# Bridge River Project Water Use Plan

## Downton Reservoir Fish Habitat and Population Monitoring

## Implementation Year 8

## Reference: BRGMON-7

***BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 8 (2020) Results***

**Study Period: April 1 2020 to March 31 2021**

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# BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 8 (2020) Results

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## Executive Summary

Data collection for Year 8 of this proposed 10-year study was completed in 2020. 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.

Five methods, which have been implemented consistently since Year 3 (2015), were again employed in Year 8 (2020) to document the biological characteristics of the fish population, generate an annual abundance index, characterize available fish habitats, and assess the effects of the modified reservoir operations. To-date, only rainbow trout and a single bridge lip sucker have been captured in the reservoir and its tributaries among all the years of sampling.

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 8 (2020) was the fifth year that the reservoir was operated to the new modified maximum elevation target (i.e., 734 m); maximum reservoir elevation in 2020 was 735.1 m. Lowest reservoir elevation in 2020 (710.4 m) was most similar to 2019 (710.7 m), 2018 (711.3 m), 2017 (711.5 m) and 2014 (709.0 m), and 9-10 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 three tributaries where spawning use has been consistently documented in past years (i.e., 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 8 (2020) 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 spawning creeks were lower than the highest counts observed in Year 1 (2013), but were on par or higher than every other year since then. Spawners were again documented in Jamie, Cathy and Ault creeks (peak counts = 15, 63 and 30, respectively) in 2020, 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 8 (3-5 June, 25-27 Aug and 14-16 Oct 2020, respectively). Mean CPUE (for all creeks sampled) was 11.3 ±2.5 fish/100 m in spring, 22.6 ±8.5 fish/100 m in summer, and 29.8 ±13.2 fish/100 m in fall. No fish were captured at 2 of 10 sites (20%) during the spring session, 1 of 13 sites (8%) during summer, and 1 of 13 sites (8%) 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., 56% and 76%, respectively) were the new year class of rainbow trout fry (forklength = 20 to 55 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 17 km of shoreline was sampled by boat electrofishing over 8 nights from 17 to 24 June, 2020 at a reservoir elevation of approx. 719 m. This reservoir elevation was at the low end of the typical range observed during sampling in most years to-date (i.e., ~719 to ~723 m), other than 2015 when elevation was higher during the annual survey (i.e., ~730 m under N2-2P conditions). In total, 1,416 rainbow trout were captured from 59 sites, which resulted in the highest total catch-per-unit-effort value to-date. Of these fish, 1,097 were newly marked with PIT tags and 33 marked fish were recaptured (11 that were marked within this sampling session, and 22 from previous years). Overall, the fish population index (CPUE) has increased for rainbow trout cohorts that incubated and reared under modified operations conditions compared to those that recruited under N2-2P conditions based on the years of data available.

Total CPUE in the reservoir was 14.2 ±2.7 fish/100 m of shoreline which was similar to the total CPUE values in Year 6 (2018; 12.2 ±1.4 fish/100 m) and Year 7 (2019; 11.8 ±1.3 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 due to increased catches of Age-1 fish in 2018, which was more than double the catch rate for that age class in 2017, increased catches of Age-2 fish in 2019, and increased catches of Age-3 fish in 2020 (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) and Age-2 in 2020 (relative to 2019) may indicate a limitation to total population size in the reservoir which ultimately caps juvenile cohort abundance or favours the older and larger age classes when recruitment increases until a new equilibrium is reached.

Highest CPUEs by habitat type in 2020 were once again at creek mouths (56.6 ±9.1 fish/100 m) and then shallow slopes (10.1 ±2.1 fish/100 m), followed by fans (7.6 ±0.8 fish/100 m) and then steep slopes (4.6 ±0.5 fish/100 m). By age, based on CPUE, the older age classes (i.e., Age-3 and up) were most dominantly represented at creek mouths over any other habitat type, whereas Age-1 and Age-2 fish were more equally represented among all habitat types. The consistency of these results across years indicates that all habitat types provide rearing areas for the younger age classes, which is particularly important when population size increases given that fish densities and competition are highest at the creek mouths. Highest total CPUE by longitudinal zone of the reservoir was recorded in the west zone in 2020; although this has varied equally among the zones across the monitoring years to-date, reflecting that rainbow trout are generally distributed and move throughout the reservoir according to the pool area available.

Data reporting in Year 8 (2020) also included analysis of length-at-age (4-parameter logistic growth curves) and condition factor (Fulton's K) assessment by age and operational regime (i.e., N2-2P vs. Modified Operations). Based on the growth curves, rainbow trout growth (i.e., median body length at age) has decreased slightly during the period of modified operations, most notably for fish aged 1 and 2. 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 perhaps c) both of these factors. Based on our speculation (informed by anecdotal observations) that the majority of the food supply comes from the creeks (as drifting invertebrates) where the effect of reduced maximum reservoir elevation may be beneficial for invertebrate production, we currently think that b) may be the most probable cause for the slight reduction in juvenile growth.

Conversely, the assessment of condition factor showed an increase in Fulton's K value (weight as a factor of length) during the modified operations years compared to N2-2P operations for Age-2, Age-3 and Age-4 fish (the condition of Age-1 and Age-5 fish were very similar among treatments). This result also suggests that adequate food is being produced in the reservoir to support the increased population size under modified operations (relative to N2-2P), although food supply may still be a significant factor limiting the maximum body size and age of rainbow trout in the reservoir, and the extent to which population size can increase as a result of operational modifications. Unfortunately it is not possible to more definitively characterize the mechanisms underlying the changes in body size and condition without a coincident time series of data on reservoir productivity and food supply which were beyond the scope of this monitor.

Ageing analysis was conducted on 198 scales across the rainbow trout length distribution in 2020 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, 2019 and 2020. 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 absolute minimum and maximums experienced within the past year for Age-1 and Age-2). At this point, a relationship does appear to be emerging between the minimum reservoir levels during a given year and the abundance index for Age-1 or Age-2 fish that recruit from those years. These relationships suggest a positive effect of lower minimum reservoir elevations, at least to the levels implemented within the monitoring years to-date (i.e., down to ~709 m).

On the other hand, this effect may actually be a reflection of another related factor which is not captured by the management questions but does appear to have support from various monitoring components at this point: The relationship between maximum reservoir elevation *during the spawning period* and the subsequent abundance of Age-1 fish that recruited under those conditions. As indicated previously, these two factors are related because the lower the reservoir is drawn down in the spring, the lower the maximum elevation reached during the spawning and incubation period tends to be, particularly under the modified operations conditions. Additional data points from the remaining study years will be important for further 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 and 2020 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 to mid 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 8 (2020) 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 8

| Primary Objectives | Management Questions and Study Hypotheses | Year 8 (2020) 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<br><br>2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative on existing reservoir fish populations, and, b) allow better future decisions regarding preferred operation of Downton Reservoir. | **1.** What are the basic biological characteristics of fish populations in Downton Reservoir and its tributaries? | • The Downton Reservoir fish population is almost entirely comprised of rainbow trout (save for 1 bridgelip sucker captured in 2016).<br>• 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, although monitoring data also suggest an increasing use of Ault and Cathy creeks in the mid and east zones under Modified Operations conditions.<br>• Relative to the upland, a higher proportion (~ 80% on average) spawn in the drawdown portion of these creeks.<br>• 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.<br>• 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.<br>• In the nearshore areas of the reservoir, the rainbow trout are distributed across the longitudinal zones (i.e., west, mid, and east).<br>• 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.<br>• 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 to 2020. The most rapid growth occurs between ages 1 and 3, after which growth rate slows.<br>**See Sections 3.4, 3.5, and 3.6 for more information.** |
| | **2.** Will the selected alternative (N2-2P) result in positive, negative or neutral impact on abundance and diversity of fish populations? | • Overall CPUE values for rainbow trout increased significantly in 2018, 2019 and 2020 (to 12.2, 11.8 and 14.2 fish/100 m of shoreline, respectively) from 8.1 to 8.9 fish/100 m between 2015 and 2017. As such, the modified operations (implemented since 2016) have had a positive impact on rainbow trout abundance relative to normal (N2-2P) operations.<br>• 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, and then by increased catches of Age-3 and Age-4 fish in 2020. CPUEs for Age-2 to Age-4 fish have been on an upward trend each year since 2016.<br>• 2020 minimum reservoir elevation (710.4 m) was very similar to 2014, 2017, 2018 and 2019, and 8-9 m lower than in 2013, 2015 and 2016; whereas maximum fill elevations since 2016 have been characterized by modified operations (i.e., 733-735 m) rather than the normal max. elevation (i.e., 749.8 m). |

| Primary Objectives | Management Questions and Study Hypotheses | Year 8 (2020) 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<br><br>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. | • 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.**<br>**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).<br><br>**$H_1$: likely rejected** at this point; however, more data are needed. The 2018-2020 results have 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 and Age-2 fish in 2020 for a cohort that recruited under modified operations suggests that the population may have hit a total abundance ceiling that favours particular age classes over others until a new equilibrium among age classes is established. Status updates will continue to be provided as more years of results become available, but full 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?<br><br>**$H_4$:** Operation of the reservoir restricts the amount of available effective spawning habitat in tributaries limiting the productivity of fish populations.<br>**$H_{4a}$:** Rainbow trout spawning density in Downton Reservoir drawdown zone is minimal and therefore operations do not limit productivity of fish populations.<br>**$H_{4b}$:** Operation of the reservoir restricts fish access to tributaries limiting the productivity of fish populations.<br>**$H_5$:** 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 data collection on habitat use linked to reservoir levels continued in Year 8 (2020), providing additional information for addressing this MQ. **See Sections 3.2 to 3.6 for more information**.<br>• The tributaries provide essential spawning habitats and, likely, food supply; however, use for rearing beyond the initial growing season post-emergence appears limited.<br>• Access to some tributaries by spawners may be impeded when reservoir levels are <713 m and inflows are low.<br>• 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.<br>• 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.<br>• 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 during that period of the year (start of spring freshet).<br>• 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.<br>• In general, the substrate size distribution and interstices in the reservoir drawdown zone are positively correlated with elevation (size range, median size and interstitial space tend to increase with the elevation).<br>• 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. |

| Primary Objectives | Management Questions and Study Hypotheses | Year 8 (2020) 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<br><br>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. | | **$H_4$: confirmed**; however, more data on relationship between reservoir level and accessible spawning habitat availability will be beneficial. Implementation of modified operation (from 2016 to 2020) reduced the portion of stream length inundated by the reservoir. Data to define this relationship for several tributaries was collected in Years 6-8 (2018-2020).<br>**$H_{4a}$: rejected**; more data will be useful. 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).<br>**$H_{4b}$: likely rejected**; more data will be useful. Some tributaries can 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 minimum reservoir elevations during the rainbow trout spawning period. Surveys for this purpose are planned to continue for the remaining study years.<br>**$H_5$: 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?<br>**$H_2$:** The annual abundance index for rainbow trout is independent of minimum reservoir elevations observed over the period of monitoring.<br>**$H_{2a}$:** The annual abundance index for Age-1 rainbow trout is independent of a minimum reservoir elevation effect (sampling year minus 1).<br>**$H_{2b}$:** The annual abundance index for Age-2 rainbow trout is independent of a minimum reservoir elevation effect (sampling year minus 2).<br>**$H_3$:** The annual abundance index for rainbow trout is independent of maximum reservoir elevations observed over the period of monitoring.<br>**$H_{3a}$:** The annual abundance index for Age-1 rainbow trout is independent of a maximum reservoir elevation effect (sampling year minus 1).<br>**$H_{3b}$:** 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 8 (2020) 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.<br>• One emerging relationship is the positive effect of lower minimum reservoir elevations (at least to the levels implemented within the monitoring years to-date; i.e., down to ~709-710 m) on the abundance index of Age-1 and Age-2 fish that recruit from those years.<br>• However, this cannot be viewed independently from the other emerging relationship which 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. These factors are not independent because lower minimum levels that occur in the spring tend to result in lower maximum levels during the spawning period in the same year.<br>• There are not yet any clear relationships between minimum reservoir levels *during the spawning period* or absolute maximum levels and the abundance index for Age-1 or Age-2 fish that can be differentiated from "*no effect*" at this point.<br>• 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.<br>**$H_2$, $H_{2a}$, $H_{2b}$: likely 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).<br>**$H_3$, $H_{3a}$, $H_{3b}$: 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). |

| Primary Objectives | Management Questions and Study Hypotheses | Year 8 (2020) Results To-Date |
|---|---|---|
| | **5.** Can refinements be made to the selected alternative to, without significant impact to instream flow conditions in the Middle Bridge River, improve habitat conditions or enhance fish populations in Downton Reservoir? | • Based on the reservoir elevation and fill rate information provided by BC Hydro, the modified operation of Downton Reservoir (i.e., reduced full pool elevation and slower fill rate) may provide benefits in terms of an increase in useable stream length above the *modified* maximum reservoir level and a reduced proportion of eggs at risk of inundation by the reservoir as it fills.<br>• The increased abundance of Age-1 fish documented in 2018, Age-2 fish in 2019, and Age-3 fish in 2020 (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 modified operations.<br>• Similarly, refinements to the selected alternative (N2-2P) that can include a reduced maximum fill elevation and slower fill rate during the rainbow trout spawning and incubation period (Jun-Aug), would likely improve spawning habitat availability and enhance recruitment for the Downton Reservoir fish population (i.e., similar to what has been documented under modified operations).<br>• Depending on inflows in a given year, *any* 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.<br>• 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 more fully 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 8 of this proposed 10-year study was completed in 2020.

## 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).

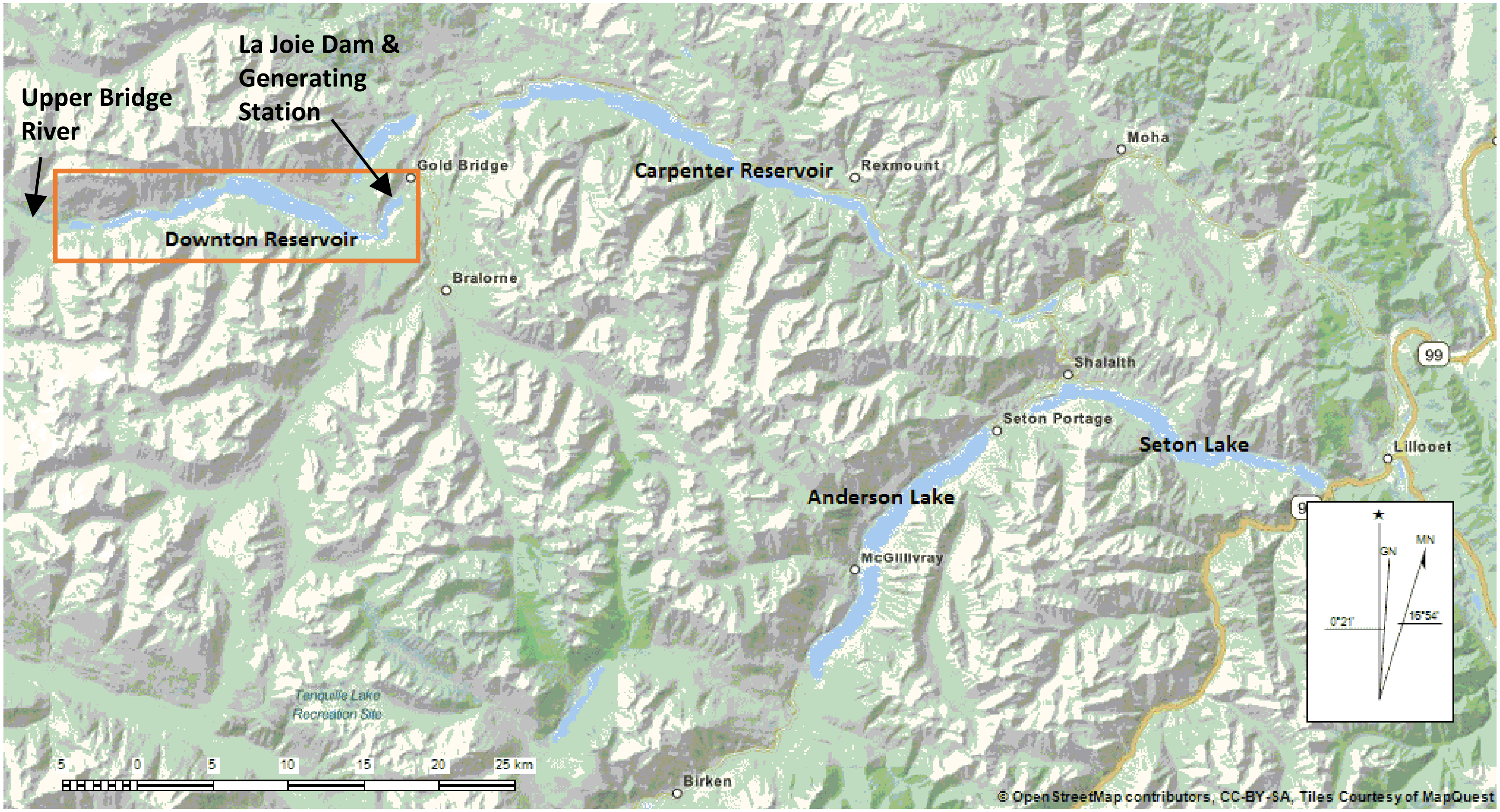


**Figure 1.1 Bridge River and Seton River watersheds. The extent of the BRGMON-7 study area, which includes all of Downton Reservoir and tributaries between the Upper Bridge River inflow and La Joie Dam, is outlined by the orange rectangle.**

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$^3\cdot$s$^{-1}$), increase in May, peak in June and July (mean = ~100 m$^3\cdot$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), Year 7 (2019) and Year 8 (2020). 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 8 (2020) 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) | 8 (2020)[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 8 (2020) activities were completed are provided in Section 1.6, 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 (starting 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 2020. The added effort (and cost) for expanding this component from one season to three per year was largely offset within the existing budget by eliminating further habitat mapping and substrate measurement activities (as described above).

## 1.6. Year 8 (2020) 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 (2020) represents monitoring year 8. The general schedule of field sampling activities is presented in Table 1.2.

**Table 1.2 Year 8 (2020) Schedule of Field Sampling Sessions and Activities.**

| Field Sampling Activities | Dates (2020) |
|---|---|
| Temperature logger deployment & retrieval | 30 Apr; 3 Jun;<br>15 Jul; 25 Aug;<br>15 Oct |
| Tributary Access Surveys | 30 Apr; 28 May; 16 Jun |
| Tributary Spawner Surveys | 28 May to 22 Jul<br>(weekly) |
| Tributary Fish Sampling | Spring: 3 to 5 Jun<br>Summer: 25 to 27 Aug<br>Fall: 14 to 16 Oct |
| Fish Population Index Survey | 17 to 24 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 appear to be the only salmonid species present (or at least susceptible to our sampling). 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 (aka Eagle Creek), Jamie Creek, and the Upper Bridge River (UBR). The loggers were installed on 30 April, checked and downloaded on 15 July and 25 August, and retrieved for the end of the monitoring period on 15 October, 2020. The locations of the temperature array and other loggers in the study area are shown on Figure 2.1.

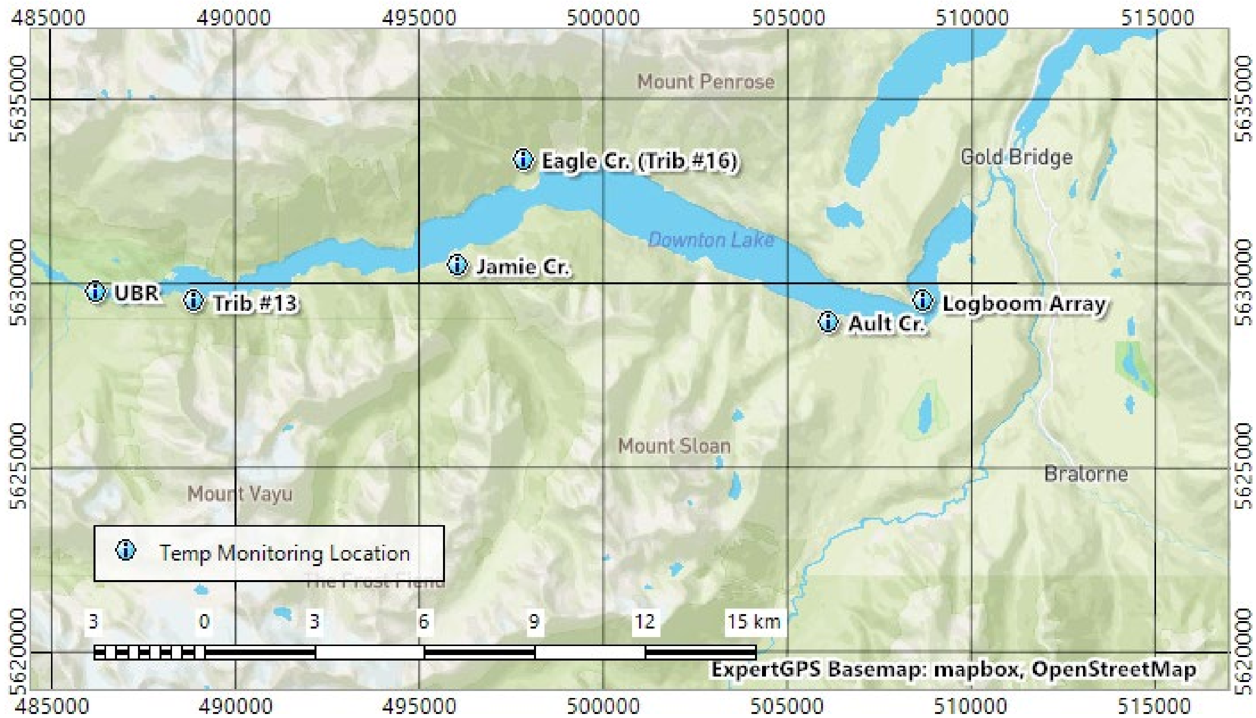


**Figure 2.1 Locations of the tributary temperature loggers and the Downton Reservoir logboom temperature array.**

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 (spawning period = late May to late July; incubation extends to late August or early September). 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 *in situ* temperatures 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 for each year.

## 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 8 (2016-2020). 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 and submersion 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-to-late 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 were also conducted at Jamie Creek, Cathy Creek (Trib. #5) and Ault Creek to document potential spawning use of these accessible, but previously 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).

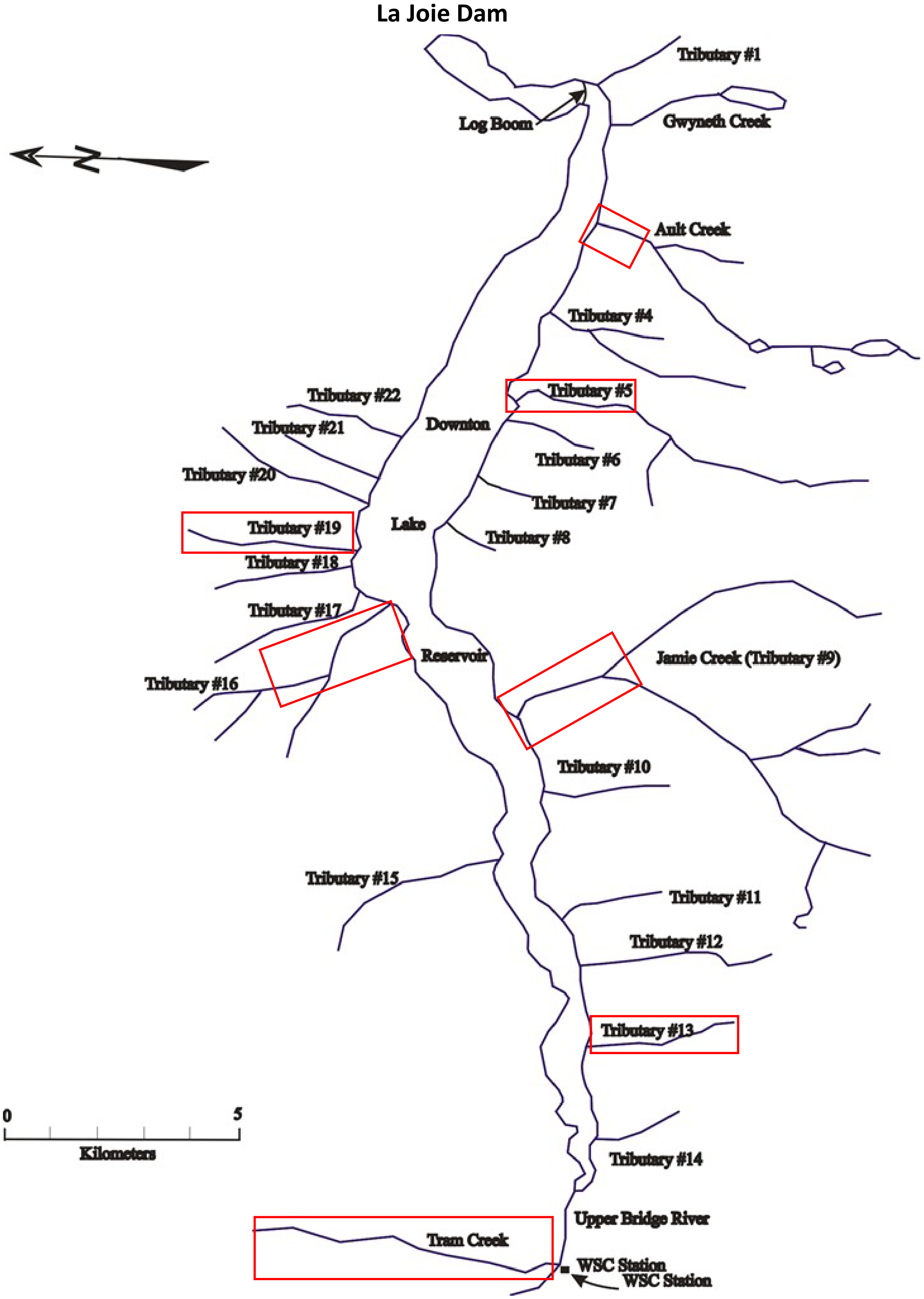


**Figure 2.2 Downton Reservoir and the relative location of tributaries. Streams that have been monitored for this program (i.e., tributary access surveys, spawner surveys, and tributary fish sampling) are outlined in red.**

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.

Starting 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 overall. 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 Years 6 and 7 (2018 and 2019), 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 and 2020 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 2020, 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, 10 tributary sites were sampled in spring (drawdown zone $n$= 6; upland $n$= 4), 13 sites were sampled in summer (drawdown zone $n$= 6; upland $n$= 7), and 13 sites were sampled in fall (drawdown zone $n$= 6; upland $n$= 7). Trib. #13 (upland and drawdown), Tram Creek (upland) and the UBR (upland) sites couldn't be accessed during the spring session due to snow avalanches blocking the Bridge-Main FSR. Trib. #19 (upland and drawdown sites) could not be sampled in summer or fall because this creek went dry (flowed to ground above our sites) for a period spanning both of those sessions.

The target length for each site was 30 m, which was modified (in a limited number of cases) if there were features such as falls or debris jams that constrained this length at certain reservoir elevations. Sampling was conducted 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 7 (2015 – 2019), the index survey in Year 8 (2020) was completed as one extended survey in the spring (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 8 (2020) 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 8 (2020) was 17 to 24 June. This was approx. two weeks later than the target timing (i.e., 3 to 10 June) due to a malfunction with the electrofisher unit that required a return to the manufacturer for repairs. The shift in sample timing was also necessary because lower reservoir elevations throughout early June 2020 (i.e., <717 masl – see Figure 3.1 in Section 3.1) would have precluded sampling at all sites in the West zone (or ~1/3 of the total sites). This slight scheduling change was not expected to significantly impact the population index results for this year. As in previous years, the reason for the selected 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 and access sites in all three longitudinal zones; 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.

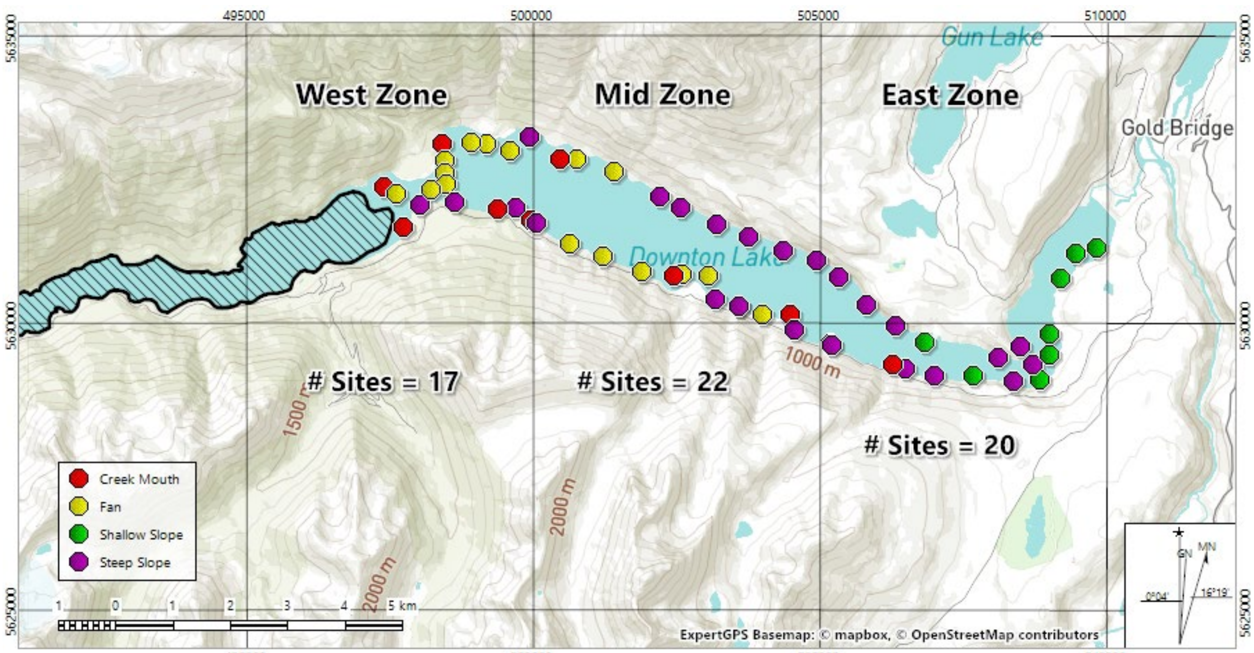


**Figure 2.3 The three longitudinal zones (west, mid, and east) and the distribution of sites for the fish population index survey conducted from 17 to 24 June 2020 (between 717 m to 721 m reservoir elevation). Note: The hashed-out area represents the dewatered portion of the reservoir basin at the time of the survey.**

Boat 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 59 sites were sampled in 2020 (creek mouth *n*= 9; fan *n*= 16; shallow *n*= 9; steep *n*= 25) covering 16,685 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 from a selection of individuals (more on this below). Individual coded (PIT) tags were applied to all captured fish of appropriate size and condition (up to a maximum of 1,100 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 5-8 (2017–2020) 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
$L_\infty$ 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 a St'at'imc Eco-Resources technician (Bailee Phillips) in preparation for ageing. Mounting involved removing the scales from the envelopes, cleaning and placing them on glass slides that can be viewed and magnified under a microscope. Digital photographs were also taken of the mounted scales. Scale reading to determine fish ages was conducted on 198 of the mounted samples (2 were noted as un-readable) by staff at Instream Fisheries Research (IFR). Ages were determined using the methods outlined in Ward and Slaney (1988), in which two or three people independently assign an age for each sample, and the final age is determined based on a consensus among readers. First, second and final scale readings to determine fish ages from the 2020 samples were conducted by Angela Ratzburg, Stephanie Lingard, and Dani Ramos-Espinoza (all from IFR), respectively.

These data 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 allows estimation of annual growth rates and condition factor of the various 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 a SER technician (Mercedes Adolph). 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 7 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 2020, which are illustrated in Figure 3.1. Daily surface elevations for monitoring years 1 to 7 (2013 to 2019) are also included for reference.

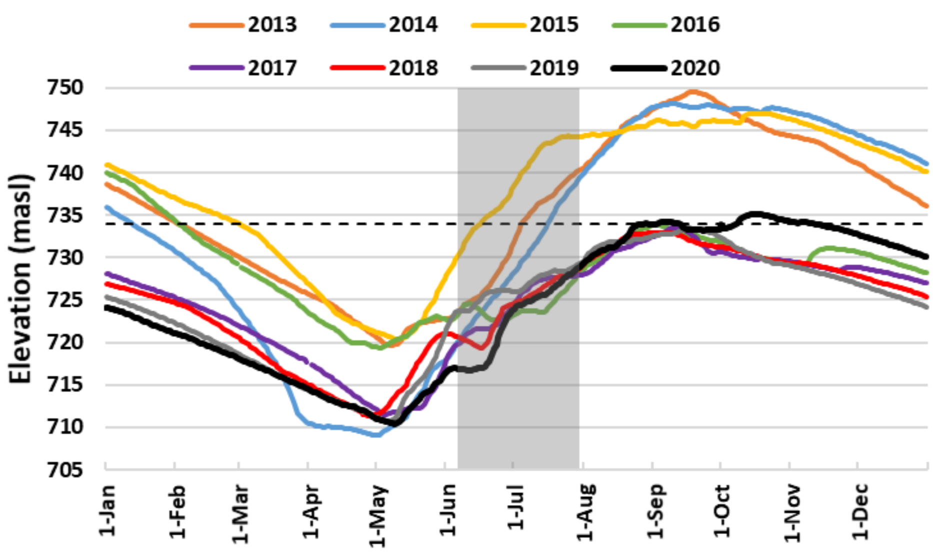


**Figure 3.1 Daily surface elevations in Downton Reservoir, 2013 to 2020. For reference, the shaded area represents the observed rainbow trout spawning period. The horizontal dashed line indicates the target modified maximum fill elevation (734 m), which was implemented in Years 4 to 8 (2016 to 2020) 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 analysis that incorporates annual fish catch results, size and condition factor with informative 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., 734.0 m) was implemented for the first time in Year 4 (2016) and again in years 5, 6, 7 and 8 (2017 to 2020). Overall, reservoir operation in 2020 followed a generally similar trajectory as 2017, 2018 and 2019 across much of the year; however, after rising from the minimum level in May, elevations in 2020 plateaued at approx. 717.0 m for the first half of June before rising quickly across the latter half of June, and maximum elevations (up to 735.1 m; i.e., ~1.1 m above the modified maximum target) occurred in mid-October rather than late August or early September as in the other modified operations years. Surface elevations at the start of the rainbow trout migration and spawning period in 2020 were lower than any other study year to-date (Figure 3.1) but had reached a similar level as all the other modified operations years by the end of the spawning and incubation periods. At the start of 2020, reservoir elevation was 724.2 m as it was drawing down from the 2019 maximum fill level of 733.5 m. The mean drawdown and fill rates for the reservoir were -10 cm/day and +16 cm/day, respectively (Table 3.1). Lowest reservoir elevation (i.e., 710.4 m) occurred from 8 to 10 May, and summer full pool elevations occurred from 12 to 21 October 2020 (max. = 735.1 m on 17 and 18 October). The reservoir had been drawn down to 730.0 m by the end of December.

**Table 3.1 Minimum and maximum reservoir elevations, and mean and maximum drawdown and fill rates for Downton Reservoir during study years 1 to 8 (2013 to 2020). The modified operations years are highlighted yellow.**

| 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 |
| 8 (2020) | 710.41 | 735.06 | 24.65 | -10 | -22 | +16 | +83 |

[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 ~25 m in 2020, which was slightly higher than the other modified operations years mostly due to the difference in maximum elevation (i.e., 1.1 to 2.1 m higher than the other mod. ops. years). 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 2020 minimum elevation (710.4 m) was most similar to 2014 (709.0 m), 2017 (711.5 m), 2018 (711.3 m) and 2019 (710.7 m), and ~8 to 9 m lower than the other study years. The mean drawdown and fill rates (-10 cm/day and +16 cm/day, respectively) were on par with the other modified operations years (i.e., 2016-2019) 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 2017–2020). 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 'normal' 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 2020) are provided in Appendix B (Figures B1 and B2).

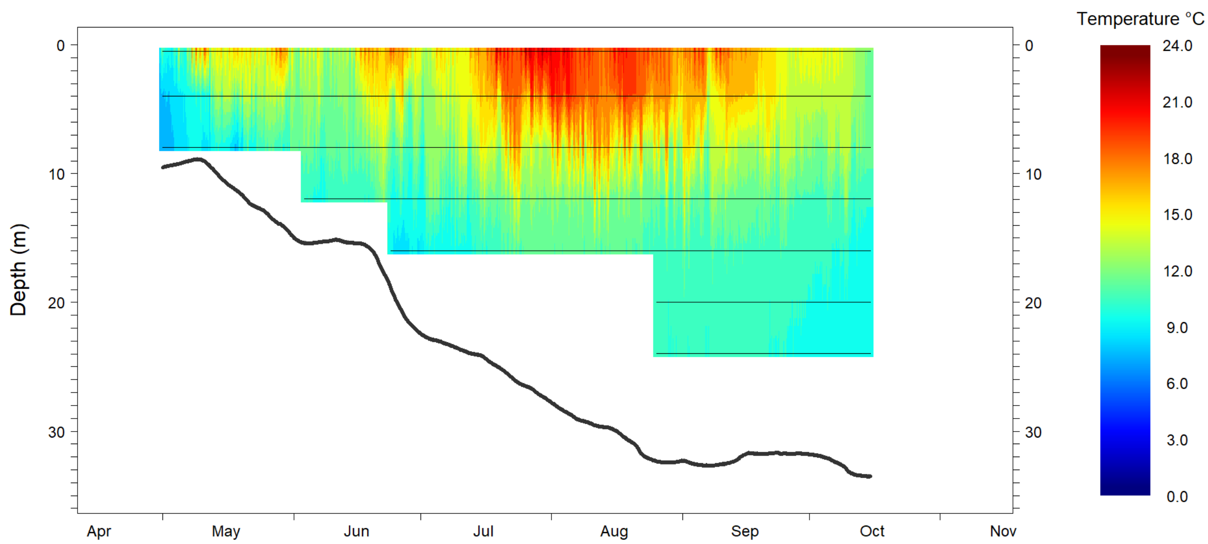


**Figure 3.2 Water temperature profile recorded in Downton Reservoir at the log boom (see Figure 2.1 for location) from April to October 2020. The horizontal lines indicate the measurement depths. Temperatures between those depths were linearly interpolated. The solid black line references the reservoir depth at the log boom.**

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 8 (2020), mean daily surface temperatures increased from 9.5°C to 17.1°C across the month of May, and then decreased to 12.0°C across the first two 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 month of July, peaked at 21.3°C on 30 July, and then gradually cooled to 12.0°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 typical depth of the thermocline (within the limits of precision available from the depth intervals of the loggers). Below 12 m, temperatures at each depth interval remained within a narrow range, between 8.2°C and 11.4°C, throughout the monitored period. Other than a higher peak temperature in 2018 (23.3°C), relative to the other monitored years (2015–2017, and 2019–2020 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 2020 were very similar to those reported for previous years (Figure 3.3; Appendix B, Figure B1; Sneep 2020).

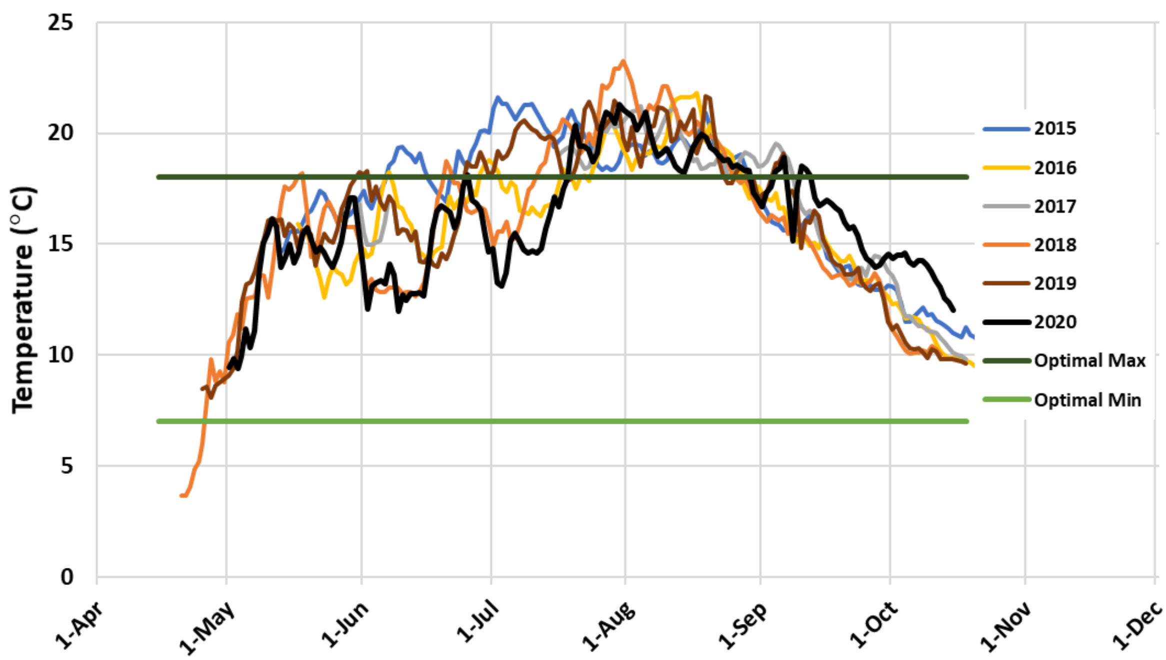


**Figure 3.3 Mean daily reservoir surface temperatures during the April to October monitoring period by study year (2015 to 2020). The light and dark green horizontal lines bracket the preferred temperature range for key life history stages of rainbow trout (McPhail 2007).**

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 UBR) to 13.5°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 closest to or within preferred ranges by life history period), relative to Jamie Creek and the UBR. Temperatures in Jamie Creek were generally below optimal thresholds for the migration, spawning and incubation periods, and the UBR was generally below optimal thresholds for most of the monitored period in every year to-date [Note: There was no temperature data for the UBR prior to late August in 2020 since snow avalanches had blocked access to this location during earlier site visits]. 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).

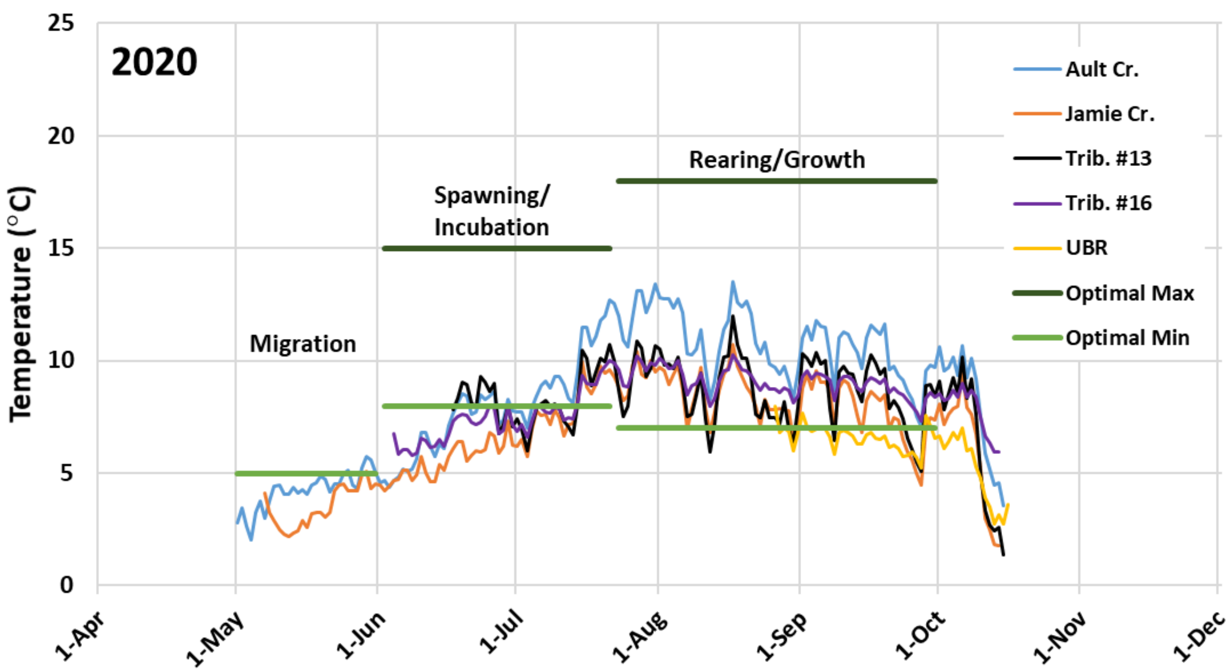


**Figure 3.4 Mean daily water temperatures in a set of Downton Reservoir tributaries, May to October 2020. The light and dark green horizontal lines bracket the preferred temperature range for key life history stages of rainbow trout (McPhail 2007).**

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 8 (2020) 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 six 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 approx. 1 to 2°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 2020). 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 2016, 2017 or 2020 (according to the creek) so far, but were generally quite similar among years (means varied by only 0.1°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 2020). 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, 2019 and 2020 (see Section 3.5; Sneep 2020). The incubation period has 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 initially sampled in tributary streams during summer (i.e., 25-27 August 2020) were still available in the sampled creeks during the fall session (14-16 October 2020) and ranged from 22 to 55 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 |
| | 2020 | - | - | 6.6 | - |
| 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 |
| | 2020 | 3.9 | 6.5 | 8.3 | 7.1 |
| 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 |
| | 2020 | - | 8.0 | 8.8 | - |
| Eagle Cr. (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 |
| | 2020 | - | 7.4 | 9.1 | - |
| 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 |
| | 2020 | 4.7 | 7.9 | 10.8 | 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 |
| | 2020 | 15.2 | 15.2 | 18.1 | 16.7 |

[a] "-" indicates temperature data not available for this period either because logger was found out of the water or lost following a period of high flows, or because logger couldn't be installed due to site access issues.

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

**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) |
| | 2020 | 1 Aug (59) | 18 Aug (55) | 13 Sep (54) |
| Eagle Creek (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) |
| | 2020 | 3 Aug (61) | 19 Aug (56) | 11 Sep (52) |

[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).

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 may not be sustainable.

## 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 8 (2020) were conducted on 30 April, 28 May and 16 June, to span the rainbow trout spawner migration period. Reservoir elevations on these dates were ~711 m, ~715 m and ~717 m, respectively. Across the duration of the rainbow trout spawning period, the reservoir filled from 717 m in early June to 728 m by the end of July (i.e., an elevational increase of 11 m). The creeks visited in Year 8 (2020) included: Ault Creek, Paul Creek, Cathy

Creek, Jamie Creek, Trib. #10, Trib. #13, Trib. #16 and Trib. #19 (Table 3.4). However, all tributaries further up the valley beyond Ault Creek could not be accessed on 30 April 2020 (711 m survey) due to rockfall blocking the Bridge-Main FSR (i.e., the only road access). Trib. #10 and Trib. #13 could not be accessed during the 28 May 2020 (715 m) survey due to a large avalanche blocking access to that portion of the Bridge-Main FSR until it was cleared in early June.

**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 (2020 dates are shown in red font).**

| 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 |
| 711 m | 30-Apr-20 | FALSE | - [b] | - | - | - | - | - | - |
| 712 m | 24-Apr-19 | FALSE | TRUE | TRUE | - | TRUE | TRUE | - | - |
| 713 m | 19-Apr-18 | FALSE | - | - | - | - | TRUE | - | - |
| 714 m | 15-May-19 | TRUE [c] | TRUE | TRUE | TRUE | TRUE | TRUE | - | - |
| 715 m | 28-May-20 | TRUE | TRUE | TRUE | TRUE | TRUE | TRUE | - | - |
| 716 m | 23-May-19 | TRUE | TRUE | TRUE | TRUE | TRUE | TRUE | TRUE | TRUE |
| 717 m | 30-May-17<br>16-Jun-20 | TRUE | TRUE | TRUE | TRUE | TRUE | TRUE | TRUE | TRUE |
| 720 m | 24-May-18<br>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<br>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 or rockfall and avalanches blocking portions of 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 8 (2020) minimum elevation of 710.4 m (on 6 May) was within the range of minimum elevations observed in Year 2 (2014; 709.0 m), Year 6 (2018; 711.3 m) and Year 7 (2019; 710.7 m), 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 711 m survey in Year 8. However, each of the dates when potential access issues were observed (8 May 2014, 19 April 2018, 24 April 2019, and 30 April 2020) were prior to the typical start of the rainbow trout spawning period for this population (see Section 3.4), and surface flow connection was established during all surveys in May and beyond each year to-date. 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 any of the other low elevation surveys, including in Year 8 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 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 again observed flowing to ground (i.e., dry within the drawdown zone) during both the summer (25-27 Aug) and fall (14-16 Oct) tributary fish sampling sessions in 2020.

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 Years 7 and 8 (2019 and 2020). 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 (under modified operations).

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 8 (2020), weekly spawner surveys were conducted across a 9-week period from 28 May to 22 July. A consistent set of repeat surveys were conducted in Trib. #13, Jamie Creek, Cathy Creek (Trib. #5), and Ault Creek throughout the 2020 spawning period. Eagle Creek (Trib. #16), Trib. #19 and Tram Creek could not be monitored consistently in Year 8 due to access issues (e.g., low reservoir elevation or road blockages). As noted on the data sheets, in-water visibility conditions in 2020 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 2020 weekly counts, spawners first started arriving in identified spawning streams during the fourth week of May (i.e., Cathy Creek; Table 3.5). This was on par with the arrival timing noted in previous years (Sneep 2020; Sneep 2019a); however, closures of the Bridge-Main FSR due to avalanche and rockfall conditions precluded surveys prior to 28 May (or 11 June in Trib. #13) during Year 8. Peak timing in 2020 was between the middle to the end of June (according to tributary), and some spawners were still observed in Ault Creek, Cathy Creek and Trib. #13 on the final (22 July) survey. Ideally, weekly surveys would have continued until counts in all creeks were zero (to confirm the end of the spawning season), but the substantial decline in observed spawners by this date suggested that the majority of the spawning period had been captured. 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; White et al. 2021). 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 were the most consistently assessed throughout the spawning period in Year 8 (2020).**

| Week | 2020 Survey Dates | Ault Cr. [a] | Cathy Creek | | | Jamie Creek | | | Trib. #13 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *n* [b] | *n* | DS % | US % | *n* | DS % | US % | *n* | DS % | US % |
| 1 | 28 May[c] | 0 | 4 | 100% | | 0 | | | - | | |
| 2 | 04 Jun[c] | 24 | 2 | 100% | | 7 | 100% | | - | | |
| 3 | 11 Jun | 17 | 52 | 100% | | 15 | 100% | | 11 | 100% | |
| 4 | 16 Jun | - | 63 | 100% | | 11 | 100% | | 30 | 100% | |
| 5 | 27 Jun | - | 40 | 100% | | 0 | | | 73 | 84% | 16% |
| 6 | 30 Jun | 3 | 40 | 100% | | - | | | 58 | 86% | 14% |
| 7 | 08 Jul | 30 | 17 | 100% | | 6 | 100% | | 33 | 24% | 76% |
| 8 | 15 Jul | 18 | 5 | 100% | | 0 | | | 42 | 79% | 21% |
| 9 | 22 Jul | 4 | 7 | 100% | | 0 | | | 13 | 62% | 38% |
| **Peak *n* & Total %** | | **30** | **63** | **100%** | **0%** | **15** | **100%** | **0%** | **73** | **77%** | **23%** |

[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. m

[c] Could not access Trib. #13 on this survey date due to avalanche blockage on Bridge-Main FSR.

Across study years, spawner counts have tended to be highest in Trib. #13 and Eagle Creek, reflecting that these two streams generally have the highest spawning use of any of those surveyed. Peak spawner count in Trib. #13 was highest in Year 1 (2013; *n*= 135), and then ranged between 20-60 spawners between Years 2 and 7 (annual max. *n*= 50, 19, 57, 30 and 33 for 2014, 2015, 2016, 2018 and 2019, respectively). The peak count in Year 8 (2020; *n*= 73) was the second highest number observed to-date (Figure 3.5). 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). Unfortunately, Eagle Creek, Trib. #19 and Tram Creek could not be assessed consistently in Year 8 (2020) due to access issues affecting the north side of the reservoir during the typical peak spawning period. However, 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). Spawner surveys were not completed in Year 5 (2017) – see Sneep 2019a report for rationale.

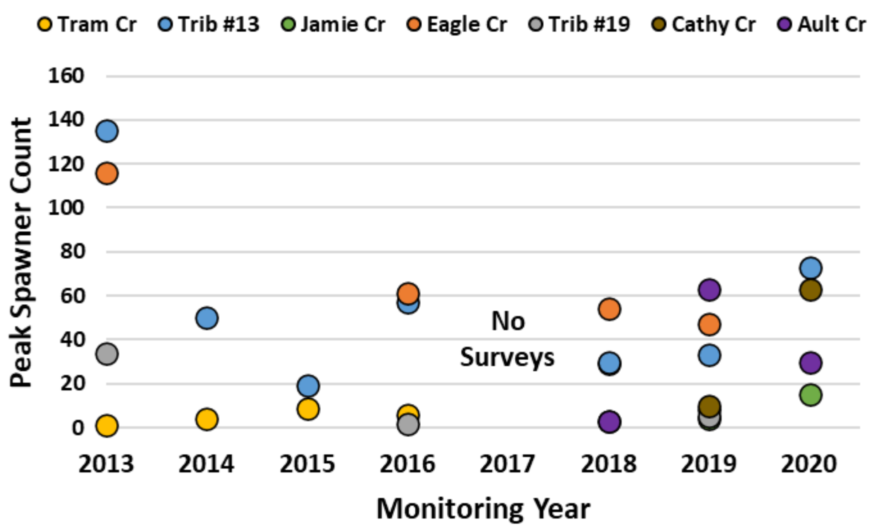


**Figure 3.5 Peak spawner counts in surveyed tributaries for BRGMON-7 monitoring years 1 to 8 (2013 to 2020). Note: Spawner counts were not conducted in Year 5 (2017) – see explanation in annual monitoring report for that year (Sneep 2019a). Tram Creek, Eagle Creek and Trib. #19 were not accessible for most of the streamwalks in Year 8 (2020) so peak counts were not available for those streams this year.**

Increased spawner use of Ault and Cathy creeks was a new phenomenon noted in Year 7 (2019) and was evident again in Year 8 (2020). In Ault Creek, a peak count of 30 spawners was observed on 8 July 2020, which was second highest to the peak count of 63 spawners observed on 11 June 2019. The 2019 and 2020 peak counts in Cathy Creek were 10 spawners and 63 spawners on 18 June 2019 and 16 June 2020, respectively. 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 initially documented in 2016 (by a consultant for the Borolex IPP; Tyler Gray, PGL, pers. comm.) and again in 2018 and 2019 (by the BRGMON-7 program). The number of observed spawners was consistently low (annual max. $n$= 2-4) during each of those years, but increased slightly to a peak count of 15 spawners in 2020 (on 11 June) despite generally fair or poor visibility conditions throughout the survey period in that creek. The general trend of spawner observations among years has remained relatively stable since 2013 with certain creeks (i.e., Eagle Creek and Trib. #13) remaining dominant spawning tributaries in each year and evidence of some year-to-year redistribution among other available creeks as creek flows and reservoir elevations allow.

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 2020 proportions suggested a mean of ~91% used the drawdown zone vs. 9% in the upland, overall. Actual proportions for each 2020 survey date and totals for each tributary are provided in Table 3.5. The relative proportions for all survey years (to-date) and normal operations versus modified operations averages are provided in Appendix C, Table C1. These results confirm a consistently higher use of the drawdown zone, but suggest an increased proportion during the Modified Operations years (i.e., 82%; 2016 to 2020) compared to the Normal N2-2P Operations years monitored (i.e., 70%; 2013 to 2015). However, the difference in sample size (# of years) between these two operational regimes should also be noted. 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, 7 and 8 (2018, 2019 and 2020) (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 the modified operations years to-date (2016 to 2020) these values were 719.6 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 193.8 m (or 68%) across the spawning period under normal operations versus an average of 139.2 m (or 38%) under modified operations. For steeper streams, such as Ault Creek, the total drawdown stream length was reduced by an average of 119.1 m (or 78%) under normal operations versus an average of 93.0 m (or 51%) under modified operations. Assuming tributary length is proportional to spawning area, the modified operations increased the available spawning habitat within the drawdown zone by approx. 2.3-fold relative to normal operations.

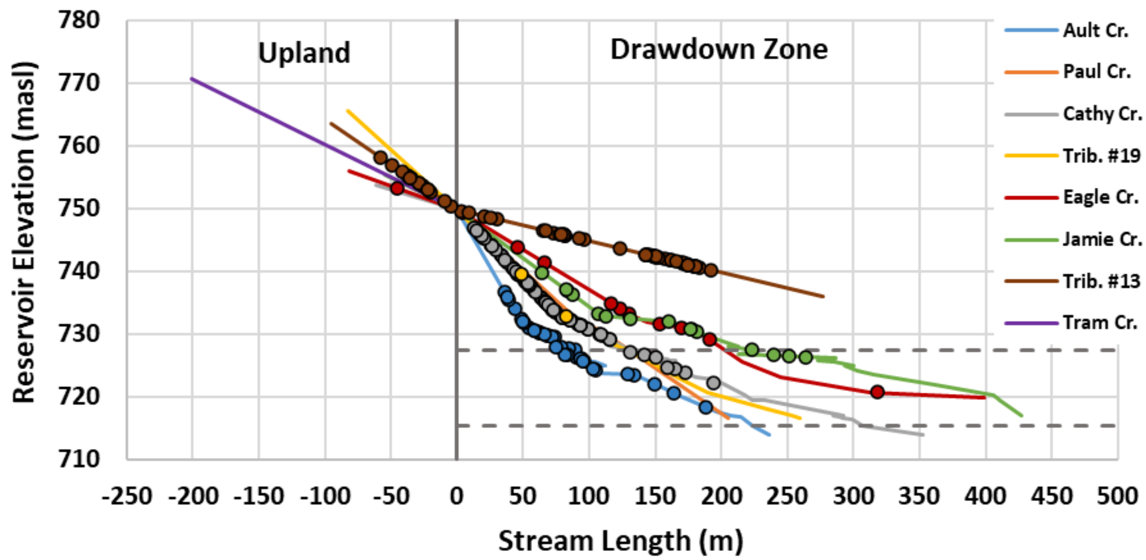


**Figure 3.6 Distribution of rainbow trout spawner observations (dots) along the longitudinal sections (lines) of each surveyed tributary to Downton Reservoir in 2020. The vertical grey line represents the top of the drawdown zone (value of 0 on the x-axis). The horizontal dashed lines bracket the minimum and maximum reservoir elevations during the rainbow trout spawning period in 2020 (i.e., 715 to 727 masl between 28 May and 22 July 2020).**

**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% | 81% |
| 3 (2015) | 4 Jun to 17 Jul | 729.23 | 743.50 | 14.27 | 74% | 77% |
| **Normal Operations Averages** | | **722.0** | **738.0** | **16.0** | **68%** | **78%** |
| 4 (2016) | 19 May to 20 Jul | 722.07 | 725.21 | 3.14 | 20% | 29% |
| 5 (2017) | 1 Jun to 20 Jul [a] | 717.95 | 727.66 | 9.71 | 49% | 58% |
| 6 (2018) | 5 Jun to 25 Jul | 719.36 | 728.00 | 8.64 | 50% | 58% |
| 7 (2019) | 4 Jun to 23 Jul [b] | 723.21 | 728.48 | 5.27 | 20% | 45% |
| 8 (2020) | 28 May to 22 Jul | 715.40 | 727.32 | 11.92 | 49% | 65% |
| **Modified Operations Averages** | | **719.6** | **727.3** | **7.7** | **38%** | **51%** |

[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.

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.

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. Further, the range of reservoir elevations during the spawning and incubation periods varies to some extent among years. By specifically documenting the locations of spawner observations in 2019 and 2020 (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 would have been inundated by the reservoir across the spawning period (defined for each monitoring year in Table 3.6) and egg incubation period (defined in Table 3.3) (Table 3.7). Based on these data, we can see that 47% of spawner locations would have been inundated by the filling reservoir during the spawning period and 77% would have been inundated by the end of the incubation period, under normal operations (assuming a similar spawning distribution to that documented in 2019 and 2020). Under modified operations, these percentages were reduced to 8% and 26%, respectively, due to the lower fill elevations during the spawning and incubation periods.

A summary of the cumulative proportions of spawner observations that were at or below specific elevations (in 4 m increments) within the reservoir operating range (drawdown zone) and in the upland for each surveyed tributary are provided in Appendix C, Table C2. This summary table highlights 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 Percentage of possible spawning locations[a] in the monitored tributaries inundated by the reservoir in each monitoring year between the start and end of the spawning and egg incubation periods.**

| Study Year | Start Reservoir Elevation (m) | End Reservoir Elevation (m) | | % Inundated [b] | |
|---|---|---|---|---|---|
| | | Spawning | Incubation | Spawning | Incubation |
| 1 (2013) | 722.29 | 736.86 | 745.82 | 44% | 82% |
| 2 (2014) | 714.57 | 733.53 | 745.64 | 31% | 81% |
| 3 (2015) | 729.23 | 743.50 | 745.42 | 66% | 69% |
| **Normal Operations Averages** | | | | **47%** | **77%** |
| 4 (2016) | 722.07 | 725.21 | 732.55 | 2% | 28% |
| 5 (2017) | 717.95 | 727.66 | 731.23 | 10% | 23% |
| 6 (2018) | 719.36 | 728.00 | 731.96 | 11% | 26% |
| 7 (2019) | 723.21 | 728.48 | 731.84 | 10% | 25% |
| 8 (2020) | 715.40 | 727.32 | 732.06 | 9% | 27% |
| **Modified Operations Averages** | | | | **8%** | **26%** |

[a] Based on spawner observations documented in 2019 and 2020. Note: specific spawner locations were not documented during the previous study years, so this analysis assumes that the same spawning distribution would also apply in those years.

[b] % Inundated refers to the percentage of spawner locations (shown in Figure 3.6) that were inundated by the reservoir during each monitoring year. Separate values are provided for the range of elevations inundated during the spawning period (defined for each monitoring year in Table 3.6) and egg incubation period (defined in Table 3.3).

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 from 2018 to 2020). 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).

Between-year differences in spawning use and distribution among tributaries (e.g., spawners being observed in Ault and Cathy creeks for the first time in 2018 and increasing in numbers in 2019 and 2020; 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.

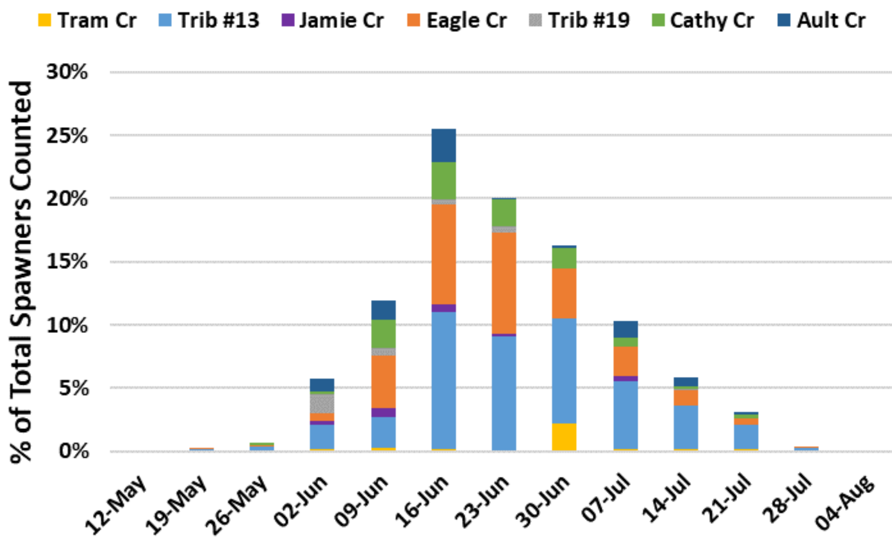


**Figure 3.7 % Contribution of weekly spawner counts to the total across the monitoring period, all study years combined. Relative proportions by tributary are included. Dates on the x-axis are typical or representative of the weekly spawner survey interval; however, actual dates have varied slightly (+/- a couple days) among years.**

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 suitability. 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 and incubation periods 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 during spring (3-5 Jun; *n*= 10 sites), summer (25-27 Aug; *n*= 13 sites), and fall (14-16 Oct; *n*= 13 sites) in 2020, including sites in the drawdown and upland zones (Table 3.8). These data supplemented seasonal tributary data that were previously collected in Year 4 (2016; spring), Year 5 (2017; summer), Year 6 (2018; fall) and Year 7 (2019; spring, summer and fall) (Sneep 2020). 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. In 2020, total catch-per-unit-effort (CPUE) was lowest in spring (11.3 ±2.5 fish/100 m), increased in summer (22.6 ±8.5 fish/100 m), and was highest in fall (29.8 ±13.2 fish/100 m) overall. In most cases, catches in the drawdown zone were higher than the upland catches in the creeks where both zones were sampled. Of the tributaries sampled in 2020, the highest CPUE values were in the drawdown zone of Eagle Creek during the summer and fall sessions (116.7 and 173.3 fish/100 m, respectively), and the drawdown zone of Cathy Creek (40.0 and 63.3 fish/100 m, respectively). Highest CPUE in spring was in the upland zone of Eagle Creek (23.3 fish/100 m) and the drawdown zone of Jamie Creek (20.0 fish/100 m). Also, a greater number of tributaries had higher CPUE values in summer: catches at 7 of 13 sites (54%) were >15 fish/100 m, whereas this was the case at only 4 of 13 sites (31%) in fall and and 4 of 10 sites (40%) in spring. Note: this percentage in spring 2020 likely would have been even lower, but access issues precluded sampling at five sites that had low catches in spring during previous years (i.e., Trib. #13 upland and drawdown, Tram Creek, UBR-1 and UBR-2).

Typically, the creeks with the highest catches have been documented as spawning tributaries for Downton Reservoir rainbow trout. For example: catches in the drawdown zone of Eagle Creek, typically one of the primary spawning tributaries (see Section 3.4), were substantially higher than in any other creek during summer and fall when the new year class of fry are available. In fact, the reason the fall Total CPUE value (29.8 ± 13.2 fish/100 m) was higher than the summer value (22.6 ± 8.5 fish/100 m) was almost entirely attributable to the catches in Eagle Creek. This also suggests that emergence of additional young-of-year fry occurred after the summer sampling survey, which is corroborated by the predicted emergence timing window provided in Table 3.3 (suggesting that emergence may have continued into the second week of September 2020 in this creek).

**Table 3.8 Summary of backpack EF effort and catch in Downton Reservoir tributaries during spring, summer and fall 2020. 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 [a] | East | Ault Cr. | Drawdown | 30 | 189 | 0 | 0.0 |
| | Mid | Paul Cr. | Drawdown | 30 | 250 | 3 | 10.0 |
| | | Cathy Cr. | Drawdown | 30 | 301 | 2 | 6.7 |
| | | | Upland | 30 | 288 | 0 | 0.0 |
| | | Trib. #19 | Drawdown | 30 | 209 | 5 | 16.7 |
| | | | Upland | 30 | 288 | 4 | 13.3 |
| | West | Eagle Cr. | Drawdown | 30 | 299 | 5 | 16.7 |
| | | | Upland | 30 | 215 | 7 | 23.3 |
| | | Jamie Cr. | Drawdown | 30 | 225 | 6 | 20.0 |
| | | | Upland | 30 | 225 | 2 | 6.7 |
| **Spring Totals** | | | | **300.0** | **2,489** | **34** | **11.3 (SE ±2.5)** |
| Summer [b] | East | Ault Cr. | Drawdown | 22 | 259 | 0 | 0.0 |
| | Mid | Paul Cr. | Drawdown | 30 | 353 | 10 | 33.3 |
| | | Cathy Cr. | Drawdown | 30 | 570 | 12 | 40.0 |
| | | | Upland | 30 | 342 | 1 | 3.3 |
| | West | Eagle Cr. | Drawdown | 30 | 507 | 35 | 116.7 |
| | | | Upland | 30 | 342 | 5 | 16.7 |
| | | Jamie Cr. | Drawdown | 30 | 184 | 5 | 16.7 |
| | | | Upland | 30 | 274 | 2 | 6.7 |
| | | Trib. #13 | Drawdown | 30 | 365 | 3 | 10.0 |
| | | | Upland | 30 | 208 | 7 | 23.3 |
| | | Tram Cr. | Upland | 30 | 284 | 5 | 16.7 |
| | | UBR-1 | Upland | 30 | 338 | 2 | 6.7 |
| | | UBR-2 | Upland | 22.5 | 215 | 1 | 4.4 |
| **Summer Totals** | | | | **374.5** | **4,241** | **88** | **22.6 (SE ±8.5)** |
| Fall [b] | East | Ault Cr. | Drawdown | 22 | 184 | 1 | 4.5 |
| | Mid | Paul Cr. | Drawdown | 30 | 337 | 4 | 13.3 |
| | | Cathy Cr. | Drawdown | 30 | 737 | 19 | 63.3 |
| | | | Upland | 25 | 300 | 0 | 0.0 |
| | West | Eagle Cr. | Drawdown | 30 | 461 | 52 | 173.3 |
| | | | Upland | 30 | 292 | 17 | 56.7 |
| | | Jamie Cr. | Drawdown | 30 | 218 | 1 | 3.3 |
| | | | Upland | 30 | 286 | 2 | 6.7 |
| | | Trib. #13 | Drawdown | 30 | 469 | 8 | 26.7 |
| | | | Upland | 30 | 219 | 4 | 13.3 |
| | | Tram Cr. | Upland | 30 | 350 | 4 | 13.3 |
| | | UBR-1 | Upland | 30 | 276 | 1 | 3.3 |
| | | UBR-2 | Upland | 22.5 | 334 | 2 | 8.9 |
| **Fall Totals** | | | | **369.5** | **4,463** | **115** | **29.8 (SE ±13.2)** |

[a] Note: Trib. #13, Tram Creek and the UBR were inaccessible during the spring session due to road blockages caused by avalanches.
[b] Sampling could not be conducted in Trib. #19 during the summer and fall sessions because it was dry.

Eighty-nine fish from the tributary catch in 2020 were a tag-able size (≥80 mm): 66 were newly marked with PIT tags, and four were recaptures (Table 3.9). All four 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. The number of days between capture events ranged from 50 days (spanning adjacent seasons in the same year), to 285 and 685 days (spanning different seasons between years).

**Table 3.9 Summary of rainbow trout recaptures during tributary fish sampling in monitoring Year 8 (2020).**

| Tag Code | Original Capture Data | | | | Recapture Data | | | | Days-at-Large |
|---|---|---|---|---|---|---|---|---|---|
| | Season | Date | Trib. | Zone | Season | Date | Trib. | Zone | |
| 980112 | Summer | 25 Aug 2020 | Eagle Cr. | Drawdown | Fall | 14 Oct 2020 | Eagle Cr. | Drawdown | 50 |
| 561009 | Summer | 25 Aug 2020 | Jamie Cr. | Upland | Fall | 14 Oct 2020 | Jamie Cr. | Upland | 50 |
| 979979 | Summer | 23 Aug 2019 | Trib. #19 | Upland | Spring | 3 Jun 2020 | Trib. #19 | Upland | 285 |
| 980176 | Fall | 10 Oct 2018 | Eagle Cr. | Upland | Summer | 25 Aug 2020 | Eagle Cr. | Upland | 685 |

The ages of captured fish ranged from Age-0+ to Age-4 in both spring and summer, and from Age-0+ to Age-2 in fall (Table 3.10; Figure 3.8). Three fish in Paul Creek, seven fish in Trib. #19, four fish in Eagle Creek, and seven fish in Jamie Creek (all ranging in age from 1 to 4) captured during the spring sampling in 2020 were sexually mature and in some stage of pre-spawning condition (15 males, 6 females; 6 green, 8 gravid, 7 ripe). The remainder of the fish sampled in each season were assessed as either sexually immature (*n*= 206) or mature (*n*= 10) 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*= 49 or 56%, and *n*= 87 or 76%, 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, as mentioned above). The catches of fish older than Age-0+ comprised a smaller number, collectively, and were more consistent across each season (*n*= 27, 39 and 28 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 2020.**

| Age | Season | n | Forklength (mm) | | | CPUE (fish/m)·100 |
|---|---|---|---|---|---|---|
| | | | Min. | | Max. | |
| 0 | Spring | 7 | 48 | - | 55 | 1.9 |
| | Summer | 49 | 20 | - | 35[a] | 11.3 |
| | Fall | 87 | 22 | - | 55[a] | 17.5 |
| 1 | Spring | 9 | 80 | - | 132 | 2.5 |
| | Summer | 15 | 68 | - | 106 | 3.3 |
| | Fall | 16 | 68 | - | 124 | 3.6 |
| 2 | Spring | 5 | 144 | - | 199 | 1.4 |
| | Summer | 15 | 120 | - | 178 | 3.1 |
| | Fall | 12 | 135 | - | 192 | 2.9 |
| 3 | Spring | 9 | 226 | - | 302 | 3.3 |
| | Summer | 6 | 185 | - | 270 | 1.3 |
| | Fall | 0 | | | | 0.0 |
| 4 | Spring | 4 | 311 | - | 311 | 1.1 |
| | Summer | 3 | 280 | - | 300 | 0.6 |
| | Fall | 0 | | | | 0.0 |

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

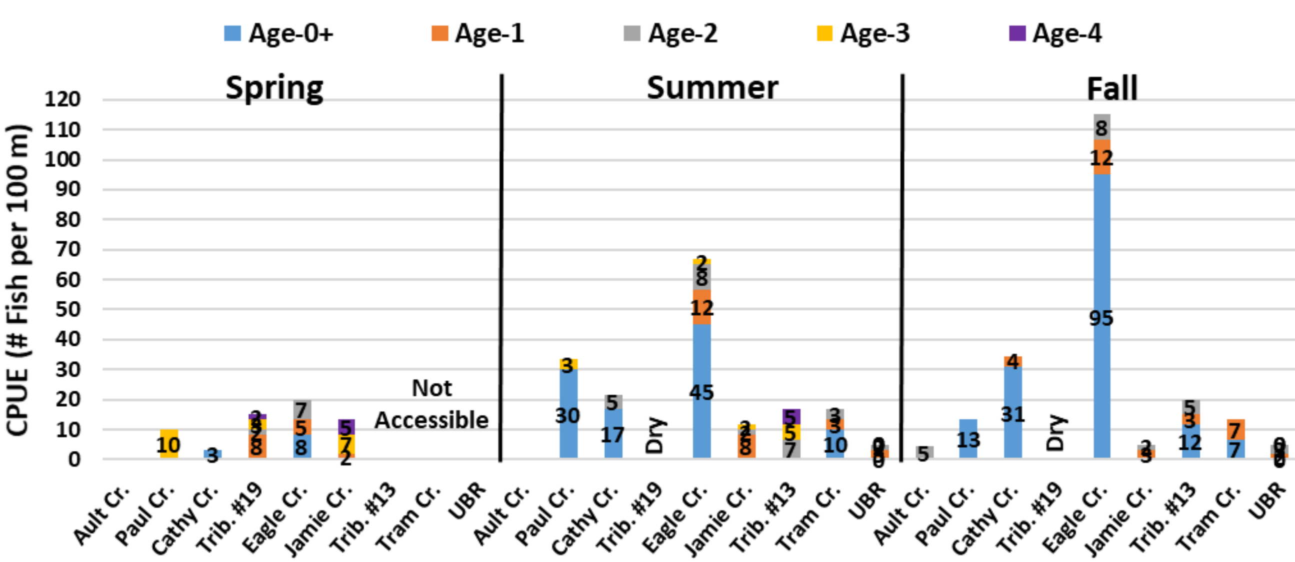


**Figure 3.8 Catch-per-unit effort (fish/100 m) by age class for each sampled tributary based on the results of backpack electrofishing surveys in spring, summer and fall 2020.**

As mentioned above, 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) in most years, 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 and Cathy 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 1,416 fish were captured by boat electrofishing during the annual fish index survey in Year 8, conducted between 17 and 24 June 2020 when reservoir elevations were filling between 717 and 721 m. Fifty-nine sites were sampled, including 9 creek mouths, 16 fans, 9 shallow shorelines, and 25 steep shorelines (Table 3.11). The total shoreline distance sampled was 16.7 km, or ~44% of the total reservoir perimeter at the mean survey elevation (~719 m). All captured fish were rainbow trout.

In total, 1,097 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. Thirty-three tagged fish were recaptured during the Boat EF survey in 2020; 11 were within-session recaptures and 22 were recaptures of fish originally tagged between 2015 and 2019 (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 8 boat electrofishing index survey in June 2020.**

| Metric | Units | Habitat Type | | | |
|---|---|---|---|---|---|
| | | Cr. Mouth | Fan | Shallow | Steep |
| **Sites** | # | 9 | 16 | 9 | 25 |
| **Effort** | total seconds | 2,205 | 11,554 | 6,317 | 15,136 |
| | total meters | 690 | 4,914 | 3,063 | 8,018 |
| **Catch** | # of fish | 375 | 364 | 333 | 344 |
| | # of fish marked | 229 | 254 | 317 | 297 |
| | # of recaptures | 16 | 9 | 3 | 5 |
| **CPUE** | fish/sec·100 (±SE) | 17.1 (±2.2) | 3.2 (±0.3) | 4.9 (±1.1) | 2.5 (±0.3) |
| | | **5.3 (±0.8)** | | | |
| | fish/meter·100 (±SE) | 56.6 (±9.1) | 7.6 (±0.8) | 10.1 (±2.1) | 4.6 (±0.5) |
| | | **14.2 (±2.7)** | | | |

2020 catch-per-unit-effort (CPUE) values (by all metrics), 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 as large. Mean CPUE values (for all types combined) were:

5.3 (SE 0.8) fish/100 sec of electrofishing; or 14.2 (SE 2.7) fish/100 m of shoreline length, which were very similar to the values reported in 2018 and 2019, and higher than the values for all prior years (2013-2017) (Table 3.12). Including consideration of the standard error, the 2018 to 2020 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 8.**

| 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) |
| 8 (2020) | 56.6 (±9.1) | 7.6 (±0.8) | 10.1 (±2.1) | 4.6 (±0.5) | **14.2** (±2.7) |
| All | **23.8** (±2.6) | **6.6** (±0.4) | **9.9** (±1.0) | **5.6** (±0.4) | **9.3** (±0.6) |

[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 ranking of 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, 7 and 8 (2015, 2017, 2018, 2019 and 2020). 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) and Year 8 (2020). However, CPUE values have been consistently highest at creek mouths in every year to-date, and the differences in CPUE between creek mouths and the other habitat types has generally been much greater than the differences among the other habitat types.

A summary of CPUE values by age class for each monitoring year to-date is provided in Figure 3.9. In Year 8 (2020), the CPUE for Age-1 fish (5.0 fish/100 m) was again the highest of any age class in the sample, and was at the upper end of the range of Age-1 CPUEs from previous study years (i.e., between 2.6 and 5.5 fish/100 m). The CPUE value for Age-2 fish (2.8 fish/100 m) was also near the top of the range for that age class from past years (i.e., between 0.7 and 3.3 fish/100 m). The CPUE for Age-3 fish in 2020 was the highest value for that age class documented to-date, which was likely a result of the strong Age-2 cohort in 2019 (which was similarly a carry-over of the strong Age-1 cohort in 2018). The Age-4 CPUE in 2020 was tied for highest for this age class with the 2019 value (2.7 fish/100 m in both cases). The high ranking of CPUE values for all of the age classes between Age-1 and Age-4, particularly since 2017, suggests successful recruitment and improved year-to-year survival under modified operations conditions, which have been consistently implemented for the past 5 years (see Figure 3.1 in Section 3.1). Both of these factors have contributed to the higher overall CPUE values in recent years.

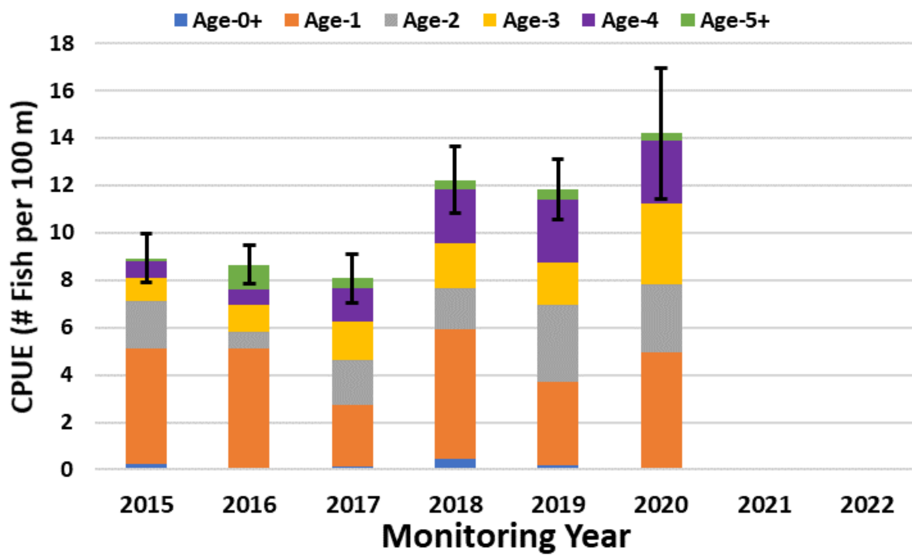


**Figure 3.9 Catch-per-unit-effort summary by age class for each monitoring year from 2015 (Year 3) to 2022 (Year 10). Currently only data up to 2020 were available for this report. Year 1 (2013) & 2 (2014) results have not been included due to incompatibility of sampling approach in those years with subsequent study years – see comment on this in text, above).**

As a result of spawn-timing for this population, the new year class of Age-0+ fish (i.e., for the current year) likely emerge from late July to early September (see Table 3.3 in Section 3.2), and are therefore not available for the population survey until the subsequent year. Age-0+ fish (i.e., recruited the previous year but not yet a full-year old) have consistently comprised a small proportion of the catch in the reservoir (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 the majority 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., <70 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 operational regimes (i.e., N2-2P vs. Mod. Ops.), 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 8 (2020), the highest mean CPUE was documented in the west zone of the reservoir (23.7 ±6.8 fish/100 m). However, 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) |
| 2020 | | 23.7 (±6.8) | 11.0 (±3.7) | 9.7 (±3.5) |

[a] As defined in Section 2.5; west is furthest from the dam and east is closest to the dam.
[b] The middle zone of the reservoir was not sampled during Year 2 (2014).

A total of 12 of the 1,416 captured fish (or <1%) in Year 8 (2020) 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 was uncertainty about the potential incidence of mortality after a longer period post-release at the start of this program. As a means of testing the post-capture and processing survival of fish, a sample of 161 fish (~11% of the 2020 catch) were held for approx. 24 hours after sampling, then re-evaluated for condition and tag loss, and then released. In total, 158 of the held fish (or 98%) were alive after 24 hours and were noted to be in vigorous condition upon release (i.e., 2% delayed mortality based on this sample). The delayed mortality results in Years 5 to 7 (2017 to 2019) were all similar (i.e., 0%, 1% and 3% mortality, respectively). Tag loss was noted for 1 of the held individuals (0.8%) in 2017, and 0 individuals in 2018, 2019 and 2020, for a combined tag loss rate of 0.2%. Going forward, we will continue to hold a sample of fish in a similar manner for the remaining years to extend the overall sample size of fish assessed, so we can better understand the incidence of latent mortality and tag loss for fish captured by boat-electrofishing in this context.

### Recaptures of Tagged Fish

A total of eleven fish that were marked with PIT tags were recaptured at different sites within the same session in Year 8 (2020; Table 3.14). Four of these fish had moved a short distance (i.e., <1 km), while the other seven had moved more substantial distances (from 1.1 to 3.3 km) across varying periods (i.e., from within the same night up to 6 nights later) 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 8 (2020).**

| Tag Code | Original Capture Data | | | Recapture Data | | | Dist. (km) |
|---|---|---|---|---|---|---|---|
| | Date | Zone | Habitat[a] | Date | Zone | Habitat[a] | |
| 621310 | 23-Jun-20 | West | FN | 23-Jun-20 | West | FN | 0.5 |
| 621341 | 23-Jun-20 | West | FN | 23-Jun-20 | West | CM | 0.5 |
| 621425 | 23-Jun-20 | West | FN | 23-Jun-20 | West | CM | 0.5 |
| 621600 | 17-Jun-20 | Mid | CM | 23-Jun-20 | West | FN | 0.9 |
| 621950 | 19-Jun-20 | Mid | CM | 20-Jun-20 | East | ST | 1.1 |
| 921530 | 17-Jun-20 | Mid | ST | 20-Jun-20 | Mid | ST | 1.3 |
| 621377 | 22-Jun-20 | East | SH | 24-Jun-20 | East | SH | 1.3 |
| 621643 | 17-Jun-20 | Mid | FN | 23-Jun-20 | West | FN | 1.8 |
| 621582 | 17-Jun-20 | Mid | CM | 23-Jun-20 | West | CM | 2.1 |
| 621927 | 20-Jun-20 | East | ST | 21-Jun-20 | East | SH | 3.3 |
| 621967 | 20-Jun-20 | East | ST | 21-Jun-20 | East | SH | 3.3 |

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

In addition to the within-session recaptures, there were 22 between-year recaptures in Year 8 (2020). Original capture and recapture information for these fish is summarized in Table 3.15. Seven of the twenty-two between-year recaptures were for fish that were initially captured in 2019 (i.e., were at-large for ~1 year). Eight of the between-year recaptures were originally tagged in 2018 (~2 years at large), five were originally tagged in 2017 (~3 years at large), and the remaining two recaptures were originally tagged in 2016 and 2015 (4 and 5 years at large, respectively). As with the within-session recaptured fish, the locations for each capture event were varying distances apart (i.e., ranging from 0.2 to 12.1 km). Approximately 70% 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.

*For fish captured and recaptured one year apart (i.e., between 2019 and 2020):* Two fish (forklengths = 91 and 110 mm) were assessed as Age-1 based on scale ageing analysis (see section below) when initially captured, and were 200 and 222 mm forklength, respectively, when recaptured a year later (at Age-2). This represented a growth range of 105 and 108 mm in one year for this cohort of fish. Three fish (forklengths = 125, 147 and 204 mm) were assessed as Age-2 when initially captured, and were 225, 199 and 239 mm a year later (at Age-3), representing 98, 50 and 33 mm of annual growth. One fish was Age-3 (280 mm) and another was Age-4 (297 mm) when initially captured and they were 291 and 320 mm a year later (at Age-4 and Age-5), representing 11 and 22 mm of annual growth for these age classes, respectively.

*For fish captured and recaptured more than one year apart:* Five fish captured in 2018 at Age-1 were recaptured in 2020 at Age-3 and had grown an average of between 85 and 98 mm/yr across those two years. Three fish captured in 2018 at Age-2 were recaptured in 2020 at Age-4 and had grown an average of between 27 and 76 mm/yr across those years. Five fish captured in 2017 at Age-1 were recaptured in 2020 at Age-4 and had grown an average of between 59 and 72 mm/yr during that period. The remaining two recaptured fish grew an average of 42 and 44 mm/year between Ages 1 and 5 and Ages 1 and 6, respectively. Collectively, 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 8 (2020). Inter-year recapture data from all study years to-date are provided in Appendix D.**

| Tag Code[a] | Original Capture Data | | | Recapture Data | | | Dist (km) | Growth (mm/yr) |
|---|---|---|---|---|---|---|---|---|
| | Date | Zone | FL (mm) | Date | Zone | FL (mm) | | |
| 734786 | 11-Jun-15 | Mid | 108 | 19-Jun-20 | Mid | 330 | 0.2 | 44 |
| 889174 | 30-May-16 | East | 143 | 23-Jun-20 | West | 312 | 11.1 | 42 |
| 975845 | 02-Jun-17 | Mid | 80 | 19-Jun-20 | Mid | 300 | 3.1 | 72 |
| 975776 | 03-Jun-17 | Mid | 82 | 21-Jun-20 | East | 293 | 2.4 | 69 |
| 975129 | 06-Jun-17 | East | 85 | 18-Jun-20 | Mid | 265 | 4.5 | 59 |
| 975777 | 04-Jun-17 | West | 101 | 18-Jun-20 | Mid | 299 | 3.5 | 65 |
| 975034 | 07-Jun-17 | East | 85 | 24-Jun-20 | West | 296 | 9.3 | 69 |
| 975530 | 01-Jun-18 | East | 146 | 23-Jun-20 | West | 288 | 10.7 | 69 |
| 975568 | 01-Jun-18 | East | 80 | 24-Jun-20 | West | 282 | 12.1 | 98 |
| 975611 | 01-Jun-18 | East | 143 | 24-Jun-20 | West | 299 | 12.1 | 76 |
| 975716 | 01-Jun-18 | East | 92 | 17-Jun-20 | Mid | 276 | 9.2 | 90 |
| 979854 | 01-Jun-18 | East | 109 | 24-Jun-20 | West | 286 | 10.6 | 86 |
| 979854 | 01-Jun-18 | East | 109 | 18-Jun-20 | Mid | 287 | 6.5 | 87 |
| 317322 | 03-Jun-18 | West | 173 | 17-Jun-20 | Mid | 228 | 2.0 | 27 |
| 316875 | 08-Jun-18 | East | 113 | 18-Jun-20 | Mid | 285 | 7.9 | 85 |
| 316373 | 07-Jun-19 | West | 147 | 23-Jun-20 | West | 199 | 1.2 | 50 |
| 316215 | 08-Jun-19 | West | 280 | 24-Jun-20 | West | 291 | 1.1 | 11 |
| 316264 | 08-Jun-19 | West | 204 | 24-Jun-20 | West | 239 | 1.6 | 33 |
| 560185 | 09-Jun-19 | Mid | 91 | 23-Jun-20 | West | 200 | 4.9 | 105 |
| 560499 | 11-Jun-19 | Mid | 110 | 23-Jun-20 | West | 222 | 5.9 | 108 |
| 560662 | 13-Jun-19 | East | 125 | 19-Jun-20 | Mid | 225 | 5.4 | 98 |
| 560892 | 13-Jun-19 | East | 297 | 24-Jun-20 | West | 320 | 8.8 | 22 |

[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 8 (2020) 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 198 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 (in some cases, complete) size overlap 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 E (Figure E1) to allow for visual comparison of results among years.

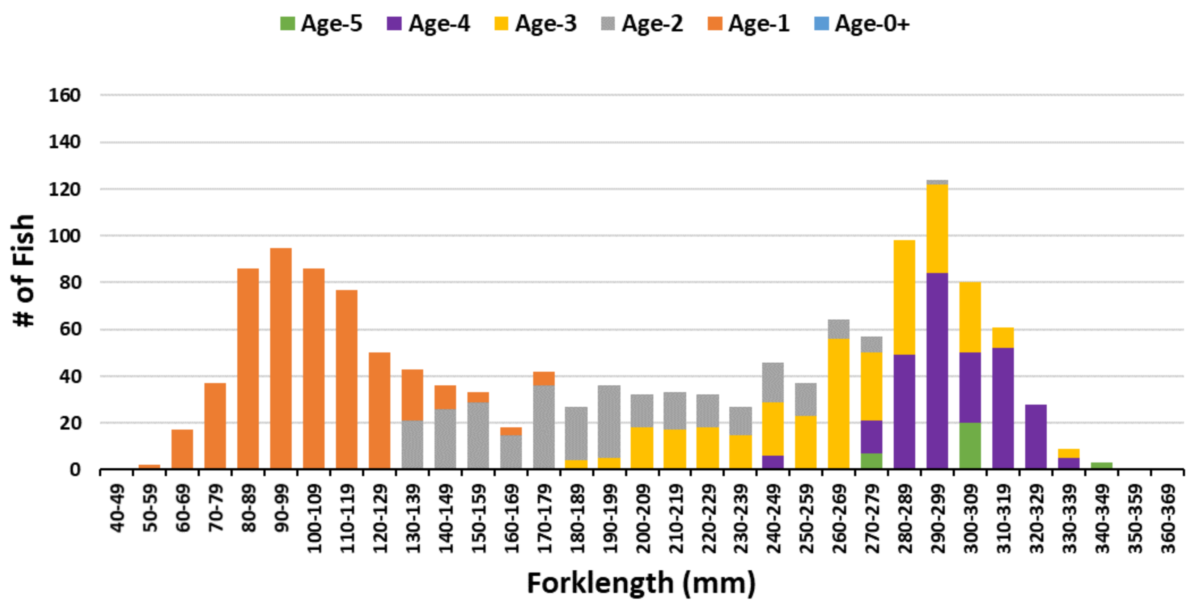


**Figure 3.10 Length-frequency histogram for rainbow trout captured during the fish population index survey in Downton Reservoir, 17 to 24 June 2020. Size ranges for each available age class are shown.**

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 1 and 3 in 2020 (Table 3.16). Differences in the median sizes in 2020 were: unknown between Age-0 and Age-1 (since fish aged 0 were not available in the sample), 85 mm between Age-1 and Age-2, 81 mm between Age-2 and Age-3; 31 mm between Age-3 and Age-4, and 5 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 2020), and the 2020 median sizes were among the highest for Age-1 to Age-4 fish for all the monitoring years to-date.

**Table 3.16 Size statistics for the range of ages of rainbow trout captured in Downton Reservoir during Year 8 (2020).**

| Age | *n* [a] | Forklength (mm) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| **0+** | 0 | - | **-** | - |
| **1** | 495 | 50 | **100** | 173 |
| **2** | 285 | 130 | **185** | 294 |
| **3** | 338 | 183 | **266** | 335 |
| **4** | 268 | 243 | **297** | 338 |
| **5** | 30 | 271 | **302** | 340 |

[a] Age-0+ were not captured and sample size for Age-5 fish was small so size characterizations were either not possible or may not be fully representative for these cohorts in Year 8 (2020).

We also computed growth curves using the 4-parameter logistic model (as explained in Section 2.5) based on the median forklength values for each age class for the 2013 to 2020 data sets to assess differences in growth among years and reservoir operational regimes based on this standardized approach (Figure 3.11; Appendix E, Figure E2). 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 and treatments. There were 3 years of size-at-age data available for fish that had reared under N2-2P conditions (i.e., 2013-2015) and currently five years of data for the Modified Operations period (i.e., 2016-2020).

The median forklengths for the oldest fish in the sample (i.e., Ages 5 and 6) did not notably differ among any of the years of monitoring to-date, suggesting that the maximum size and age of fish in the reservoir has not changed. Although it should be noted that these age classes also represent the smallest portions of the sample each year (i.e., typically <5% combined). There was greater variation in median sizes for fish between Age-1 and Age-3 among years (see differences in annual growth curves in Appendix E, Figure E2). In relative terms, growth for this age range was high in 2015 and 2016; reduced in 2017 and 2018; lowest in 2019; and then rebounded back to the high end of the range in 2020. As a result of these changes, the medians when summarized according to operational regime were lower during the Mod. Ops. years (2016-2020) than during N2-2P operations (2013-2015) for Age-0+, Age-1 and Age-2 (Figure 3.11). This information suggests that growth (in terms of body length) was slightly reduced overall for these younger age classes since 2016, when the modified operations of the reservoir were initiated.

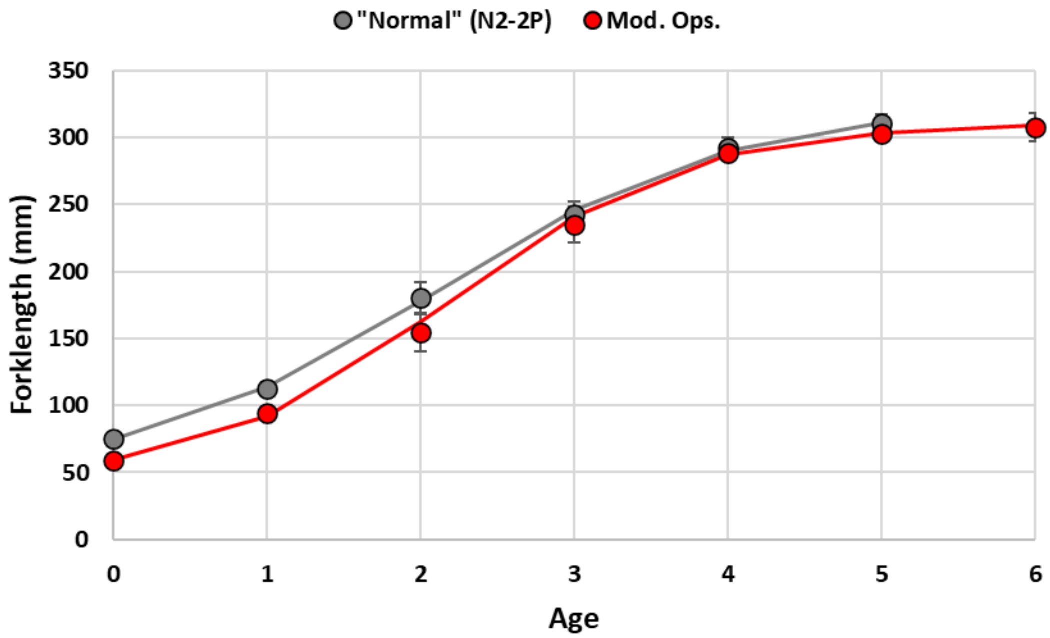


**Figure 3.11 Median sizes (± SE) and 4-parameter Logistic growth curves for rainbow trout captured during the annual fish population index survey in Downton Reservoir during "Normal" (N2-2P; 2015) and Modified Operations (2016-2020) periods. Note: There was only 1 year of size-at-age data available for the period of N2-2P operations. Curves for each of the individual monitoring years are provided in Appendix E, Figure E2.**

The lengths and weights of rainbow trout in Downton Reservoir were highly correlated in all years ($R^2$ ≥0.98 from 2013-2020; Figure 3.12; Table 3.17). Slight differences in the slope and y-intercept values may have been attributable to differences in sample size (related to mark-recapture approach) in Year 2, but were very small among all years in general. The year-specific regressions almost completely overlapped one another. This analysis shows that there were no substantive changes in the relationship between fish length and weight among years and operational regimes, and no effect of anomalous values was documented across the period of monitoring.

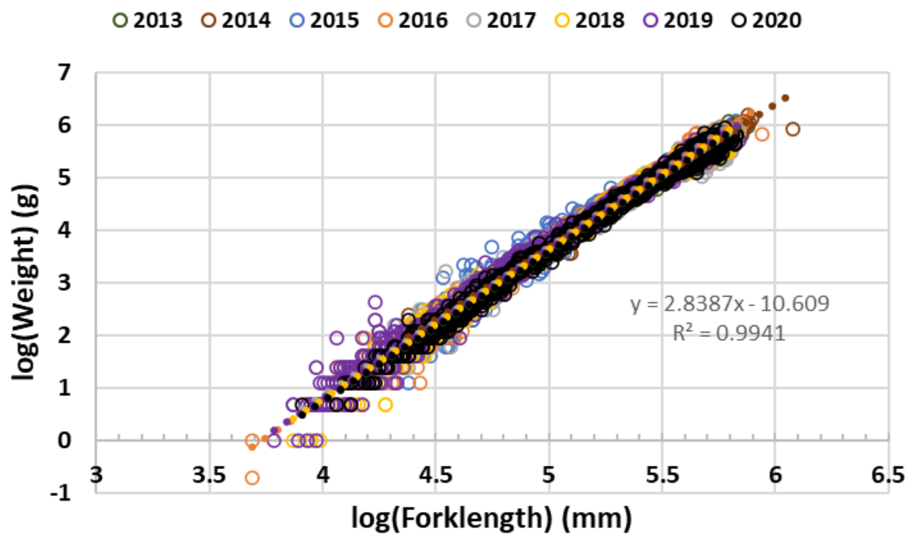


**Figure 3.12 Log-transformed length-weight relationships for Downton Reservoir rainbow trout in Years 1 to 8 (2013 to 2020). Open circles are the individual data points (colour-coded by year) and the dotted lines represent the year-specific regressions. See Table 3.17 for the sample size, slope, y-intercept 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 | $R^2$ |
|---|---|---|---|---|
| **1 (2013)** | 108 | 2.85 | -10.64 | 0.99 |
| **2 (2014)** | 182 | 2.73 | -9.97 | 0.98 |
| **3 (2015)** | 882 | 2.91 | -10.85 | 0.98 |
| **4 (2016)** | 1,018 | 2.89 | -10.77 | 0.99 |
| **5 (2017)** | 1,079 | 2.79 | -10.31 | 0.99 |
| **6 (2018)** | 1,054 | 2.85 | -10.62 | 0.99 |
| **7 (2019)** | 1,546 | 2.83 | -10.51 | 0.99 |
| **8 (2020)** | 1,111 | 2.84 | -10.61 | 0.99 |

We also generated mean condition factor (Fulton's K; ±SE) values to assess differences or changes in body condition by age and operational regime (i.e., N2-2P vs Mod. Ops.; Figure 3.13). Condition factor generally declines as fish age and this was apparent during both operational regimes in Downton Reservoir; however, the timing of the changes were different among them. During the N2-2P years (2013-2015) Fulton's K values were highest and equivalent for Age-0 and Age-1, declined sharply by Age-2, and then remained relatively consistent for the remaining years. Under Modified Operations (2016-2020), Fulton's K values were about the same as during N2-2P for Age-0 and Age-1 (considering overlap in error bars), but were higher for Age-2, Age-3 and Age-4 fish, reflecting a later and more gradual decline in condition factor with age compared to the N2-2P results. Condition factor for Age-5 fish, which is effectively the maximum age for rainbow trout in the reservoir, was equivalent for both operational treatments.

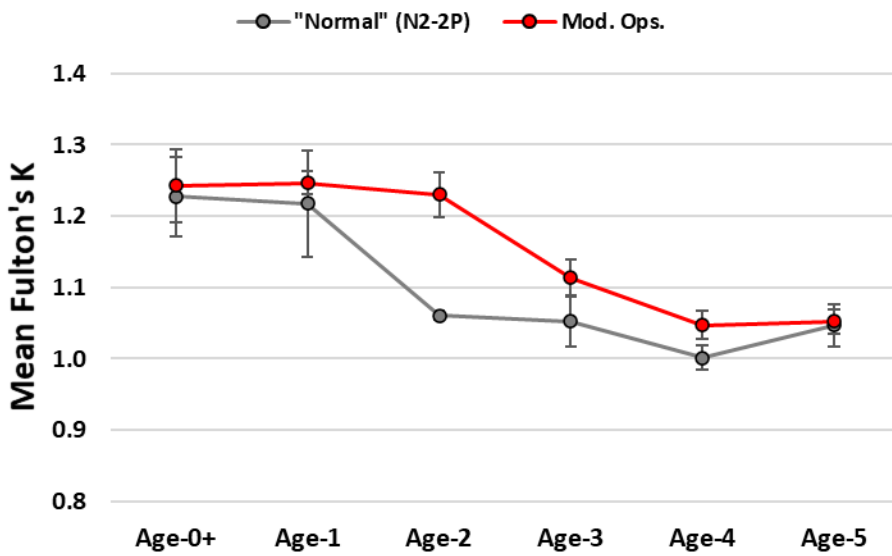


**Figure 3.13 Mean condition factor (± SE) by age class during "Normal" (N2-2P; 2014-2015) and Modified Operations (2016-2020) periods for rainbow trout in Downton Reservoir based on fish sampled during the annual fish population indexing survey between late May and late June each year.**

As a means of documenting the year-to-year changes, the differences in median size between years for individual cohorts (i.e., by recruitment year) have been summarized in Table 3.18. As was noted for Figure 3.11, the greatest growth rates occur between Age-1 and Age-4 with differences in median size up to or greater than 100 mm per year in several cases. However, the differences in growth among age classes for each cohort have also been highly variable among years (i.e., as low as 17 or 18 mm per year in some cases). It is not yet apparent what factors contribute to the highest and lowest growth rates among cohorts and years based on the available data, and would likely require a coincident assessment of productivity in the reservoir and changes to the food base among years to identify those factors (which were not included as a part of this study).

**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 = green; 2015 results = brown; 2016 results = blue; 2017 results = orange; 2018 results = grey; 2019 results = gold; 2020 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 | **296.5 (+101.5)** | 268 |
| **2016** | **58** | 16 | **92 (+34)** | 742 | **110 (+18)** | 461 | **266 (+156)** | 338 | | |
| **2017** | **62** | 59 | **79 (+17)** | 492 | **185 (+106)** | 285 | | | | |
| **2018** | **53** | 29 | **100 (+47)** | 495 | | | | | | |
| **2019** | **-** | 0 | | | | | | | | |

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 8 (2020), catch rates of Age-1 fish were highest and almost equivalent in shallow slopes and at creek mouths, and lowest on fans and steep-sloped shorelines. Age-2 fish were most prevalent at creek mouths, followed by shallow slopes, fans and then steep shorelines. As in past years, older fish (Age-3 and up) were most prevalent at creek mouths and at much lower densities 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 staging areas for spawning by mature fish in spring. However, the biggest differences in 2020, relative to previous years, was the increased CPUE of Age 3 and Age 4 fish, particularly at creek mouths (i.e., 20.5 and 21.3 fish/100 m, respectively). The increased abundance of Age 3 fish provided additional follow-up evidence for the increased abundance of Age 1 fish reported in Year 6 (2018) (Sneep 2019b) and Age 2 fish reported in Year 7 (2019) (Sneep 2020), suggesting that improved recruitment had occurred starting in 2016 (when this cohort incubated and emerged). The continued strength of this age class cohort as well as the

Age 4 fish also suggest that conducive rearing conditions have persisted through the modified operations years to-date. However, the total life expectancy has not changed as the oldest fish were Age 5. The recruitment of fish to Age 1 and Age 2 has also remained strong during the modified operations period. The higher densities of Age 1 fish along shallow shorelines, steep shorelines and fans relative to the other age classes may be the result of higher competition and risk of predation at the more densely populated creek mouths for these young fish, particularly when abundances overall in the reservoir have been higher.

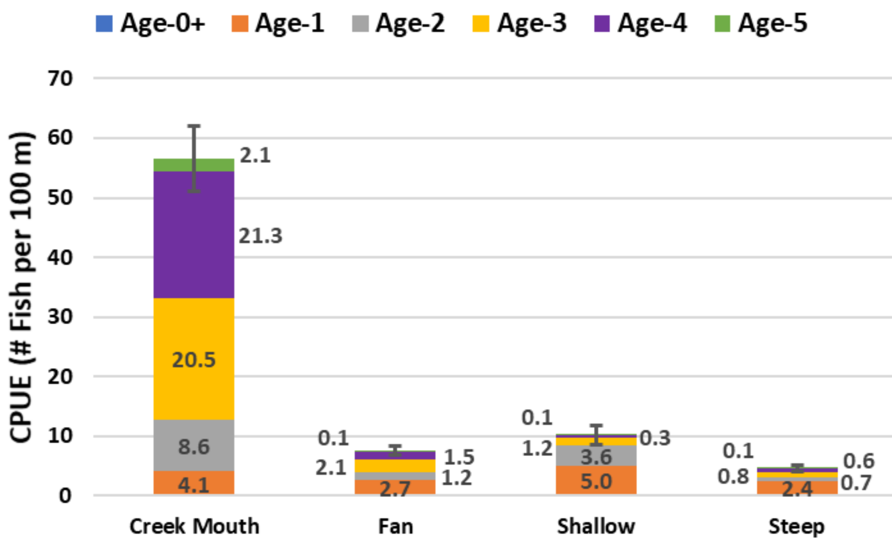


**Figure 3.14 Catch-per-unit-effort (fish/100 m) by age class for each habitat type in Downton Reservoir based on the results of the boat electrofishing survey in Year 8, 17 to 24 June 2020.**

The relative contribution of each age class to the catch in 2020, compared to 2015-2019 is shown in Table 3.19. The CPUE value and percent contribution for Age-1 fish in 2020 (i.e., 2018 recruits) rebounded after a bit of a drop in 2019 (i.e., 2017 recruits) and was on par with catch rates for this age class in 2018 (i.e., 2016 recruits) and 2016 (i.e., 2014 recruits). The CPUE value for Age 2 fish declined slightly in 2020 in keeping with the reduced catch rates for this cohort as Age 1 fish in 2019, whereas the CPUE value for Age-3 fish in 2020 increased dramatically over every previous study year (following the trend of increased densities for this cohort since it was recruited in 2016 as noted above). The contributions of Age-4 fish generally increased from 2015 to 2019, and then levelled off in 2020, 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), 7 (2019) and 8 (2020). 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** | **2020** |
| 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%) | 5.0 (35%) |
| 2 | 2.0 (22%) | 0.7 (8%) | 1.9 (23%) | 1.7 (14%) | 3.3 (28%) | 2.8 (20%) |
| 3 | 1.0 (11%) | 1.2 (14%) | 1.6 (20%) | 1.9 (16%) | 1.8 (15%) | 3.4 (24%) |
| 4 | 0.7 (8%) | 0.6 (7%) | 1.4 (18%) | 2.3 (19%) | 2.7 (22%) | 2.7 (19%) |
| 5 | 0.1 (1%) | 0.8 (9%) | 0.2 (3%) | 0.4 (3%) | 0.5 (4%) | 0.3 (2%) |
| 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)** | **14.2 (2.7 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 complete for the 10-year monitoring time frame, 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 8 (2020), the Age-0+ rainbow trout were recruited in 2019, the Age-1 fish were recruited in 2018, and the Age-2 fish were recruited in 2017.

**Table 3.20 Sampling years for the Age-0+, Age-1 and Age-2 classes according to recruitment year. The grey-shaded cells indicate cohorts that will be sampled in upcoming study years. Black cells indicate cohorts that will not be sampled within the current study timeframe.**

| 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 |
| **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. Similar correlations are apparent in the plot of CPUE and annual minimum reservoir elevations (bottom left plot on Figure 3.15), which also makes sense given that the minimum elevations achieved during the early spring directly influence the maximum elevations during the spawning period (which occurs later in the spring). In other words, there is an operational linkage between the x-axis values on these two plots. Other than these emerging relationships, the regressions on the other plots are either more flat (i.e., consistent with "*no effect*"; top left plot) or the potential relationships are somewhat confounded between the two age classes (bottom right plot). These figures and regressions will continue to be populated and updated as each new year of data becomes available.

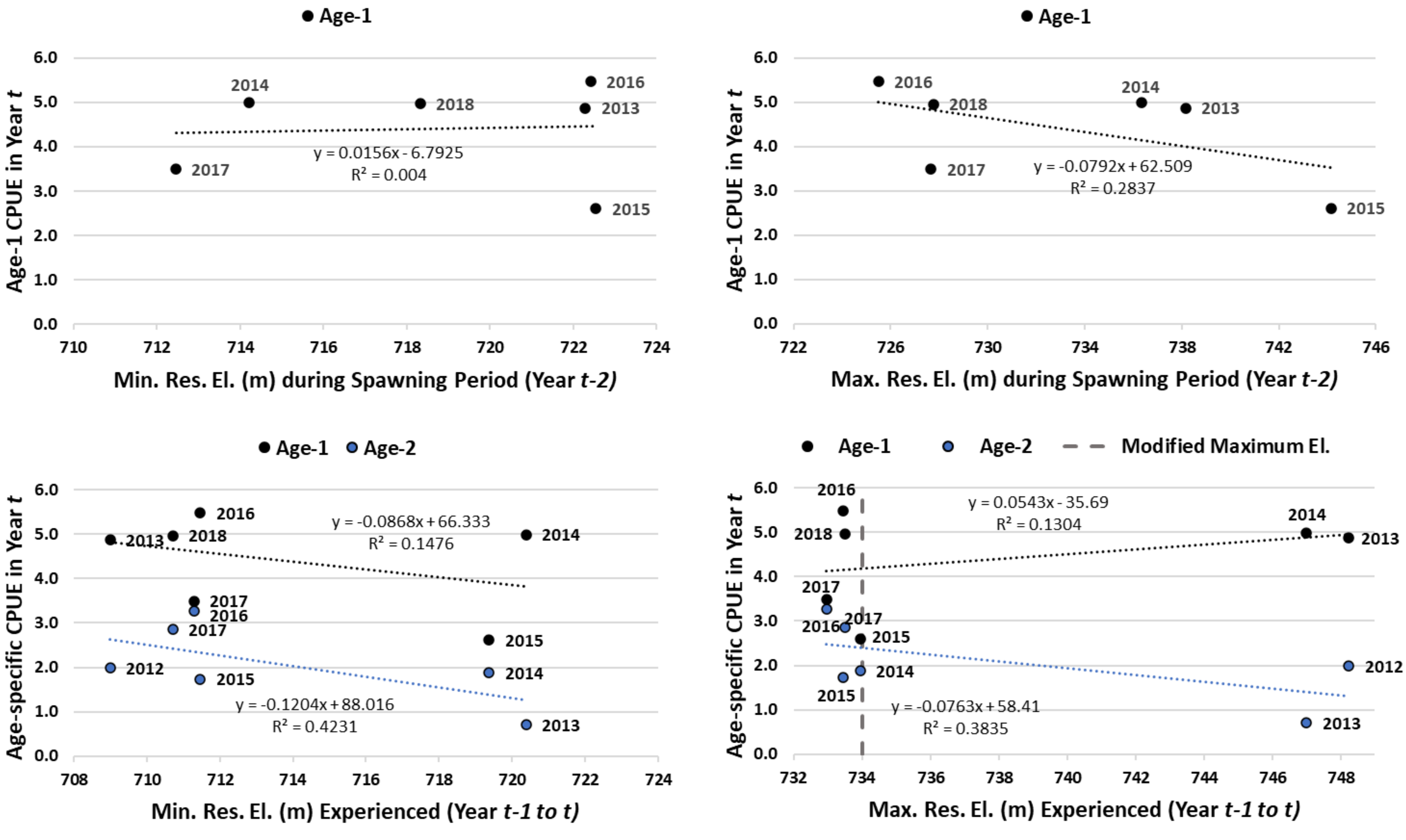


**Figure 3.15** Plots of annual age-specific CPUE for Age-1 fish against minimum and maximum reservoir elevations during the spawning period in their recruitment year (*t-2*; upper panels); and Age-1 and Age-2 CPUEs against the minimum and maximum reservoir levels experienced in the previous year (*t-1* to *t*; lower panels). 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 8), 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 2018-2020) where spawning had not, or only minimally, been observed previously supports that Downton Reservoir rainbow trout can be 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% in each monitoring year) spawn in the drawdown portion of the selected 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, 7 and 8 (2018, 2019 and 2020) 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.

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), 2019 (CPUE = 22 fish/100 m; forklength range = 20 to 46 mm), and 2020 (CPUE = 11 fish/100 m; forklength range = 20 to 35 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), 2019 (CPUE = 10 fish/100 m; forklength range = 27 to 56 mm), and 2020 (CPUE = 18 fish/100 m; forklength range = 22 to 55 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 0-4 fish/100 m in every season sampled), suggesting that the majority of the Age-0+ fry move into the reservoir sometime before the following spring, where a range of suitable temperatures for growth are available (according to depth), food (likely in the form of drifting invertebrates at the creek mouths or amphipods in the reservoir – see Photo A12 in Appendix A) is provided, the year-round turbidity provides cover, and the risk of habitat loss from changing reservoir elevations is low (as opposed to within the drawdown zone of the tributaries).

In the nearshore areas of the reservoir, the rainbow trout are distributed among each of the longitudinal zones (i.e., west, mid, and east; shown on Figure 2.3), 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. The lowest densities have most consistently been associated with steep shorelines; however, densities at steep slopes 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 were also consistently the habitat type where the greatest capture success by angling occurred throughout the year during past surveys, 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 forklength); 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, 2019 and 2020. After Age 4, survival in this context seems to be very low as catches of fish aged 5 or older have been consistently very low or negligible (CPUE <1 fish/100 m) each year. 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 forklength for each age class in each year, suggest that growth has slowed slightly since initiation of modified operations in 2016. However, condition factor has actually been higher (particularly for Age 2 to Age 4 fish) and survival to Age 4 has increased. These results suggest that rearing conditions in the reservoir under modified operations have been good (or at least better than the N2-2P years monitored). However, we do not have access to reservoir productivity or food base information which would be required to characterize the mechanisms behind the observed differences in growth or condition factor among years or operational regimes.

## 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 five years of modified operations to-date, minimum elevations were 719.38, 711.47, 711.29, 710.69, and 710.41 m, and maximum fill elevations were 733.94, 733.46, 732.96, 733.50, and 735.06 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 increased significantly for rainbow trout that recruited during the modified operations years to-date (i.e., 2018-2020 fish population index survey results) to between 11.8 and 14.2 fish/100 m of shoreline (SE 1.3-2.7), from 8.1 to 8.9 fish/100 m (SE 0.8-1.0) during 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, Age 2 and Age 4 fish in 2019, and Age 3 and Age 4 fish in 2020. CPUEs for Age-2 to Age-4 fish have increased since 2016 when they were at or near 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 has continued through to 2020.

These results suggest that the modified operations may be improving recruitment conditions, reservoir rearing conditions, or both. However, the results also suggest that there are limits to population growth in this context. 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). And a similar thing occurred for Age 2 fish between 2019 and 2020 despite strong recruitment to ages 1, 3 and 4 in 2020 (see Table 3.19). Furthermore, despite the increased densities of fish up to and including Age 4 for 3 consecutive years, the maximum age for this population has remained around 5 years. Taken together, 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 should still be considered preliminary 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*," is tentatively rejected at this stage of the program. The 2018 to 2020 results have provided three consecutive data points suggesting that the annual abundance index has *increased* under the initial years of modified operations (2016-2020). More years of data will be beneficial for supporting this result before inferences can become more conclusive. This program has established an effective method for tracking this information (Fish Population Index Survey) that is being successfully implemented and there are currently 6 years of comparable abundance index data points available at this point (3 years of recruitment under normal operations and 3 years under modified operations; refer to sections 2.5 and 3.6) with 2 more years yet-to-be completed before the end of the currently prescribed monitoring period. While status updates will continue to be provided as the remaining years of results become available, final conclusions will ultimately require rainbow trout population index values across the entire monitoring period (up to, and including, Year 10 in 2022) 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 for years 7 and 8 (2019 and 2020) 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 available 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 – see Photo A12 in Appendix A). 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 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; *n*= 4 in 2020) 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; 2020 CPUE = 22.6 ±8.5 fish/100 m) and fall (i.e., mid October; 2020 CPUE = 29.8 ±13.2 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; 2020 CPUE = 11.3 ±2.5 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). Continued 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) and repeated in Year 8 (2020) – 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 fish from the reservoir may be impeded when reservoir levels are <713 m (observed in 2014, 2017, 2018, 2019 and 2020) during April and early May before the onset of freshet flows in the creeks (see Photo A10 in Appendix A). However, it is important to add that these conditions were fairly short-lived (i.e., until inflows increased), typically prior to the start of the rainbow trout spawning period, and/or occurred in creeks that have not been primary spawning tributaries. 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 – see Photo A11 in Appendix A); and, b) when the snow pack in smaller drainages depletes (observed in Trib. #19 and Trib. #10 in August 2017, August 2020 and October 2020).

Targeted data collection on accessible stream-length according to reservoir elevation for the known spawning tributaries conducted in Years 6 to 8 (2018-2020) 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 193.8 m (or 68%) across the spawning period under normal operations versus an average of 139.2 m (or 38%) 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 119.1 m (or 78%) under normal operations versus an average of 93.0 m (or 51%) 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.

Higher use of the drawdown zone for spawning (based on observations of spawner locations) has been noted relative to the upland zone of the selected tributaries during each monitoring year to-date (Appendix C, Table C1). During the period of monitoring normal operations (i.e., 2013 to 2015) the relative proportions were 70% and 30% (on average) for the drawdown zone and upland, respectively. During the modified operations years to-date (2016 to 2020), relative use of the drawdown zone has increased to 82% of observed spawners and use of the upland zone has decreased to 18%. Starting in Year 7 (2019), we have 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 the inital two years 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 riskiest in terms of potential recruitment impacts (see Table C2 in Appendix C). Reservoir elevations under modified operations have tended to inundate a smaller portion of this zone than under normal operations (see Table 3.7 in Section 3.4). As this data set continues to build over the remaining years of monitoring, this will 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 ineffective. 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 4 of the 6 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 post-emergence rearing appears to occur in the reservoir (with all age classes represented in the reservoir sample, and particularly Age-1 and Age-2 fish). Creek mouths are the most utilized habitat type by the broadest range of age classes; however, the youngest age classes also utilize the other shoreline types (most notably shallow slopes and fans) for rearing based on the annual spring reservoir sample. 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 at the time of the survey) 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 (refer to the habitat survey results in the Year 6 report; Sneep 2019a). Due to the cross-sectional 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 has been 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 implemented during the study to-date. 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 availability of interstial spaces in the reservoir drawdown zone are positively correlated with elevation (size range, median size and interstitial space each increase with the elevation; Sneep 2019a)), 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 age class & habitat-stratified fish distributions (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 2019b). 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 reservoir productivity and 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 to bolster support for this conclusion. 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 three most recent years (2018-2020). 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 2019a, 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 8 (2020) 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. At this point, a relationship does appear to be emerging between the minimum reservoir levels during a given year and the abundance index for Age-1 or Age-2 fish that recruit from those years (see the regressions, slopes and $R^2$ values on the lower-left plot of Figure 3.15 in Section 3.6). These relationships suggest a positive effect of lower minimum reservoir elevations, at least to the levels implemented within the monitoring years to-date (i.e., down to ~709 m).

On the other hand, this effect may actually be a reflection of another related factor which is not captured by this management question but does appear to have support from various monitoring components at this point: The relationship 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). As indicated previously, these two factors are related because the lower the reservoir is drawn down in the spring, the lower the maximum elevation reached during the spawning and incubation period tends to be, particularly under the modified operations conditions.

Based on the Age-1 CPUE data up to Year 8 (2020), the slope (-0.08) and $R^2$ (0.28) values for this negative correlation were stronger than the other relationships based on the data currently available. 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 and a larger Age-2 cohort (relative to the Year 6 results) and the Year 8 (2020) results continued that pattern, showing reduced abundance of Age-2 fish and a larger Age-3 cohort (relative to previous 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.

Presently there are not clear or consistent correlations between minimum reservoir levels *during the spawning period* or absolute maximum reservoir elevations and juvenile recruitment (top-left and lower-right plots on Figure 3.15, respectively), or at least there is not a strong enough signal to differentiate potential relationships from an inference of "*no effect*", at this stage. Furthermore, 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, Age-2 fish in 2019, and Age-3 fish in 2020 (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 (as well as maximum age and body size) limits driven by parameters other than 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. Ongoing 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)), could 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 8 (2015 to 2020). We have fit regression lines to the Age-1 and Age-2 CPUE vs. reservoir operation (minimum or maximum levels) relationships; however, the full 10-year complement of data points will be needed to strengthen 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 in-season temperature profiles.
- Since habitat mapping and comparable amounts of substrate measurement data have been collected at each of the targeted set of elevations (as of Year 6), we propose to put

any further data collection for these components on hold 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 as was done in Year 8 (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. It is understood that every year there are challenges and obstacles to accessing certain creeks due to avalanche hazard & slides, road closures, and low reservoir elevations (i.e., for accessing creeks by boat). Continue collecting data on the specific locations where spawners were observed in the creeks (started in Year 7), 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 has been done since Year 7 (2019). Seasonal sampling will target a spring session in early June, a summer session in early September, and a fall session in mid 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 approximately the same dates (early to mid 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 711.1 m on 30 April, 2020.

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

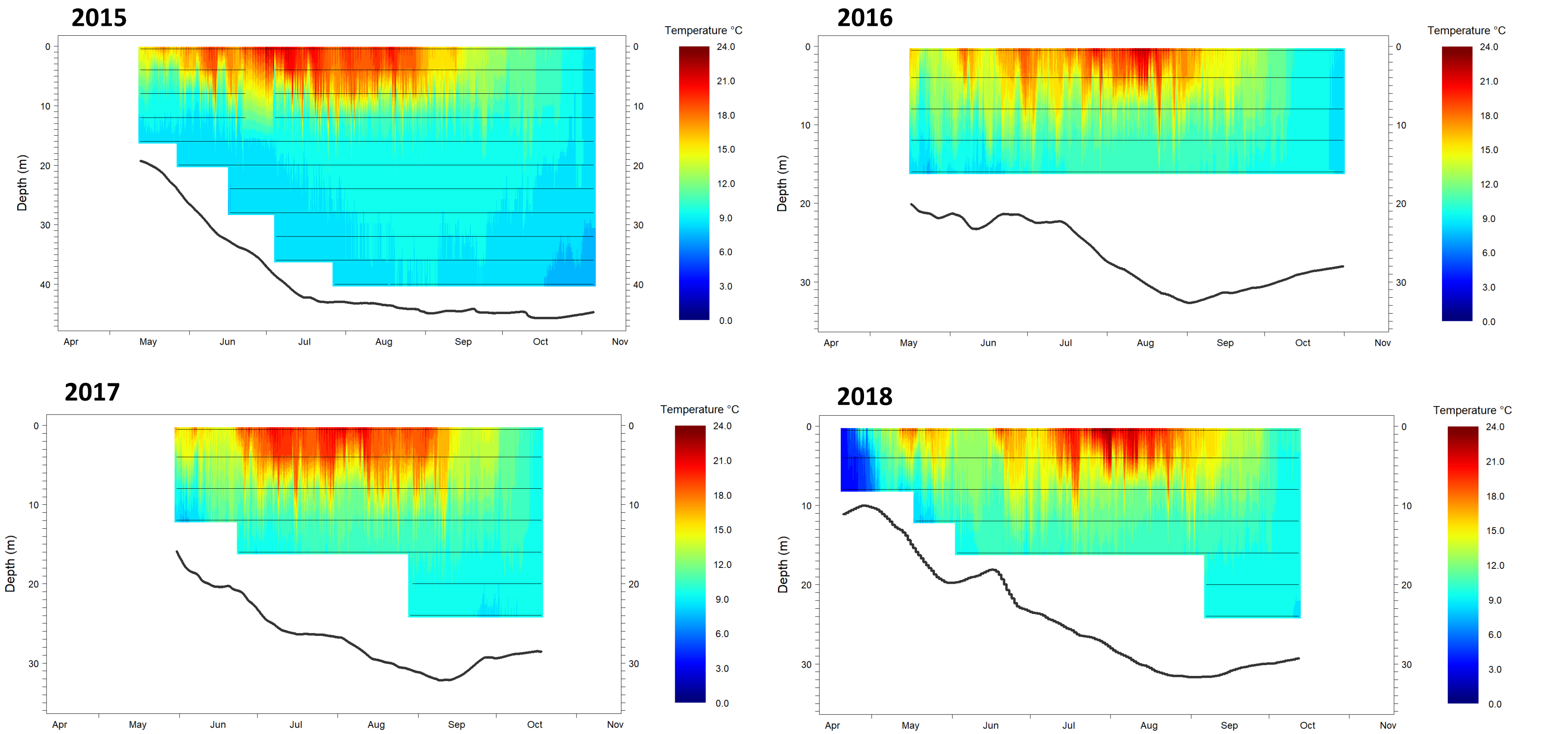


**Figure B1 Water temperature profiles recorded in Downton Reservoir at the log boom (see Figure 2.1 for location), April to November 2015 (upper left), 2016 (upper right), 2017 (lower left), and 2018 (lower right). The horizontal lines indicate the measurement depths. Temperatures between those depths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

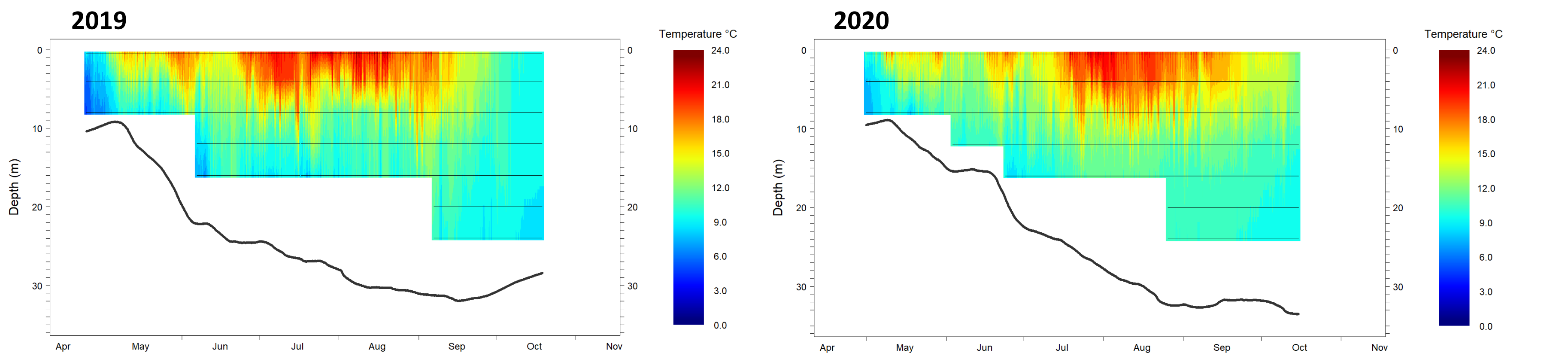


**Figure B1 Cont.** **Water temperature profiles recorded in Downton Reservoir at the log boom (see Figure 2.1 for location), April to November 2019 (left) and 2020 (right). The horizontal lines indicate the measurement depths. Temperatures between those depths were linearly interpolated. The solid black lines reference the reservoir depth at the log boom.**

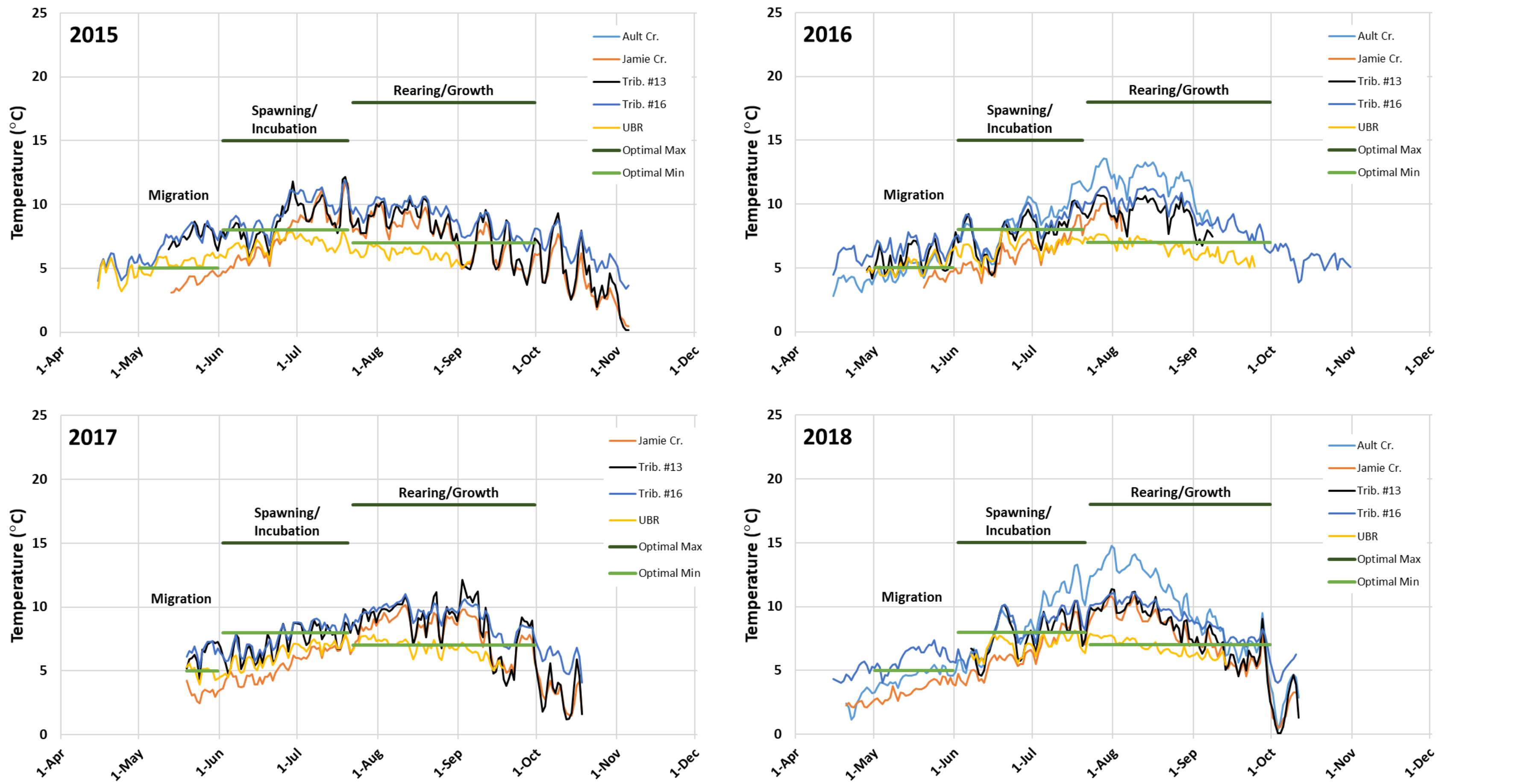


**Figure B2 Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to October 2015 (upper left), 2016 (upper right), 2017 (lower left), and 2018 (lower right). The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages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

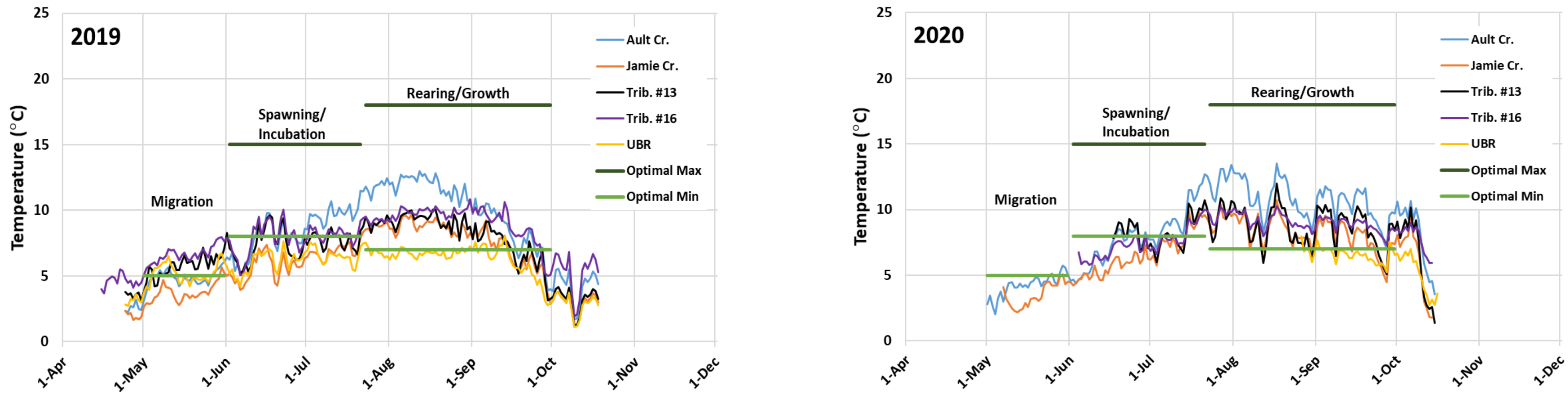


**Figure B2 Cont.** **Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to October 2019 (left) and 2020 (right). The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of rainbow trout (McPhail 2007).**

# Appendix C – Distribution of Spawner Locations According to Reservoir Elevation

**Table C1 Relative percentages of total spawner observations documented within the reservoir drawdown zone versus the upland of the surveyed tributaries by study year and operations regime (i.e., Normal vs. Modified operations).**

| Study Year | % of Total Spawner Observations | |
|---|---|---|
| | Res. Drawdown Zone | Upland |
| **1 (2013)** | 68% | 32% |
| **2 (2014)** | 86% | 14% |
| **3 (2015)** | 58% | 42% |
| **Normal Operations Averages** | **70%** | **30%** |
| **4 (2016)** | 76% | 24% |
| **5 (2017)** | -- Not Surveyed -- | |
| **6 (2018)** | 58% | 42% |
| **7 (2019)** | 82% | 18% |
| **8 (2020)** | 91% | 9% |
| **Modified Operations Averages** | **82%** | **18%** |

**Table C2 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., <25%), or were in the upland, are highlighted green in the "Total" column. Elevations that corresponded with higher total spawner proportions (i.e., >25%) 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] | 10% | 34% | 0% | 21% | 100% | **13%** |
| **749.81** | 100% | 100% | 90% | 66% | 100% | 79% | | **87%** |
| **746** | 100% | 95% | 90% | 61% | 100% | 74% | | **84%** |
| **742** | 100% | 77% | 90% | 55% | 100% | 57% | | **71%** |
| **738** | 100% | 54% | 70% | 47% | 88% | 20% | | **49%** |
| **734** | 94% | 33% | 60% | 39% | 78% | | | **33%** |
| **730** | 49% | 13% | | 8% | 24% | | NA [a] | **14%** |
| **726** | 16% | 4% | | 2% | | | | **4%** |
| **722** | 2% | | | 2% | | NA [a] | | **1%** |
| **718** | | | | | | | | |
| **714** | | | NA [a] | NA [a] | NA [a] | | | |
| **710** | - [c] | NA [a] | | | | | | |

[a] "NA" refers to elevations that were not accessible or not applicable in a given tributary (e.g., if the elevation of the creek mouth is higher than the given reservoir elevation). Ault Creek has a large falls at the top of the drawdown zone precluding access to the upland for fish from the reservoir; Trib. #13 joins the UBR channel within the drawdown zone above the 734 m target modified maximum elevation; and the entire length of Tram Creek is within the upland zone above the reservoir basin (it's a tributary to the UBR).

[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.

[c] The drawdown zone of Ault Creek at or below 710 m reservoir elevation may not be accessible because this creek typically flows to ground across the fan before reaching the reservoir surface at this elevation.

## Appendix D – 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] These are the last 6 unique digits of the tag code; The prefix to each of these tag codes is either: 900 226000 (2013-2018) or 900 226001 (2019-2020)

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 | 06-Jun-19 | Mid | 308 | 1.7 | 17 |
| 889306 | 02-Jun-16 | Mid | 84 | 07-Jun-19 | West | 307 | 2.3 | 74 |
| 888690 | 01-Jun-17 | Mid | 113 | 08-Jun-19 | West | 296 | 3.9 | 91 |
| 975967 | 04-Jun-17 | West | 110 | 10-Jun-19 | Mid | 247 | 4.8 | 68 |
| 317323 | 04-Jun-18 | West | 301 | 09-Jun-19 | West | 296 | 0.5 | -5 |
| 316690 | 06-Jun-18 | Mid | 302 | 08-Jun-19 | West | 324 | 9.4 | 22 |
| 316805 | 08-Jun-18 | East | 270 | 11-Jun-19 | West | 279 | 11.4 | 9 |
| 317033 | 08-Jun-18 | East | 98 | 12-Jun-19 | Mid | 207 | 5.5 | 108 |
| 316955 | 08-Jun-18 | East | 110 | 06-Jun-19 | Mid | 219 | 7.5 | 110 |
| 316818 | 08-Jun-18 | East | 109 | 11-Jun-19 | Mid | 251 | 5.7 | 141 |
| 316978 | 08-Jun-18 | East | 105 | 12-Jun-19 | East | 260 | 1.7 | 153 |
| 734786 | 11-Jun-15 | Mid | 108 | 19-Jun-20 | Mid | 330 | 0.2 | 44 |
| 889174 | 30-May-16 | East | 143 | 23-Jun-20 | West | 312 | 11.1 | 42 |
| 975845 | 02-Jun-17 | Mid | 80 | 19-Jun-20 | Mid | 300 | 3.1 | 72 |
| 975776 | 03-Jun-17 | Mid | 82 | 21-Jun-20 | East | 293 | 2.4 | 69 |
| 975129 | 06-Jun-17 | East | 85 | 18-Jun-20 | Mid | 265 | 4.5 | 59 |
| 975777 | 04-Jun-17 | West | 101 | 18-Jun-20 | Mid | 299 | 3.5 | 65 |
| 975034 | 07-Jun-17 | East | 85 | 24-Jun-20 | West | 296 | 9.3 | 69 |
| 975530 | 01-Jun-18 | East | 146 | 23-Jun-20 | West | 288 | 10.7 | 69 |
| 975568 | 01-Jun-18 | East | 80 | 24-Jun-20 | West | 282 | 12.1 | 98 |
| 975611 | 01-Jun-18 | East | 143 | 24-Jun-20 | West | 299 | 12.1 | 76 |
| 975716 | 01-Jun-18 | East | 92 | 17-Jun-20 | Mid | 276 | 9.2 | 90 |
| 979854 | 01-Jun-18 | East | 109 | 24-Jun-20 | West | 286 | 10.6 | 86 |
| 979854 | 01-Jun-18 | East | 109 | 18-Jun-20 | Mid | 287 | 6.5 | 87 |
| 317322 | 03-Jun-18 | West | 173 | 17-Jun-20 | Mid | 228 | 2.0 | 27 |
| 316875 | 08-Jun-18 | East | 113 | 18-Jun-20 | Mid | 285 | 7.9 | 85 |
| 316373 | 07-Jun-19 | West | 147 | 23-Jun-20 | West | 199 | 1.2 | 50 |
| 316215 | 08-Jun-19 | West | 280 | 24-Jun-20 | West | 291 | 1.1 | 11 |
| 316264 | 08-Jun-19 | West | 204 | 24-Jun-20 | West | 239 | 1.6 | 33 |
| 560185 | 09-Jun-19 | Mid | 91 | 23-Jun-20 | West | 200 | 4.9 | 105 |
| 560499 | 11-Jun-19 | Mid | 110 | 23-Jun-20 | West | 222 | 5.9 | 108 |
| 560662 | 13-Jun-19 | East | 125 | 19-Jun-20 | Mid | 225 | 5.4 | 98 |
| 560892 | 13-Jun-19 | East | 297 | 24-Jun-20 | West | 320 | 8.8 | 22 |

[a] These are the last 6 unique digits of the tag code; The prefix to each of these tag codes is either: 900 226000 (2013-2018) or 900 226001 (2019-2020)

# Appendix E – Length-Frequency and Size-at-Age Figures by Study Year

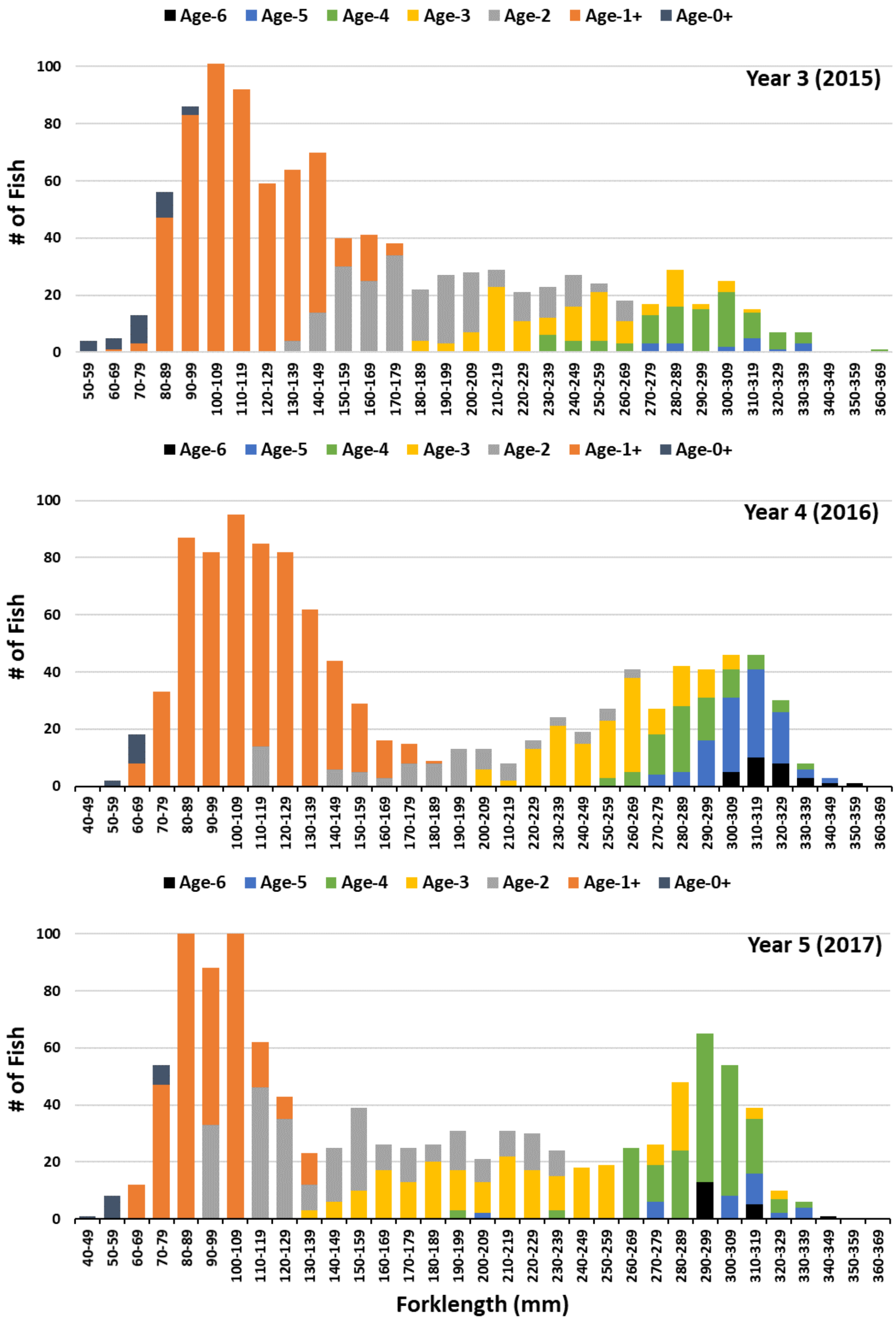


**Figure E1 Length-frequency histograms for each study year showing the distribution of age classes for rainbow trout in Downton Reservoir in late May to early June. Note: results for years 1 and 2 are not included due to different sampling approach in those years.**

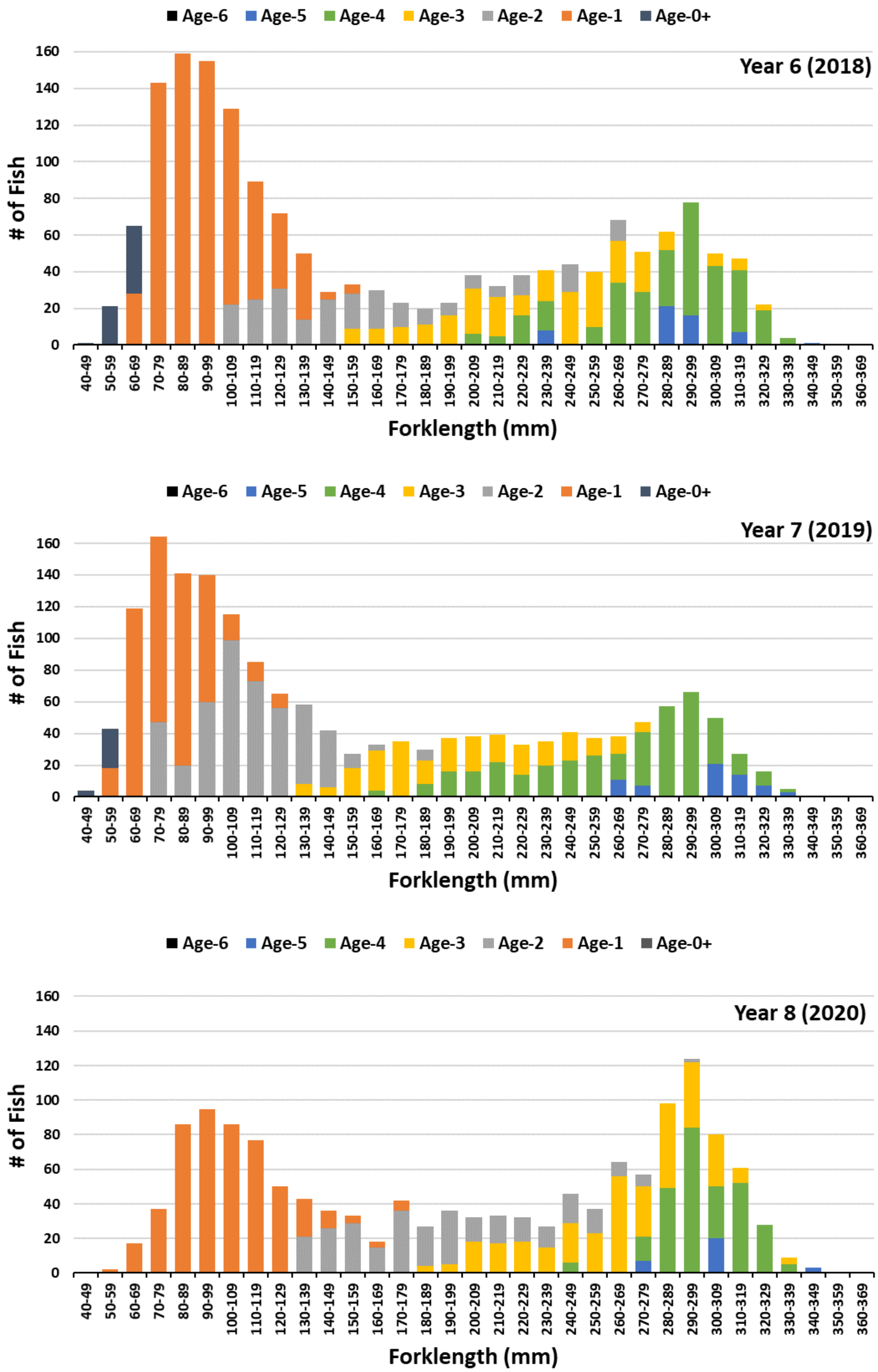


**Figure E1 Continued (see description on previous page).**

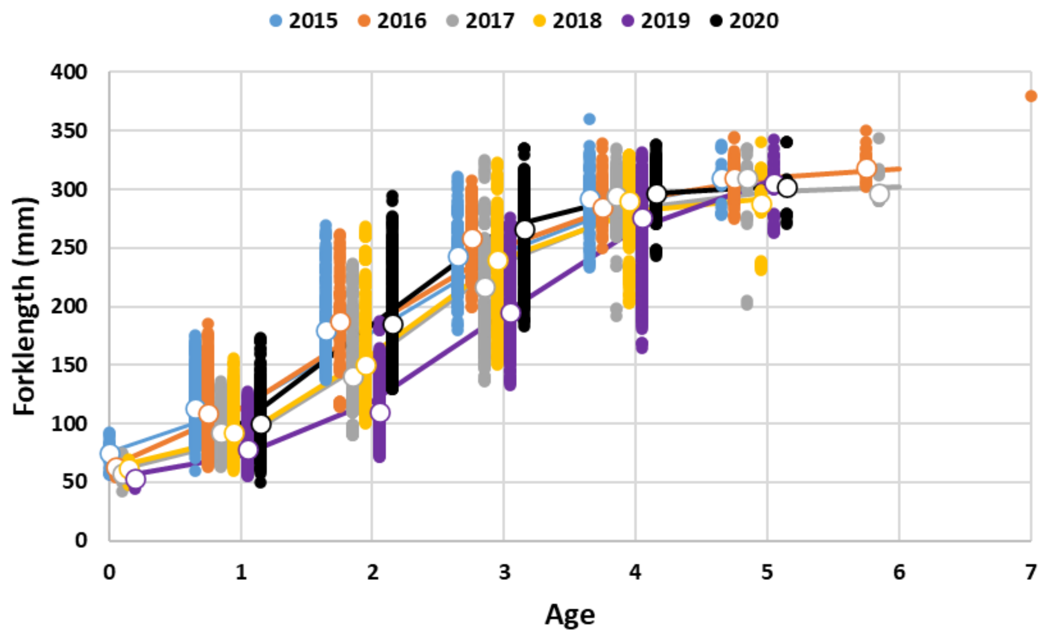


**Figure E2** **Size-at-age plot for rainbow trout captured during the annual fish population index survey, Years 3 to 8 (2015 to 2020). The lines represent the year-specific 4-parameter Logistic growth curves based on the median size values (open circles) for each available age class in Downton Reservoir. The individual length data points for each age class are also shown (filled circles).**