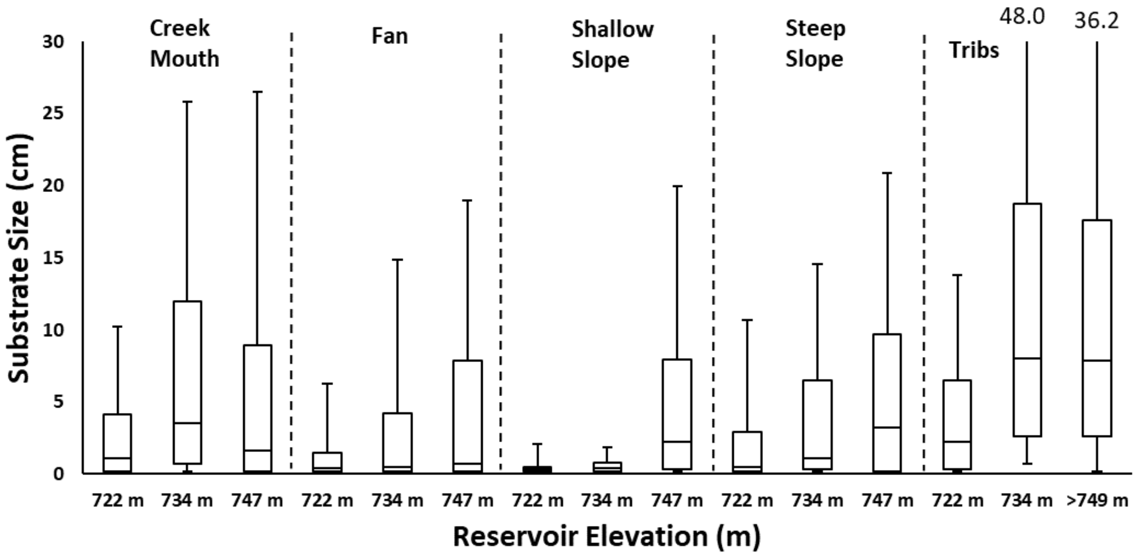

Figure 3.6 "Box-and-whisker" plot representing substrate sizes (b-axis values) for three elevations in each habitat type. The boxes are bounded on the top by the 75th percentile, and on the bottom by the 25th percentile. The median divides each box. The whiskers represent the 10th and 90th percentiles.

Table 3.6 Median substrate sizes (i.e., D50 in cm) by elevation for each habitat type in the reservoir as well as tributaries.

Habitat Type	Elevation (above sea level) [a]		
	722 m	734 m	747 m
Creek Mouth	1.1 (Small Gravel)	3.5 (V. Lg. Gravel)	1.6 (Small Gravel)
Fan	0.4 (Small Gravel)	0.5 (Small Gravel)	0.7 (Small Gravel)
Shallow Slope	0.3 (Small Gravel)	0.4 (Small Gravel)	2.3 (Large Gravel)
Steep Slope	0.5 (Small Gravel)	1.1 (Small Gravel)	3.2 (Large Gravel)
All Reservoir	**0.5 (Small Gravel)**	**0.9 (Small Gravel)**	**2.3 (Large Gravel)**
Tributaries	**2.2 (Large Gravel)**	**8.1 (Small Cobble)**	**7.9 (Small Cobble)**

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

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 (generally in the range of small gravels). The higher elevations on fans had a broader distribution of sizes available, whereas the range was very small at both 722 m and 734 m on shallow slopes (Figure 3.6). This result suggests that below 747 m, shallow slopes may be the most susceptible to the deposition or retention of fines (related to reservoir operation) of all the surveyed habitat types.

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

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

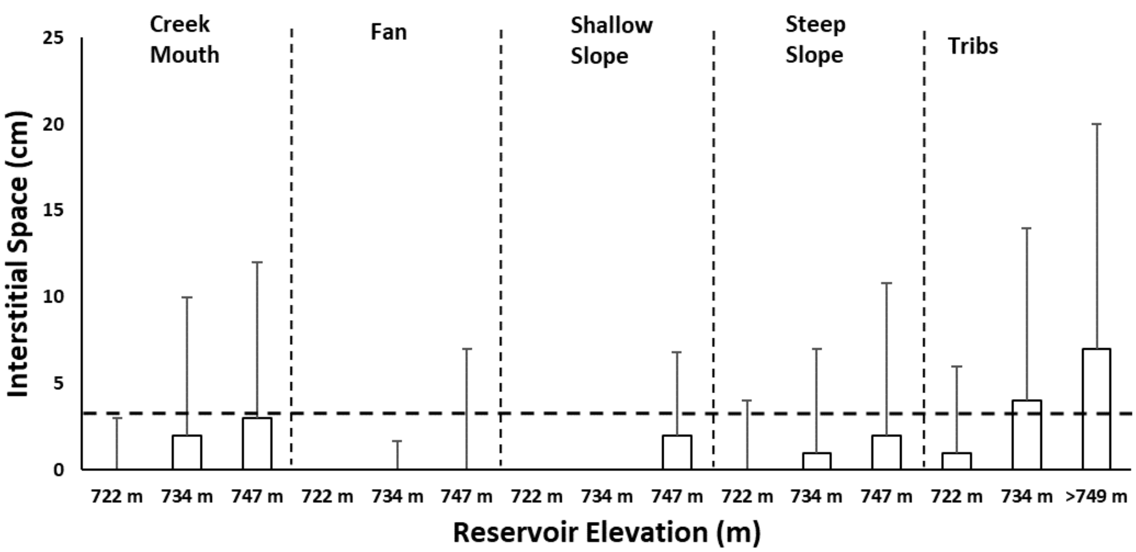

Figure 3.7 "Box-and-whisker" plot (as explained for Figure 3.6, above) representing interstitial space measurements for three elevations in each habitat type. In this case, the minimum, 25th percentile and median values were all zero for each elevation and habitat. The horizontal dashed line approximates 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 2 of the habitat-type-and-elevation combinations surveyed, and both were in the tributaries (at 734 m and >749 m). Median values were below the threshold for all habitats and elevations.

3.4. Tributary Access Surveys

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

The tributary access surveys in Year 6 (2018) were conducted on 19 April and 24 May, to coincide with the early part of the rainbow trout migration period. Reservoir elevations on these dates were ~713 m and ~720 m. Across the duration of the rainbow trout migration and spawning period, the reservoir filled from 716 m in mid-May to 728 m by the end of July (i.e., an elevational increase of 12 m). The creeks visited in Year 6 (2018) included: Ault Creek, Paul Creek, Cathy Creek, Jamie Creek, Trib. #10, Trib. #13, Trib. #16 and Trib. #19 (Table 3.7). However, many of these creeks could not be accessed during the 713 m survey due to closure of the Bridge-Main FSR (i.e., the only road access to most of these locations) caused by avalanche hazard and snow conditions at that time.

Table 3.7 Tributary-Reservoir surface flow connectivity scores as assessed during the tributary access surveys (TRUE = connected; FALSE = disconnected). Survey dates are included for each elevation.

Tributary	Reservoir Zone [a]	Reservoir Elevations Observed (m)						
		710 m 8-May-14	713 m 19-Apr-18	717 m 30-May-17	720 m 24-May-18	721 m 6-May-15	722 m 18-May-16 23-Jun-17	729 m 4-Jun-15
Ault Creek	East	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #4 (Paul Cr.)	Mid	TRUE	- [b]	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #5 (Cathy Cr.)	Mid	TRUE	-	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #19	Mid	TRUE	-	TRUE	FALSE [c]	TRUE	TRUE	TRUE
Trib. #16	West	TRUE	-	TRUE	TRUE	TRUE	TRUE	TRUE
Jamie Creek	West	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #10	West	FALSE	-	TRUE	TRUE	TRUE	TRUE	TRUE
Trib. #13	West	TRUE	-	TRUE	TRUE	TRUE	TRUE	TRUE

[a] Reservoir longitudinal zone as described in Section 2.6.
[b] Paul Cr., Cathy Cr., Trib. #19, Trib. #16, Trib. #10 and Trib. #13 could not be assessed on this survey date (19 Apr 2018) due to avalanche hazard and snow conditions on the Bridge-Main FSR.
[c] Trib. #19 went dry (flowed to ground) within the drawdown zone on 15 June 2018 at reservoir elevation ~720 m due to effect of cold air temperatures on flow volumes in the creek.

The Year 6 (2018) minimum elevation of 711.3 m (on 28 April) was only 2.5 m higher than those observed in Year 2 (2014) when Ault Creek was observed flowing to ground before reaching the reservoir edge. This was again observed at the 713 m survey in Year 6 (see Photo A10 in

Appendix A). However, Ault Creek has not been identified as a significant spawning tributary to-date, and the dates when potential access issues were observed (8 May 2014 and 19 April 2018) were prior to the typical start of the rainbow trout spawning period for this population. Tributary #10 has also been observed to flow to ground at this time of year (i.e., 8 May 2014 at 710 m reservoir elevation), but could not be accessed on the 19 April 2018 survey at 713 m, as stated above. Similarly, Trib. #10 has not been observed to be a significant tributary for spawning use.

A creek that was noted to have connectivity issues at a higher reservoir elevation (i.e., 720 m) was Trib. #19 on 15 June 2018 (see Photo A11 in Appendix A). This was not a pre-selected tributary access survey date, but was observed during the weekly spawner surveys as this has been a spawning tributary, at least in some years. The creek was observed to have run dry (or to ground somewhere in the upland) on this date, which was just before the typical peak spawning time for the Downton Reservoir rainbow trout population (see Section 3.5). The dry conditions were likely related to a period of cold air temperatures prior to this date that reduced snow melt, and therefore flow volumes in the creek. The risk of connectivity issues appears to be higher in this creek in general, as it has also been observed to periodically run dry in both summer and fall in some previous years; though it must be noted that the factors and conditions involved cannot be attributed to reservoir operation in this case.

Beyond these observations, access issues were not identified at any of the other surveyed tributaries on either of the survey dates during this monitoring year.

3.5. Tributary Spawner Surveys

In Year 6 (2018), weekly spawner surveys were conducted across a 12-week period from 17 May to 1 August. For consistency with previous years, repeat surveys were conducted in Trib. #13, Eagle Creek (Trib. #16), Trib. #19 and Tram Creek, which have all had documented spawning use. However, as noted in Section 3.4, Trib. #19 was observed to go dry (within the drawdown zone, precluding access for fish from the reservoir) on 15 June 2018, so spawners did not appear to use this creek this year. Additional tributaries that were routinely monitored in Year 6 included Jamie Creek, Cathy Creek and Ault Creek. As noted on the data sheets, in-water visibility conditions in 2018 were generally fair or good on most survey dates (see Section 2.4 for definition of these qualitative terms), and discharges changed from low to high and then to moderate 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 (and more routinely in Jamie Creek which is more chronically turbid).

Based on the 2018 weekly counts, spawners first started arriving in the first week of June (i.e., Trib. #13; Table 3.8). This was a few weeks later than arrival timing noted in previous years (Sneep 2018b); however, the Bridge-Main FSR closure due to avalanche and snow conditions precluded surveys in May at most sites in 2018. Peak timing in 2018 was between the middle to the end of June (according to tributary), and the last remaining spawner was observed in Trib. #13 on the final (1 August) survey. This represents a ~9-week migration and spawning period with peak abundance occurring ~2 to 3 weeks after the first arrivals. Based on these results, spawn timing in the Downton Reservoir tributaries is approximately 1-2 months later than *Oncorhynchus mykiss* populations lower in the watershed (i.e., Lower Bridge River; Ramos-Espinoza et al. 2018). 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.

Table 3.8 Summary of weekly spawner count data for surveyed tributaries in Year 6 (2018).

Week	2018 Survey Dates	Eagle Creek			Jamie Creek			Trib. #13			Tram Cr. [b]
		n [a]	DS %	US %	*n*	DS %	US %	*n*	DS %	US %	*n*
1	17 May	- [c]			-			- [c]			- [c]
2	24 May	- [c]			0			- [c]			- [c]
3	29 May	- [c]			0			- [c]			- [c]
4	5 Jun	0			-			1	100%		0
5	14 Jun	3	67%	33%	3	100%		1	100%		1
6	22 Jun	54	76%	24%	0			17	94%	6%	0
7	27 Jun	45	67%	33%	0			30	67%	33%	29
8	3 Jul	26	69%	31%	0			22	50%	50%	0
9	9 Jul	11	55%	45%	0			16	100%		1
10	16 Jul	8	63%	37%	0			17	53%	47%	3
11	25 Jul	3	100%		0			5	60%	40%	2
12	1 Aug	0			0			1	100%		-
Peak *n* & Total %		**54**	**70%**	**30%**	**3**	**100%**	**0%**	**30**	**71%**	**29%**	**29**

[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 Cr. are outside the influence of reservoir operation, so the count for each week represents upland only.

[c] Could not access Eagle Creek, Trib. #13 or Tram Creek on these survey dates due to avalanche closure of Bridge-Main FSR.

Across study years, peak spawner count in Trib. #13 was highest in Year 1 (2013; *n*= 135), and then ranged between 20-60 spawners in each year since (annual max. *n*= 50, 19, 57 and 30 for Years 2, 3, 4 and 6, respectively; no surveys were completed in Year 5 (2017); Figure 3.8). Peak spawner counts in Eagle Creek (Trib. #16) have been similar to Trib. #13 in the years available (annual max. *n*= 116, 61 and 54 for Years 1, 4 and 6, respectively). Eagle Creek and Trib. #19 could not be surveyed in 2014 and 2015 due to access issues on the north side of the reservoir, so annual trends across all study years could not be assessed for these creeks. Spawner counts in Trib. #19 and Tram Creek have generally been lower than the other surveyed creeks (annual max. *n*= 34, 2 and 0 for Years 1, 4 and 6, respectively, in Trib. #19; and *n*= 1, 4, 9, 6 and 29 for Years 1 to 6 in Tram Creek).

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 ~74% used the drawdown zone vs. 26% in the upland, overall. Actual proportions for each survey date and totals for each tributary are provided in Table 3.8. As indicated by the substrate measurement results (described in Section 3.3), suitable-sized spawning substrates are available above and across the range of reservoir drawdown elevations in the tributaries.

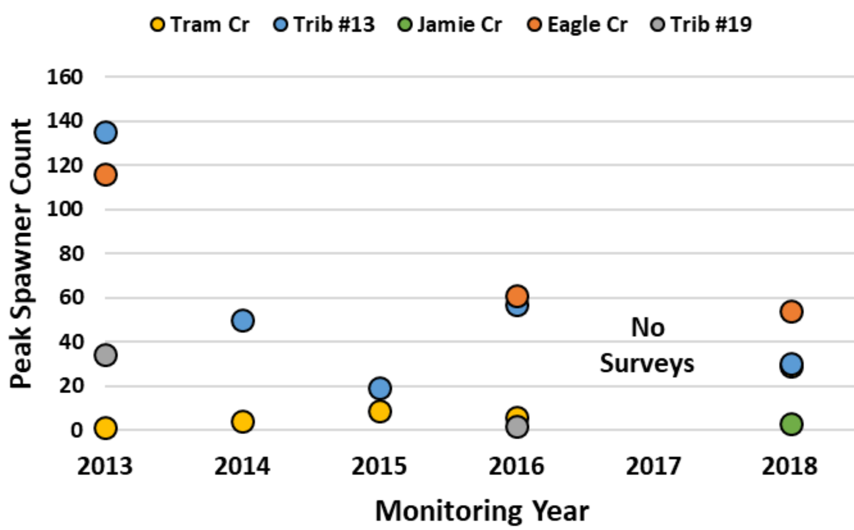

Figure 3.8 Peak spawner counts in each surveyed tributary for BRGMON-7 monitoring years 1 to 6 (2013 to 2018). Note: Spawner counts were not conducted in Year 5 (2017) – see explanation in annual monitoring report for that year (Sneep 2019).

Changes in the length of accessible creek channel (versus inundated within the drawdown zone) among reservoir elevations was assessed for a number of tributaries in Year 6 (2018) (Figure 3.9). This provides some useful information about the relative amount of tributary habitat available for spawners at the range of reservoir elevations. In spawning streams with a lower gradient (i.e., Eagle Creek), total stream length changed from 399 m (at the start of the spawning period; 719 m reservoir elevation) to 216 m (at the end; 728 m elevation), a reduction of 183 m or ~46%. For steeper streams, such as Ault Creek, the total stream length changed from 177 m at 719 m to 74 m at 728 m, a reduction of 103 m or ~58%. 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 (or at all since the elevation of its mouth is greater than the modified maximum of 734 m). As such, the length of useable channel in this stream does not change within the modified operation range (i.e., the vertical portion of the purple line on Figure 3.9), and eggs deposited in this creek have not been at risk of inundation by the reservoir since 2016.

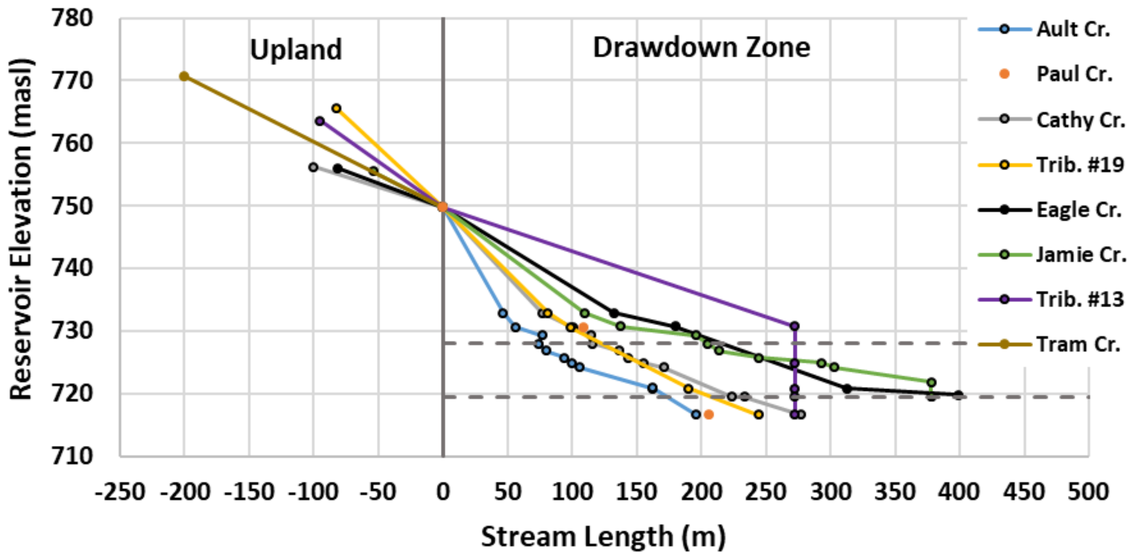

Figure 3.9 **Accessible stream lengths within the drawdown zone and upland of various tributaries according to Downton Reservoir surface elevations. The vertical grey line represents the top of the drawdown zone (value of 0 on the x-axis). The horizontal dashed lines bracket the minimum and maximum reservoir elevations during the rainbow trout spawning period in 2018 (i.e., 719 to 728 masl between 5 June and 25 July 2018).**

With these data, it will be possible to calculate the proportion of each spawning stream that is inundated by the reservoir during the spawning period for each study year based on the record of reservoir elevations and spawn timing. For reference, a summary of the range of reservoir elevations and fill rates during the observed rainbow trout spawning periods are provided in Table 3.9 for each study year to-date. We also intend to more specifically document the locations of spawner observations (and any redds) by georeferencing them, starting with the surveys in Year 7 (2019). Based on the measured distances from the top of the drawdown area we will then be able to add the spawner observations to Figure 3.9 and estimate the proportion of *spawned* area that was inundated. This will provide another useful input to operations about the "riskiest" elevations during the spawning period and assist with answering Management Questions #3 and #5 (see Section 1.2).

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, later June in 2016, and mid-to-late June in 2018). 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 3.10).

Between-year differences in spawning use and distribution among tributaries (e.g., small numbers of rainbow trout spawners being observed in Jamie Creek for the first time in 2016; Tyler Gray, PGL, pers. comm.; and again in 2018, Table 3.8) raise the possibility that, to some degree, both 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, stream flows, 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.

Table 3.9 Minimum and Maximum reservoir elevations and fill rates during the observed rainbow trout spawning period for each study year to-date.

Study Year	Observed Spawning Period	Reservoir Elevations (m)			Fill Rates (cm/day)[b]	
		Min.	Max.	Diff.	Mean	Max.
1 (2013)	21 May to 15 Jul	722.29	736.86	14.57	0.26	0.73
2 (2014)	22 May to 15 Jul	714.57	733.53	18.97	0.35	0.81
3 (2015)	4 Jun to 17 Jul	729.23	743.50	14.27	0.33	0.55
4 (2016)	19 May to 20 Jul	722.07	725.21	3.14	0.05	0.42
5 (2017)	1 Jun to 20 Jul [a]	717.95	727.66	9.71	0.20	0.63
6 (2018)	5 Jun to 25 Jul	719.36	728.00	8.64	0.17	0.67

[a] Spawning period dates in 2017 are based on the average across years (see Figure 3.10) since spawner surveys were not conducted in that year.
[b] Calculated between the start and end of the observed rainbow trout spawning period for each year.

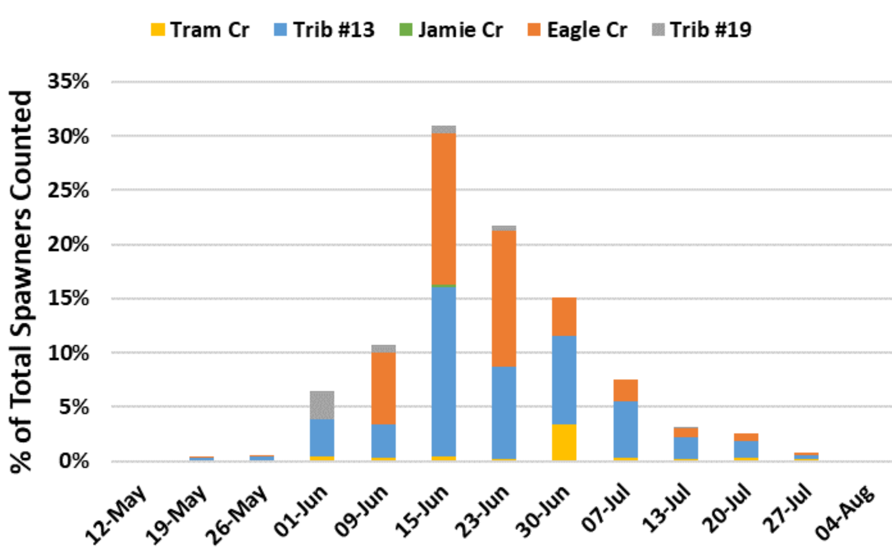

Figure 3.10 % Contribution of weekly spawner counts to the total across the monitoring period, all study years combined. Relative proportions by tributary are included.

Another potential hypothesis was 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 has only been minimally observed (i.e., 2-3 spawners observed as peak counts in Cathy Creek

(Trib. #5) and Ault Creek in 2018), despite the presence of suitable flows, temperatures, gradient and substrate in at least some of them. The substrate measurement results have not revealed any significant differences in physical habitat parameters between the seemingly suitable creeks that are not (currently) being used, from the ones that are. So the key difference may be that the eastern-most streams are less selected by rainbow trout because they become inundated first and to a greater proportion of their length; whereas the streams in the western portion of the reservoir basin become inundated later and less, or not at all, particularly under the modified operations. In other words, spawning stream selection is likely already highly selective for minimizing inundation risk during the incubation period.

3.6. Tributary Fish Sampling

Fish sampling by backpack electrofishing was conducted in nine tributaries to Downton Reservoir in fall 2018 (10-12 October), including sites in the drawdown (*n*= 7) and upland (*n*= 8) zones. These data supplemented spring and summer seasonal tributary data that was previously collected in Year 4 (2016) and Year 5 (2017), respectively (Table 3.10). Water clarity during the fall sampling period was noted as good (clear) in all of the tributaries except Jamie Creek, which was considered moderate, and the Upper Bridge River, which was considered poor, due to chronic turbidity.

As noted in past reports, fish presence and abundance were variable among tributaries, and elevation zones within tributaries, during each season. Total catch-per-unit-effort (CPUE) in fall (20 fish/100 m) was higher than the value for summer (15 fish/100 m) and more than triple the value for spring (6 fish/100 m). Of the tributaries sampled in 2018, the highest CPUE values in fall were in the upland zone of Cathy Creek, and the drawdown zone of Eagle Creek and Trib. #13 (i.e., 53, 37, and 37 fish/100 m, respectively). Also, a greater number of tributaries had higher CPUE values in fall: catches at 9 of 15 sites were >15 fish/100 m, whereas this was only the case at 1-2 sites in spring and summer. Highest CPUE in spring and summer was in the drawdown zone of Trib. #19 (33 fish/100 m) and Eagle Creek (40.0 fish/100 m), respectively. Typically, the creeks with the highest catches have been documented as spawning tributaries for Downton Reservoir rainbow trout. No fish were captured at 6 of 11 sites (55%) during the spring session, 2 of 8 sites (25%) during summer, and 3 of 15 sites (20%) in fall. In almost all cases, catches in the drawdown zone were higher than the upland catches in the creeks where both zones were sampled.

Table 3.10 Summary of backpack EF effort and catch in Downton Reservoir tributaries during spring (2016), summer (2017) and fall (2018). 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	7
			Upland	30	208	0	0
		Trib. #19	Drawdown	30	165	10	33
			Upland	30	165	3	10
	West	Trib. #13	Drawdown	30	86	0	0
			Upland	30	63	0	0
		Trib. #16	Drawdown	30	90	3	10
		Tram Cr.	Upland	30	257	2	7
		UBR-1[a]	Upland	30	251	0	0
		UBR-2[a]	Upland	30	300	0	0
Spring Totals				**330**	**2,322**	**20**	**6**
Summer	East	Ault Cr.	Drawdown	-[b]	-	-	-
	Mid	Paul Cr.	Drawdown	30	250	7	23
			Upland	30	160	0	0
		Cathy Cr.	Drawdown	30	289	0	0
			Upland	30	241	2	7
	West	Eagle Cr.	Drawdown	45	311	18	40
			Upland	26	251	4	15
		Jamie Cr.	Drawdown	44	758	5	11
			Upland	30	336	3	10
Summer Totals				**265**	**2,596**	**39**	**15**
Fall	East	Ault Cr.	Drawdown	30	215	0	0
	Mid	Paul Cr.	Drawdown	30	379	5	17
		Cathy Cr.	Drawdown	30	295	4	13
			Upland	30	620	16	53
		Trib. #19	Drawdown	30	257	0	0
			Upland	30	324	9	30
	West	Eagle Cr.	Drawdown	30	463	11	37
			Upland	30	268	5	17
		Jamie Cr.	Drawdown	30	530	8	27
			Upland	30	350	6	20
		Trib. #13	Drawdown	30	478	11	37
			Upland	30	260	4	13
		Tram Cr.	Upland	30	483	4	13
		UBR-1	Upland	30	805	8	27
		UBR-2	Upland	30	361	0	0
Fall Totals				**450**	**6,088**	**91**	**20**

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

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

Sixteen fish from the tributary catch in fall 2018 were a tag-able size, and fifteen were newly marked with PIT tags (there were no recaptures in the creeks that year). The ages of captured fish (based on post-field scale analysis) ranged from Age-0+ to Age-4 in both spring and summer, and from Age-0+ to Age-2 in fall (Table 3.11; Figure 3.11). Two fish in Cathy Creek (both Age-3) and two fish in Trib. #16 (Age-2 and Age-4) captured during the spring sampling in 2016 were sexually mature and in some stage of pre-spawning condition (all males; 1 gravid, 3 ripe). The remainder of the fish sampled in each season were assessed as either sexually immature (*n*= 147) or mature (*n*= 6) based on size or age, but were not in spawn-ready condition at the time of sampling.

Table 3.11 The size range of rainbow trout by age class and season for tributaries sampled by backpack electrofishing in spring (2016), summer (2017), and fall (2018).

Age	Season	n	Forklength (mm)			CPUE (fish/m)·100
			Min.		Max.	
0	Spring	9	40	-	63	3
	Summer	24	23	-	33 [a]	9
	Fall	75	20	-	58 [a]	21
1	Spring	6	65	-	116	2
	Summer	10	65	-	105	4
	Fall	12	70	-	122	3
2	Spring	2	148	-	189	1
	Summer	2	110	-	159	1
	Fall	4	118	-	167	1
3	Spring	2	242	-	248	1
	Summer	3	180	-	235	1
	Fall	0				0
4	Spring	1		285		<1
	Summer	3	275	-	282	1
	Fall	0				0

[a] New year-class present (emerged in approx. August – see Table 3.3 in Section 3.2).

The new year class of recently emerged fry made up the bulk of the catch in both summer and fall (i.e., *n*= 24 or 57%, and *n*= 75 or 82%, respectively), and were the single factor that made total CPUE values substantially higher in summer and fall than in spring. The higher catches and proportion of this age class in the fall, compared to summer, was likely because the fry were larger at that time resulting in higher capture efficiency, whereas at the time of the summer sampling in August 2017, some proportion of fry may have been too small to effectively sample. These results also serve to generally confirm the emergence timing predicted by the ATU calculations (see Section 3.2; Table 3.3). The catches of fish older than Age-0+ comprised a much smaller number and were more consistent across each season (*n*= 11, 18 and 16 in spring, summer and fall, respectively).

The results from these surveys highlight that the highest catches of fish in the creeks generally correspond with the known spawning tributaries (i.e., Eagle Creek, Trib. #16, Trib. #19, Tram

Creek), suggesting that these creeks are selected (to some degree) for rearing use in addition to spawning use. Also, the presence of 20 to 30 mm Age-0+ fish in Paul Creek, Cathy Creek and Jamie Creek further supports that some degree of spawning does occur in these tributaries as well. However, other than the contribution of the new year-class of Age-0+ fish, the CPUE values for fish Age-1 and older were lower on average than most of the habitat types in the reservoir based on boat EF (see Section 3.6, below). This was despite the likelihood that capture efficiencies by backpack EF in the tributaries were higher than by boat EF in the reservoir.

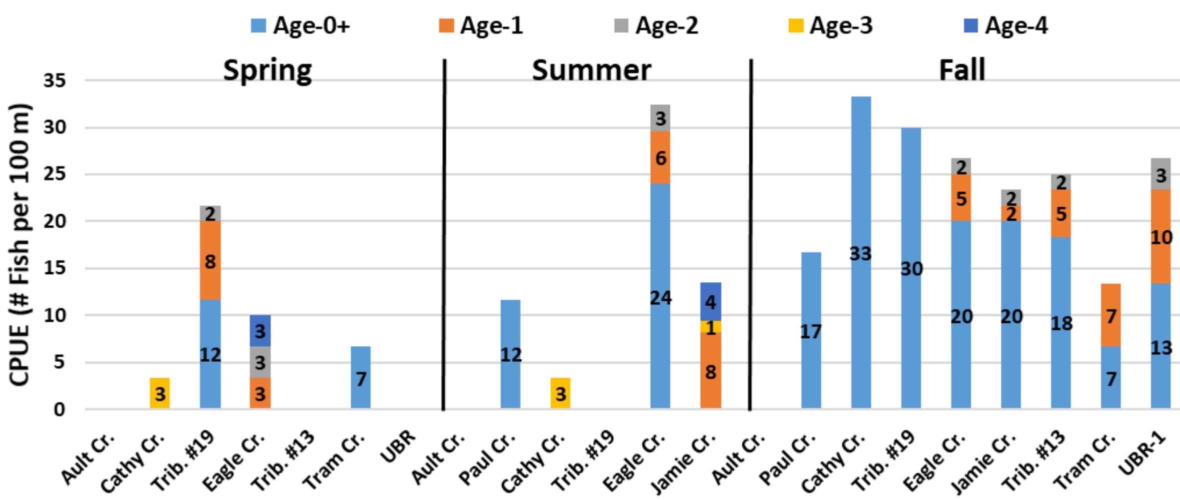

Figure 3.11 Catch-per-unit effort (fish/100 m) by age class for each sampled tributary based on the results of backpack electrofishing surveys in spring (2016), summer (2017) and fall (2018).

Tributary sampling planned for Year 7 (2019) will target sampling each season (spring, summer and fall) within the same year (see Section 5 – Recommendations). This will be useful for tracking the same age cohorts across the seasons in a year, and is expected to reduce some of the variability associated with sampling the different seasons in different years.

3.7. Fish Population Index Survey

A total of 1,658 fish were captured by boat electrofishing during the annual fish index survey in Year 6, conducted between 1 and 8 June 2018 at a reservoir elevation of ~721 m. Sixty-one sites were sampled, including 9 creek mouths, 16 fans, 8 shallow shorelines, and 28 steep shorelines (Table 3.12). The total shoreline distance sampled was just over 17 km, or ~43% of the total reservoir perimeter at the survey elevation (~721 m). All captured fish were rainbow trout.

In total, 1,317 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. Fifteen tagged fish were recaptured during the Boat EF survey in 2018; 6 were within-session recaptures and 9 were recaptures of fish originally tagged between 2014 and 2017 (Tables 3.14 and 3.15 in the “Recaptures of Tagged Fish” sub-section, below).

Table 3.12 Summary of rainbow trout capture results from the Year 6 boat electrofishing index survey in early June 2018.

Metric	Units	Habitat Type			
		Cr. Mouth	**Fan**	**Shallow**	**Steep**
Sites	#	9	16	8	28
Effort	total seconds	2,440	11,020	6,136	17,489
	total meters	657	5,012	2,860	8,713
Catch	# of fish	147	337	401	773
	# of fish marked	126	257	386	548
	# of recaptures	3	4	5	3
CPUE	fish/site (±SE)	16.3 (±2.8)	21.1 (±2.8)	50.1 (±14.4)	27.6 (±3.3)
		27.2 (±2.8)			
	fish/sec·100 (±SE)	5.9 (±0.8)	3.2 (±0.4)	7.6 (±2.1)	5.0 (±0.8)
		5.0 (±0.5)			
	fish/meter·100 (±SE)	23.5 (±3.8)	6.9 (±0.9)	17.0 (±5.1)	10.3 (±1.8)
		12.2 (±1.4)			

2018 Catch-per-unit-effort (CPUE) values (by all measures), were greatest at creek mouths, followed by Shallow shorelines, and then by Steep shorelines and Fan habitats. Mean CPUE values (for all types combined) were: 27.2 (SE 2.8) fish/site; 5.0 (SE 0.5) fish/100 sec of electrofishing; or 12.2 (SE 1.4) fish/100 m of shoreline length, which were the highest values for any study year to-date (Table 3.13). Including consideration of the standard error, the 2018 CPUE values represented a significant increase in fish abundance in the reservoir, whereas differences among previous years (2015-2017) were not significant. Going forward, these CPUE metric values (pooled by habitat type and total for the reservoir) will continue to be generated annually and compared as a reflection of trends in population index between monitoring years (Figure 3.12).

Trends in CPUE values among habitat types was generally consistent with previous monitoring years, except the relative values for fans, shallow slopes and steep slopes have varied among years. CPUEs for fans were higher than for shallow slopes in Years 2 and 4 (2014 and 2016); whereas the opposite was true in Years 3, 5 and 6 (2015, 2017 and 2018). Also the value for steep habitats was higher than for fans for the first time in Year 6 (2018). CPUE values have been consistently highest at creek mouths in every year to-date.

Table 3.13 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 6.

Study Year	Habitat Type				
	Creek Mouth	Fan	Shallow Slope	Steep Slope	All
1 (2013)[a]	3.5 (±1.1)	1.2 (±0.4)	ns[b]	0.7 (±0.2)	**1.3** (±0.3)
2 (2014)	13.7 (±2.6)	3.6 (±1.1)	1.3 (±0.3)	2.6 (±0.2)	**6.8** (±1.6)
3 (2015)	20.9 (±4.1)	7.3 (±1.2)	8.6 (±1.5)	6.2 (±1.0)	**8.9** (±1.0)
4 (2016)	14.5 (±3.6)	11.5 (±1.4)	7.7 (±1.8)	6.4 (±0.7)	**8.7** (±0.8)
5 (2017)	20.4 (±4.7)	6.7 (±1.0)	9.5 (±1.6)	4.0 (±0.5)	**8.1** (±1.0)
6 (2018)	23.5 (±3.8)	6.9 (±0.9)	17.0 (±5.1)	10.3 (±1.8)	**12.2** (±1.4)
All	**16.3** (±1.7)	**5.8** (±0.5)	**9.9** (±1.4)	**5.3** (±0.5)	**7.7** (±0.5)

[a] Note: Data for Year 1 was collected by a different consultant and capture efficiencies were anomalously low relative to each year since. As such, results for this first year should be viewed with caution.
[b] Shallow slope habitats were not sampled in June 2013.

A summary of CPUE values by age class for each monitoring year to-date is provided in Figure 3.12. In Year 6 (2018), the CPUE for Age-1 fish (5.5 fish/100 m) was again the highest of any age class in the sample, and was comparable to Age-1 CPUEs in 2015 and 2016 (4.9 and 5.0 fish/100 m, respectively). CPUE values for Age-2 and Age-3 fish were similar (1.7 and 1.9 fish/100 m, respectively) and Age-4 CPUE was the second highest of any age class in 2018 (2.3 fish/100 m).

The data are still a bit sparse for sorting out specific 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). However, the higher abundance of fish overall in 2018, and Age-1 fish in particular, may correspond with the implementation of the modified maximum elevation of the reservoir, which started in 2016 (2018 was the year the recruits from 2016 were present in the sample as Age-1 fish). If this result is repeated, it may reflect better recruitment and rearing conditions associated with the lower maximum fill elevations during the spawning period and consistent reservoir operations in the past 3 years (see Figure 3.1 in Section 3.1).

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 as they are likely biased low (i.e., 1.3 ±0.3 and 6.8 ±1.6 fish/100 m, respectively). 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), and so they have been removed from some figures in this section. 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.

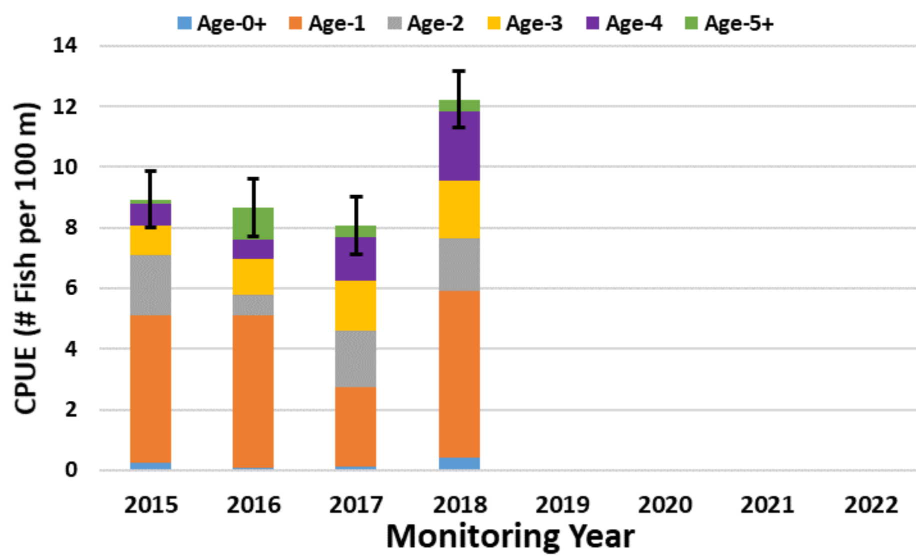

Figure 3.12 Catch-per-unit-effort summary by age class for each monitoring year from 2015 (Year 3) to 2022 (Year 10). Currently only data up to 2018 were available for this report. Year 1 (2013) & 2 (2014) results have not been included due to incompatibility of sampling approach in those years with subsequent study years – see comment on this in text, above).

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

Due to the poor capture efficiency for the Age-0+ fish, focus remains on the Age-1 and Age-2 classes for monitoring trends and the effects of operations by this program. However, it must also be noted that using Age-1 and Age-2 fish as the indicator for monitoring the effects of operations also incorporates the effects across more than one year, which adds additional uncertainty to the interpretation of results. Fish condition (i.e., Fulton's condition factor, K) is another suitable metric for assessing the quality of conditions where fish reside on an annual basis. Assessment of condition factor by age, and comparison of this metric among years, is provided in Figure 3.16 in the sub-section "Length-Frequency, Size-at-Age, and Age-specific trends" below.

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 3.14. In Year 6 (2018), the highest mean CPUE was documented in the east zone of the reservoir. However, based on the years of monitoring to-date, rainbow trout utilize the entire extent of Downton Reservoir; highest catch rates have been recorded in each of the three zones among years.

Table 3.14 Summary of fish distribution according to longitudinal zone of Downton Reservoir during the annual fish indexing survey for each study year. The zone with the highest mean catch rate in each year is highlighted green.

Study Year	Metric	Longitudinal Zone of the Reservoir [a]		
		West	Mid	East
2013	CPUE (fish/m)·100 (±SE)	1.0 (±0.4)	2.1 (±0.6)	0.8 (±0.3)
2014		7.4 (±2.1)	ns[b]	5.2 (±2.5)
2015		7.8 (±1.4)	8.3 (±2.1)	11.1 (±2.1)
2016		7.0 (±1.0)	10.8 (±1.9)	8.1 (±1.2)
2017		11.6 (±2.8)	6.5 (±1.3)	7.0 (±1.0)
2018		10.9 (±2.5)	7.7 (±1.3)	18.3 (±2.7)

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

A total of 18 of the 1,658 captured fish (or 1%) in Year 6 (2018) were noted as mortalities upon release after processing (i.e., sampling-induced mortality). This low incidence of immediate mortality was consistent with previous years and considered a success, but there has been uncertainty about the potential incidence of mortality after a longer period post-release. As a means of testing the post-capture and processing survival of fish, a sample of 141 fish (~9% of the 2018 catch) were held for approx. 24 hours after sampling, then re-evaluated for condition and tag loss, and then released. In total, 139 of the held fish (or 99%) were alive after 24 hours and were noted to be in vigorous condition upon release (i.e., 1% delayed mortality based on this sample). The delayed mortality results in Year 5 (2017) were very similar (i.e., 100% survival). Tag loss was noted for 1 of the held individuals (0.8%) in 2017, and 0 individuals in 2018, for a combined tag loss rate of 0.3%. Going forward, we will continue to hold a sample of fish in a similar manner each year to build a larger sample size of fish assessed, so we can better understand the incidence of latent mortality and tag loss for fish captured by boat-electrofishing in this context.

Recaptures of Tagged Fish

A total of six fish that were marked with PIT tags were recaptured at different sites within the same session in Year 6 (2018; Table 3.15). Four of these fish had moved a short distance (i.e., <1 km), and two had moved more substantial distances (2.9 and 10.8 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 3.15 Summary of within-session rainbow trout recaptures during monitoring Year 6 (2018).

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)
	Date	Zone	Habitat[b]	Date	Zone	Habitat[b]	
979784	1-Jun-18	East	SH	1-Jun-18	East	SH	0.4
975683	1-Jun-18	East	SH	3-Jun-18	West	FN	10.8
975580	1-Jun-18	East	SH	8-Jun-18	East	SH	0.3
975632	1-Jun-18	East	SH	8-Jun-18	East	ST	0.6
317441	2-Jun-18	East	ST	8-Jun-18	East	ST	2.9
317264	6-Jun-18	Mid	ST	6-Jun-18	Mid	FN	0.3

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

In addition to the within-session recaptures, there were 9 between-year recaptures in Year 6 (2018). Original capture and recapture information for these fish is summarized in Table 3.16. Four of the nine between-year recaptures were for fish that were initially captured in 2017 (i.e., were at-large for ~1 year). Three of the between-year recaptures were originally tagged in 2016 (~2 years at large), and the remaining two recaptures were originally tagged in 2015 and 2014 (~3 and 4 years at large, respectively). As with the within-session recaptured fish, the locations for each capture event were varying distances apart (i.e., ranging from 0.7 to 11.2 km). Approximately half of the recaptured fish (both within-year and between years) were captured in different habitat types between events. One fish originally captured and tagged in Trib. #19 was recaptured at a nearby fan habitat in the reservoir, 2 years later. These results further support that rainbow trout move and mix among locations, habitat types, and longitudinal zones throughout Downton Reservoir on both daily and longer time scales.

Three fish (forklengths = 88, 112 and 131 mm) were assessed as Age-2 based on scale ageing analysis (see section below) when initially captured, and were 198, 243 and 221 mm forklength when recaptured a year later (at Age-3). This represented a growth range of between 90 and 134 mm in one year for this cohort of fish. One fish was 165 mm (Age-3) when initially captured and 283 mm a year later (at Age-4), representing 120 mm of annual growth. Three fish were Age-1 (101, 112 and 116 mm) when initially captured and 272, 231 and 237 mm two years later (at Age-3), representing an average range of 59 to 86 mm of growth per year. The remaining two recaptured fish grew an average of 52 and 27 mm/year between Ages 2 and 4 and Ages 2 and 5, respectively. These results provide one line of evidence of dramatic changes in annual growth for Downton Reservoir rainbow trout as they age (i.e., particularly after Age-3). This is explored further by analysis of length-at-age for the entire sample of fish in the next sub-section.

Table 3.16 Summary of inter-year rainbow trout recaptures in Year 6 (2018). Inter-year recapture data from all study years to-date are provided in Appendix C.

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)	Growth (mm/yr)
	Date	Zone	FL (mm)	Date	Zone	FL (mm)		
650223	6-Oct-14	West	209	4-Jun-18	Mid	307	6.7	27
734739	10-Jun-15	East	150	5-Jun-18	West	306	11.2	52
889249	18-May-16	Mid	116	3-Jun-18	West	237	1.4	59
889392	2-Jun-16	Mid	112	2-Jun-18	Mid	231	0.7	60
888403	3-Jun-16	Mid	101	1-Jun-18	East	272	6.4	86
975991	4-Jun-17	West	88	6-Jun-18	Mid	198	5.4	109
975126	7-Jun-17	East	131	6-Jun-18	Mid	221	4.5	90
975302	8-Jun-17	East	112	1-Jun-18	East	243	1.9	134
975311	8-Jun-17	East	165	1-Jun-18	East	283	1.9	120

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

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

A length-frequency histogram for rainbow trout captured by boat electrofishing in Year 6 (2018) is presented in Figure 3.13. The coloured bars in this figure represent the contribution of the different age classes as determined by analysis of 185 scale samples spanning the full range of available size classes (broken into 10 mm size increments between 50 and 340 mm). The assigned ages from the scale reading were applied to all of the captured fish according to size. As has been reported previously, there was extensive size overlap (in some cases, complete) between certain age classes, particularly for ages >3. This suggests that growth rate diminishes once fish in the reservoir reach this threshold age and size. Length-frequency histograms for each study year are provided in Appendix D (Figure D1) to allow for visual comparison of results among years.

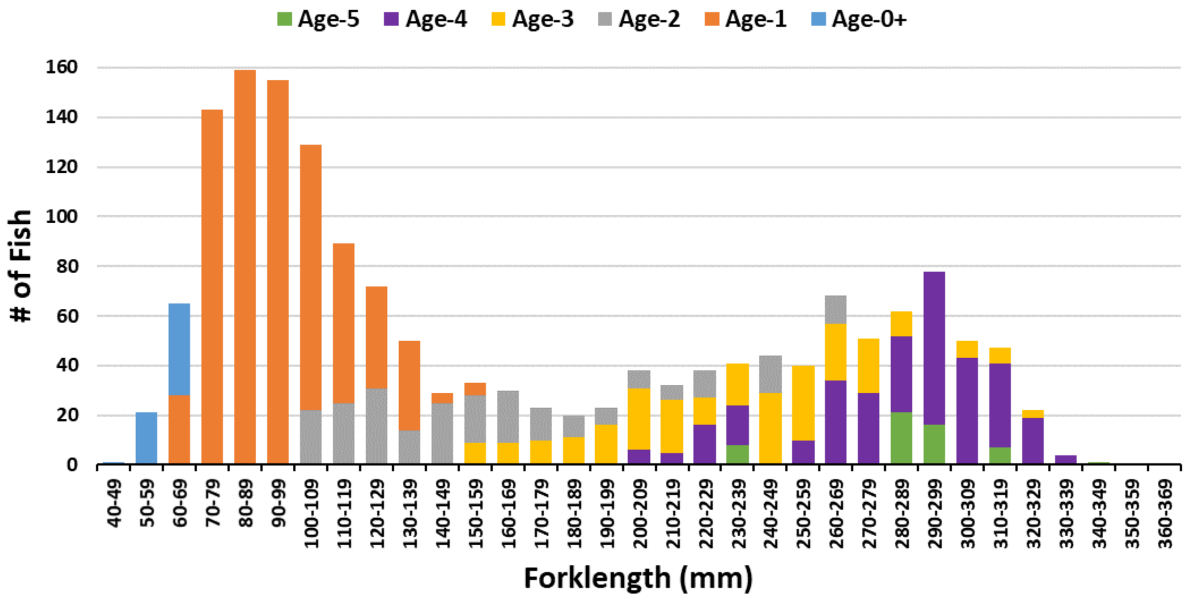

Figure 3.13 Length-frequency histogram for rainbow trout captured during the fish population index survey in Downton Reservoir, 1 to 8 June 2018. Size ranges for each available age class are shown.

According to the median size values for fish aged between 1 and 5 at the time of sampling in 2018, the greatest size differences were apparent between ages 1 and 3 (i.e., median differences of 58 mm between Age-1 and Age-2; and 90 mm between Age-2 and Age-3; Table 3.17). After Age-3 the median size increased by 50 mm to Age-4, and then there was no change in median size between Age-4 and Age-5. This is very similar to what has been reported in previous years, except in 2017 when the greatest size differences were between ages 2 and 4 (Sneep 2018b; Sneep 2019). The reason for the difference in that year was lower median sizes for Age-2 and Age-3 fish (Appendix D; Figure D1).

Table 3.17 Size statistics for the range of ages of rainbow trout captured in Downton Reservoir during Year 6 (2018).

Age	*n* [a]	Forklength (mm)		
		Minimum	Median	Maximum
0+	59	48	**62**	69
1	742	60	**92**	156
2	236	100	**150**	268
3	259	150	**240**	323
4	309	203	**290**	330
5	53	231	**288**	340

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

We also computed von Bertalanffy growth curves based on the median size values for each age class for the 2015 to 2018 data sets to assess differences in growth among years based on this standardized method (Figure 3.14). The differences in the estimated growth curves are not dramatic, but some differences among years to-date are apparent. The median sizes of Age-1, Age-2, and Age-3 fish were all lower in 2017 and 2018 than the values in 2015 and 2016, suggesting reduced growth for these age classes occurred within the 12-month period prior to sampling for these two most recent years (i.e., June 2016 to May 2017, and June 2017 to May 2018), which coincided with the period of modified operations.

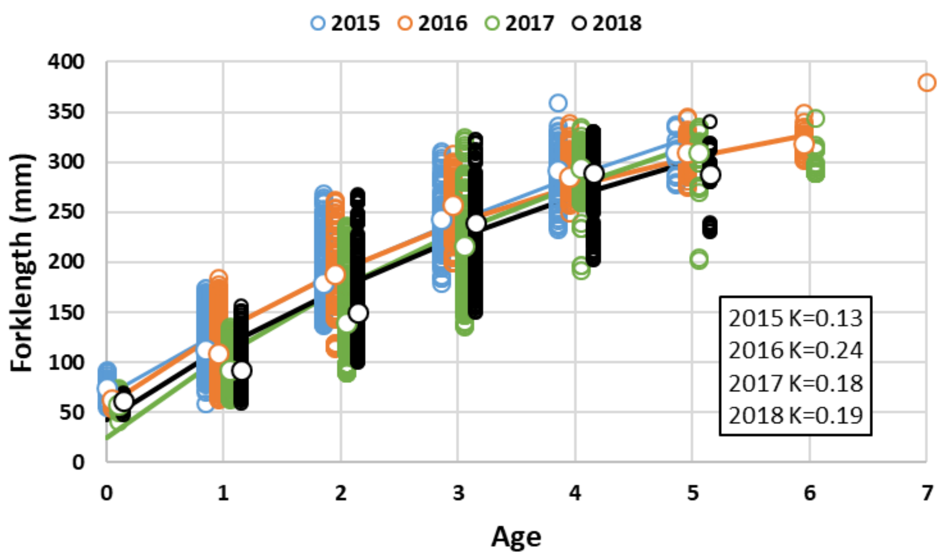

Figure 3.14 Size-at-age plot for rainbow trout captured during the annual fish population index survey, Years 3 to 6 (2015 to 2018). The lines represent the year-specific von Bertalanffy growth curves based on the median size values for each available age class in Downton Reservoir. "K" value is the curvature parameter.

The lengths and weights of rainbow trout in Downton Reservoir were highly correlated in all years (R^2 ≥0.98 from 2013-2018; Figure 3.15; Table 3.18). Slight differences in the slope and y-intercept values may have been attributable to differences in sample size in the first two years, but were very small among all years in general. The year-specific regressions almost completely overlapped one another.

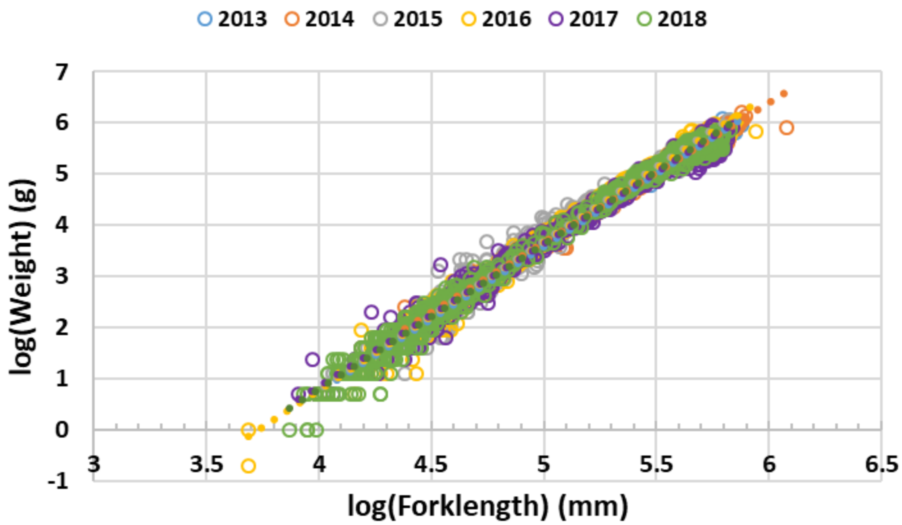

Figure 3.15 Log-transformed length-weight relationships for Downton Reservoir rainbow trout in Years 1 to 6 (2013 to 2018). Open circles are the individual data points (colour-coded by year) and the dotted lines represent the year-specific regressions. See Table 3.18 for the sample size, slope, y-intercept and R^2 values for each year.

Table 3.18 Sample size (*n*), slope, y-intercept and R^2 values for the year-specific length-weight relationships based on log-transformed values (shown in Figure 3.15).

Year	*n*	slope	y-intercept	R^2
2013	108	2.85	-10.64	0.99
2014	182	2.73	-9.97	0.98
2015	882	2.91	-10.85	0.98
2016	1,018	2.89	-10.77	0.99
2017	1,079	2.79	-10.31	0.99
2018	1,054	2.85	-10.62	0.99

We also plotted mean condition factor (Fulton's K; ±SE) to assess differences or changes by age and among years (Figure 3.16). In general, differences among consecutive years were small although there was a general trend of reduced condition factor across the sampling years for some age classes (i.e., Age-2, Age-3 and Age-4), and when the data for all ages were combined (bolded black line in Figure 3.16). Condition factor for Age-1 fish did not notably change across years. K value for Age-5 fish was reduced in 2017, but rebounded in 2018. Interestingly, a reduction in condition factor has been noted for rainbow trout in Carpenter Reservoir as well (since 2014; Putt et al. 2018). This may be coincidental, or may point to a general change in food base or productivity affecting both reservoirs in the system. However, mean condition factor of rainbow trout has been consistently higher in Downton Reservoir than in Carpenter Reservoir for the available study years to-date.

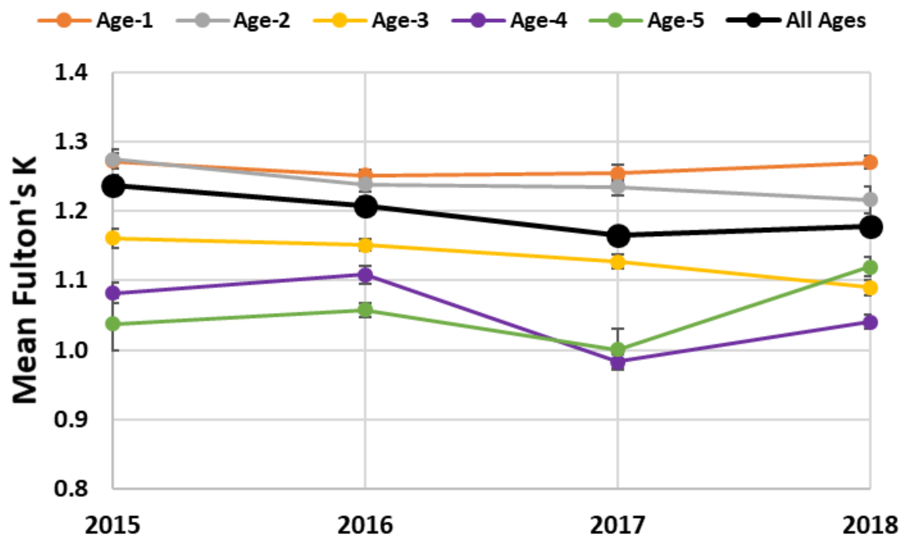

Figure 3.16 Mean condition factor (± SE) by age class and study year for Downton Reservoir rainbow trout sampled during the annual fish population indexing survey in late May to early June each year. The bolded black line shows the overall trend for all ages combined.

Overall, the condition factor assessment supports the conclusions from the comparison of median sizes and von Bertalanffy growth curves among years: that growth and condition were slightly reduced in 2017 and 2018 compared to 2015 and 2016. These parameters may be important factors to correlate with reservoir operational characteristics and fish abundance (measured as CPUE) for the synthesis at the end of the monitor for linking operational effects with fish population health in the reservoir (i.e., Management Question #5).

As an additional means of assessing year-to-year changes, the growth rates for individual cohorts (i.e., by recruitment year) are also being tracked (Table 3.19). However, there are still too few annual data points to draw comparisons between cohorts at this point, especially if the data sets for Years 1 and 2 (2013 and 2014) are excluded for reasons noted above. The oldest fish in the Year 6 (2018) sample were assessed as Age-5 (based on scale ageing; *n*= 5). The largest fish captured was 340 mm, which was very similar to the maximum size in every other study year to-date. Overall, Age 1 fish were, by far, the most abundant age class in the 2018 sample.

Table 3.19 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. Highlight colour: 2014 results = orange; 2015 results = blue; 2016 results = yellow; 2017 results = green; 2018 results = white.

Recruitment Year	Median Size (mm)									
	Age-0+	*n*	Age-1	*n*	Age-2	*n*	Age-3	*n*	Age-4	*n*
2013	**76**	4	**113 (+37)**	532	**188 (+75)**	84	**217 (+29)**	220	**290 (+73)**	309
2014	**75**	30	**109 (+34)**	596	**140 (+31)**	251	**240 (+100)**	259		
2015	**63**	12	**92 (+29)**	349	**150 (+58)**	236				
2016	**58**	16	**92 (+34)**	742						
2017	**62**	59								

The assignment of ages also allowed for the comparison of CPUE for each age class by habitat type (Figure 3.17). The range of available age classes were represented in each habitat type (except Age-0+ fish were very poorly sampled regardless of habitat type, as has been the case in each previous monitoring year). In Year 6 (2018), Age-1 fish were most abundant in shallow and steep slope habitats, and contributed the most of any age class to the significantly higher total CPUEs for these two habitat types relative to all previous years (see Table 3.13, above). Age-1 abundance at creek mouths and fan habitats were fairly equivalent. Age-2 fish were also most prevalent in shallow habitats, followed by creek mouths. As in past years, older fish (Age-3 and up) were most prevalent at creek mouths and less abundant in the other habitat types.

These results suggest that, to varying degrees, each habitat type is used by rainbow trout for rearing, and that creek mouths are likely significant feeding areas for the broadest distribution of age classes, as well as potential staging areas for spawning by mature fish. However, the single biggest difference in 2018, relative to previous years, was the increased CPUE of Age-1 fish in shallow and steep slope habitats suggesting that improved recruitment had occurred in 2016 (Table 3.13) (when these fish incubated and emerged), and conducive rearing conditions had continued through 2017 and up to the sampling period in 2018. The increased abundance of this age class along shallow and steep shorelines may be the result of higher competition and risk of predation at the more densely populated creek mouths for these young fish when abundances overall in the reservoir were higher.

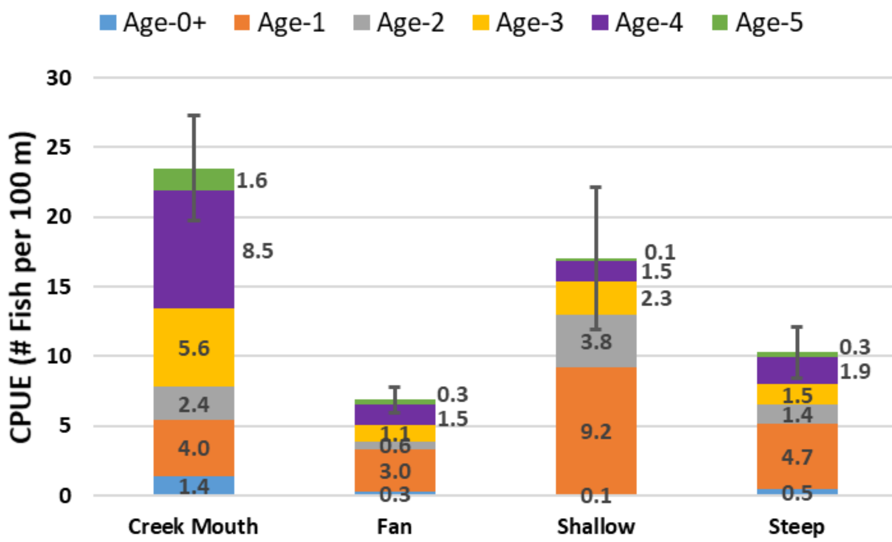

Figure 3.17 Catch-per-unit-effort (fish/100 m) by age class for each habitat type in Downton Reservoir based on the results of the boat electrofishing survey in Year 6, 1 to 8 June 2018.

The relative contribution of each age class to the catch in 2018, compared to 2015-2017 is shown in Table 3.20. The CPUE value and percent contribution for Age-1 fish rebounded in 2018 (i.e., 2016 recruits) after being reduced by about 50% in 2017 (i.e., 2015 recruits). The CPUE value for Age-2 fish in 2018 was equivalent to 2015 and 2017, and more than 2-fold higher than this age class in 2016 (i.e., 2013 recruits). The contributions of Age-3 and Age-4 fish have both increased each year since 2016, whereas Age-5 fish have remained at <1 fish/100 m.

Table 3.20 Comparison of catch-per-unit-effort (fish/100 m) by age class for monitoring years 3 (2015), 4 (2016), 5 (2017) and 6 (2018). The percent contribution of each age class to the yearly total is provided in brackets.

Age	CPUE – fish/100 m (% contribution)			
	2015	2016	2017	2018
0+	0.3 (3%)	0.1 (1%)	0.1 (1%)	0.4 (4%)
1	4.9 (55%)	5.0 (58%)	2.6 (32%)	5.5 (45%)
2	2.0 (22%)	0.7 (8%)	1.9 (23%)	1.7 (14%)
3	1.0 (11%)	1.2 (14%)	1.6 (20%)	1.9 (16%)
4	0.7 (8%)	0.6 (7%)	1.4 (18%)	2.3 (19%)
5	0.1 (1%)	0.8 (9%)	0.2 (3%)	0.4 (3%)
6		0.2 (3%)	0.1 (2%)	
All	**8.9 (1.0 SE)**	**8.7 (0.8 SE)**	**8.1 (1.0 SE)**	**12.2 (1.4 SE)**

The reduced contribution of Age-1 fish from 2016 to 2017 (i.e., from 5.0 to 2.6 fish/100 m; or 58% to 32% of the sample), may indicate poor recruitment or reduced survival in the reservoir for this age class prior to the 2017 sampling event. This cohort was recruited in 2015, the year with the highest reservoir elevations during the spawning period (i.e., up to 744.1 m), which may have impacted spawning success or incubation conditions. On the other hand, the Age-1 fish that were sampled in 2018 and had recruited in 2016 (the first year of reduced maximum fill level under modified operations) had improved recruitment and survival (i.e., Age-1 CPUE rebounded from 2.6 to 5.5 fish/100 m; or 32 to 45% of the sample). Also, the abundances of Age-2 to Age-4 have been on a trend of improvement since the start of modified operations in 2016. However, the specific causes of these changes in abundance by age class and cohort, and the degree to which they are linked to reservoir operation, are still uncertain. Until the remaining years of monitoring data are collected, it is difficult to put the degree of observed change between survey events in context. Tracking these kinds of age-specific changes are a key component of the analysis for this program that will continue to develop our understanding as more years of data are collected.

To that end, year-specific CPUEs for Age-1 and Age-2 fish were compared according to reservoir operating levels among years (Figure 3.18). Total CPUE for Age-1 fish (in Year *t*) was plotted against minimum and maximum levels experienced during the spawning period (i.e., ~21 May to ~21 July) in the year of recruitment (i.e., Year *t-2*; Table 3.21). 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 the number of data points are still not large, we fit regression lines to the points to assess for any emerging trends.

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 3.21. In Year 6 (2018), the Age-0+ rainbow trout were recruited in 2017, the Age-1 fish were recruited in 2016, and the Age-2 fish were recruited in 2015.

Table 3.21 Sampling years for the Age-0+, Age-1 and Age-2 classes according to recruitment year. The shaded cells indicate cohorts that will be sampled in upcoming study years.

Recruitment Year	Year Sampled		
	Age-0+	Age-1	Age-2
2013	2014	2015	2016
2014	2015	2016	2017
2015	2016	2017	2018
2016	2017	2018	2019
2017	2018	2019	2020
2018	2019	2020	2021

One pattern that appears to be emerging is a negative correlation between maximum reservoir elevation during the spawning period and the subsequent abundance of Age-1 fish that recruited under those conditions (top right plot on Figure 3.18). The R^2 value for this relationship (0.68) is reasonable based on the data currently available. This result seems intuitive: the higher the reservoir fills during the spawning period, the smaller the available spawning habitat area becomes (see Figure 3.9), and the greater the inundation risk for incubating eggs by the reservoir. Other than this apparent relationship, the regressions on the other plots are more flat and with lower R^2 values. In these cases, it is not possible to differentiate potential relationships from an inference of "*no effect*", at this stage. These figures and regressions will continue to be populated and updated as each new year of data becomes available.

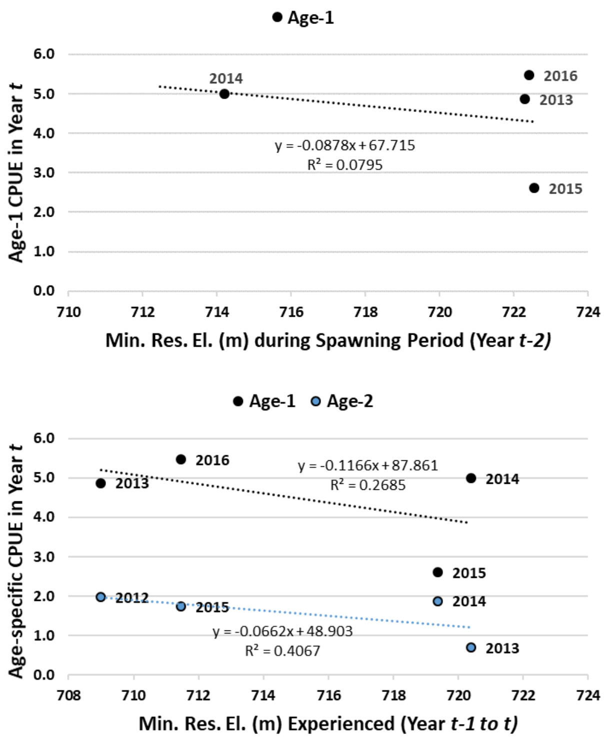

Figure 3.18 Plots of annual age-specific CPUE for Age-1 fish (upper panels) against minimum and maximum reservoir elevations during the spawning period in their recruitment year (*t-2*); and Age-1 and Age-2 CPUEs (lower panels) against the minimum and maximum reservoir levels experienced in the previous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

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 6), the Downton Reservoir fish population is entirely comprised of rainbow trout (save for 1 bridgelip sucker captured in 2016). The rainbow trout population spawns between late May and mid July (peak in mid to late June, according to year) 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 (or minimal extent) 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, temperature, gradient, and substrate composition), may reflect local adaptation by this population to earlier reservoir inundation risk at these locations.

Differences in temperature may also play a role in some cases, as creeks selected for spawning tend to have temperatures that reach the optimal range for rainbow trout during the spawning period, whereas other tributaries (e.g., Jamie Creek and the Upper Bridge River) are generally colder. However, the presence of the new year class of recently emerged fry in some creeks (i.e., Paul Creek, Cathy Creek and Jamie Creek; documented in fall 2018) where spawning has not, or only minimally, been observed supports that Downton Reservoir rainbow trout are flexible in selection of spawning stream among years according to conditions. As such, we will endeavor to continue monitoring potential spawning use in as wide a range of tributaries as possible to characterize any changes among years.

A higher proportion of trout (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). Targeted data collection on accessible stream-length according to reservoir elevation for the known spawning tributaries in Year 6 (2018) provided more information on this reservoir level vs. available spawning habitat relationship. See response to Management Question #3 in Section 4.3 for more information on this topic, below.

Following spawning and incubation in the selected tributaries, fry emergence is predicted to occur between the end of July and the beginning of September, with the peak in approx. the third week of August, based on ATU calculations using the available temperature data. The difference in predicted emergence timing among study years has been minimal to-date, varying by only 1-8 days (see Table 3.3 in Section 3.2). This timing was also generally confirmed by the sampling of recently emerged fry (CPUE = 9 fish/100 m; forklength range = 23 to 33 mm) during summer sampling at the end of August 2017, and during fall 2018 (CPUE = 21 fish/100 m; forklength range = 20 to 58 mm), in several creeks.

Beyond this post-emergence period within their first growing season, fish use of the tributaries for rearing appears to be low (i.e., CPUE for all other age classes was between 0-4 fish/100 m in every season sampled), suggesting that the majority of the Age-0+ fry move into the reservoir sometime before the following spring, where a range of suitable temperatures for growth are available (according to depth), food (likely in the form of drifting invertebrates at the creek mouths or amphipods in the reservoir – see Photo A12 in Appendix A) is provided, the year-round turbidity provides cover, and the risk of habitat loss from changing reservoir elevations is low (as opposed to within the drawdown zone of the tributaries).

In the nearshore areas of the reservoir, the rainbow trout are distributed among each of the longitudinal zones (i.e., west, mid, and east; shown on Figure 2.4), and highest abundance has varied between them among years (Table 3.14). The highest densities have routinely occurred at the creek mouths, generally followed by shallow slope and fan habitats; however, abundance at steep slopes was higher than fans for the first time in 2018 (due to a high contribution of Age-1 recruits that year). Otherwise, the lowest numbers have more consistently been associated with steep shorelines. Offshore sampling (i.e., by gill netting) in Year 5 (2017) suggested that use of pelagic habitats by rainbow trout in Downton Reservoir is low during the spring sample period, and fish were only captured within 2.4 m of the surface, despite sampling at a range of depths between the surface and the near-bottom.

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

Across the years to-date, the age range of the sample has spanned from 0+ to 7 years (20 to 437 mm); the majority of sampled fish are typically between ages 1 to 3, although there was also an increased catch of Age-4 fish in 2018. The most rapid growth has tended to occur between ages 0+ and 3, after which growth rate slows and there is considerable size overlap among the older age classes.

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

As summarized in Section 1.4, the key operating parameters of the selected alternative (N2-2P) included conditional minimum and maximum reservoir elevations of 710.00 m and 749.81 m, respectively (BC Hydro 2011). In practice, during the N2-2P years monitored under this program between 2013 and 2015, minimum elevations were 719.69, 709.00 and 720.4 m, and maximum fill elevations were 749.53, 748.23 and 746.98 m. Under modified operations, implemented since 2016, the target maximum elevation was reduced to 734.00 m (intended to reduce seismic risk at the La Joie Dam and Generating Station) and the minimum target (710.00 m) was unchanged, although in practice the minimum reservoir level may reach that target in more years than under N2-2P. In the three years of modified operations to-date, minimum elevations were 719.38, 711.47 and 711.29 m, and maximum fill elevations were 733.94, 733.46 and 732.96 m.

It is important to note that by the end of the current monitoring period in 2022, limited data will be available to represent the full range of “N2-2P” operations (i.e., possibly only 2 years of fish abundance index data that are comparable with the subsequent modified operations years). The discrepancy in number of years for each treatment within the study period may constrain comparison of N2-2P operation with modified operations due to substantial differences in sample size between these operational treatments, and may preclude answering this management question as originally intended. However, the results will speak to the operational range tested, which is a sub-set of the normal operating range (i.e., lower maximum, but similar minimum elevations).

Overall CPUE values for rainbow trout were up significantly in 2018 to 12.2 fish/100 m (SE 1.4) of shoreline from 8.1 to 8.9 fish/100 m (SE 0.8-1.0) from 2015 to 2017 (the other three years available to-date when sampling methods and effort were consistent). This difference was primarily due to increased catches of Age-1 fish in 2018, which improved by more than 2-fold from the lower abundance of this age class reported for 2017. Additionally, CPUEs for Age-2 to Age-4 fish have increased (albeit more modestly) each year since 2016 when they were near or at their lowest. It seems possible that the Age-1 cohort was smaller in 2017 due to the high reservoir elevations that occurred during the spawning period of their recruitment year (2015), affecting spawning success or incubation conditions that year. The substantially increased contribution of Age-1 fish in 2018 (that recruited in 2016), and generally increasing abundance of older fish (ages 2-4) since 2016 may be related to the modified operation of the reservoir (particularly the reduced maximum fill elevation that has occurred during the spawning period), which was implemented starting in 2016 and continued in 2017 and 2018.

These results suggest that the modified operations may be improving recruitment conditions, reservoir rearing conditions, or both. However, with the number of years of data presently available, these conclusions must still be considered tenuous at this point, and will be further informed by results from the remaining years of monitoring. These results do appear to confirm that the selected monitoring approach, based on the consistent application of methods and effort as described in this report, are appropriately sensitive for characterizing trends in the abundance and diversity of the Downton Reservoir fish population. This will be essential for ultimately linking the observed patterns and trends in abundance to specific operational characteristics by the end of the monitoring period.

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 reliably confirmed or rejected at this stage of the program. However, the 2018 results provided an initial data point which suggested that the annual abundance index increased under the initial years of modified operations (2016-2018). More years of data are required to support this result before inferences can become more conclusive. While the program has established an effective method for tracking this information (Fish Population Index Survey) that is being successfully implemented, there are currently 4 years of comparable abundance index data points available at this point (refer to sections 2.5 and 3.6) with 4 more years yet-to-be completed before the end of the currently prescribed monitoring period. 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 (up to, and including, Year 10) to provide a more definitive response to this management question and confirmation or rejection of the H_1 hypothesis.

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

Specific, targeted habitat data collection linked to key reservoir operation elevations in Year 6 (2018), provided additional information for addressing this MQ that supplemented the results collected and reported previously (Sneep 2019; also refer to Section 3.3 for specific habitat survey results). The key habitats for Downton reservoir fish are: a) selected tributaries, for spawning and egg incubation, initial post-emergence rearing, food production and thermal refuge; and b) shoreline habitats in the reservoir for rearing by the highest abundance and widest range of age classes of rainbow trout. The primary shoreline habitat types are creek mouths and shallow habitats, although all shoreline types are used by the rainbow trout population. Key habitat factors in the tributaries include connectivity with the reservoir, accessible stream length, appropriate thermal regime, and suitable substrates for spawning. In the reservoir, the key habitat factors include the consistent array of habitat conditions available across the range of elevations, appropriate temperatures to support rearing and growth, turbidity (which provides cover), and food supply (primarily at the creek mouths, but also zooplankters in the reservoir itself). The composition of bottom sediments vary with elevation in the reservoir basin, but this factor does not appear to be a significant driver for fish population trends to-date.

Tributary Habitats

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 (not measured by this program, but anecdotal). However, based on tributary fish sampling results to-date, use of the creeks for rearing by the rainbow trout population appears limited beyond a short period (<1 year) after emergence. In select creeks (i.e., those associated with spawning use), highest abundance occurred in summer (i.e., late August; 15 fish/100 m) and fall (i.e., mid October; 20 fish/100 m) related to the presence of newly or recently emerged fry during those months.

However, the abundance of fish in the creeks was diminished in spring (i.e., mid May; 6 fish/100 m), by which time the fish have likely migrated out of the creeks to the reservoir, and the abundance of fish >Age-0+ was relatively low in the tributaries during all seasons (Section 3.6). Additional seasonal sampling replication in the creeks is required in upcoming monitoring years to further improve confidence in these inferences. Tributary fish sampling to document use of the range of available creeks during each season (spring, summer and fall) within the same year is currently being planned as a part of the Year 7 (2019) activities (see Section 5 – Recommendations). This should help address some of the additional variability in fish abundance or use between the seasons that would be more inherent among years.

Due to low inflows, some creeks have been observed to periodically go dry (or flow to ground) in spring and/or summer (e.g., Trib. #19, Trib. #10, Ault Creek), or may freeze solid in winter. Access to some tributaries by spawners may be impeded when reservoir levels are <713 m (observed in 2014, 2017 and 2018) during May before the onset of freshet flows in the creeks (see Photo A10 in Appendix A). However, it is important to add that these conditions were fairly short-lived (until inflow increased), typically prior to the start of the rainbow trout spawning period, and/or occurred in creeks that are not primary spawning creeks. Other conditions that have caused tributaries to go dry are: a) when cold weather patterns reduce snow melt in the spring (observed in Trib. #19 during June 2018); and, b) when the snow pack in smaller drainages depletes (observed in Trib. #19 and Trib. #10 in August 2017).

Targeted data collection on accessible stream-length according to reservoir elevation for the known spawning tributaries in Year 6 (2018) provided more information on the reservoir level versus available spawning habitat relationship. Depending on gradient within the drawdown zone and location in the reservoir basin, the loss of accessible stream length due to reservoir inundation in 2018 was between 46% (Eagle Creek; lower gradient, in the West zone of the reservoir) and 58% (Ault Creek; higher gradient, in the East zone), respectively. These data will allow us to assess the proportion of each stream that was inundated during the spawning period in each study year based on the reservoir elevation record. Starting in Year 7 (2019), we plan to collect more specific information about the location of spawner observations (and any redds) within the drawdown zone so that we can assess which reservoir elevations may pose the greatest risk for inundating the incubating eggs before fry emerge (assuming spawner location is an adequate surrogate for spawning location). As this data set builds over the remaining years of monitoring, this should contribute another useful input for informing reservoir operation management decisions.

Temperatures in the monitored spawning tributaries tend to reach optimal ranges within the observed migration, spawning and incubation periods (Figure 3.3 and Appendix B, Figure B2). 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. Potential spawning use of the UBR has been unconfirmed by this program due to the channel width, extensive length, difficult access and chronically high turbidity, rendering the visual-based methods employed in the other tributaries useless. However, based on the results of the backpack electrofishing surveys for juveniles, use of the UBR for rearing has been low relative to some of the other tributaries and considering the amount of wetted area that it provides. In 2 of the 4 years of available data, temperatures in Jamie Creek have been below the optimal range for all or most of the rainbow trout spawning and early incubation period (mid May to end of July), which may be at least partly why spawning use of this tributary has been low and 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 et al. 2018), likely contributes to the later spawn-timing for the Downton Reservoir population.

Reservoir Habitats

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. The creek mouths may also provide an important thermal refuge during the summer months (July and August) when reservoir surface temperatures can exceed optimal levels, especially considering that rainbow trout tend to be a surface oriented species (confirmed by the various sampling methods at a range of depths employed to-date).

Relative to the near-normal full pool elevation (i.e., 745 m, which almost fully inundated the reservoir basin) and the 733 m modified maximum elevation surveyed in summer, the total habitat length of functional creek mouths (i.e., that were receiving flow) was actually higher at the low pool elevations surveyed in spring (722 m in 2016; 716 m in 2017) because the creeks were in pre-freshet condition and all intermittent drainages were flowing. Due to the shape of the reservoir basin, only steep shoreline habitats were substantially reduced (by ~50%) at the low pool elevations, which has typically been the habitat type associated with the lowest catch rates of fish during the annual index survey. This suggested that there is no significant loss of any habitat type that is shown to be more important for fish rearing use (i.e., creek mouths, shallow slopes or fans) at the lower reservoir elevations. The percent contributions of each habitat type were quite similar between the two maximum elevation surveys (i.e., 745 and 733 m), and between the two low-elevation surveys (i.e., 722 m and 716 m). The main differences among the high elevation and low elevation surveys were the length of the reservoir (i.e., 25.6, 22.5, 17.8 and 14.2 km at 745 m, 734 m, 722 m and 716 m), and the total lengths of the available shoreline habitat (i.e., 60.3, 53.7, 40.9 and 34.5 km), which were ~100%, 89%, 68% and 57% of the normal full pool values, respectively.

In general, the substrate size distribution and embeddedness in the reservoir drawdown zone are positively correlated with elevation (size range, median size and interstitial space each increase with the elevation), although there are not enough fish abundance index data points to correlate access to different maximum elevations with recruitment or size-at-age metrics at this point. This will likely need to be included as part of a multivariate analysis of the fish abundance results with an array of habitat and reservoir operational variables as a part of the synthesis at the end of the monitor to determine the relative importance of substrate differences compared to other habitat factors. The substrate composition and embeddedness data collected in Year 6 (2018) supplemented the sample size (particularly for the 722 m fish sampling elevation), but did not significantly alter the results or conclusions reported previously (Sneep 2018b). Rather the added data has helped to accrue confidence in the inferred differences among habitat types and elevations. Based on the information gathered to-date, it is expected that the main factors limiting population size in Downton Reservoir are food supply, inundation of spawning habitat during the spawning and incubation period (May to July), and possibly overall spawning habitat area available in the tributaries.

Overall highest catch rates for rainbow trout in the reservoir during the annual fish population index survey have consistently been at the creek mouths, where all age classes are represented. Given the important food sources that the tributaries likely provide, it is not surprising that the highest fish densities tend to be concentrated around creek mouths and their adjacent habitats. Similar to the results of a productivity assessment in Carpenter Reservoir in 2000, high natural turbidity and large seasonal fluctuation in surface elevation may limit food production within most of the reservoir drawdown zone (Josh Korman, lead investigator, 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 contributors to overall fish abundance & condition, and the observed patterns in habitat-stratified fish distribution (see Section 3.7).

If the concentration of rainbow trout at creek mouths reflects the primary source of their food supply, then it's possible that reservoir operation may not directly impact that existing food supply (unless reservoir operations affect food production within the lower extent of the tributaries, which is unknown). Food production in the reservoir itself may be comparatively poor due to the ongoing cycle of drawdown and inundation, which may also be reflected by the much lower relative use of pelagic habitats by rainbow trout in the reservoir (refer to pelagic sampling results in in the Year 5 report). If that is the case, then management decisions for the reservoir (e.g., N2-2P vs. modified operations) may not directly affect the current food supply for rainbow trout in the reservoir; however, a more targeted study on the specific sources of the rainbow trout food supply would be required to address uncertainties around this. Amphipods (a form of zooplankton) were anecdotally observed in the reservoir in spring 2017 (see photo A12 in Appendix A). These invertebrates would serve as a sizable food item for a fish and would likely be part of the rainbow trout diet. However, within the current scope of this program it is not known how abundant these amphipods are in the reservoir (i.e., as a food source relative to drift from the creeks), or how various reservoir operations may impact them.

Management Question Hypotheses

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 characterizing the specific spawning distribution within the drawdown portion of the selected tributaries are needed. Data collection to support this is proposed to begin in Year 7 (2019; see Section 5 – Recommendations). Evidence suggests that rainbow trout primarily and most consistently use tributaries in the western portion of the reservoir basin for spawning since habitats in these streams inundate later in the year (i.e., after the incubation period). Use of accessible tributaries in the mid and east zones (such as Ault and Cathy creeks) has been observed, but only very minimally (i.e., peak counts of 2-3 fish), despite the presence of suitable habitat. This may be due to greater and earlier inundation risk at these locations, particularly under normal (N2-2P) operations. Implementation of modified operations (starting in 2016) reduced the portion of stream length inundated by the reservoir due to the reduced fill level relative to normal N2-2P operations (refer to Figure 3.9 in Section 3.5), and fish recruitment and abundance appears to have responded favorably (based on 2018 results). Continued assessment in the remaining monitoring years will document whether spawning distribution expands or shifts to include these tributaries under modified operations.

The secondary null hypothesis (H_{4a}), which states**:** "*Rainbow trout spawning density in Downton Reservoir drawdown zone is minimal and therefore operations do not limit productivity of fish populations*" is tentatively rejected; however, more data are needed to define the relationship between operations (e.g., min. and max. reservoir elevations and drawdown and fill rates) and rainbow trout recruitment and survival. While some tributaries are not used at all, or minimally (see above), the drawdown zone of Tribs. #13 and Eagle Creek have been used extensively (Sneep 2018b and Section 3.5 of this report)**.**

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 fully confirmed or rejected at this point, although the information collected to-date suggests that this is not generally the case. More data from the tributary access surveys for the range of low reservoir elevations and inflow levels during the spawning period are needed. Evidence to-date suggests that connectivity of some tributaries may be cut off when reservoir levels are <713 m during May before the onset of freshet (due to creeks flowing to ground), although effects on the primary spawning tributaries have not yet been observed. Trib. #19 was observed to go dry in mid June 2018 (due to the effect of cold air temperatures on snow melt volumes); as a result, rainbow trout did not spawn in that creek in 2018. However, this was not caused by reservoir operations in this case. Full support for rejection of this null hypothesis requires additional access surveys across the range of reservoir elevations during the rainbow trout pre-spawning migration period. Surveys for this purpose are planned to continue for the remaining 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 rejected based on current findings (see Section 3.3). Efforts in Year 6 (2018) supplemented data collection initiated in previous study years to define substrate characteristics at 747, 734, and 722 m, and provided habitat type distribution information at the 734 m modified maximum level. See descriptions of substrate composition, interstitial space availability, and habitat distribution among selected high and low reservoir elevations provided above for the rationale for rejecting this hypothesis at this stage. Towards completion of this monitoring program in 2022, this 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?

In addition to another year of data on operational and physical habitat parameters, Year 6 (2018) monitoring contributed an additional data point to the annual index of abundance, and provided another set of results for documenting trends in the age structure, growth and condition factor of the rainbow trout population in Downton Reservoir. There are not yet any clear relationships between minimum (absolute or during spawning period) or absolute maximum reservoir levels and the abundance index for Age-1 or Age-2 fish at this point (see the regressions, slopes and R^2 values on the upper-left, lower-left, and lower-right plots of Figure 3.18 in Section 3.7). Or at least there is not a strong enough signal to differentiate potential relationships from an inference of "*no effect*", at this stage. As such, any inferences about such relationships made from the available results must still be considered tenuous at this point and will be further supported (one way or other) by inclusion of data points from the remaining monitoring years.

One emerging relationship, which is not actually captured by this management question but does appear to have some more support at this point, is between maximum reservoir elevation *during the spawning period* and the subsequent abundance of Age-1 fish that recruited under those conditions (top right plot on Figure 3.18). The slope (-0.14) and R^2 (0.68) values for this negative correlation are stronger than the other relationships based on the data currently available. As mentioned in Section 3.7, this result seems intuitive: the higher the reservoir fills during the spawning period, the smaller the available spawning habitat area becomes (see Figure 3.9), and the greater the inundation risk for incubating eggs by the reservoir. However, this also remains tenuous until the results from the remaining monitoring years can be included.

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 reliably confirmed or rejected as more annual abundance estimates coupled with year-specific operational parameters (as described above) are needed. The years monitored to-date have provided an ample degree of operational contrast (i.e., varying minimum and maximum levels, and fill and drawdown rates), but in order to fully define the potential relationships and reduce uncertainty, values for all monitoring years (to 2022) will be required.

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

Based on the reservoir elevation and fill rate information provided by BC Hydro (see Figure 3.1 and Table 3.1), the modified operation of Downton Reservoir (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. The increased abundance of Age-1 fish in 2018 (i.e., the first cohort that recruited under the lower modified operations levels) seems to support this (see Section 3.7). Observed increases in Age-2 to Age-4 fish abundance during the modified operations years also suggests good, or even potentially improved, rearing conditions in the reservoir under those operations. However, it is still premature 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. This will ultimately be evaluated at the end of the monitoring period when all years of data are available for a synthesis, and we propose using a multivariate statistical analysis approach that incorporates annual fish catch results, size and condition factor with key physical and habitat variables (e.g., minimum and maximum reservoir elevations, drawdown and fill rates, habitat type distribution, substrate size classes available, etc.).

Determining the effects of various operational scenarios for the management of Downton Reservoir on Middle Bridge River flows could only be determined based on BC Hydro flow modelling that is outside the scope of this monitoring program. However, this would be a useful exercise for BC Hydro to undertake, with relevant inputs from this program, during the period of monitoring to inform operating decisions and the final report (in Year 10). Potentially relevant inputs from this program could include identification of Downton Reservoir elevation ranges and associated date ranges that are important for spawning use and protecting the most significant amount of rainbow trout spawning habitat in reservoir tributaries, as observed under modified operations. Data collection on the relationship between reservoir elevation and stream channel length in the drawdown zone initiated in Year 6 (2018), and additional work to characterize spawning distribution within the drawdown zone more specifically (proposed to start in Year 7 (2019)), will provide such inputs.

Also, as stated earlier, the modified operations are a departure from the N2-2P operations in terms of the maximum fill elevation and potential frequency of deeper drawdowns related to mitigating seismic concerns at La Joie Dam. According to BC Hydro's current capital schedule, the modified operations will continue until at least the end of the BRGMON-7 monitoring period in 2022 (Matt Casselman, BC Hydro NRS, pers. comm.). As such, there will be more years of monitoring the modified operations than the N2-2P operations. The modified operations *do* have a significant impact on 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., 734.0 m instead of 749.8 m). These modifications may require changes in how this question is interpreted and addressed relative to its original intent, at the end of the BRGMON-7 program.

5. Recommendations

Going forward, the CPUE metric values provided in this report will continue to be generated annually and compared as a reflection of trends in population index between monitoring years. To-date, there have been some variation and changes in total CPUE values, trends between habitat types, and relative abundance among the age classes in Years 3 to 6 (2015, 2016, 2017 and 2018). We fit regression lines to the Age-1 and Age-2 CPUE vs. reservoir operation (minimum or maximum levels) relationships starting in 2018; however, there were still too few data points to have full confidence in the inferences, or confirm the significance of the observed differences or changes in context. The figures and tables generated for this report will continue to be populated as each new year of data becomes available to update the results and provide guidance for monitoring activities in the remaining study years.

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 have been consistently well represented in the sample to-date, primarily occupy the reservoir throughout the year, and are the most appropriate ages for potentially linking the effects of reservoir operations with recruitment. Differences in the abundance of the oldest age classes (i.e., ages 4 and up) across years will be noted, but won't solely 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.).

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 directly measure the growth of individuals between capture and recapture events, and may allow estimation of population size (using an open population model) as well as a potential catchability assessment of the boat EF method in this context. While the resolution of the population estimates alone may not be high enough to track changes with specific operations among years, it can be helpful to have multiple lines of evidence to provide context or support to population trends assessed by CPUE, by the end of the monitor.

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

- Target installation of the temperature array in Downton Reservoir for mid April (or as early as possible given ice and snow conditions in the spring) and removal by end of October (or as late as possible for the same reasons in the fall) to fully bracket the period of thermal stratification in this context, such that changes in the timing of thermal stratification development or collapse can be assessed among years in addition to the specific temperature profiles.
- Now that habitat mapping and comparable amounts of substrate measurement data have been collected at each of the targeted set of elevations, we propose to put any further

data collection for these components on hold (at least for now) to provide budget and effort room for completing some other high priority activities, such as conducting three tributary fish sampling surveys (i.e., for spring, summer and fall) in a single year and collecting more specific data on spawner locations within the drawdown zone of the tributaries (see more on these ideas below). If a need for any additional habitat data collection is identified, it could be incorporated into one or more of the remaining study years, according to information priorities at that time.

- Continue to conduct weekly spawner count streamwalks (including 2 tributary access surveys) in the widest range of tributaries possible (e.g., Tram Cr., Trib. #13, Jamie Cr., Eagle Cr., Trib. #19, Cathy Cr., and Ault Cr.) between mid May and the end of July to document start, peak, and end of spawn timing as well as relative abundance among creeks. Starting in Year 7 (2019) we also propose to collect data on the specific locations where spawners (and any redds) are observed in the creeks, particularly for the drawdown zone, so that the elevational distributions can be plotted on Figure 3.9 to contribute to an understanding of which elevational ranges pose the greatest and least inundation risk for incubating eggs. The added effort (and cost) for adding this component can be covered within the existing budget by eliminating further habitat mapping and substrate measurement activities (as described above).
- Conduct tributary fish sampling (by backpack EF) during three seasons in the same year starting in Year 7 (2019). Seasonal sampling will target a spring session in June, a summer session in August, and a fall session in October at a range of tributaries (e.g., Ault Cr., Paul Cr., Cathy Cr., Trib. #19, Eagle Cr., Jamie Cr., Trib. #13, Tram Cr., and Upper Bridge River). As for seasonal sampling in past years, spatial distribution of sites will include the drawdown zone and the upland zone (where accessible to fish from the reservoir) in the selected tributaries. The added effort (and cost) for expanding this component from 1 season to 3 per year can be covered within the existing budget by eliminating further habitat mapping and substrate measurement activities (as described above).
- As in every year since 2015, repeat the fish population index sampling by boat electrofishing on the same dates (early June), maintaining the same approach, effort, crew, equipment, etc. each year to the extent possible.

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Appendix A – Representative Photos of Reservoir and Tributary Habitats

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

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

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

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

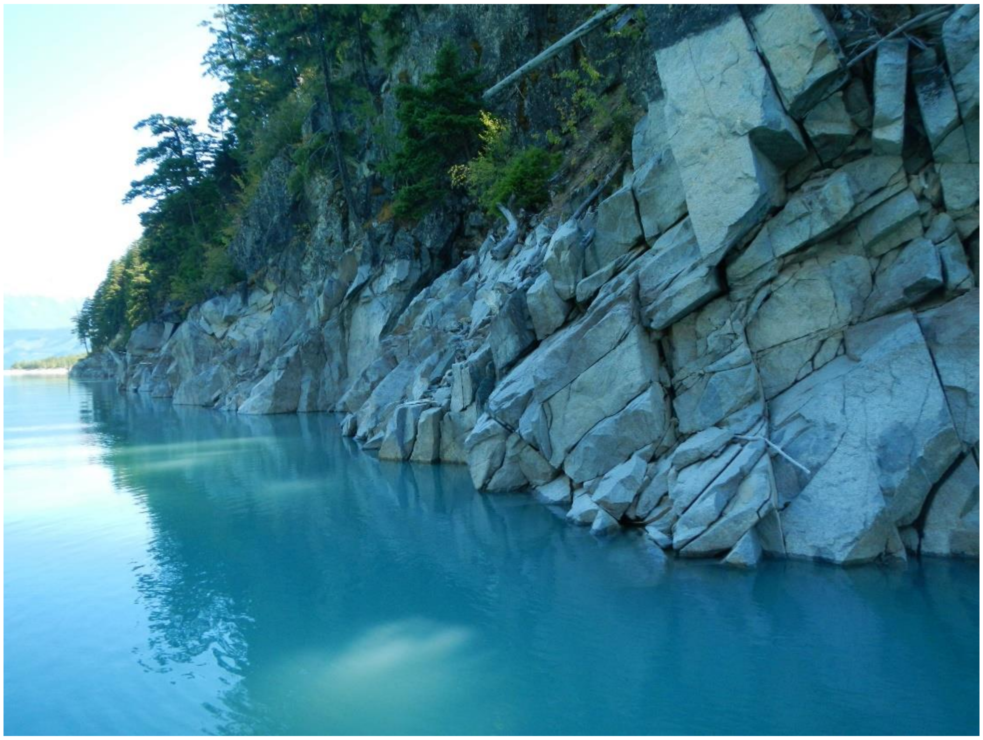

Photo A5 Reservoir Habitat Type 4: **Steep Slope** (Sub-type Bedrock)

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

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

Photo A8 **Tributary** Habitat – Upland

Photo A9 **Tributary** Habitat – Drawdown

Photo A10 Ault Creek observed flowing to ground (shown by red arrow) at a reservoir elevation of 712.5 m on 19 April, 2018.

Photo A11 Trib. #19 channel was dry within the drawdown zone (flowed to ground in the upland) on 15 June, 2018. Reservoir elevation was ~720 m. The red arrow indicates the location of the channel

Photo A12 A couple of amphipods opportunistically collected near the surface in a nearshore habitat of Downton Reservoir. These are a likely food source for rainbow trout in the reservoir (Chris Perrin, pers. comm.). Scale shown is in millimeters.

Appendix B – Temperature Figures for Each Study Year Available

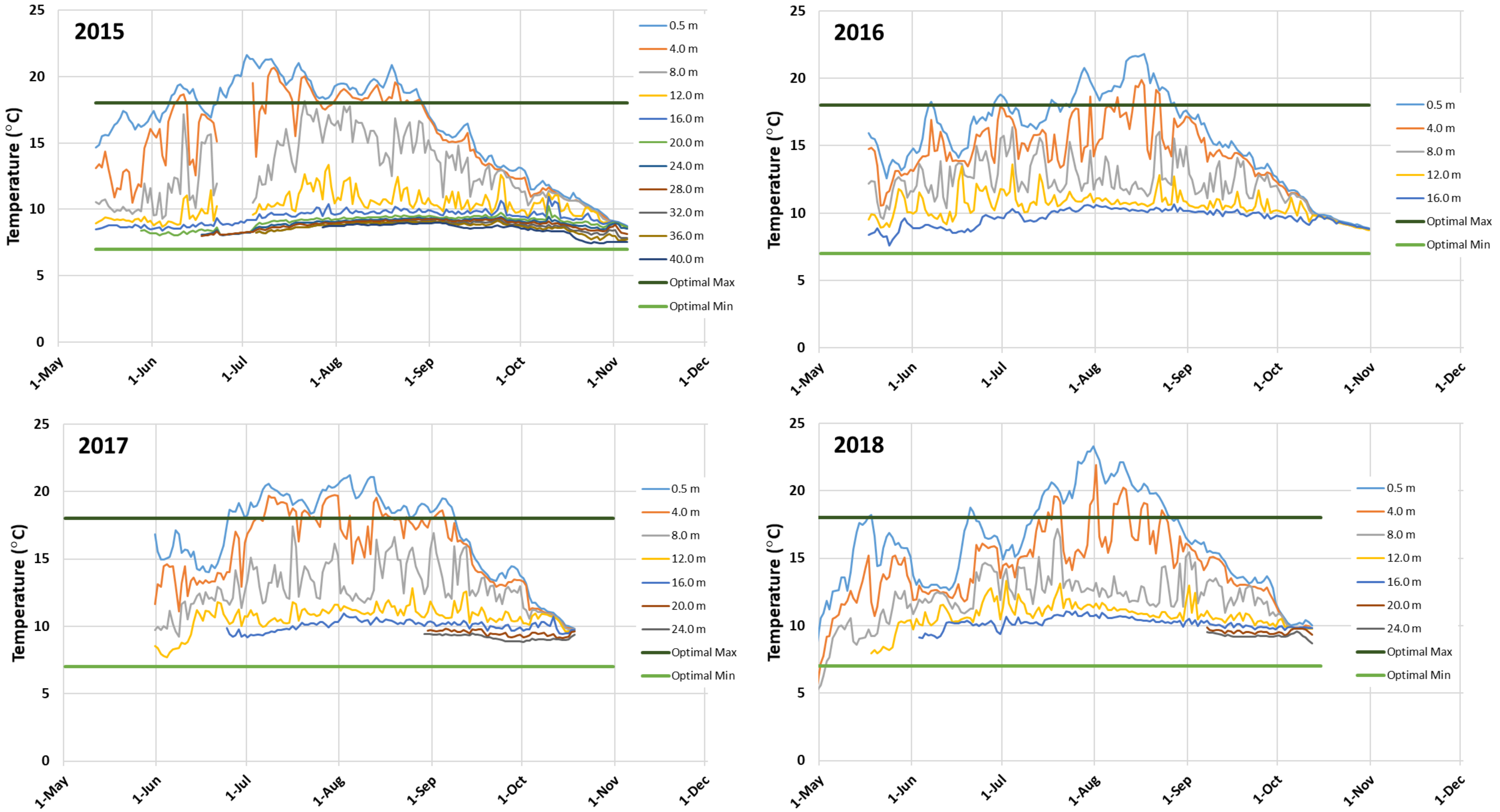

Figure B1 Mean daily water temperatures by depth from the Downton Reservoir log boom array, May to November 2015 (upper left), 2016 (upper right), 2017 (lower left), and 2018 (lower right). The light and dark green horizontal lines bracket the preferred temperature range of rainbow trout (McPhail 2007).

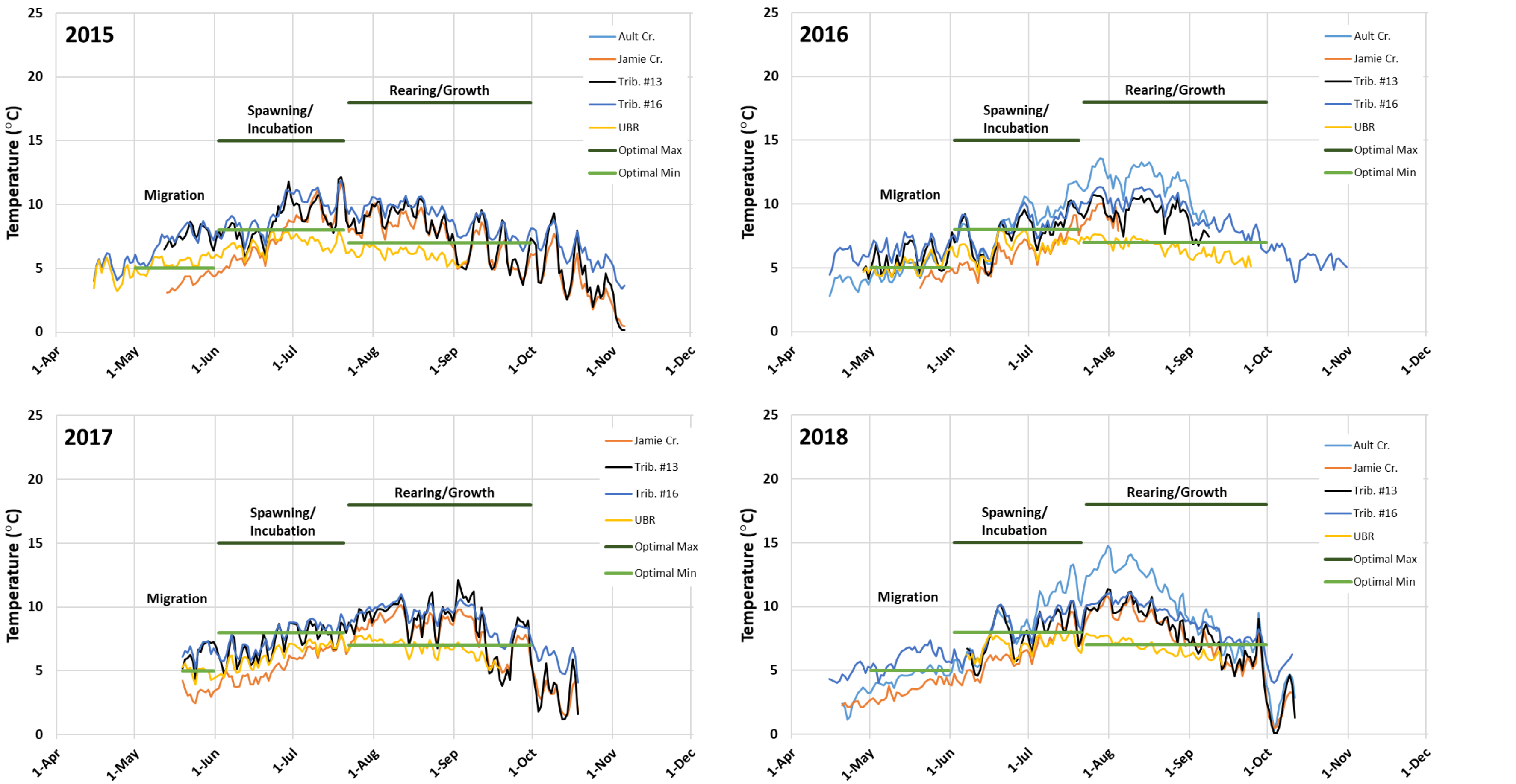

Figure B2 **Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to October 2015 (upper left), 2016 (upper right), 2017 (lower left), and 2018 (lower right). The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of rainbow trout (McPhail 2007).**

Appendix C – Summary of Inter-Year Rainbow Trout Recaptures (All Years To-date).

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)	Growth (mm/yr)
	Date	Zone	FL (mm)	Date	Zone	FL (mm)		
086704	22-May-13	East	329	9-Jun-14	East	324	0.0	0
077392	25-Jun-13	East	302	9-Jun-14	East	300	0.0	0
650514	9-Jun-14	West	320	6-Oct-14	West	320	4.7	0
585156	8-Oct-13	West	172	7-Oct-14	East	280	7.6	108
586629	16-Jul-13	West	326	6-Oct-14	West	322	0.2	0
585701	10-Jun-14	East	337	10-Jun-15	East	337	0.0	0
734711	12-May-15	East	293	16-Jun-15	West	298	11.0	52
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
656574	15-Jun-15	West	161	31-May-16	West	238	0.1	77
889046	18-May-16	Mid	114	2-Jun-16	Mid	123	0.1	-
734749	11-Jun-15	Mid	141	2-Jun-16	Mid	227	1.8	86
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
656534	16-Jun-15	Mid	154	3-Jun-16	Mid	286	3.7	132
888413	3-Jun-16	Mid	294	3-Jun-17	Mid	300	1.0	6
889032	31-May-16	West	103	4-Jun-17	West	192	1.6	88
889411	1-Jun-16	West	104	5-Jun-17	West	204	1.4	99
656582	16-Jun-15	Mid	176	5-Jun-17	West	295	2.3	60
888393	4-Jun-16	Mid	89	6-Jun-17	West	172	3.8	83
889107	30-May-16	East	152	6-Jun-17	East	250	3.4	96
889225	31-May-16	West	311	6-Jun-17	West	315	0.2	4
889393	31-May-16	West	105	7-Jun-17	East	202	9.0	95
889234	30-May-16	East	273	29-Aug-17	West	275	13.0	2
888463	4-Jun-16	East	91	30-Aug-17	West	180	10.7	72
650223	6-Oct-14	West	209	4-Jun-18	Mid	307	6.7	27
734739	10-Jun-15	East	150	5-Jun-18	West	306	11.2	52
889249	18-May-16	Mid	116	3-Jun-18	West	237	1.4	59
889392	2-Jun-16	Mid	112	2-Jun-18	Mid	231	0.7	60
888403	3-Jun-16	Mid	101	1-Jun-18	East	272	6.4	86
975991	4-Jun-17	West	88	6-Jun-18	Mid	198	5.4	109
975126	7-Jun-17	East	131	6-Jun-18	Mid	221	4.5	90
975302	8-Jun-17	East	112	1-Jun-18	East	243	1.9	134
975311	8-Jun-17	East	165	1-Jun-18	East	283	1.9	120

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

Appendix D – Length-Frequency Figures by Study Year

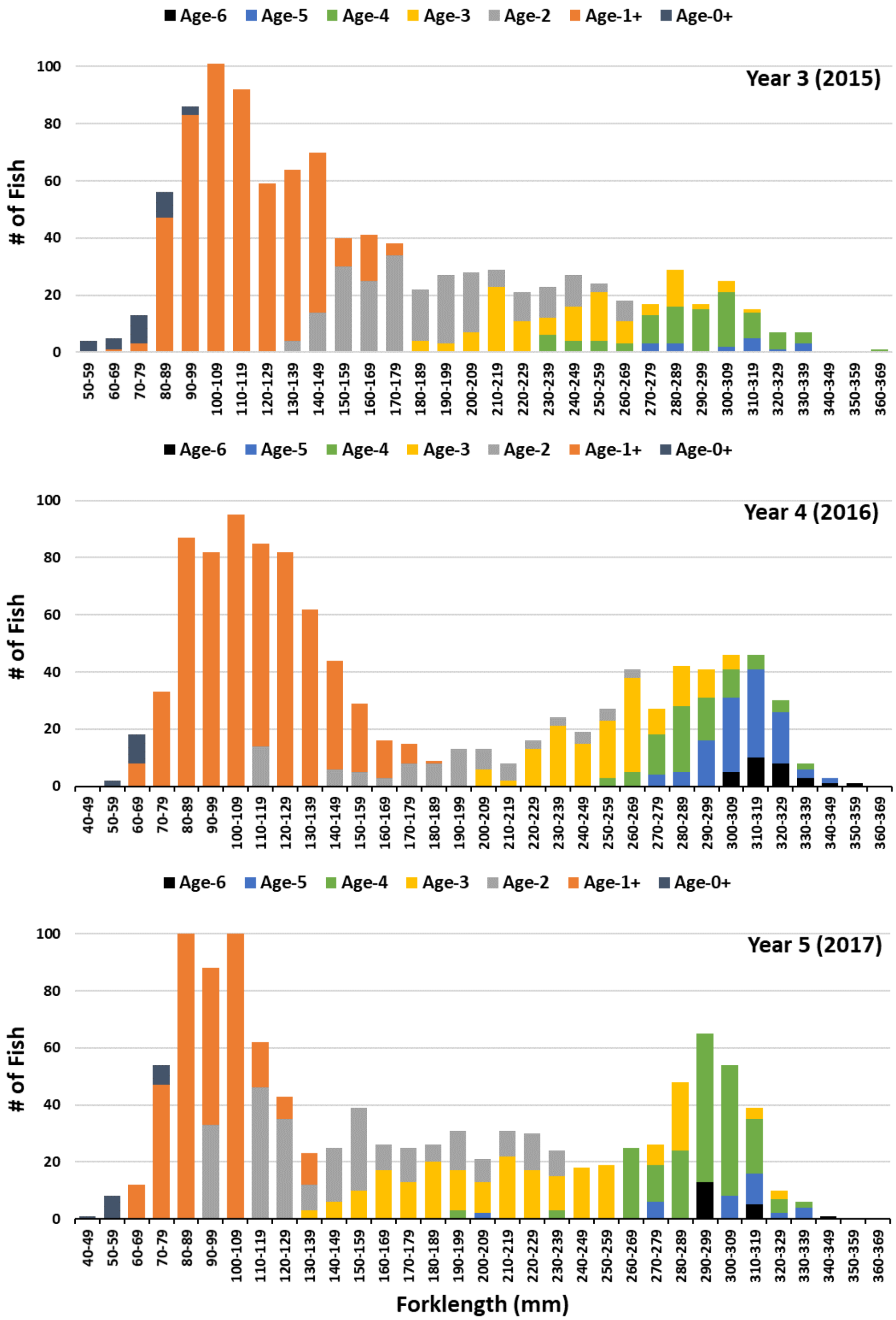

Figure D1 Length-frequency histograms for each study year showing the distribution of age classes for rainbow trout in Downton Reservoir in late May to early June. Note: results for years 1 and 2 are not included due to different sampling approach in those years.

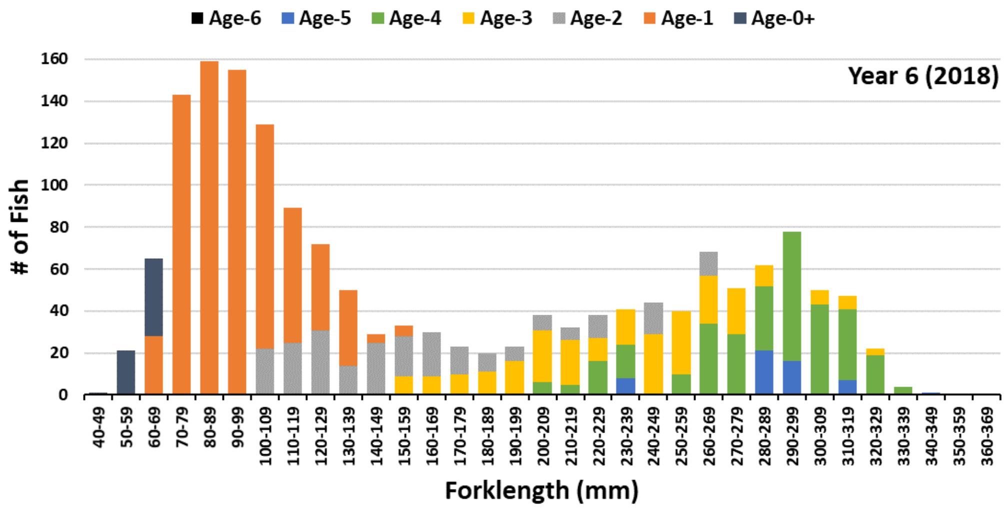

Figure D1 Continued.