Bridge River Project Water Use Plan

Downton Reservoir Fish Habitat and Population Monitoring

Implementation Year 7

Reference: BRGMON-7

BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 7 (2019) Results

Study Period: April 2019 to March 2020

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BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 7 (2019) Results

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Executive Summary

Data collection for Year 7 of this proposed 10-year study was completed in 2019. 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. Six methods were employed in Year 7 (2019) 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, which have been implemented consistently since Year 3 (2015).

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 7 (2019) was the fourth year that the reservoir was operated within the new modified maximum elevation (i.e., 734 m); maximum reservoir elevation in 2019 was 733.5 m. Lowest reservoir elevation in 2019 (710.7 m) was most similar to 2018 (711.3 m), 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).

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 had not been, or only minimally, confirmed (i.e., Jamie Creek, Cathy Creek and Ault Creek). Based on the Year 7 (2019) 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 each of the known spawning tributaries. 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. Spawners were again documented in Jamie, Cathy and Ault creeks (peak counts = 4, 10 and 63, respectively) in 2019, representing an expanded spawner distribution and increased use of these creeks (particularly Ault and Cathy) since the modified operations were initiated in 2016. 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 spring, summer and fall during Year 7 (3-5 June, 21-23 Aug and 16-18 Oct 2019, respectively). Mean CPUE (for all creeks sampled) was 7.9 ±2.9 fish/100 m in spring, 29.4 ±11.9 fish/100 m in summer, and 14.9 ±5.0 fish/100 m in fall. No fish were captured at 6 of 14 sites (43%) during the spring session, 3 of 15 sites (20%) during summer, and 4 of 13 sites (31%) in fall. Captured rainbow trout ranged in age from 0+ to 4, but the majority

of the fish captured in summer and fall (i.e., 83% and 79%, respectively) were the new year class of rainbow trout fry (forklength = 20 to 56 mm) that had newly or recently emerged from the gravel. The contribution of Age-0+ fish was the single factor that made the total CPUE values substantially higher in summer and fall than in spring. 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 in each season as they have been in previous years.

Approximately 18 km of shoreline was sampled by boat electrofishing over 8 nights from 6 to 14 June, 2019 at a reservoir elevation of approx. 724 m. This reservoir elevation was close to 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, 1,668 rainbow trout were captured from 61 sites, which was the highest catch to-date. Of these fish, 1,277 were newly marked with PIT tags and 17 marked fish were recaptured (6 that were marked within this sampling session, and 11 from previous years).

Total CPUE in the reservoir was 11.8 ±1.3 fish/100 m of shoreline which was very similar to the total CPUE in Year 6 (2018; 12.2 ±1.4 fish/100 m), and significantly higher than CPUE in Year 3 (2015; 8.9 ±1.0), Year 4 (2016; 8.7 ±0.8) and Year 5 (2017; 8.1 ±1.0 fish/100 m). The change was primarily due to increased catches of Age-1 fish in 2018, which was more than double the catch rate for that age class in 2017, and Age-2 fish in 2019 (i.e., the same cohort as the Age-1 fish in 2018). CPUEs for Age-2 to Age-4 fish have generally been increasing since the modified operations (including lower maximum fill elevation) of the reservoir were initiated in 2016. The more limited recruitment of fish to Age-1 in 2019 (relative to 2018) may indicate a limitation to total population size in the reservoir which ultimately favours the older and larger age classes when recruitment increases until a new equilibrium is reached.

Highest CPUEs by habitat type were at creek mouths (26.9 ±5.4 fish/100 m) and then shallow slopes (9.9 ±1.6 fish/100 m), followed by fans (9.5 ±0.8 fish/100 m) and then steep slopes (8.1 ±0.5 fish/100 m). These CPUE values in all habitats other than creek mouths were fairly equivalent in 2019 (especially when error margins are considered), indicating broad use of habitats throughout the reservoir by rainbow trout, and suggesting that these habitat types may provide rearing areas for the younger age classes (i.e., Age-1 and Age-2) particularly given that fish densities and competition among age classes is highest at the creek mouths. Highest total CPUE by longitudinal zone of the reservoir was recorded in the east zone in 2019; although this has varied among years to-date, reflecting that rainbow trout are generally distributed and move throughout the reservoir.

Data reporting in Year 7 (2019) also included analysis of length-at-age (4-parameter logistic 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 has decreased during the period of modified operations, most notably for fish aged 1-3 and particularly so in 2019. This change could either indicate: a) poorer production of food sources for rainbow trout caused by the modified operation of the reservoir; b) higher competition within the rainbow trout population for the limited food available; or c) both of these factors. Based on speculation (informed by anecdotal observations) that the majority of the food supply comes from the creeks (as drifting invertebrates) where the effect of reservoir operation changes may be more limited, mechanism b) may be the most probable cause for the reduced growth.

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 a slight decline in Fulton's K value (for all ages combined) between 2015 and 2017 (from 1.24 to 1.17), followed by some recovery in 2018 and 2019 (to 1.18 and 1.21, respectively). Interestingly, a similar trajectory of condition factor has been noted for rainbow trout in Carpenter Reservoir as well (Putt et al. 2019). This may be coincidental, or may point to general changes in food base, physical conditions (e.g., temperature) 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, and lowest observed growth and condition coincided with the study years (2017-2019) 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) making a potential effect of temperature seem less probable.

Ageing analysis was conducted on 199 scales across the rainbow trout length distribution in 2019 and the sampled fish ranged from Age-0+ to Age-5. 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 and 2019. 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. 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 the remaining 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 to better characterize spawning distribution within the drawdown zone; 4) Continue to conduct tributary fish sampling in three seasons within a year (spring, summer and fall) at the same range of creeks as in 2019 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 7 (2019) 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 7

<table>
<tr><th>Primary Objectives</th><th>Management Questions and Study Hypotheses</th><th>Year 7 (2019) Results To-Date</th></tr>
<tr><td rowspan="2">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.</td><td>1. What are the basic biological characteristics of fish populations in Downton Reservoir and its tributaries?</td><td>• 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 increased in 2018 and 2019 relative to previous years largely due to increased rearing use by Age-1 and 2 fish that were recruited under modified operations.
• 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, although increased recruitment to Age-4 has occurred in 2018 and 2019. The most rapid growth occurs between ages 1 and 3, after which growth rate slows.
See Sections 3.4, 3.5, and 3.6 for more information.</td></tr>
<tr><td>2. Will the selected alternative (N2-2P) result in positive, negative or neutral impact on abundance and diversity of fish populations?</td><td>• Overall CPUE values for rainbow trout increased significantly in 2018 and 2019 (to 12.2 and 11.8 fish/100 m of shoreline, respectively) from 8.1 to 8.9 fish/100 m between 2015 and 2017.
• The change was primarily due to increased catches of Age-1 fish in 2018, which improved by more than 2-fold from 2017 catches, followed by increased catches of Age-2 and Age-4 fish in 2019. CPUEs for Age-2 to Age-4 fish have been on an upward trend each year since 2016.
• 2019 minimum reservoir elevation was very similar to 2014, 2017 and 2018, and 8-9 m lower than in 2013, 2015 and 2016; whereas maximum 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 3.6 for more information.</td></tr>
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Primary Objectives	Management Questions and Study Hypotheses	Year 7 (2019) 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.	**Note:** By the end of the current monitoring period in 2022, limited data will be available for typical N2-2P operations (probably 2-3 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). **H_1:** not confirmed or rejected at this point; more data needed. The 2018 and 2019 results suggested that the annual abundance index increased for fish that recruited under modified operations (since 2016) relative to those that recruited before. However, reduced abundance of Age-1 fish in 2019 for a cohort that recruited under modified operations suggests that the population may have hit a total abundance ceiling that favours larger fish at least until a new equilibrium among age classes is established. 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 7 (2019), providing additional information for addressing this MQ. **See Sections 3.2 to 3.6 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. Other habitat types (fans and shallow & steep shorelines are also used for rearing particularly by Age-1 and Age-2 fish. • 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 (from 2016 to 2019) reduced the portion of stream length inundated by the reservoir. Data to define this relationship for several tributaries was collected in Years 6 and 7 (2018 & 2019).

Primary Objectives	Management Questions and Study Hypotheses	Year 7 (2019) 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_{4a}:** tentatively rejected; more data needed. While some tributaries are used minimally, the drawdown zone of Trib. #13 and Eagle Creek have been used extensively and consistently. Spawners are distributed throughout the drawdown zone of selected tributaries, particularly between 730 m and 738 m elevation (Figure 3.6 and Table 3.7). **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 for the remaining study years. **H_5:** tentatively rejected based on current findings. Efforts up to Year 6 (2018) compiled a data set for defining habitat type distribution and substrate characteristics at 747, 734, and 722 m. We have put further data collection for these parameters on hold to make budget room for additional tributary fish sampling sessions per year.
	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 7 (2019) 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 3.15. • 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 3.15). • 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 3.15). • 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 3.9 and Figure 3.15 (Section 3.6). **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 3.15 (Section 3.6).
	5. Can refinements be made to the selected alternative to, without significant impact to instream flow conditions in the Middle Bridge	• 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 an increase in useable

Primary Objectives	Management Questions and Study Hypotheses	Year 7 (2019) Results To-Date
	River, improve habitat conditions or enhance fish populations in Downton Reservoir?	stream length above the *modified* maximum reservoir level and a reduced proportion of eggs at risk of inundation by the reservoir as it fills. • The increased abundance of Age-1 fish documented in 2018 and Age-2 fish in 2019 (i.e., the first cohort that recruited under the lower modified operations levels in 2016) 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 (i.e., similar to what has been documented under modified operations). • 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 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 for the Middle Bridge River and inflows to Downton Reservoir. These will ultimately be evaluated for the preparation of the end-of-monitoring synthesis report.

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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 7 of this proposed 10-year study was completed in 2019.

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).

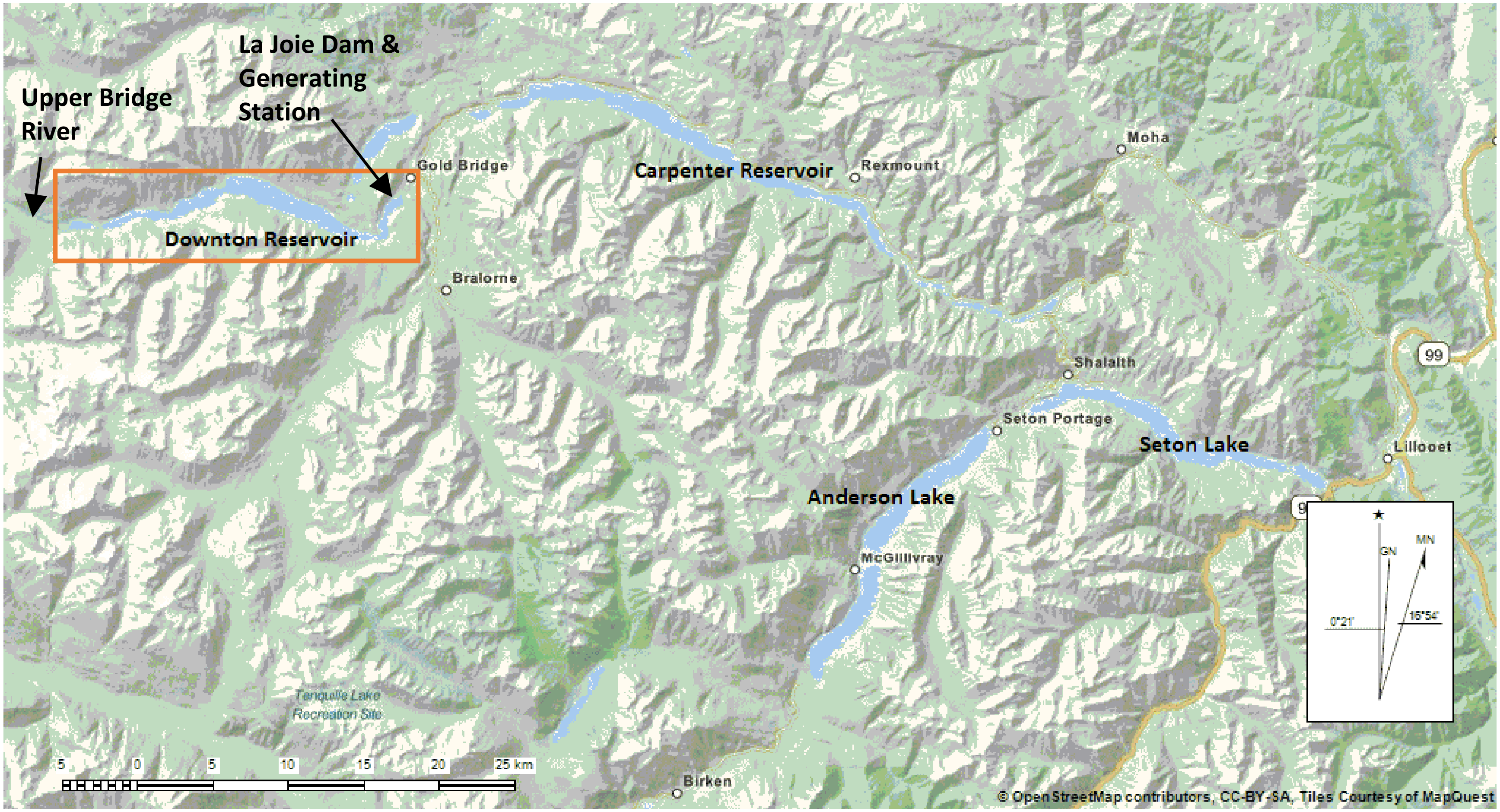

Figure 1.1 Bridge River and Seton River watersheds. The extent of the BRGMON-7 study area, which includes all of Downton Reservoir and tributaries between the Upper Bridge River inflow and La Joie Dam, is outlined by the orange rectangle.

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), Year 6 (2018) and Year 7 (2019). 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 7 (2019) 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.

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)	7 (2019)[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)							
• 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 7 (2019) activities were completed are provided in Section 0, Table 1.2.

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.

As per the recommendations in the Year 6 (2018) report, the habitat surveys, including habitat mapping of the reservoir shoreline and substrate particle size and embeddedness measurements, were discontinued in Year 7 (2019) to accommodate tributary fish sampling in three seasons (spring, summer and fall) instead of one season per year as was done previously. After four consecutive years of habitat surveys covering a broad range of reservoir elevation conditions, a sufficient sample size of reservoir habitat data had been collected to characterize conditions across the range of operations and habitat types within the reservoir drawdown zone and upland.

The multi-seasonal tributary fish sampling (by backpack EF) was recommended for tracking the abundance and age distribution of a single cohort of fish in the selected streams across the growing season. Characterizing seasonal tributary use is a priority for documenting the relative importance of stream habitats by the Downton Reservoir rainbow trout population and for addressing the management questions. A spring session was completed in June, a summer session was completed in August, and a fall session was completed in October 2019. The added effort (and cost) for expanding this component from one season to three per year was offset within the existing budget by eliminating further habitat mapping and substrate measurement activities (as described above).

1.6. Year 7 (2019) 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 (2019) represents monitoring year 7. The general schedule of field sampling activities is presented in Table 1.2.

Table 1.2 Year 7 (2019) Schedule of Field Sampling Sessions and Activities.

Field Sampling Activities	Dates (2019)
Temperature logger deployment & retrieval	24 Apr; 6 Jun; 13 Jun; 21 Aug; 18 Oct
Tributary Access Surveys	24 Apr; 15 & 23 May
Tributary Spawner Surveys	15 May to 16 Jul (weekly)
Tributary Fish Sampling	Spring: 3 to 5 Jun Summer: 21 to 23 Aug Fall: 16 to 18 Oct
Fish Population Index Survey	6 to 14 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 24 April, checked and downloaded on 6 June, 13 June, and 21 August, and retrieved for the end of the monitoring period on 18 October, 2019. The locations of the temperature array and other loggers in the study area are shown on Figure 2.1.

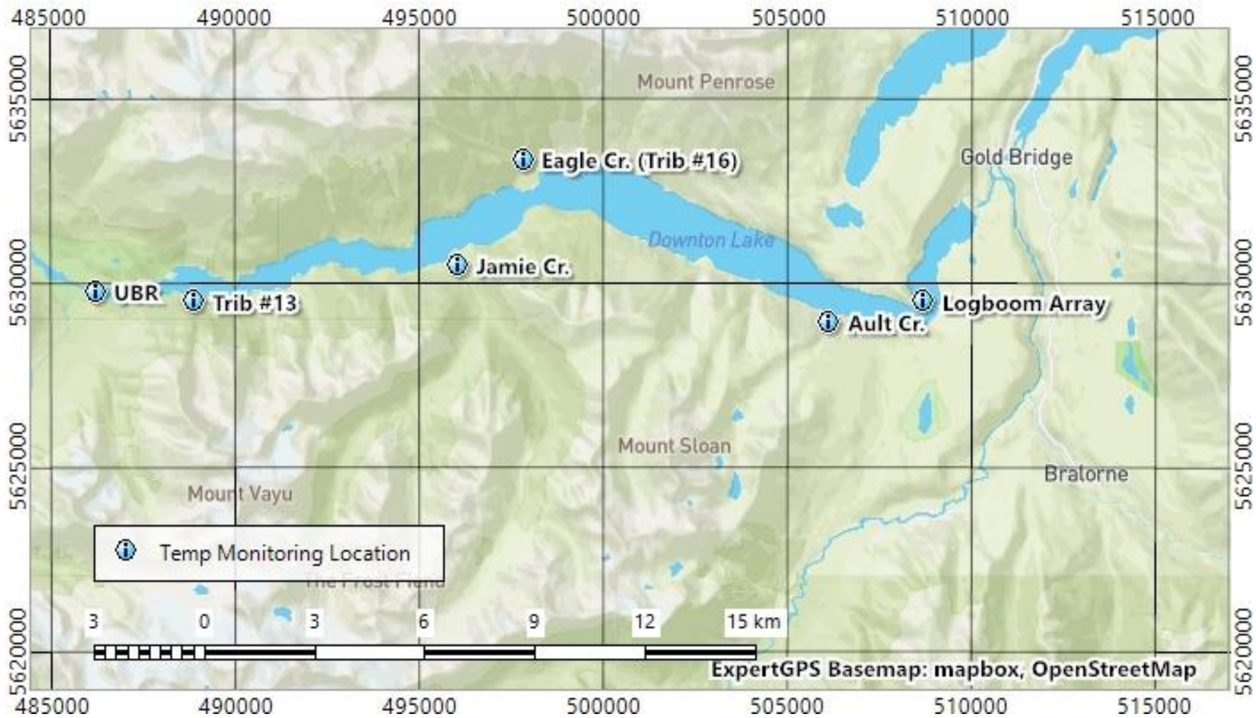

Figure 2.1 Locations of the tributary temperature loggers and the Downton Reservoir logboom temperature array.

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 in the reservoir 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 ~8.7 m at 710.0 m reservoir elevation to ~32.7 m at the 734.0 m *modified* maximum elevation and ~48.5 m at the 749.8 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 in place and 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. 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 had been 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 each of years 4 to 7 (2016-2019). 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.

2.3. 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 7 (2019) 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).

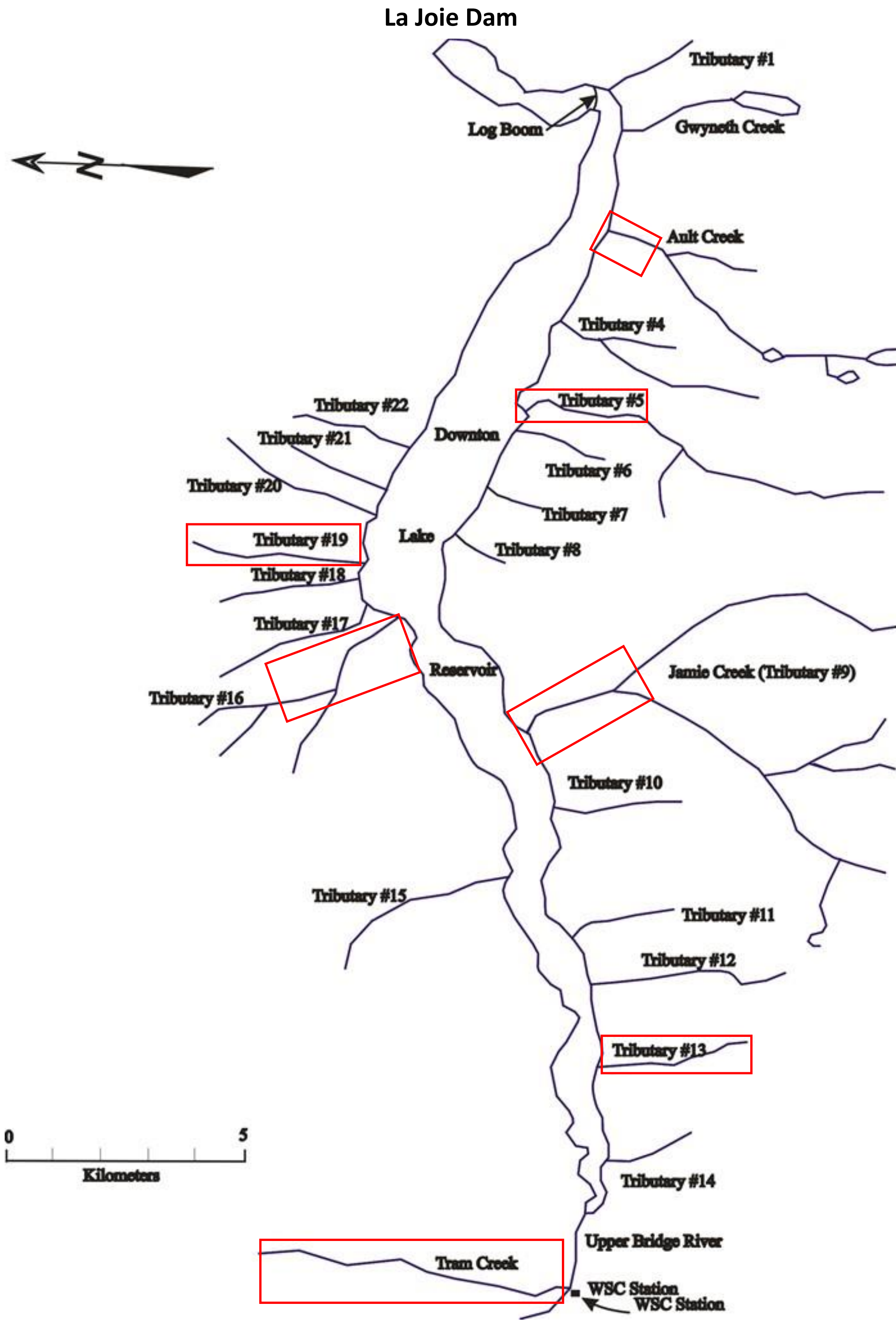

Figure 2.2 Downton Reservoir and the relative location of tributaries. Streams that were monitored for this program in Year 7 (2019) are outlined in red.

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 were reconciled between the two observers in the field and recorded on standardized data sheets for each survey.

For the first time in Year 7 (2019), the specific locations of observed spawners within the drawdown zone of each surveyed creek were documented with UTM coordinates (by marking waypoints on the GPS unit) to facilitate plotting the elevational distributions and contribute to an understanding of which elevational ranges pose the greatest and least inundation risk for incubating eggs. This approach was based on the assumption that the locations of observed spawners approximated the locations of spawning. Marking of actual spawning locations was not possible because the visibility of redds in this context is variable among tributaries and generally quite low. Other parameters recorded during each survey included: date, time of day, water temperature, visibility & discharge (as described above), and any comments pertaining to the conditions of the survey.

As in Year 6 (2018), stream length was again 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 at the mouth of the stream (reservoir edge) and along the route as the technician walked upstream along the stream axis to the top of the drawdown zone. This length was recorded on the data sheet in meters for each survey. 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.

As indicated in previous reports, it’s important to emphasize that the spawner estimates from 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 the selected tributaries where spawning use has been identified.

2.4. 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 spring, summer and fall surveys completed in 2019 were intended to supplement the information on seasonal rearing use previously collected in spring (2016), summer (2017) and fall (2018), which were documented in the Year 6 (2018) 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 2.3). For sample timing of each seasonal survey in 2019, refer to Table 1.2 in Section 1.6.

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 (described in the Year 6 (2018) report; Sneep 2019b), 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 was not sampled either because the habitat above the full pool 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). In total, 14 tributary sites were sampled in spring (drawdown zone n= 6; upland n= 8), 15 sites were sampled in summer (drawdown zone n= 7; upland n= 8), and 13 sites were sampled in fall (drawdown zone n= 7; upland n= 6). Paul Creek (drawdown site) was not sampled in spring, and Tram Creek and UBR-2 (upland sites) were not sampled in fall due to heavy rain conditions that contravened safe sampling protocols.

Sites were each 30 m long and were sampled during the day by a two-person crew using a Smith-Root Model LR-24 electrofisher (settings: 400 Volts DC, 70 Hertz and 30% Duty Cycle). 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 a diluted clove oil-ethanol blend, identified to species, scanned for the presence of a PIT tag (i.e., recaptures), and measured (fork length to the nearest mm). Unmarked fish of a suitable size (≥80 mm FL) were injected with a PIT tag under the skin. All data were recorded onto standardized data forms, which also included the following parameters for each site: Date, site name, elevation zone (i.e., drawdown or upland), UTM coordinates, sampled length, electrofishing effort (seconds), and water temperature. Fish were allowed to fully recover in a bucket of aerated water before being returned to the section of stream where they were sampled.

2.5. Fish Population Index Survey

The fish population index surveys are intended to provide information on the inter-annual variation in the relative abundance, distribution and 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 6 (2015 – 2018), the index survey in Year 7 (2019) 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 7 (2019) 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 2019a). 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 Year 6 (2018) report; Sneep 2019b); 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 7 (2019) was 6 to 14 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 includes 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.

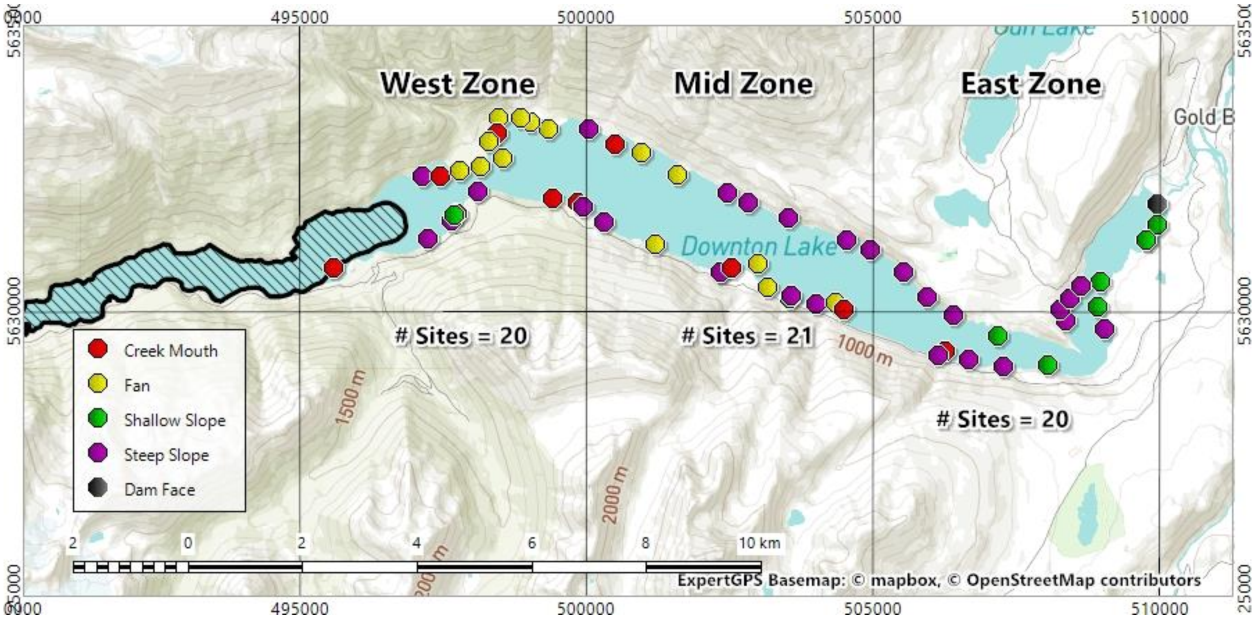

Figure 2.3 The three longitudinal zones (west, mid, and east) and the distribution of sites for the fish population index survey conducted from 6 to 14 June 2019 (at 723 m to 724 m reservoir elevation). Note: The hashed-out area represents the dewatered portion of the reservoir basin at the time of the survey.

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.

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*= 10; fan *n*= 15; shallow *n*= 10; steep *n*= 26) covering 17,708 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 ~30 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 (up to a maximum of 1,300 tags available) 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 55 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 Years 5-7 (2017–2019) Downton Reservoir fish population index surveys 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 2.6). We used Akaike Information Criterion (AIC) and Schwarz Criterion (SC) scores to distinguish among a set of possible models describing the relationship between fish size and age in the program Growth II (Henderson and Seaby 2006). The 4-parameter Logistic model was selected based on the closeness of fit of the points to the model and the number of parameters used by the model (reflected as the lowest AIC and SC scores), and because it allows for a non-zero lower asymptote. The 4-parameter logistic growth equation is as follows:

$$L_t = \alpha + \frac{(L_\infty - \alpha)}{(1 + e^{(k-t)/\delta})}$$

Where:

L_t is Length at Age $_t$;

α is the lower asymptote

L_∞ is the upper asymptote;

k is the growth rate; and

δ is a shape parameter that determines the steepness of the rising curve.

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.

2.6. 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 199 of the mounted samples (1 was noted as un-readable due to regeneration) 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.

2.7. Data Management

All field data collected for this project were recorded into field notebooks or on standardized datasheets specifically developed for this program. A standardized data entry template was developed in MS Excel, and all data entry was conducted by SER technicians (Kelsey Alec and Roxx Ledoux). 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 6 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 2019, which are illustrated in Figure 3.1. Daily surface elevations for monitoring years 1 to 6 (2013 to 2018) are also included for reference.

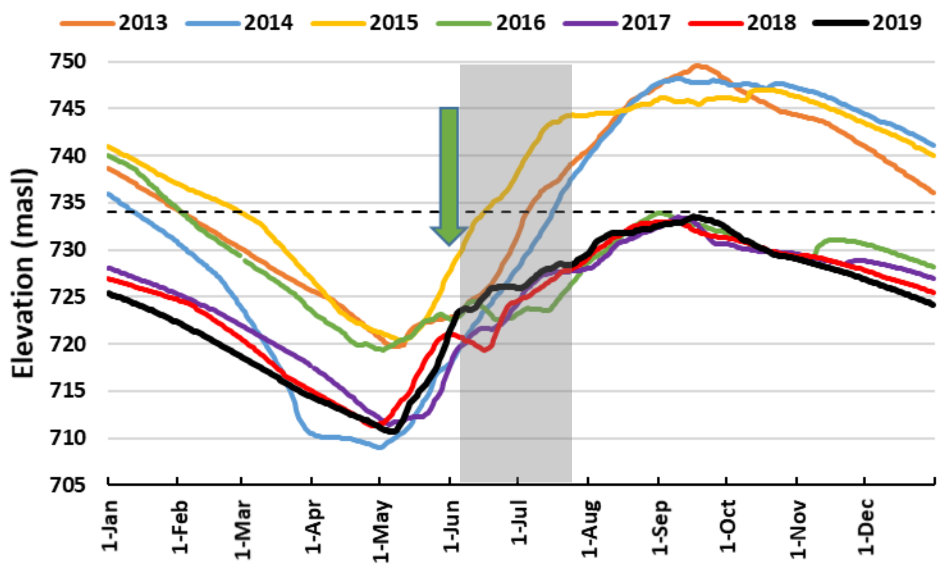

Figure 3.1 Daily surface elevations in Downton Reservoir, 2013 to 2019. For reference, the shaded area represents the observed rainbow trout spawning period and the green arrow indicates the timing of the annual population index survey. The horizontal dashed line indicates the target modified maximum fill elevation (734 m), which was implemented in Years 4 to 7 (2016 to 2019) to-date.

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.).

The modified maximum elevation target (i.e., 734 m) was implemented for the first time in Year 4 (2016) and again in years 5, 6 and 7 (2017 to 2019). Overall, reservoir operation in 2019 followed a very similar trajectory as 2017 and 2018 across the year; however, elevations were slightly lower at the beginning and end of the year and the reservoir began filling quickly from the minimum elevation in May such that surface elevations were higher at the start of the rainbow trout migration and spawning period in 2019 (on par with levels in 2013 and 2016 at this time of the year; Figure 3.1). At the start of 2019, reservoir elevation was 725.4 m as it was drawing down from the 2018 maximum fill level of 733.0 m. The mean drawdown and fill rates for the reservoir were -9 cm/day and +17 cm/day, respectively (Table 3.1). Lowest reservoir elevation (i.e., 710.7 m) occurred from 4 to 7 May, and summer full pool elevations occurred from 12 to 25 September 2019 (max. = 733.5 m on 16 September). The reservoir had been drawn down to 724.2 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 2019).

Study Year	Reservoir Elevations (m)			Drawdown Rates [a] (cm/day)		Fill Rates [b] (cm/day)	
	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
7 (2019)	710.69	733.50	22.81	-9	-17	+17	+73

[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 ~23 m in 2019, which was similar to the other years of modified operations (particularly 2017 and 2018). 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 2019 minimum elevation (710.7 m) was most similar to 2014 (709.0 m), 2017 (711.5 m) and 2018 (711.3 m), and ~8 to 9 m lower than the other study years. The mean drawdown and fill rates (-9 cm/day and +17 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 that did not strictly conform to the two operational treatment periods (i.e., ~720 m in 2013, 2015 and 2016; ~710 m in 2014, and 2017–2019). 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

Hourly water temperatures for the April to October period at the reservoir log boom array and in the monitored tributaries are displayed in Figure 3.2 and Figure 3.4, respectively. Comparable figures for all available study years to-date (i.e., 2015 to 2018) are provided in Appendix B (Figures B1 and B2).

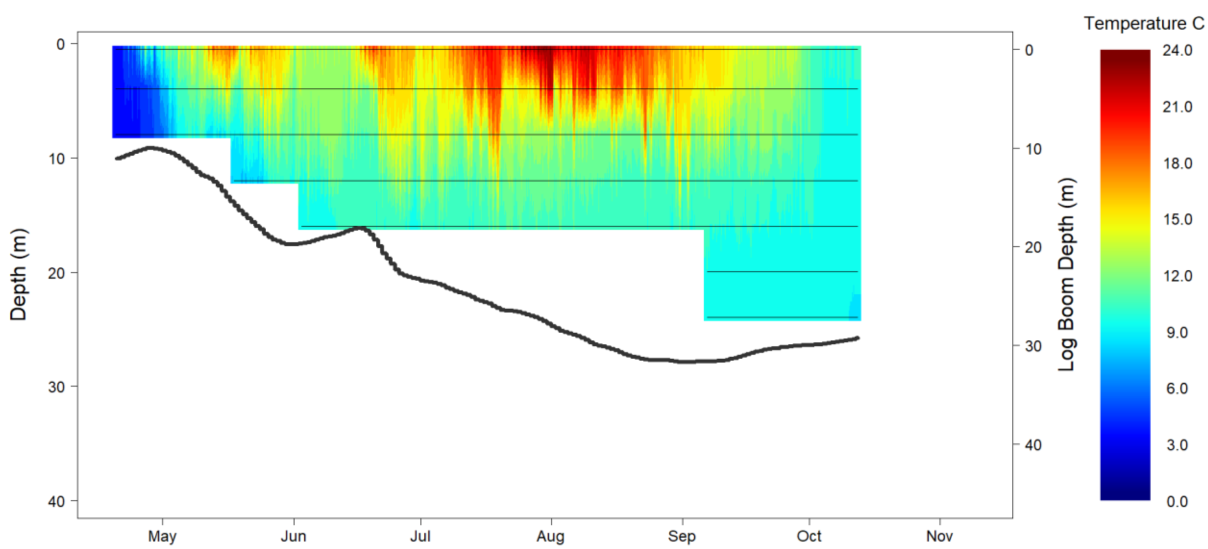

Figure 3.2 Water temperature profile recorded in Downton Reservoir at the log boom (see Figure 2.1 for location) from April to October 2019. The horizontal lines indicate the measurement depths (1° y-axis). Temperatures between those depths were linearly interpolated. The solid black line references the reservoir depth at the log boom on the 2° y-axis.

Based on the log boom array data, thermal stratification in the reservoir begins in late April or early May and extends until late September to mid October. This general timing pattern has not changed across the monitoring years to-date (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 7 (2019), mean daily surface temperatures increased from 8.5°C to 18.2°C from late April to the end of May, and then decreased to 14.0°C across the first three weeks of June as snow melt-driven 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 months of July and August, peaked at 21.7°C on 19 August, and then gradually cooled to 9.8°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 7.0°C and 12.0°C, throughout the monitored period. Other than a higher peak temperature in 2018 (23.3°C), relative to the other monitored years (2015 to 2017, and 2019 range = 21.2°C to 21.8°C), and generally variable temperatures during the snow melt period in June and the first half of July each year, the temperatures and patterns in 2019 were very similar to those reported for previous years (Figure 3.3; Appendix B, Figure B1; Sneep 2019b).

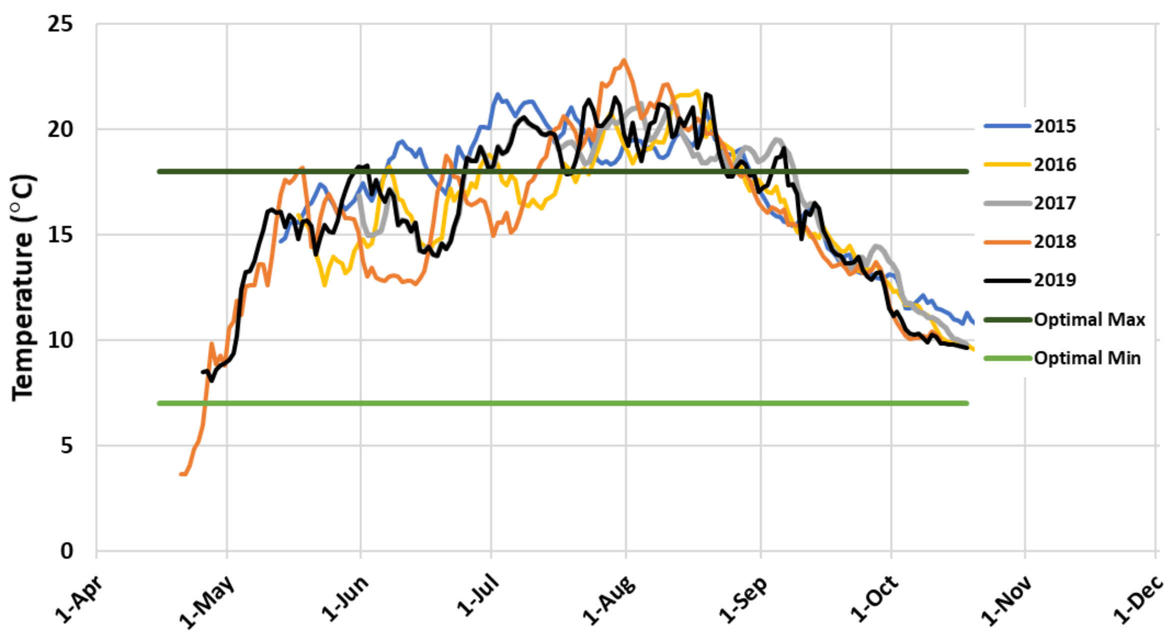

Figure 3.3 Mean daily reservoir surface temperatures during the April to October monitoring period by study year (2015 to 2019). The light and dark green horizontal lines bracket the preferred temperature range for key life history stages of rainbow trout (McPhail 2007).

The light and dark green lines in Figure 3.3 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 during periods when surface temperatures in the reservoir are above the optimal threshold.

Relative to the reservoir, temperatures in the tributaries tended to be much cooler, and were variable among streams. Maximum daily mean temperatures ranged from 8.0°C (in the Upper Bridge River) to 13.0°C (in Ault Creek). Based on the preferred temperature ranges as displayed in Figure 3.4, 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 migration, spawning and incubation periods, 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 3.4 and 3.5).

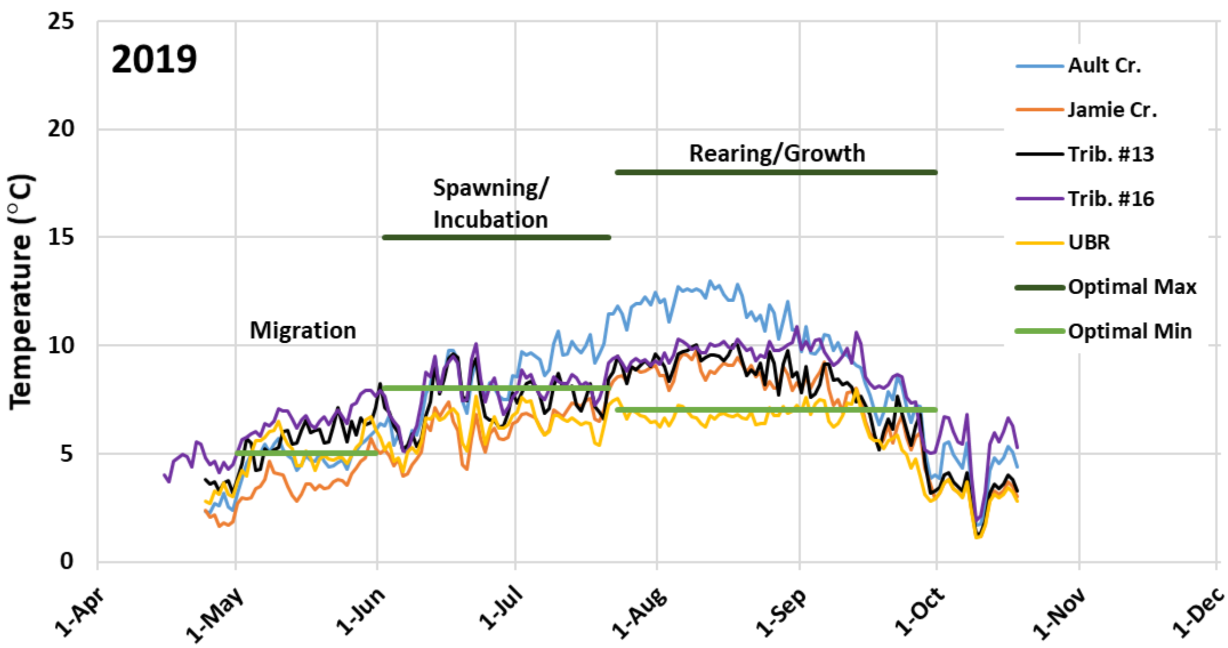

Figure 3.4 Mean daily water temperatures in a set of Downton Reservoir tributaries, April to October 2019. The light and dark green horizontal lines bracket the preferred temperature range for key life history stages of rainbow trout (McPhail 2007).

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 7 (2019) 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 2019b). 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 likely has not varied significantly across the years available to-date (2015 to 2019). 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 (20 to 46 mm forklength) in several tributaries sampled by backpack electrofishing at the end of August in 2017 and 2019 (see Section 3.5; Sneep 2019a). 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 2019 (i.e., 16-18 October) were still available in the sampled creeks, though diminished in abundance relative to the summer sample, and ranged from 27 to 56 mm by that time (see Section 3.5).

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
	2019	5.1	6.2	6.4	6.2
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
	2019	4.0	6.1	7.9	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
	2019	6.2	7.5	8.3	7.9
Trib. #16	2015	7.8	9.4	9.0	9.0
	2016	6.7	8.3	9.4	8.7
	2017	6.6	7.6	9.3	8.4
	2018	6.5	8.1	9.1	8.4
	2019	6.9	7.9	9.2	8.5
Ault. Cr.	2015	-	-	-	-
	2016	5.3	8.7	11.0	9.5
	2017	-	-	-	-
	2018	4.9	8.7	10.3	9.0
	2019	4.9	8.4	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
	2019	15.9	17.6	17.9	17.5

[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 (or intermittently selected): 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)
	2019	4 Aug (62)	20 Aug (57)	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)
	2019	1 Aug (59)	18 Aug (55)	8 Sep (50)

[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. 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 7 (2019) were conducted on 24 April and 15 & 23 May, to coincide with the early part of the rainbow trout migration period. Reservoir elevations on these dates were ~712 m, ~714 m and ~716 m, respectively. Across the duration of the rainbow trout migration and spawning period, the reservoir filled from 714 m in mid-May to 728 m by the end of July (i.e., an elevational increase of 14 m). The creeks visited in Year 7 (2019) included: Ault Creek, Paul Creek, Cathy Creek, Jamie Creek, Trib. #10, Trib. #13, Trib. #16 and Trib. #19 (Table 3.4). However, Trib. #10 and Trib. #13 could not be accessed during the 712 m and 714 m surveys due to a large avalanche blocking access to that portion of the Bridge-Main FSR (i.e., the only road access to these creeks) until it was cleared during the third week of May.

Table 3.4 Tributary-Reservoir surface flow connectivity scores as assessed during the tributary access surveys (TRUE = connected; FALSE = disconnected). Survey dates are included for each elevation.

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

[a] Reservoir longitudinal zone as described in Section 2.5.
[b] "-" means the tributary access could not be assessed on this survey date due to avalanche hazard and snow conditions on the Bridge-Main FSR.
[c] Only 1 of 3 branches of Ault Creek was connected to the reservoir at 714 m elevation on this date.
[d] 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 7 (2019) minimum elevation of 710.7 m (on 6 May) was in between the minimum elevations observed in Year 2 (2014; 709.0 m) and Year 6 (2018; 711.3 m), which were the previous two years when Ault Creek was observed flowing to ground before reaching the reservoir edge (see Photo A10 in Appendix A). This was again observed at the 712 m survey in Year 7. However, the dates when potential access issues were observed (8 May 2014, 19 April 2018 and 24 April 2019) were prior to the typical start of the rainbow trout spawning period for this population (see Section 3.4), and a surface flow connection of one of three branches of Ault Creek (across the fan) was observed during the subsequent survey on 15 May 2019. 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, or the 2019 surveys at 712 m and 714 m, as stated above. Trib. #10 has not been observed to be a significant tributary for spawning use to-date.

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 3.4). 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 for a period of time. 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 these conditions are attributable to low creek flows and porous substrate materials within the upland rather than reservoir operations in this case. Trib. #19 was not observed flowing to ground (i.e., dry within the drawdown zone) on any visits to the site in 2019.

There were also some supplementary fish access observations recorded during the tributary fish sampling surveys (see Section 3.5) on Trib. #19 and Cathy Creek (i.e., Trib. #5) in Year 7 (2019). There is a large deposit of woody debris at the top of the drawdown zone (i.e., drawdown-upland interface) of many tributaries to Downton Reservoir, including Trib. #19 and Cathy Creek. In the case of these two creeks, however, the debris has created an interlocked jam that withholds fluvial sediments, creating an elevational drop across it. When the reservoir is filled to the normal maximum elevation (749.8 m) the debris field and elevational drop are flooded such that fish can access the upland. However, since the implementation of the modified maximum fill level (734.0 m), there is a set of small falls caused by the elevational drop that may limit or preclude fish access from the reservoir. This has been corroborated by catch totals diminishing to zero (or near-zero) within the upland zone of these two creeks since the debris field has no longer been flooded within the past four years.

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.

3.4. Tributary Spawner Surveys

In Year 7 (2019), weekly spawner surveys were conducted across a 10-week period from 15 May to 16 July. 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. Additional tributaries that were routinely monitored in Year 7 included Jamie Creek, Cathy Creek and Ault Creek. As noted on the data sheets, in-water visibility conditions in 2019 were generally fair or good on most survey dates (see Section 2.3 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 2019 weekly counts, spawners first started arriving in identified spawning streams during the fourth week of May (i.e., Trib. #13; Table 3.5). This was on par with the arrival timing noted in previous years (Sneep 2018b); however, the Bridge-Main FSR closure due to avalanche and snow conditions precluded surveys in tributaries to the upper portion of the reservoir basin prior to 23 May in Year 7. Peak timing in 2019 was between the middle to the end of June (according to tributary), and some spawners were still observed in Trib. #13 and Eagle Creek (the two main spawning tributaries) on the final (16 July) survey. In past years, spawner observations have extended to the 3rd or 4th week of July, but the budget for this component of the program had been fully utilized after the 16 July survey in 2019. This temporal distribution represents a ~9-week migration and spawning period with peak abundance occurring ~2 to 4 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 3.5 Summary of weekly spawner count data for surveyed tributaries that had the highest maximum spawner counts or were the most consistently assessed throughout the spawning period in Year 7 (2019).

Week	2019 Survey Dates	Ault Cr. [a]	Eagle Creek			Jamie Creek			Trib. #13		
		n [b]	***n*** [a]	**DS %**	**US %**	***n***	**DS %**	**US %**	***n***	**DS %**	**US %**
1	15 May [c]	0	-			0			-		
2	23 May	-	-			0			4	100%	
3	30 May	-	-			0			0		
4	4 Jun	18	14	14%	86%	3	100%		7	71%	29%
5	11 Jun	63	7	43%	57%	0			25	36%	64%
6	18 Jun	3	28	82%	18%	4	100%		32	78%	22%
7	25 Jun	0	47	83%	17%	2	100%		33	94%	6%
8	3 Jul	-	30	83%	17%	3	100%		28	100%	
9	10 Jul	0	18	78%	22%	0			15	100%	
10	16 Jul	-	5	80%	20%	0			12	92%	8%
Peak *n* & Total %		**63**	**47**	**74%**	**26%**	**4**	**100%**	**0%**	**33**	**82%**	**18%**

[a] The upland of Ault Creek is inaccessible to reservoir fish due to an impassable falls, so the count for each week represents the drawdown zone only.

[b] "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.

[c] Could not access Eagle Creek or Trib. #13 on this survey date 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, 30 and 33 for Years 2, 3, 4, 6 and 7, respectively) (Figure 3.5). Spawner surveys were not completed in Year 5 (2017) – see Sneep 2019a report for rationale. Peak spawner counts in Eagle Creek (Trib. #16) have been similar and sometimes higher than Trib. #13 in the years available (annual max. *n*= 116, 61, 54 and 47 for Years 1, 4, 6 and 7, respectively), reflecting that these two streams have generally had the highest spawning use of any of those surveyed. Eagle Creek and Trib. #19 could not be assessed in years 2 and 3 (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, 0 and 5 for Years 1, 4, 6 and 7, respectively, in Trib. #19; and *n*= 1, 4, 9, 6, 29 and 8 for Years 1 to 7 in Tram Creek).

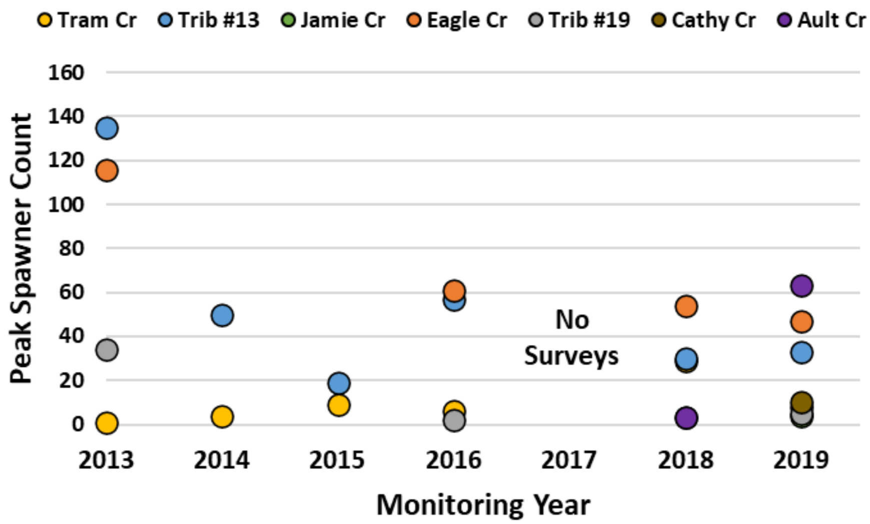

Figure 3.5 Peak spawner counts in surveyed tributaries for BRGMON-7 monitoring years 1 to 7 (2013 to 2019). Note: Spawner counts were not conducted in Year 5 (2017) – see explanation in annual monitoring report for that year (Sneep 2019a).

Increased spawner use of Ault and Cathy creeks was a new phenomenon in Year 7 (2019). In Ault Creek, a peak count of 63 spawners was observed on 11 June, which was the highest peak count of any surveyed stream this year. The peak count in Cathy Creek was 10 spawners on 18 June. Previously spawner observations in these two creeks had been consistently low (annual max. *n*= 3 and 2 in 2018, respectively; zero in other years) despite the presence of useable spawning habitat and good visibility during most surveys. Spawning use of Jamie Creek was again documented in 2019, as it was in 2016 (by a consultant for the Borolex IPP; Tyler Gray, PGL, pers. comm.) and 2018, but the number of observed spawners has been consistently low (annual max. *n*= 2-4) during each of those years.

As in previous years, a higher proportion of spawners were consistently 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 ~82% used the drawdown zone vs. 18% in the upland, overall. Actual proportions for each survey date and totals for each tributary are provided in Table 3.5. As indicated by the substrate measurement results (described in in the Year 6 (2018) report; Sneep 2019b), suitable-sized spawning substrates are available above and across the range of reservoir drawdown elevations in the tributaries.

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 years 6 and 7 (2018 and 2019) (Figure 3.6). This provided some useful information about the relative amount of tributary habitat available for spawners within the drawdown zone at the range of reservoir elevations. During normal operations years (i.e., 2013 to 2015), the average reservoir elevation at the *start* of the spawning period was 722.0 m and the average elevation at the *end* of the spawning period was 738.0 m (Table 3.6). During modified operations years (2016-2019) these values were 720.6 m and 727.3 m, respectively. In spawning streams with a lower gradient (e.g., Eagle Creek), total drawdown stream length was reduced by an average of 186.2 m (or 67%) across the spawning period under normal operations versus an average of 121.8 m (or 37%) under modified operations. For steeper streams, such as Ault Creek, the total drawdown stream length was reduced by an average of 116.8 m (or 78%) under normal operations versus an average of 70.0 m (or 43%) under modified operations. Assuming tributary length is proportional to spawning area, the modified operations increased the available spawning habitat within the drawdown zone by more than 2.3-fold relative to normal operations.

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) (Figure 3.6). As such, the length of useable channel in this stream does not change within the modified operation range, and eggs deposited in this creek have not been at risk of inundation by the reservoir since 2016.

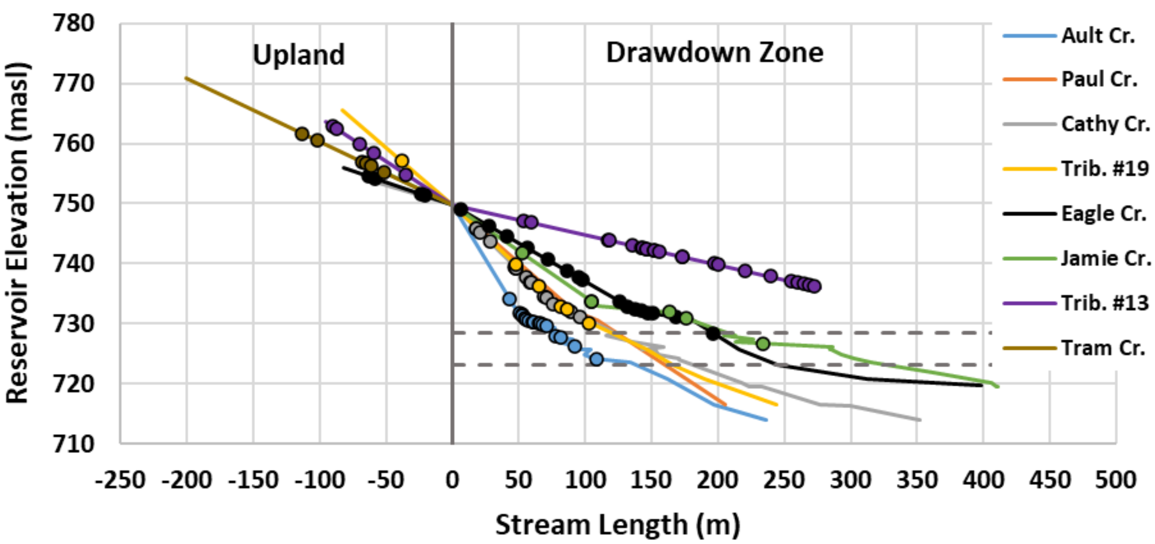

Figure 3.6 Distribution of rainbow trout spawner observations (dots) along the longitudinal sections (lines) of each surveyed tributary to Downton Reservoir in 2019. The vertical grey line represents the top of the drawdown zone (value of 0 on the x-axis). The horizontal dashed lines bracket the minimum and maximum reservoir elevations during the rainbow trout spawning period in 2019 (i.e., 723 to 728 masl between 4 June and 23 July 2019).

Table 3.6 Start and End reservoir elevations and percent reduction in tributary length within the drawdown zone for a lower gradient creek (Eagle) and higher gradient creek (Ault) during the observed rainbow trout spawning period for each study year to-date.

Study Year	Observed Spawning Period	Reservoir Elevations (m)			% Reduction of Stream Length in Drawdown Zone	
		Start	End	Diff.	Eagle Cr.	Ault Cr.
1 (2013)	21 May to 15 Jul	722.29	736.86	14.57	63%	76%
2 (2014)	22 May to 15 Jul	714.57	733.53	18.97	68%	80%
3 (2015)	4 Jun to 17 Jul	729.23	743.50	14.27	74%	77%
Normal Operations Averages		**722.0**	**738.0**	**16.0**	**67%**	**78%**
4 (2016)	19 May to 20 Jul	722.07	725.21	3.14	20%	32%
5 (2017)	1 Jun to 20 Jul [a]	717.95	727.66	9.71	49%	55%
6 (2018)	5 Jun to 25 Jul	719.36	728.00	8.64	50%	57%
7 (2019)	4 Jun to 23 Jul [b]	723.21	728.48	5.27	20%	45%
Modified Operations Averages		**720.6**	**727.3**	**6.7**	**37%**	**43%**

[a] Spawning period dates in 2017 are based on the average across years (see Figure 3.7) since spawner surveys were not conducted in that year.

[b] The spawning period end date in 2019 is estimated since surveys ended on 16 Jul that year.

It is understood, however, that spawner habitat may not be equally distributed across the entire stream length available, and spawners may preferentially select particular areas or elevations within each stream. By specifically documenting the locations of spawner observations in 2019 (as shown in Figure 3.6), it was possible to see how the spawners were distributed within the drawdown zone and upland for each surveyed tributary. From that information we calculated the proportion of spawner observations that were at or below selected elevations within the reservoir operating range (drawdown zone) and in the upland (Table 3.7). Based on these data, we can see that a larger proportion of spawners (~2/3) were distributed within the highest band of elevations within the drawdown zone (i.e., 734.00 m to 749.81 m; normal operations range) than at the lower elevations (i.e., <734.00 m; modified operations range) where ~1/3 were observed. This information provides another useful input to operations decisions about the "riskiest" elevations during the spawning period and will assist with answering Management Questions #3 and #5 (see Section 1.2).

Table 3.7 Cumulative percentage of spawner observations at or below selected elevations (by 4 m increments) within the reservoir drawdown zone and in the upland. Elevations that corresponded with low spawner proportions (i.e., <10%), or were in the upland, are highlighted green in the "Total" column. Elevations that corresponded with higher total spawner proportions (i.e., >10%) are highlighted red. The horizontal lines in the table reflect the Mod. Ops. target fill elevation (i.e., 734 m) and the Normal Maximum fill elevation (i.e., 749.81 m).

Elevation (m)	Surveyed Tributaries							Total
	Ault Cr.	Cathy Cr.	Trib. #19	Eagle Cr.	Jamie Cr.	Trib. #13	Tram Cr.	
>750 (Upland)	NA [a]	0% [b]	13%	43%	0%	18%	100%	**18%**
749.81	100%	100%	88%	57%	100%	82%	NA [a]	**82%**
746	100%	100%	88%	53%	100%	81%		**81%**
742	100%	80%	88%	47%	100%	70%		**74%**
738	100%	55%	75%	43%	75%	53%		**63%**
734	95%	15%	63%	37%	75%			**34%**
730	27%				25%			**8%**
726	6%							**1%**
722								
718								
714								
710								

[a] "NA" refers to elevations that were not accessible or not applicable. Ault Creek has a large falls at the top of the drawdown zone precluding access to the upland for fish from the reservoir, and the entire length of Tram Creek is within the upland zone above the reservoir basin (it's a tributary to the Upper Bridge River).

[b] The upland of Cathy Creek may be inaccessible to fish when the reservoir is not filled to the normal maximum fill elevation (i.e., 749.81 m) due to a falls caused by large woody debris accumulation at the top of the drawdown zone.

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 and 2019). 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 3.7).

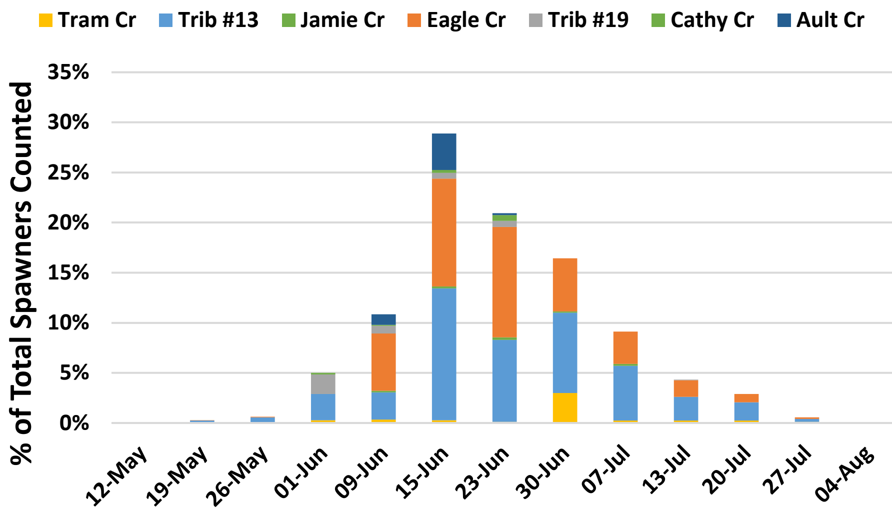

Figure 3.7 % Contribution of weekly spawner counts to the total across the monitoring period, all study years combined. Relative proportions by tributary are included.

Between-year differences in spawning use and distribution among tributaries (e.g., spawners being observed in Ault Creek for the first time in 2018 and increasing in numbers in 2019; Figure 3.5) continue to 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.

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 had not been observed prior to the start of modified operations, despite the presence of suitable flows, temperatures, gradient and substrate in at least some of them (i.e., Ault, Paul (Trib. #4) and Cathy (Trib. #5) creeks). The substrate measurement results reported previously (see Sneep 2019b) did not reveal any significant differences in physical habitat parameters between the seemingly suitable creeks that were not previously being used, from the ones that always were.

So the key difference likely had more to do with inundation risk than habitat availability. It may be that, under normal operations, the eastern-most streams were 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. Under modified operations, the risk of inundation of spawning habitats is reduced or or in some cases eliminated (i.e., Trib. #13). In other words, the lower extent of reservoir fill during the spawning period under modified operations reduces inundation risk in a broader band of the drawdown zone and may facilitate spawning in some tributaries that were under-utilized under normal operations.

3.5. Tributary Fish Sampling

Fish sampling by backpack electrofishing was conducted in tributaries to Downton Reservoir in spring (*n*= 14 sites), summer (*n*= 15 sites), and fall (*n*= 13 sites) 2019, including sites in the drawdown and upland zones (Table 3.8). These data supplemented spring, summer and fall seasonal tributary data that were previously collected in Year 4 (2016), Year 5 (2017) and Year 6 (2018), respectively (Sneep 2019b). Water clarity during each 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) was lowest in spring (7.9 ±2.9 fish/100 m), highest in summer (29.4 ±11.9 fish/100 m), and moderate in fall (14.9 ±5.0 fish/100 m). Of the tributaries sampled in 2019, the highest CPUE values were in the drawdown zone of Trib. #19 and Eagle Creek during summer (170.0 and 93.3 fish/100 m, respectively), and the drawdown zone of Trib. #13 in fall (60.0 fish/100 m). Highest CPUE in spring was in the drawdown zone of Eagle Creek (33.3 fish/100 m). Also, a greater number of tributaries had higher CPUE values in summer: catches at 7 of 15 sites (47%) were >15 fish/100 m, whereas this was the case at 5 of 13 sites (38%) in fall and and only 3 of 14 sites (21%) in spring. 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 14 sites (43%) during the spring session, 3 of 15 sites (20%) during summer, and 4 of 13 sites (31%) 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 3.8 Summary of backpack EF effort and catch in Downton Reservoir tributaries during spring, summer and fall 2019. 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	223	0	0.0
	Mid	Cathy Cr.	Drawdown	30	273	0	0.0
			Upland	25	149	0	0.0
		Trib. #19	Drawdown	30	152	5	16.7
			Upland	30	170	0	0.0
	West	Eagle Cr.	Drawdown	30	500	10	33.3
			Upland	30	142	8	26.7
		Jamie Cr.	Drawdown	30	212	1	3.3
			Upland	30	290	0	0.0
		Trib. #13	Drawdown	30	263	4	13.3
			Upland	30	99	1	3.3
		Tram Cr.	Upland	30	121	3	10.0
		UBR-1[a]	Upland	30	241	0	0.0
		UBR-2[a]	Upland	22.5	188	1	4.4
Spring Totals				**407.5**	**3,023**	**33**	**7.9 (SE ±2.9)**
Summer	East	Ault Cr.	Drawdown	30	273	1	3.3
	Mid	Paul Cr.	Drawdown	30	319	1	3.3
		Cathy Cr.	Drawdown	30	473	13	43.3
			Upland	25	404	2	8.0
		Trib. #19	Drawdown	30	359	51	170.0
			Upland	30	244	1	3.3
	West	Eagle Cr.	Drawdown	30	446	28	93.3
			Upland	30	328	10	33.3
		Jamie Cr.	Drawdown	30	408	1	3.3
			Upland	30	205	0	0.0
		Trib. #13	Drawdown	30	586	8	26.7
			Upland	30	146	7	23.3
		Tram Cr.	Upland	30	338	9	30.0
		UBR-1	Upland	30	314	0	0.0
		UBR-2	Upland	22.5	326	0	0.0
Summer Totals				**437.5**	**5,169**	**132**	**29.4 (SE ±11.9)**
Fall	East	Ault Cr.	Drawdown	30	363	0	0.0
	Mid	Paul Cr.	Drawdown	30	379	1	3.3
		Cathy Cr.	Drawdown	30	603	11	36.7
			Upland	25	498	0	0.0
		Trib. #19	Drawdown	30	376	8	26.7
			Upland	30	349	0	0.0
	West	Eagle Cr.	Drawdown	30	455	6	20.0
			Upland	30	389	7	23.3
		Jamie Cr.	Drawdown	30	409	1	3.3
			Upland	30	347	0	0.0
		Trib. #13	Drawdown	30	722	18	60.0
			Upland	30	220	4	13.3
		UBR-1	Upland	30	377	2	6.7
Fall Totals				**385**	**5,267**	**58**	**14.9 (SE ±5.0)**

Forty-one fish from the tributary catch in 2019 were a tag-able size (≥80 mm): 32 were newly marked with PIT tags, and five were recaptures. All 5 of the recaptured fish were caught in the same stream and elevational zone where they were originally captured but the capture events spanned different seasons or years, suggesting some degree of stream residency for these fish (Table 3.9). The number of days between capture events ranged from 55-78 days (spanning adjacent seasons in the same year), to 315 days (spanning different seasons between adjacent years).

Table 3.9 Summary of rainbow trout recaptures during tributary fish sampling in monitoring Year 7 (2019).

Tag Code	Original Capture Data				Recapture Data				Days-at-Large
	Season	Date	Trib.	Zone	Season	Date	Trib.	Zone	
980200	Summer	22 Aug 2019	Trib.# 13	Upland	Fall	16 Oct 2019	Trib. #13	Upland	55
980230	Summer	23 Aug 2019	Cathy Cr.	Drawdown	Fall	17 Oct 2019	Cathy Cr.	Drawdown	55
316409	Spring	4 Jun 2019	Eagle Cr.	Upland	Summer	21 Aug 2019	Eagle Cr.	Upland	78
980008	Fall	10 Oct 2018	Jamie Cr.	Drawdown	Summer	21 Aug 2019	Jamie Cr.	Drawdown	315
980236	Fall	10 Oct 2018	Eagle Cr.	Upland	Summer	21 Aug 2019	Eagle Cr.	Upland	315

The ages of captured fish ranged from Age-0+ to Age-4 in both spring and summer, and from Age-0+ to Age-3 in fall (Table 3.10; Figure 3.8). Eight fish in Eagle Creek (ranging in age from 2-4), one fish in Trib. #13 (Age-3), one fish in Trib. #19 (Age-3), and one fish in Tram Creek (Age-2) captured during the spring sampling in 2019 were sexually mature and in some stage of pre-spawning condition (all males; 4 gravid, 7 ripe). The remainder of the fish sampled in each season were assessed as either sexually immature (*n*= 201) or mature (*n*= 8) based on size or age, but were not in spawn-ready condition at the time of sampling.

The new year class of recently emerged fry made up the bulk of the catch in both summer and fall (i.e., *n*= 109 or 83%, and *n*= 46 or 79%, respectively), and were the single factor that made total CPUE values substantially higher in summer and fall than in spring. 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*= 17, 23 and 12 in spring, summer and fall, respectively).

Table 3.10 The size range of rainbow trout by age class and season for tributaries sampled by backpack electrofishing in spring, summer, and fall 2019.

Age	Season	n	Forklength (mm) Min.		Max.	CPUE (fish/m)·100
0	Spring	16	39	-	63	3.3
	Summer	109	20	-	46[a]	22.0
	Fall	46	27	-	56[a]	10.4
1	Spring	5	70	-	120	1.5
	Summer	9	58	-	112	1.9
	Fall	5	78	-	100	1.1
2	Spring	5	110	-	152	1.3
	Summer	6	117	-	163	1.1
	Fall	4	114	-	129	0.9
3	Spring	5	174	-	224	1.0
	Summer	5	163	-	210	1.1
	Fall	3	137	-	166	0.6
4	Spring	2	259	-	291	0.4
	Summer	3	166	-	305	0.6
	Fall	0				0.0

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

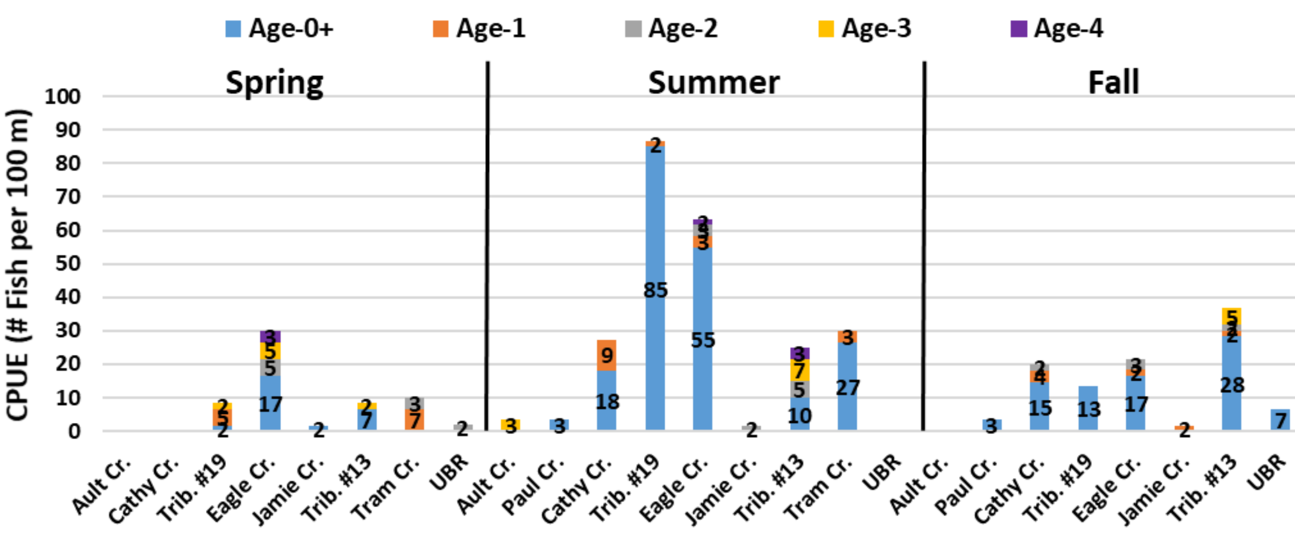

Figure 3.8 Catch-per-unit effort (fish/100 m) by age class for each sampled tributary based on the results of backpack electrofishing surveys in spring, summer and fall 2019.

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. #13, 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 40 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.

3.6. Fish Population Index Survey

A total of 1,668 fish were captured by boat electrofishing during the annual fish index survey in Year 7, conducted between 6 and 14 June 2019 at a reservoir elevation of ~724 m. Sixty-one sites were sampled, including 10 creek mouths, 15 fans, 10 shallow shorelines, and 26 steep shorelines (Table 3.11). The total shoreline distance sampled was 17.7 km, or ~40% of the total reservoir perimeter at the survey elevation (~724 m). All captured fish were rainbow trout.

In total, 1,277 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. Seventeen tagged fish were recaptured during the Boat EF survey in 2019; 6 were within-session recaptures and 11 were recaptures of fish originally tagged between 2016 and 2018 (see Table 3.14 and Table 3.15 in the "Recaptures of Tagged Fish" sub-section, below).

Table 3.11 Summary of rainbow trout capture results from the Year 7 boat electrofishing index survey in early June 2019.

Metric	Units	Habitat Type			
		Cr. Mouth	Fan	Shallow	Steep
Sites	#	10	15	10	26
Effort	total seconds	2,536	9,410	6,926	17,281
	total meters	825	4,479	3,407	8,997
Catch	# of fish	196	427	322	723
	# of fish marked	169	320	297	491
	# of recaptures	3	6	2	6
CPUE	fish/sec·100 (±SE)	7.2 (±0.9)	4.5 (±0.3)	4.8 (±0.8)	4.2 (±0.3)
		4.9 (±0.3)			
	fish/meter·100 (±SE)	26.9 (±5.4)	9.5 (±0.8)	9.9 (±1.6)	8.1 (±0.5)
		11.8 (±1.3)			

2019 Catch-per-unit-effort (CPUE) values (by all measures), were greatest at creek mouths, followed by shallow shorelines, and then by fans and steep shorelines, although the differences between the latter three were not large (i.e., overlapping margins of error). Mean CPUE values (for all types combined) were: 4.9 (SE 0.3) fish/100 sec of electrofishing; or 11.8 (SE 1.3) fish/100 m of shoreline length, which were very similar to the values reported in 2018 and higher than the values for all prior years (2013-2017) (Table 3.12). Including consideration of the standard error, the 2018 and 2019 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 (see Figure 3.9, below).

Table 3.12 Summary of catch-per-unit-effort values (fish per 100 m of shoreline) by habitat type from the fish population indexing survey, monitoring years 1 to 7.

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)
7 (2019)	26.9 (±5.4)	9.5 (±0.8)	9.9 (±1.6)	8.1 (±0.5)	**11.8** (±1.3)
All	**18.3** (±1.8)	**6.4** (±0.5)	**9.9** (±1.1)	**5.8** (±0.5)	**8.4** (±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.

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.

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, 6 and 7 (2015, 2017, 2018 and 2019). The value for steep habitats was higher than for fans for the first time in Year 6 (2018), but returned to the lowest relative value among the available habitat types in Year 7 (2019), although still significantly higher than the Year 2-5 (2014-2017) values for this habitat type. CPUE values have been consistently highest at creek mouths in every year to-date.

A summary of CPUE values by age class for each monitoring year to-date is provided in Figure 3.9. In Year 7 (2019), the CPUE for Age-1 fish (3.5 fish/100 m) was again the highest of any age class in the sample, and was within the range of Age-1 CPUEs from previous study years (i.e., between 2.6 and 5.5 fish/100 m), but it declined relative to the Age-1 CPUE in 2018. On the other hand, CPUE values for Age-2 fish (3.3 fish/100 m) increased by almost 2-fold from the 2018 value (1.7 fish/100 m), which was likely caused by the strong Age-1 cohort in 2018. The CPUE values for Age-3 and Age-4 fish have increased modestly during the modified operations years to-date (Age-3 CPUE range = 1.0 to 1.2 fish/100 m in 2015-2016, and 1.6 to 1.9 fish/100 m in 2017-2019; Age-4 CPUE range = 0.6 to 0.7 fish/100 m in 2015-2016, and 1.4 to 2.7 fish/100 m in 2017-2019). The Age-4 CPUE in 2019 was the highest for this age class of any year to-date (2.7 fish/100 m).

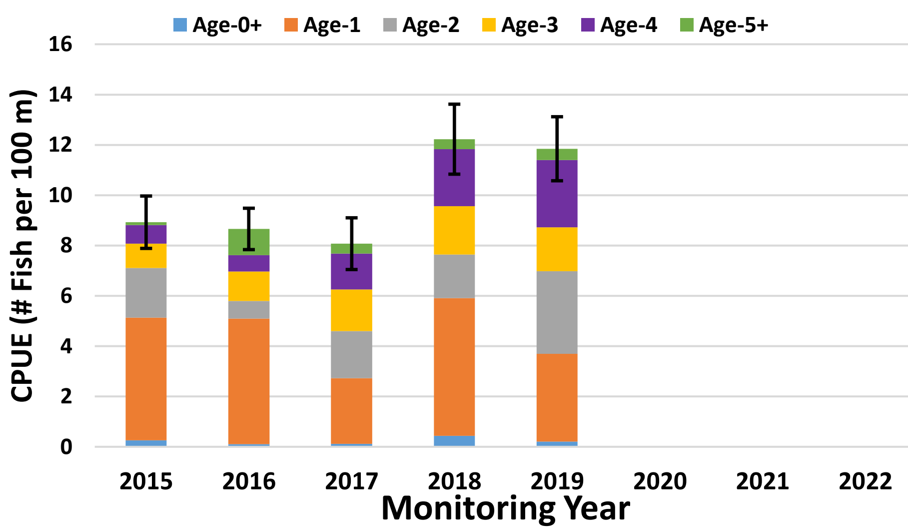

Figure 3.9 Catch-per-unit-effort summary by age class for each monitoring year from 2015 (Year 3) to 2022 (Year 10). Currently only data up to 2019 were available for this report. Year 1 (2013) & 2 (2014) results have not been included due to incompatibility of sampling approach in those years with subsequent study years – see comment on this in text, below).

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 2019, and Age-1 and Age-2 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, and Age-2 fish in 2019). If these results, coupled with the increased contribution of Age-3 and 4 fish, are repeated, they 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 4 years (see Figure 3.1 in Section 3.1).

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 (0.0 to 0.4 fish/100 m). 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 3.13 in the sub-section "Length-Frequency, Size-at-Age, and Age-specific trends" below.

A summary of catch rates (CPUE) by longitudinal zone of the reservoir (as defined in Section 2.5) is provided in Table 3.13. In Year 7 (2019), the highest mean CPUE was documented in the east zone of the reservoir (12.7 ±2.3 fish/100 m). However, the CPUE values for each zone were similar in 2019 (overlapping margins of error) and, based on all 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 3.13 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)
2019		12.5 (±2.4)	10.4 (±1.9)	12.7 (±2.3)

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

A total of 48 of the 1,668 captured fish (or 3%) in Year 7 (2019) 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 210 fish (~13% of the 2019 catch) were held for approx. 24 hours after sampling, then re-evaluated for condition and tag loss, and then released. In total, 203 of the held fish (or 97%) were alive after 24 hours and were noted to be in vigorous condition upon release (i.e., 3% delayed mortality based on this sample). The delayed mortality results in Years 5 and 6 (2017 and 2018) were even lower (i.e., 100% and 99% survival, respectively). Tag loss was noted for 1 of the held individuals (0.8%) in 2017, and 0 individuals in 2018 and 2019, for a combined tag loss rate of 0.2%. 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 7 (2019; Table 3.14). One of these fish had moved a short distance (i.e., <1 km), while the other five had moved more substantial distances (from 1.5 to 7.9 km) within a few days between capture and recapture events. As indicated in past reports, these data reveal that rainbow trout can exhibit significant movements within the reservoir, even on a daily basis.

Table 3.14 Summary of within-session rainbow trout recaptures during monitoring Year 7 (2019).

Tag Code	Original Capture Data			Recapture Data			Dist. (km)
	Date	Zone	Habitat[a]	Date	Zone	Habitat[a]	
316443	6-Jun-19	Mid	FN	10-Jun-19	East	ST	5.3
316447	6-Jun-19	Mid	ST	13-Jun-19	East	ST	6.1
316343	7-Jun-19	West	FN	12-Jun-19	East	ST	7.9
560012	9-Jun-19	Mid	FN	11-Jun-19	Mid	FN	0.3
560412	11-Jun-19	Mid	ST	12-Jun-19	East	ST	5.3
560585	12-Jun-19	East	SH	13-Jun-19	East	SH	1.5

[a] CM = Creek Mouth; FN = Fluvial Fan; SH = Shallow Slope; ST = Steep Slope.

In addition to the within-session recaptures, there were 11 between-year recaptures in Year 7 (2019). Original capture and recapture information for these fish is summarized in Table 3.15. Seven of the eleven between-year recaptures were for fish that were initially captured in 2018 (i.e., were at-large for ~1 year). Two of the between-year recaptures were originally tagged in 2017 (~2 years at large), and the remaining two recaptures were originally tagged in 6 (~3 years at large). As with the within-session recaptured fish, the locations for each capture event were varying distances apart (i.e., ranging from 0.5 to 11.4 km). Approximately two-thirds of the recaptured fish (within-year and between-year data combined) were captured in different habitat types between events. 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.

Four fish (forklengths = 98, 105, 109 and 110 mm) were assessed as Age-2 based on scale ageing analysis (see section below) when initially captured, and were 207, 260, 251 and 219 mm forklength, respectively, when recaptured a year later (at Age-3). This represented a growth range of between 108 and 153 mm in one year for this cohort of fish. Three fish (forklengths = 270, 301 and 302 mm) were assessed as Age-3 when initially captured, and were 279, 296 and 324 mm a year later (at Age-4), representing 0 to 22 mm of annual growth. Two fish were Age-2 (110 and 113 mm) when initially captured and 247 and 296 mm two years later (at Age-4), representing an average range of 68 to 91 mm of growth per year. The remaining two recaptured fish grew an average of 74 and 17 mm/year between Ages 1 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 3.15 Summary of inter-year rainbow trout recaptures in Year 7 (2019). 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)		
889157	31-May-16	Mid	258	6-Jun-19	Mid	308	1.7	17
889306	2-Jun-16	Mid	84	7-Jun-19	West	307	2.3	74
888690	1-Jun-17	Mid	113	8-Jun-19	West	296	3.9	91
975967	4-Jun-17	West	110	10-Jun-19	Mid	247	4.8	68
317323	4-Jun-18	West	301	9-Jun-19	West	296	0.5	-5
316690	6-Jun-18	Mid	302	8-Jun-19	West	324	9.4	22
316805	8-Jun-18	East	270	11-Jun-19	West	279	11.4	9
317033	8-Jun-18	East	98	12-Jun-19	Mid	207	5.5	108
316955	8-Jun-18	East	110	6-Jun-19	Mid	219	7.5	110
316818	8-Jun-18	East	109	11-Jun-19	Mid	251	5.7	141
316978	8-Jun-18	East	105	12-Jun-19	East	260	1.7	153

[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 7 (2019) is presented in Figure 3.10. The coloured bars in this figure represent the contribution of the different age classes as determined by analysis of 199 scale samples spanning the full range of available size classes (broken into 10 mm size increments between 40 and 350 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 is another line of evidence suggesting 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.

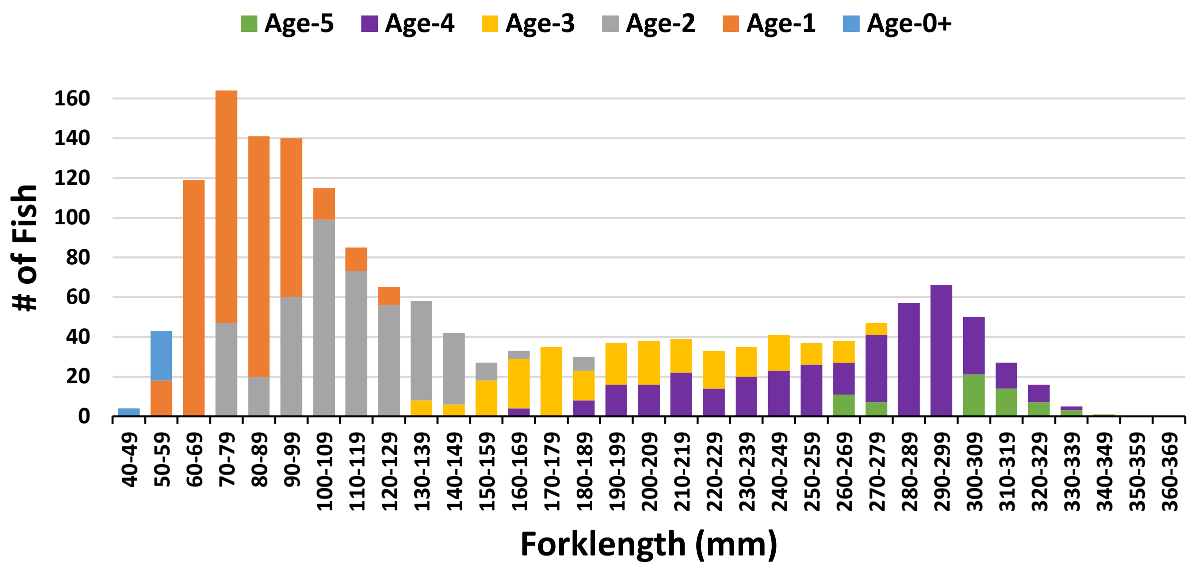

Figure 3.10 Length-frequency histogram for rainbow trout captured during the fish population index survey in Downton Reservoir, 6 to 13 June 2019. Size ranges for each available age class are shown.

According to the median size values for fish aged between 1 and 5 at the time of sampling, the greatest size differences were apparent between ages 2 and 4 in 2019 (Table 3.16). Differences in the median sizes were: 25.5 mm between Age-0 and Age-1, 31.5 mm between Age-1 and Age-2, 85 mm between Age-2 and Age-3; 81 mm between Age-3 and Age-4, and 29 mm between Age-4 and Age-5; Table 3.16). This trend of growth among age classes for Downton Reservoir rainbow trout was similar to what has been reported in previous years (Sneep 2019b), except the median sizes were notably lower for Age-1 to Age-4 fish in 2019 (Appendix D; Figure D1).

Table 3.16 Size statistics for the range of ages of rainbow trout captured in Downton Reservoir during Year 7 (2019).

Age	*n* [a]	Forklength (mm)		
		Minimum	Median	Maximum
0+	29	44	**53**	56
1	492	55	**78.5**	127
2	461	72	**110**	187
3	247	133	**195**	276
4	375	165	**276**	332
5	64	263	**305**	343

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

We also computed growth curves using the 4-parameter logistic model (as explained in Section 2.5) based on the median size values for each age class for the 2015 to 2019 data sets to assess differences in growth among years based on this standardized approach (Figure 3.11). This model best fits the sigmoidal growth trajectory of the Downton Reservoir rainbow trout length-at-age data (lowest AIC scores of the growth models evaluated). The curves highlight where there were similarities and differences in growth among years. The median sizes for the youngest and oldest aged fish in the sample (i.e., Age-0+ and Ages 5 and 6, respectively) have not notably changed among the years of monitoring to-date. Although it should be noted that these age classes also represent the smallest portions of the sample each year (i.e., typically <5% each). The growth curves from Age-1 to Age-4 were highest in 2015 and 2016, dropped slightly in 2017 and 2018, and then dropped more substantively in 2019. This information suggests that growth has slowed for these age classes since 2016, when the modified operations of the reservoir were initiated. It is uncertain whether these changes could be due to reduced production of food sources for fish in the reservoir associated with the lower reservoir levels (as was considered in the original terms of reference; BC Hydro 2012), or if it reflects higher competition for limited food resources when fish abundance is higher, or both.

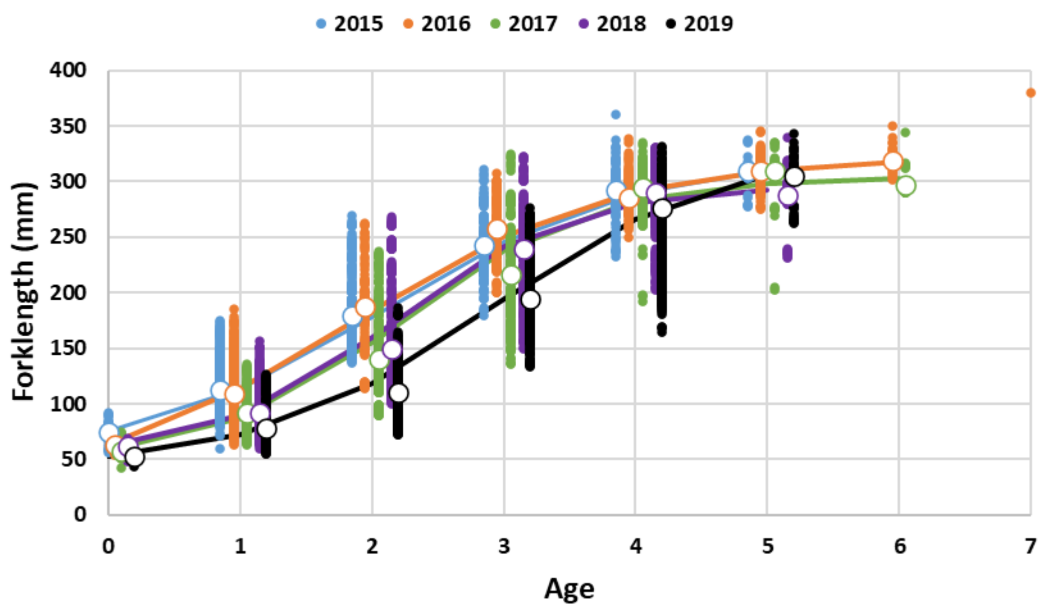

Figure 3.11 Size-at-age plot for rainbow trout captured during the annual fish population index survey, Years 3 to 7 (2015 to 2019). The lines represent the year-specific 4-parameter Logistic growth curves based on the median size values (open circles) for each available age class in Downton Reservoir. The individual length data points for each age class are also shown (filled circles).

The lengths and weights of rainbow trout in Downton Reservoir were highly correlated in all years (R^2 ≥0.98 from 2013-2019; Figure 3.12; Table 3.17). 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.

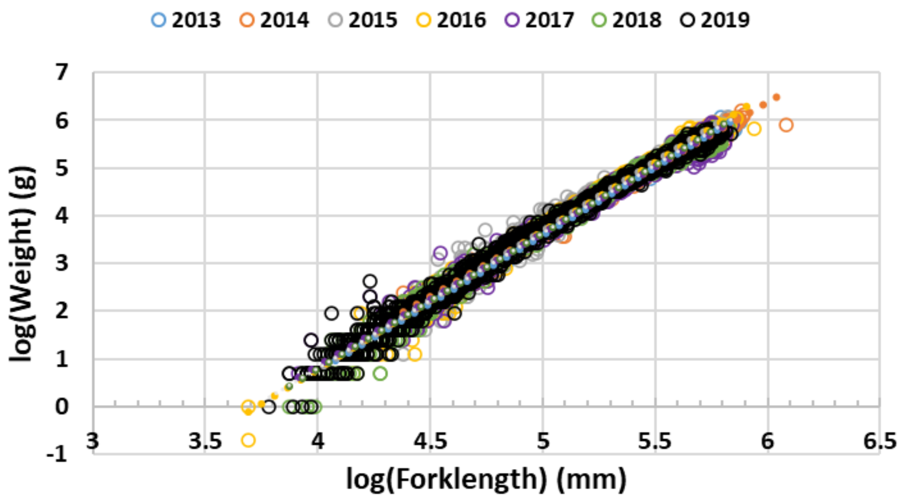

Figure 3.12 Log-transformed length-weight relationships for Downton Reservoir rainbow trout in Years 1 to 7 (2013 to 2019). Open circles are the individual data points (colour-coded by year) and the dotted lines represent the year-specific regressions. See Table 3.17 for the sample size, slope, y-intercept and R^2 values for each year.

Table 3.17 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 3.12).

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
2019	1,546	2.83	-10.51	0.99

We also generated mean condition factor (Fulton's K; ±SE) values to assess differences or changes by age and among years (Figure 3.13). In general, differences among consecutive years were small although there was a slight trend of reduced condition factor from 2015 to 2017, followed by slight recovery in 2018 and 2019 for all age classes combined (bolded black line in Figure 3.13). Condition factor for Age-1 fish has not notably changed across years (range = 1.25 to 1.27). K value for Age-2 and Age-3 fish diminished from 1.27 ± to 1.22 and 1.16 to 1.09, respectively between 2015 and 2018, but rebounded to 1.32 and 1.15 in 2019 (SE values were 0.01 to 0.02 in all cases). Condition factors for Age-4 and Age-5 fish were lowest (K values tend to diminish with age) and varied between 0.98 and 1.12 across years with no obvious trends apparent.

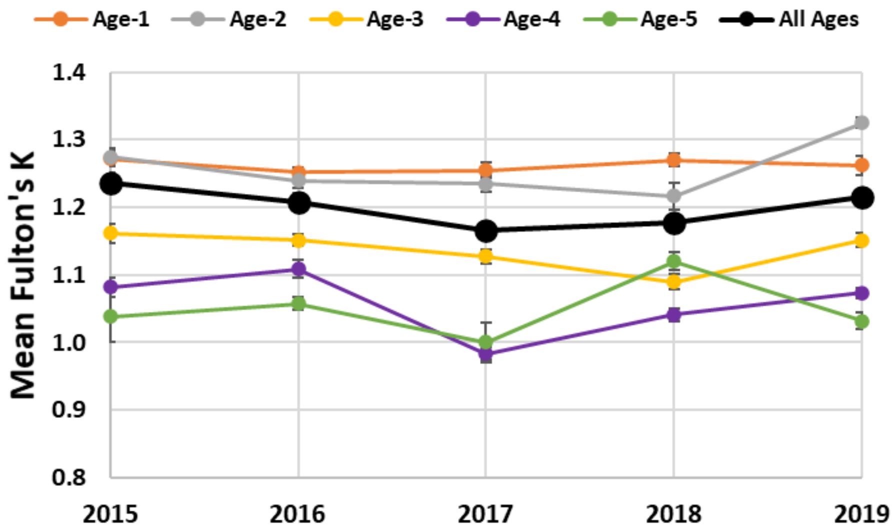

Figure 3.13 Mean condition factor (± SE) by age class and study year for Downton Reservoir rainbow trout sampled during the annual fish population indexing survey in late May to early June each year. The bolded black line shows the overall trend for all ages combined.

Interestingly, a similar trajectory of condition factor has been noted for rainbow trout in Carpenter Reservoir as well (Putt et al. 2019). This may be coincidental, or may point to general changes 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.

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 3.18). 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 7 (2019) sample were assessed as Age-5 (based on scale ageing; *n*= 14). The largest fish captured was 343 mm, which was very similar to the maximum size in every other study year to-date. Overall, Age 1 and Age 2 fish were the most abundant age class in the 2018 sample.

Table 3.18 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 = blue; 2015 results = orange; 2016 results = grey; 2017 results = yellow; 2018 results = purple; 2019 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	**276 (+36)**	375
2015	**63**	12	**92 (+29)**	349	**150 (+58)**	236	**195 (+45)**	247		
2016	**58**	16	**92 (+34)**	742	**110 (+18)**	461				
2017	**62**	59	**79 (+17)**	492						
2018	**53**	29								

The assignment of ages also allowed for the comparison of CPUE for each age class by habitat type (Figure 3.14). 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 7 (2019), Age-1 fish were almost equivalently abundant in steep slopes, creek mouths and fan habitats, and least abundant in shallow habitats. Age-2 fish were most prevalent in shallow habitats, followed by steep slopes and 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 biggest differences in 2019, relative to previous years, was the increased CPUEs of Age 2 fish in shallow slope, steep slope and fan habitats and Age 4 fish at creek mouths and fans. The increased abundance of Age 2 fish provided follow-up evidence for the increased abundance of Age 1 fish reported in Year 6 (2018) (Sneep 2019b), suggesting that improved recruitment had occurred starting in 2016 (when this cohort incubated and emerged), and conducive rearing conditions had continued through 2017 and 2018, and up to the sampling period in 2019. The increased abundance of Age 1 and Age 2 classes along shallow shorelines, steep shorelines and fans 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.

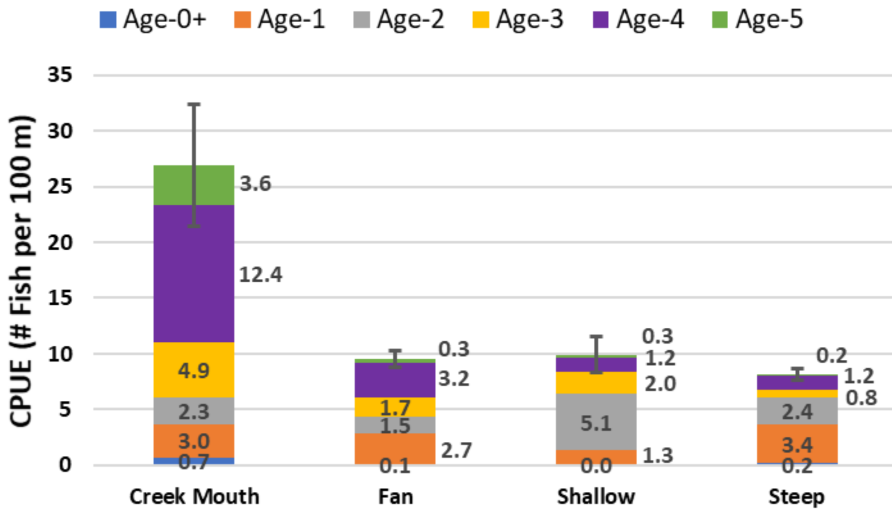

Figure 3.14 Catch-per-unit-effort (fish/100 m) by age class for each habitat type in Downton Reservoir based on the results of the boat electrofishing survey in Year 7, 6 to 13 June 2019.

The relative contribution of each age class to the catch in 2019, compared to 2015-2018 is shown in Table 3.19. The CPUE value and percent contribution for Age-1 fish dropped in 2019 (i.e., 2017 recruits) after increasing in 2018 (i.e., 2016 recruits), whereas the CPUE value for Age-2 fish in 2019 increased dramatically over every previous study year. The contributions of Age-3 fish generally increased from 2015 to 2018, and then levelled off in 2019. Age-4 fish have increased each year since 2016, whereas Age-5 fish have remained at <1 fish/100 m.

Table 3.19 Comparison of catch-per-unit-effort (fish/100 m) by age class for monitoring years 3 (2015), 4 (2016), 5 (2017), 6 (2018) and 7 (2019). 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	2019
0+	0.3 (3%)	0.1 (1%)	0.1 (1%)	0.4 (4%)	0.2 (2%)
1	4.9 (55%)	5.0 (58%)	2.6 (32%)	5.5 (45%)	3.5 (29%)
2	2.0 (22%)	0.7 (8%)	1.9 (23%)	1.7 (14%)	3.3 (28%)
3	1.0 (11%)	1.2 (14%)	1.6 (20%)	1.9 (16%)	1.8 (15%)
4	0.7 (8%)	0.6 (7%)	1.4 (18%)	2.3 (19%)	2.7 (22%)
5	0.1 (1%)	0.8 (9%)	0.2 (3%)	0.4 (3%)	0.5 (4%)
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)**	**11.8 (1.3 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 the remaining 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 3.15). 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 3.20). 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 3.20. In Year 7 (2019), the Age-0+ rainbow trout were recruited in 2018, the Age-1 fish were recruited in 2017, and the Age-2 fish were recruited in 2016.

Table 3.20 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
2019	2020	2021	2022

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 3.15). This result seems intuitive: the higher the reservoir fills during the spawning period, the smaller the available spawning habitat area becomes (see Figure 3.6 and Table 3.6), 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.

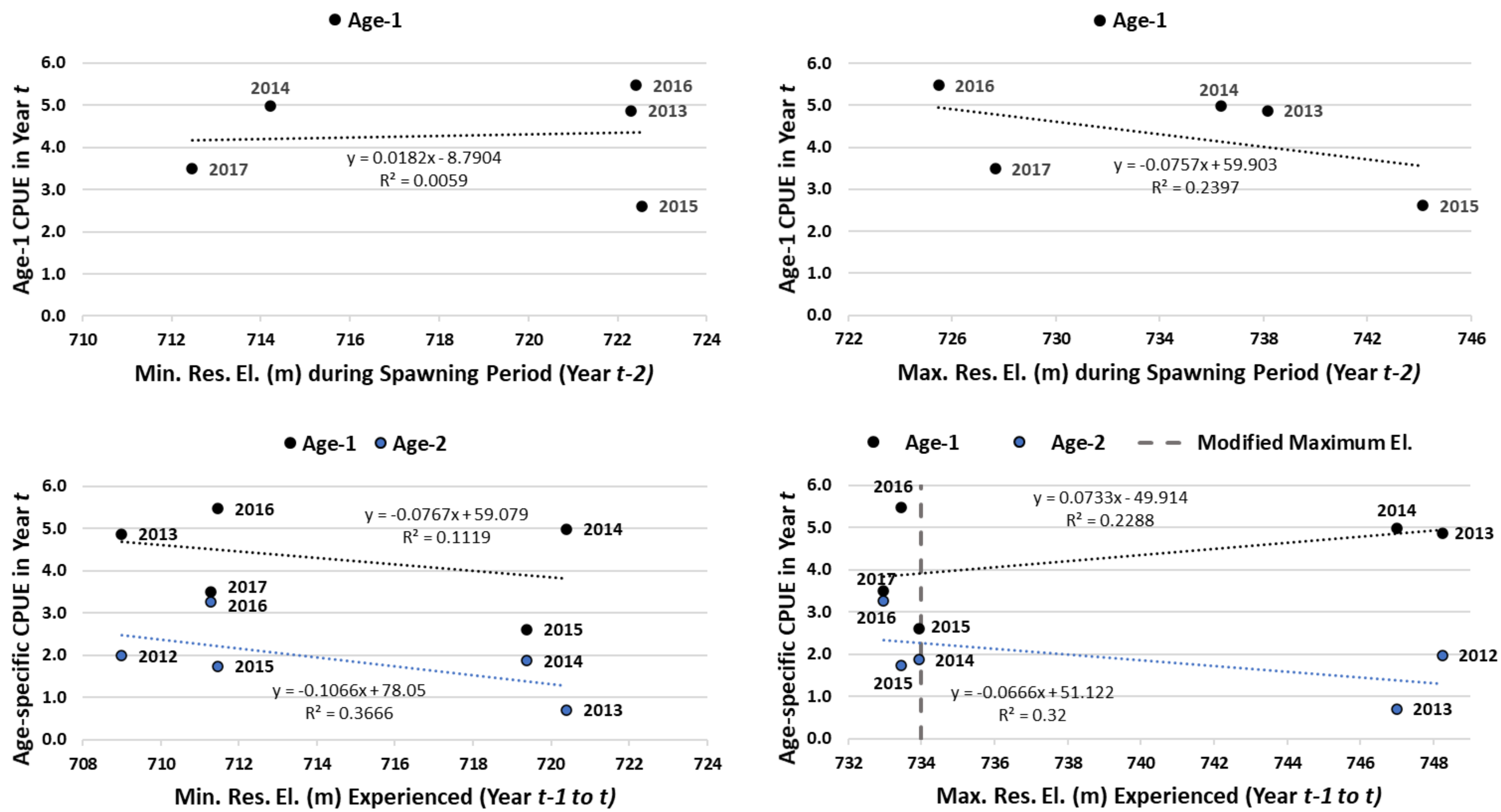

Figure 3.15 Plots of annual age-specific CPUE for Age-1 fish (upper panels) against minimum and maximum reservoir elevations during the spawning period in their recruitment year (*t-2*); and Age-1 and Age-2 CPUEs (lower panels) against the minimum and maximum reservoir levels experienced in the previous year (*t-1* to *t*). Labels next to each data point indicate the *recruitment* year (i.e., not the sampling 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 7), 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. Previously, 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), likely reflected local adaptation by this population to earlier reservoir inundation risk at these locations under normal reservoir operations. Under modified operations, however, there is some evidence of increased use of Ault and Cathy creeks for spawning, which may be due to the reduced inundation risk when reservoir levels are kept lower.

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 2018 and 2019) 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 Years 6 and 7 (2018 and 2019) 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 has also generally been confirmed by the sampling of recently emerged fry in late August 2017 (CPUE = 9 fish/100 m; forklength range = 23 to

33 mm), and in late August 2019 (CPUE = 22 fish/100 m; forklength range = 20 to 46 mm), in several creeks. Young-of-the-year fry were also sampled during the fall session in mid October 2018 (CPUE = 14 fish/100 m; forklength range = 20 to 58 mm), and 2019 (CPUE = 10 fish/100 m; forklength range = 27 to 56 mm).

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 0-3 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 2.3), and highest abundance has varied between them among years (Table 3.13). The highest densities have routinely occurred at the creek mouths, generally followed by shallow slope and fan habitats. Previously, the lowest numbers were more consistently associated with steep shorelines; however, abundance at steep slopes has increased in 2018 and 2019 (due to a high contribution of Age-1 and Age-2 recruits in those years, respectively). 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 and 2019. The most rapid growth has tended to occur between ages 1 and 4, after which growth rate slows and there is considerable size overlap among the older age classes. Growth rates, as compared using 4-parameter logistic growth curves based on median sizes for each age class in each year, suggest that growth has slowed since initiation of modified operations in 2016, and this was particularly the case in 2019. Whether this diminished growth is caused by reduced production of food for fish associated with the modified operations of the reservoir, or increased competition for limited food resources associated with the increased abundance of fish in 2018 and 2019 remains uncertain.

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 four years of modified operations to-date, minimum elevations were 719.38, 711.47, 711.29 and 710.69 m, and maximum fill elevations were 733.94, 733.46, 732.96 and 733.50 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 increased significantly in 2018 and 2019 to 12.2 ± 1.4 fish/100 m and 11.8 ± 1.3 fish/100 m of shoreline, respectively, 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, and Age-2 and Age-4 fish in 2019. CPUEs for Age-2 to Age-4 fish have increased 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 from 2017 to 2019.

These results suggest that the modified operations may be improving recruitment conditions, reservoir rearing conditions, or both. However, the recruitment of fish to Age 1 in 2019 was reduced relative to 2018 (from 5.5 to 3.5 fish/100 m, respectively) even though the total abundance of fish was on par between those two years (i.e., due to the increased recruitment to Age-2 and Age-4 in 2019). These results suggest that while lower reservoir elevations during the spawning period may improve spawning and recruitment conditions in the short term, there may be other bottlenecks to production in the system, such as limited food resources, that may limit the total number of fish that can survive in the system. In that case, when improved recruitment increases population size, conditions may start to favour the older age classes in the reservoir (due to their size and foraging capability) until a balance among age classes is re-established.

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 and 2019 results provided two data points which suggested that the annual abundance index has increased under the initial years of modified operations (2016-2019). 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 5 years of comparable abundance index data points available at this point (3 years of recruitment under normal operations and 2 years under modified operations; refer to sections 2.5 and 3.6) with 3 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 Years 3 to 6 (2015 to 2018) provided information for addressing this MQ (refer to Section 3.3 in Sneep 2019b for specific habitat survey results). Due to the sample size already compiled across those years, additional habitat data collection was put on hold in Year 7 (2019) in favour of additional tributary fish sampling and spawner distribution data collection (as per the recommendations in the Year 6 report). The information that follows is based on the data and observations gathered from each relevant monitoring component across all study years to-date.

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). Based on tributary fish sampling results to-date, recaptures of tagged fish (*n*= 6 in 2019) across seasons and years provides some evidence of stream residency up to Age-3 in a small number of cases; however, use of the creeks for rearing by the rainbow trout population appears limited beyond a short period (typically <1 year) after emergence for the vast majority of recruits. In select creeks (i.e., those associated with spawning use), highest abundance occurred in summer (i.e., late August; 29.4 ±11.9 fish/100 m) and fall (i.e., mid October; 14.9 ±5.0 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., early June; 7.9 ±2.9 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 (Table 3.10 in Section 3.5). 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 was completed for the first time in Year 7 (2019) – as opposed to one season per year as was done in Years 4, 5 and 6 (2016-2018) – and is recommended to continue for the remaining years of the program (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, 2018 and 2019) 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 shortlived (until inflow increased), typically prior to the start of the rainbow trout spawning period, and/or occurred in creeks that have not been 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. In spawning streams with a lower gradient (e.g., Eagle Creek in the west zone of the reservoir), total drawdown stream length was reduced by an average of 186.2 m (or 67%) across the spawning period under normal operations versus an average of 121.8 m (or 37%) under modified operations. For steeper streams, such as Ault Creek in the east zone, the total drawdown stream length was reduced by an average of 116.8 m (or 78%) under normal operations versus an average of 70.0 m (or 43%) under modified operations. Using these data for all surveyed streams, it is clear that modified operations have increased the accessible stream length during the rainbow trout spawning period by more than 2-fold overall relative to the normal operations years assessed.

During each monitoring year to-date, higher use of the drawdown zone for spawning (i.e., ~80% of observed spawners) in the selected tributaries relative to the upland zone (i.e., ~20% of observed spawners) has been consistently documented. Starting in Year 7 (2019), we also collected more specific information on the locations of spawner observations within the drawdown zone to 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). Based on this initial year of data collection for this component, the majority of spawners in the drawdown zone used the section between approx. 730 m and 738 m elevation, meaning that inundation of elevations >730 m during the spawning and incubation period tends to be the the riskiest in terms of potential recruitment impacts (see Table 3.7 in Section 3.4). Reservoir elevations under modified operations have tended to inundated a smaller portion of this zone than under normal operations. As this data set continues to build 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 3.4 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 3 of the 5 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. 2019), 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 surveyed in August 2015, which almost fully inundated the reservoir basin) and the 733 m modified maximum elevation surveyed in summer 2018, 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 would likely need to be included as part of a potential 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. However, 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 spawning habitat and food sources that the tributaries provide, it is not surprising that the highest fish densities tend to be concentrated around creek mouths and their adjacent habitats, where mature individuals stage for spawning in the spring and all age classes can feed throughout the growing season. 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 3.6).

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; Sneep 2019a). 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 began in Year 7 (2019) and is proposed to continue (see Section 5 – Recommendations). Evidence suggests that rainbow trout have primarily and most consistently used 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) was not observed during the years of normal (N2-2P) operations, despite the presence of suitable habitat. In previous reports we speculated that this was because these creeks get inundated by the reservoir earliest as it fills (since their mouths are the lowest in elevation and closest to the dam), and the portion of Ault Creek above 734 m is very steep which likely limits fish use to the lower portion only (Sneep 2019b). However, under modified operations the reservoir tends to start at a lower elevation and fills less across the rainbow trout spawning period than it did under normal operations and spawners have been observed in these creeks during the past two years (2018 and 2019). This change in inundation risk may make spawning habitats in Ault and Cathy creeks suitable for a longer period, which the fish have begun to exploit. Continued assessment in the remaining monitoring years will document whether this expanded spawning distribution is sustained 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; The data collected to-date have consistently shown that the majority of rainbow trout spawners use the available habitat in the drawdown portion of selected tributaries (~80% of observations), relative to the upland zone (~20% of observations). However, more data are needed to define the relationship between operations (e.g., min. and max. reservoir elevations) and rainbow trout recruitment and survival. While some tributaries are not used at all, or minimally, the drawdown zone of Tribs. #13 and Eagle Creek have been used extensively and consistently (Section 3.4 of this report). There is also some evidence of spawning distribution expansion into Ault and Cathy creeks where they were not previously observed during normal (N2-2P) operations years (see above).

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. 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 or during the spawning period 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 and inflow volumes 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 3.4 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 habitat survey results in Sneep 2019b, Section 3.3). Efforts conducted between study years 3 and 6 (2015-2018) provided data to define substrate characteristics at 747, 734, and 722 m, and provided habitat type distribution information for a range of reservoir operating levels. See descriptions of substrate composition, interstitial space availability, and habitat distribution among selected high and low reservoir elevations provided in the Year 6 (2018) report 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 7 (2019) 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 3.15 in Section 3.6). 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 support from various monitoring components 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 3.15). Based on the Age-1 CPUE data up to Year 6 (2018), the slope (-0.14) and R^2 (0.68) values for this negative correlation were stronger than the other relationships based on the data currently available (Sneep 2019b). This result seems intuitive and is supported by the reservoir elevation-tributary length relationship (Table 3.6) and the spawner distribution observations (Table 3.7): the higher the reservoir fills during the spawning period, the smaller the available spawning habitat area becomes, and the greater the inundation risk for incubating eggs by the reservoir. However, the results from Year 7 (2019) showed reduced abundance of Age-1 fish recruited under modified operations conditions and a larger Age-2 cohort (relative to the Year 6 results). This suggests that recruitment of fish to the youngest age classes (favoured by modified operations) may be restricted by total population size limits (driven by food source availability and competition within and among age classes) – additional comments about this are made under MQ #2, above. Given these variable patterns among years that are just emerging, the conclusions remain 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 and Age-2 fish in 2019 (i.e., the first cohort that recruited under the lower modified operations levels) seems to support this (see Section 3.6). 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, as stated for MQs #2 and #4 (above), there is some evidence for potential population size limits driven by parameters other than just recruitment (e.g., limited food sources and competition within and among age classes) that may also be coming apparent. As such, 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 would 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 (initiated 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 7 (2015 to 2019). We have fit regression lines to the Age-1 and Age-2 CPUE vs. reservoir operation (minimum or maximum levels) relationships; 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 (from the sample) 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 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 recommendations in the following bullets). If a need for any additional habitat data collection is identified, it could be incorporated into one or more of the remaining study years (as long as the budget allows), 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 began collecting data on the specific locations where spawners were observed in the creeks, particularly for the drawdown zone, so that the elevational distributions could be plotted (Figure 3.6) and summarized (Table 3.7) to contribute to an understanding of which elevational ranges pose the greatest and least inundation risk for incubating eggs. For now, the added effort (and cost) for completing this component may be offset within the existing budget by eliminating further habitat mapping and substrate measurement activities (as described in the bullet above).
- Conduct tributary fish sampling (by backpack EF) during three seasons in the same year as was done 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). Same 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 was offset within the existing budget in Year 7 (2019) by eliminating further habitat mapping and substrate measurement activities (as described above). However, some additional funds may be required to sustain this effort through the remaining study years.
- 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)

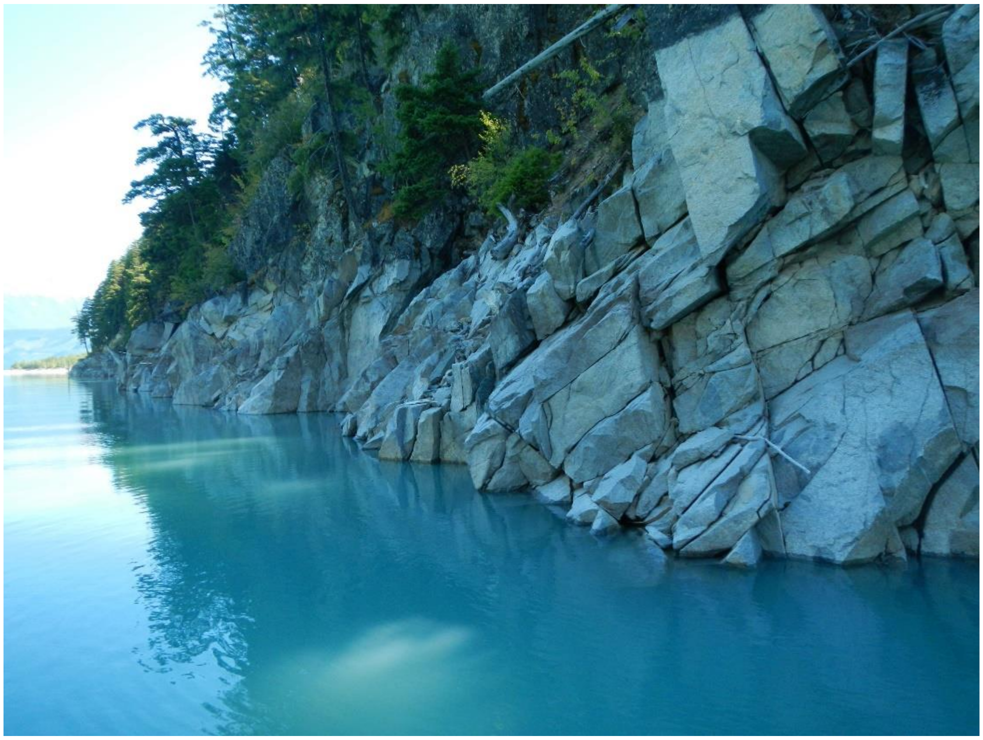


Photo A5 Reservoir Habitat Type 4: **Steep Slope** (Sub-type Bedrock)

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 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.

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, Limnotek Research & Development Inc., pers. comm.). Scale shown is in millimeters.

Appendix B – Temperature Figures for Each Study Year Available

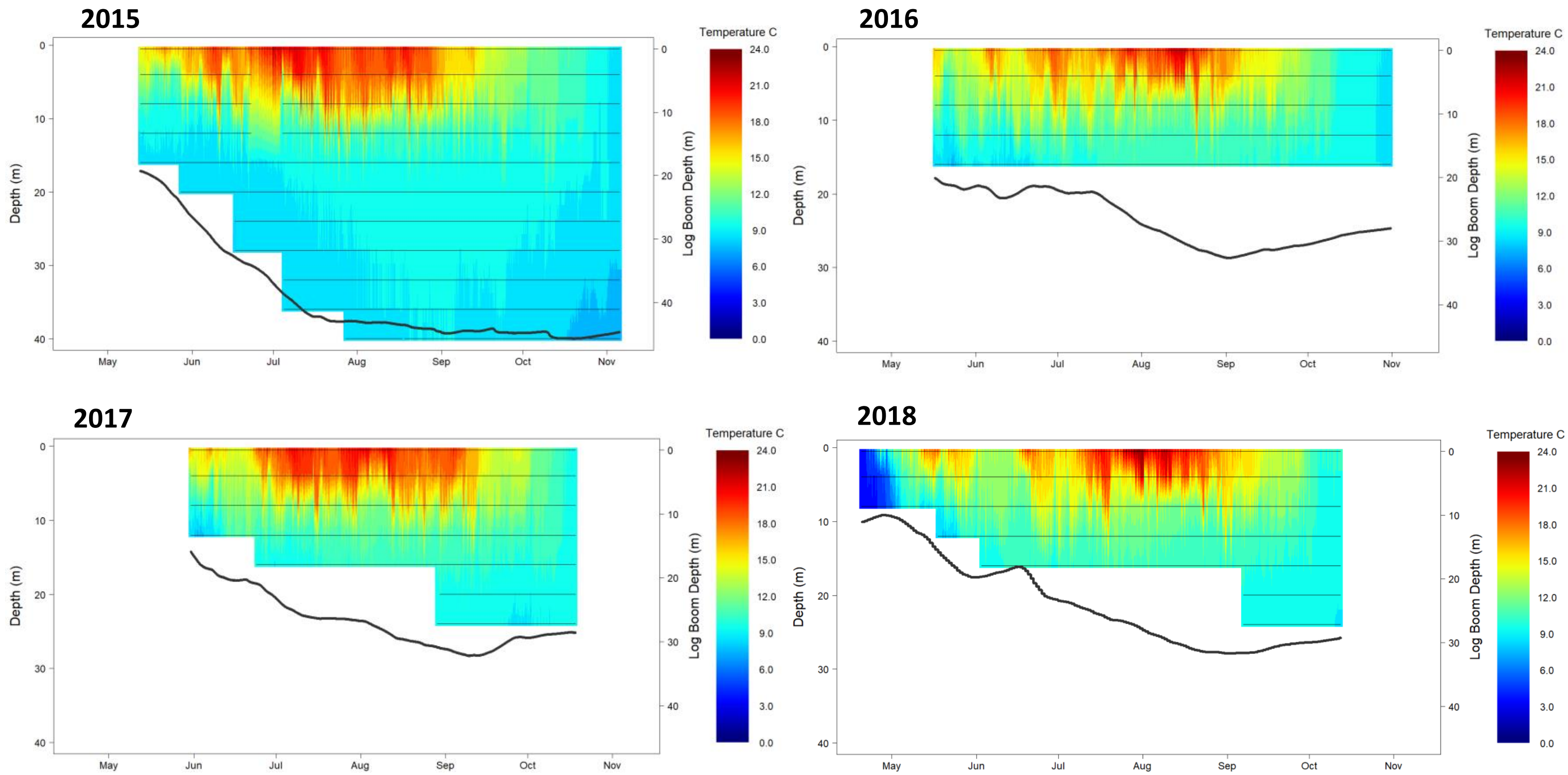


Figure B1 Water temperature profiles recorded in Downton Reservoir at the log boom (see Figure 2.1 for location), May to November 2015 (upper left), 2016 (upper right), 2017 (lower left), and 2018 (lower right). The horizontal lines indicate the measurement depths (1° y-axis). Temperatures between those depths were linearly interpolated. The solid black lines reference the reservoir depth at the log boom on the 2° y-axis.

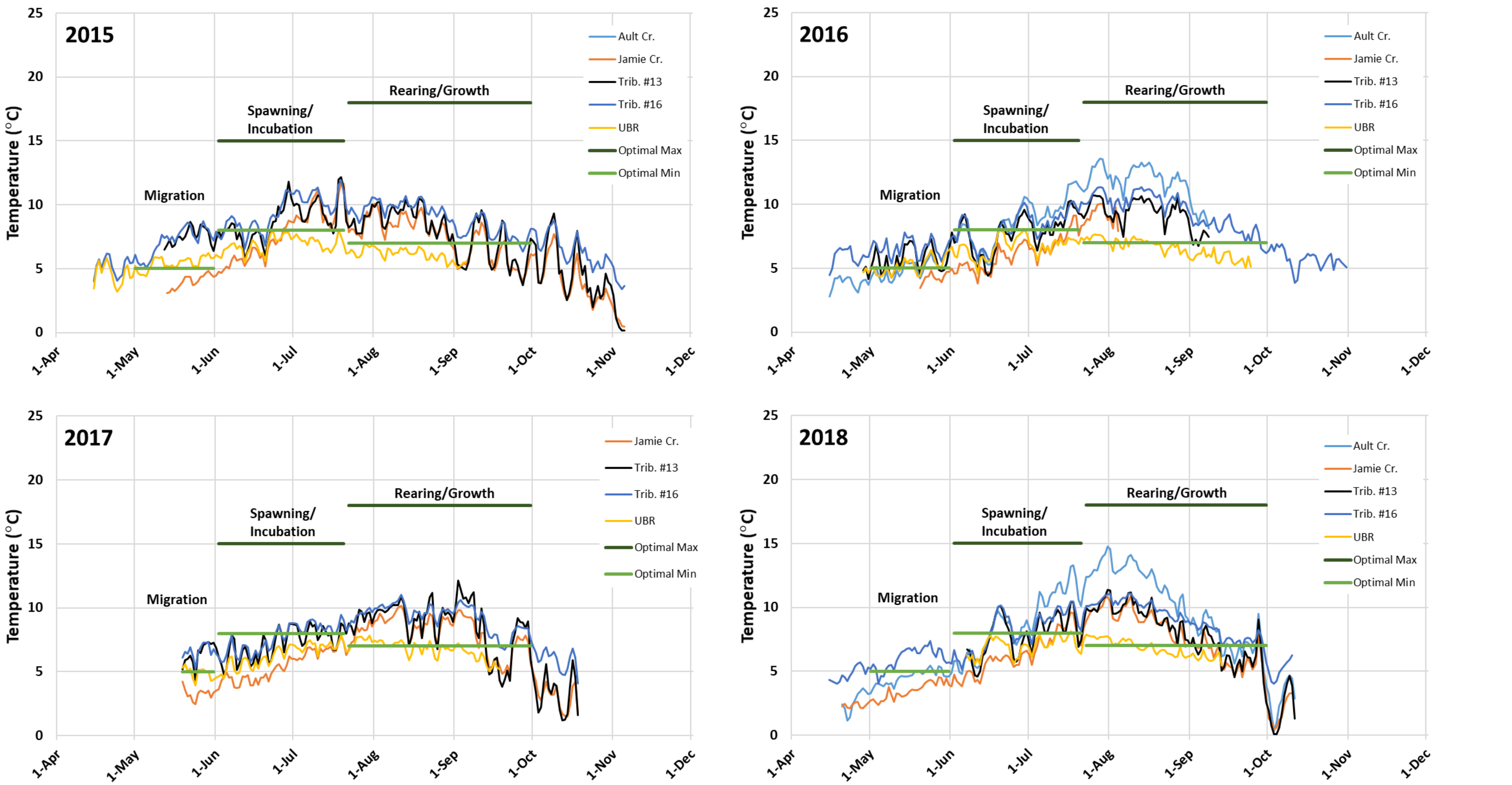


Figure B2 Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to October 2015 (upper left), 2016 (upper right), 2017 (lower left), and 2018 (lower right). The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of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

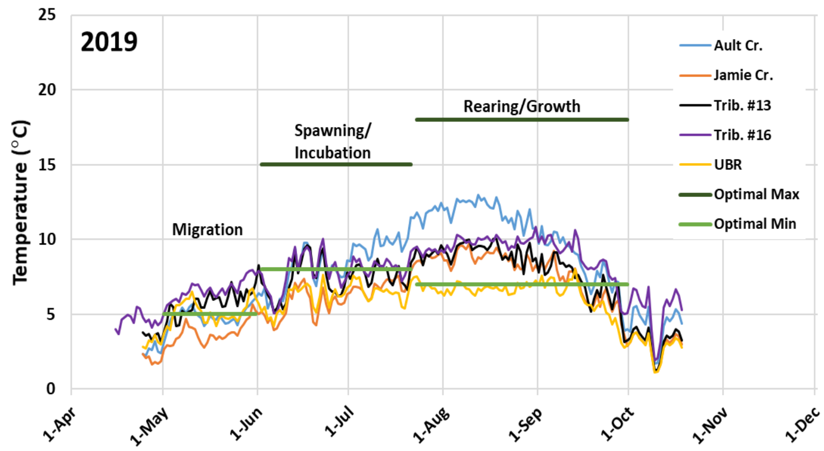


Figure B2 Cont. **Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to October 2019. The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of rainbow trout (McPhail 2007).**

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

Continued…

Tag Code[a]	Original Capture Data			Recapture Data			Dist. (km)	Growth (mm/yr)
	Date	Zone	FL (mm)	Date	Zone	FL (mm)		
889157	31-May-16	Mid	258	6-Jun-19	Mid	308	1.7	17
889306	2-Jun-16	Mid	84	7-Jun-19	West	307	2.3	74
888690	1-Jun-17	Mid	113	8-Jun-19	West	296	3.9	91
975967	4-Jun-17	West	110	10-Jun-19	Mid	247	4.8	68
317323	4-Jun-18	West	301	9-Jun-19	West	296	0.5	-5
316690	6-Jun-18	Mid	302	8-Jun-19	West	324	9.4	22
316805	8-Jun-18	East	270	11-Jun-19	West	279	11.4	9
317033	8-Jun-18	East	98	12-Jun-19	Mid	207	5.5	108
316955	8-Jun-18	East	110	6-Jun-19	Mid	219	7.5	110
316818	8-Jun-18	East	109	11-Jun-19	Mid	251	5.7	141
316978	8-Jun-18	East	105	12-Jun-19	East	260	1.7	153

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

Appendix D – Length-Frequency Figures by Study Year

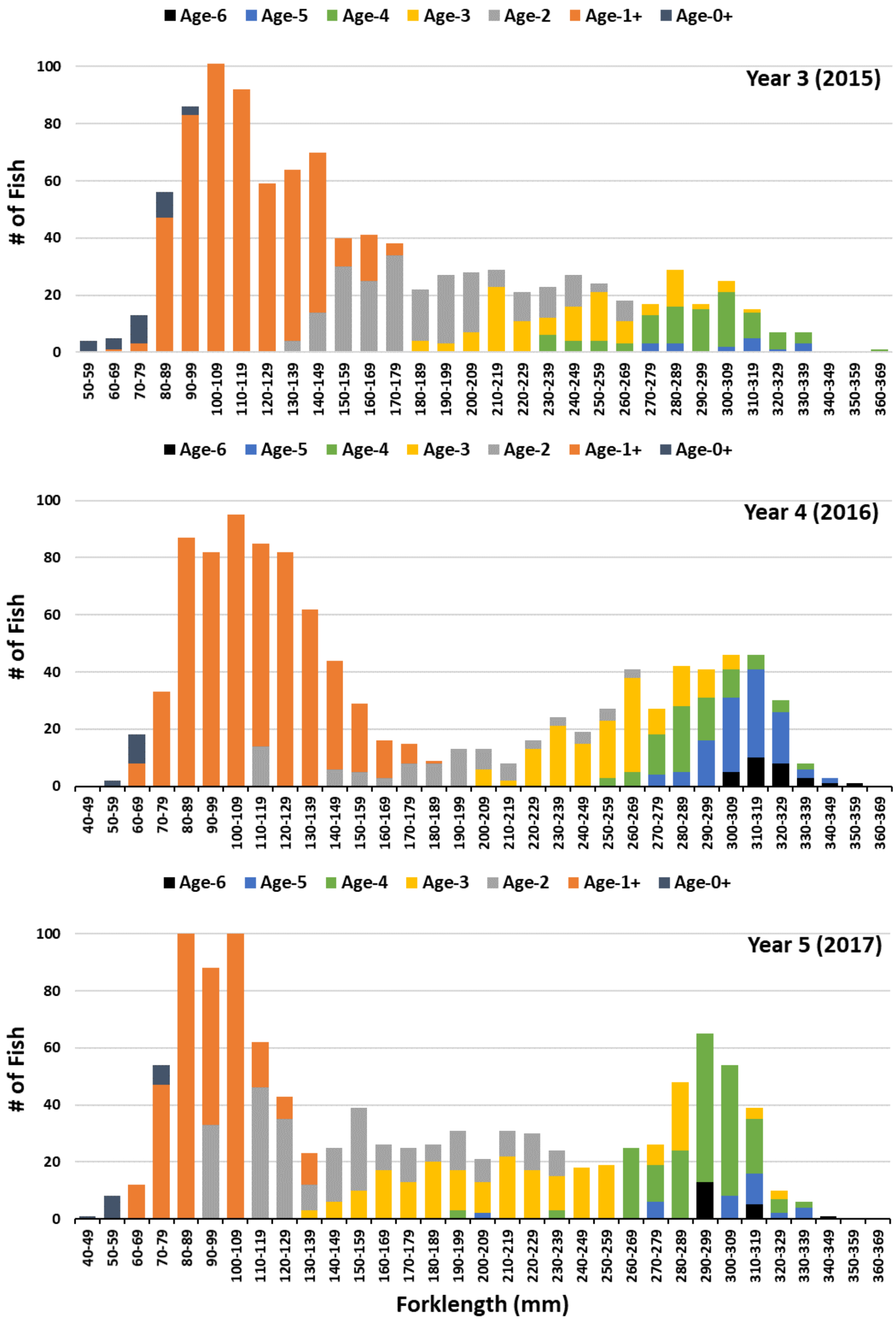
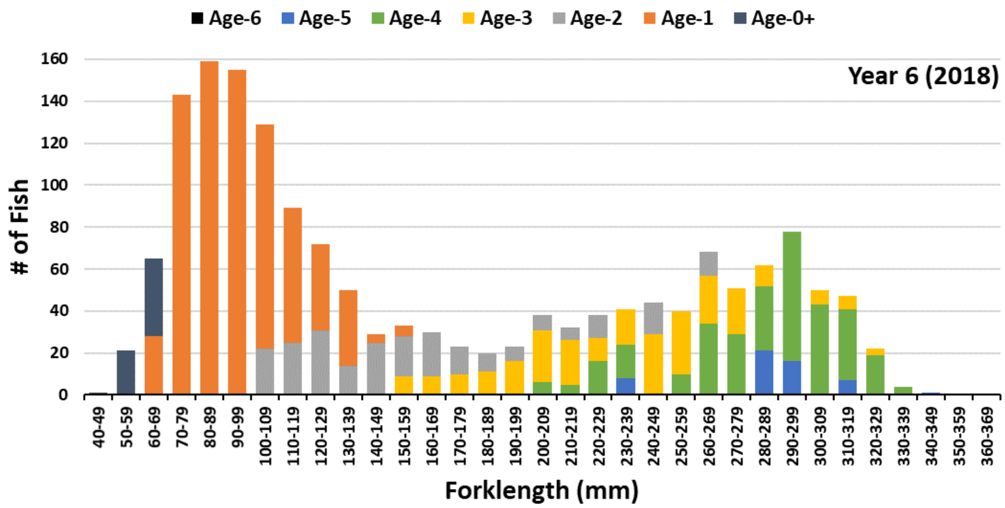


Figure D1 Length-frequency histograms for each study year showing the distribution of age classes for rainbow trout in Downton Reservoir in late May to early June. Note: results for years 1 and 2 are not included due to different sampling approach in those years.



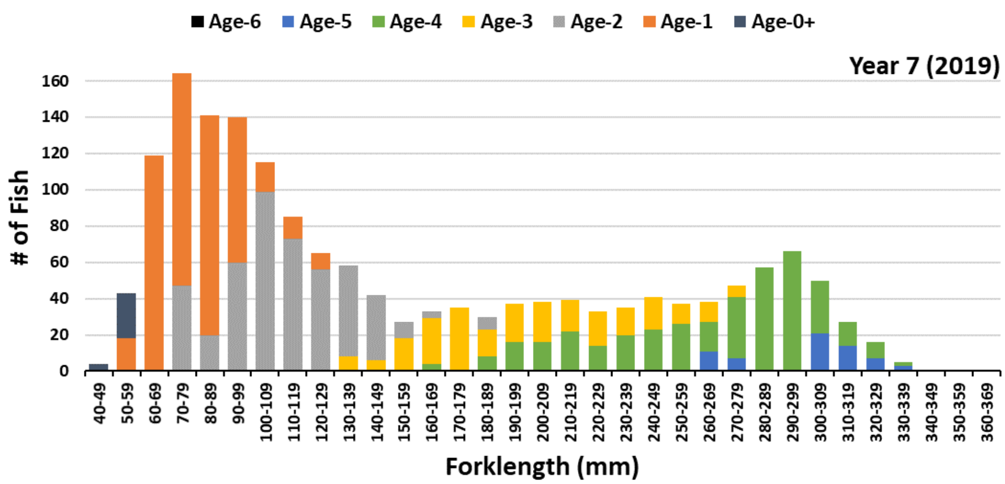


Figure D1 Continued.