Bridge River Project Water Use Plan

Downton Reservoir Fish Habitat and Population Monitoring

Implementation Year 9

Reference: BRGMON-7

BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 9 (2021) Results

Study Period: April 1 2021 to March 31 2022

Jeff Sneep and St'at'imc Eco-Resources

January 31, 2023

BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 9 (2021) Results

Prepared for:

St'at'imc Eco-Resources and BC Hydro

Prepared by:

Jeff Sneep

Lillooet, BC

Canada

Reference: BRGMON-7

January 2023

Executive Summary

Data collection for Year 9 of this 10-year study was completed in 2021. 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 9 (2021) 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 9 (2021) was the sixth consecutive year that the reservoir was operated based on the modified maximum elevation target of 734 m; however, maximum reservoir elevation in 2021 exceeded this target by 4.5 m (i.e., reaching a maximum of 738.5 m). Lowest reservoir elevation in 2021 (710.5 m) was most similar to the range from 2017 to 2020 (i.e., 710.4 - 711.5 m) and in 2014 (709.0 m), and 9-10 m lower than 2013, 2015, and 2016 (when the range was between 719.4 - 720.4 m).

Stream walks were conducted in four tributaries (i.e., Ault Creek, Cathy Creek, Jamie Creek, and Trib. #13) in Year 9 (2021) where spawning use has been documented in past years. Two known spawning tributaries (i.e., Trib. #19 and Eagle Creek) could not be surveyed in Year 9 due to access challenges. Peak spawner counts in Year 9 were on 23 June, which was two weeks earlier than in Year 3 (2015; 4 July), but within a week of the peak timing for Downton Reservoir rainbow trout in every other study year to-date. Spawning was again confirmed in each of the monitored tributaries and use of Cathy and Ault creeks represented an expanded spawner distribution since the modified operations were initiated in 2016. While the spawner numbers documented can only be considered a relative index (e.g., visibility conditions were noted as fair or poor on several survey dates in 2021), the results of these surveys have been useful for tracking general changes in spawn timing and distribution (among creeks, between the upland and drawdown zones, and within the drawdown zone) across the 10-year monitoring period.

Tributary fish sampling was conducted in spring, summer and fall during Year 9 (31 May to 2 June, 1-3 Sep and 13-14 Oct 2021, respectively). Mean CPUE (for all creeks sampled) was 2.2 ±1.1 fish/100 m in spring, 16.0 ±5.1 fish/100 m in summer, and 4.1 ±2.5 fish/100 m in fall. No fish were captured at 6 of 12 sites (50%) during the spring session, 4 of 15 sites (27%) during summer, and 5 of 9 sites (56%) 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., 58% and 60%, respectively) were the new year class of rainbow trout fry (forklength = 21 to 43 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 3 to 10 June, 2021 at a reservoir elevation of approx. 718 m. This reservoir elevation was at the low end of the typical range observed during sampling in most years to-date (i.e., ~718 to ~723 m), other than 2015 when elevation was higher during the annual survey (i.e., ~730 m under N2-2P conditions). In total, 1,527 rainbow trout were captured from 61 sites, which resulted in a total catch-per-unit-effort equivalent to values in every year since 2018. Of these fish, 1,089 were newly marked with PIT tags and 9 marked fish were recaptured that were marked within this sampling session, and 13 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 11.9 ±1.5 fish/100 m of shoreline which was similar to the total CPUE values in Year 6 (2018; 12.2 ±1.4 fish/100 m), Year 7 (2019; 11.8 ±1.3 fish/100 m) and Year 8 (2020; 14.2 ±2.7 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 the contributions of Age-2 to Age-4 fish which 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), Age-2 in 2020 (relative to 2019), and Age-3 and Age-4 in 2021 (relative to 2020) likely reflects a limitation to total population size in the reservoir which ultimately caps the abundance of particular cohorts when recruitment increases until a new equilibrium is reached.

Highest CPUEs by habitat type in 2021 were once again at creek mouths (34.7 ±5.8 fish/100 m) and then shallow slopes (16.0 ±2.8 fish/100 m), followed by steep slopes (7.7 ±0.8 fish/100 m) and fans (5.9 ±1.0 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 2021; although this has varied 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 9 (2021) also included updated 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 been very similar between regimes; however, median weight-at-age has diminished slightly for older age classes >Age-3 under modified operations. 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 weight-at-age for older fish.

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 fish; whereas K values were equivalent among regimes for every other age class. 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 203 scales across the rainbow trout length distribution in 2021 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 from 2018 to 2021. Once again, the older age classes displayed extensive size overlap, confirming that growth rate decreases above Age-3.

We also plotted total annual rainbow trout CPUE against minimum and maximum reservoir elevations. In reference to Management Question 4, there was a slight correlation between minimum reservoir levels and total fish abundance, although it was weak (R^2= 0.14). Notably, 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 the maximum reservoir levels and total fish abundance (R^2= 0.86) which suggests a positive effect of lower maximum reservoir elevations associated with modified operations. To some extent, annual minimum and maximum reservoir elevations are related because the reservoir tended to be drawn lower in the spring during years with a lower target maximum.

Recommendations for monitoring in Year 10 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) Continue spawner count streamwalks and tributary access surveys in widest range of tributaries possible between mid May and the end of July, including specific documentation of spawner locations for characterizing spawning distribution within the drawdown zone; 3) Continue to conduct tributary fish sampling in three seasons within a year (spring, summer and fall) at the same range of creeks as in 2019-2021 to re-assess seasonal rearing use of tributary habitats; and 4) 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 9 (2021) 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 9

Primary Objectives	Management Questions and Study Hypotheses	Year 9 (2021) Results To-Date
1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and 2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative on existing reservoir fish populations, and, b) allow better future decisions regarding preferred operation of Downton Reservoir.	**1.** What are the basic biological characteristics of fish populations in Downton Reservoir and its tributaries?	• The Downton Reservoir fish population is almost entirely comprised of rainbow trout (save for 1 bridgelip sucker captured in 2016). • The rainbow trout population spawns between late May and late July (peak in mid to late June) in accessible tributaries, primarily in the mid and west zones of the reservoir, although monitoring data also suggest an increasing use of Ault and Cathy creeks in the mid and east zones under modified operations conditions. • Relative to the upland, a higher proportion (82% on average) spawn in the drawdown portion of these creeks. • Beyond the post-emergence period within their first growing season, fish use of the tributaries for rearing appears to be low, suggesting that the majority of the fry move into the reservoir prior to their first spring where risk of habitat loss from changing reservoir elevations is low. • Highest abundance is at creek mouths where food (likely in the form of drifting invertebrates) is available, followed by shallow slopes, alluvial fans, and steep shorelines. Catches in steep habitats has increased from 2018 to 2021 relative to previous years largely due to increased rearing use by Age-1 and 2 fish that were recruited under modified operations. • In the nearshore areas of the reservoir, the rainbow trout are distributed across the longitudinal zones (i.e., west, mid, and east). • Sampling in offshore habitats (i.e., by gill netting) was conducted in Year 5 (2017), which documented that use of pelagic habitats in June was low and limited to within 2.4 m from the reservoir surface. • The age range of sampled fish has spanned from 0+ to 7 years (40 to 437 mm); the majority are between ages 1 to 3, although increased recruitment to Age-4 has occurred in 2018 to 2020. The most rapid growth occurs between ages 1 and 3, after which growth rate slows. **See Sections 3.4, 3.5, and 3.6 for more information.**
	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 during 2018 to 2021 (range: 11.8 to 14.2 fish/100 m of shoreline) 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. • 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 and Age-2 and Age-3 fish in 2021 (relative to N2-2P contributions by these age classes). • 2021 minimum reservoir elevation (710.5 m) was very similar to 2014, 2017, 2018, 2019 and 2020, 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., 733-738 m) rather than the normal max. elevation (i.e., 749.8 m).

Primary Objectives	Management Questions and Study Hypotheses	Year 9 (2021) Results To-Date
1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and 2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative on existing reservoir fish populations, and, b) allow better future decisions regarding preferred operation of Downton Reservoir.	**H_1:** The annual abundance index for rainbow trout in Downton Reservoir is stable over the monitoring period.	• These results suggest that the modified operations have improved recruitment conditions, reservoir rearing conditions, or both. **See Section 3.6 for more information.** **Note:** By the end of the current monitoring period in 2022, limited data will be available for typical N2-2P operations (probably 2-3 years), and the remainder will reflect results associated with *modified* reservoir operation. However, the results will speak to the operational range tested, which is a sub-set of the normal operating range (i.e., lower maximum, but similar minimum elevations). **H_1: Rejected**. The 2018-2021 results consistently showed 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 from 2018 to 2019, Age-2 fish from 2019 to 2020, and Age-3 fish from 2020 to 2021 (i.e., a cohort that recruited under modified operations) suggests that the population has hit a total abundance ceiling that alternately favours certain age classes over others until a new equilibrium among age classes is established.
	3. Which are the key habitat factors that contribute to reduced or improved productivity of Downton Reservoir fish populations? **H_4:** Operation of the reservoir restricts the amount of available effective spawning habitat in tributaries limiting the productivity of fish populations. **H_{4a}:** Rainbow trout spawning density in Downton Reservoir drawdown zone is minimal and therefore operations do not limit productivity of fish populations. **H_{4b}:** Operation of the reservoir restricts fish access to tributaries limiting the productivity of fish populations. **H_5:** Habitat availability in Downton Reservoir is independent of reservoir operation, i.e., habitat characteristics are not significantly different between minimum, maximum and modified maximum reservoir elevations.	Specific, targeted data collection on habitat use linked to reservoir levels continued in Year 9 (2021), providing additional information for addressing this MQ. **See Sections 3.2 to 3.6 for more information**. • The tributaries provide essential spawning habitats and, likely, food supply; however, use for rearing beyond the initial growing season post-emergence appears limited. • Access to some tributaries by spawners may be impeded when reservoir levels are <713 m and inflows are low; however, to-date this has only been observed prior to the typical start of the spawning migration. • The majority of rearing seems to occur in the reservoir, and the creek mouths are the most utilized habitat type by the broadest range of age classes. Other habitat types (fans and shallow & steep shorelines are also used for rearing particularly by Age-1 and Age-2 fish. • Temperatures in the reservoir are more broadly spread across the optimal range (according to depth) for growth, relative to the tributaries, which are colder throughout the growing season. Temperature is likely one of the key factors for spawning stream selection. • 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 in spring because all intermittent drainages were flowing during that period of the year (start of freshet). • Due to the shape of the reservoir basin, only steep shoreline habitats were substantially reduced (by ~50%) at the low pool elevation, which is the habitat type associated with the lowest catch rates of fish during the annual index survey. • In general, the substrate size distribution and interstices in the reservoir drawdown zone are positively correlated with elevation (size range, median size and interstitial space tend to increase with the elevation). • Based on all the habitat data collected, the main factors limiting population size in Downton Reservoir seem likely to be food supply, inundation of spawning habitat during the spawning and incubation period (May to August), and possibly overall spawning habitat area available in the tributaries.

Primary Objectives	Management Questions and Study Hypotheses	Year 9 (2021) Results To-Date
1) To collect comprehensive information on the life history, biological characteristics, distribution, abundance and composition of the fish community in Downton Reservoir, and 2) To provide information required to link the effects of reservoir operation on fish populations to a) document impacts of the operating alternative on existing reservoir fish populations, and, b) allow better future decisions regarding preferred operation of Downton Reservoir.		**H_4: Confirmed**. Implementation of modified operations (from 2016 to 2021) reduced the portion of stream length inundated by the reservoir. Data to define this relationship for several tributaries was collected in Years 6-9 (2018-2021). **H_{4a}: Rejected**. 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, Table 3.7 and Appendix C, Table C2). **H_{4b}: Rejected**. Some tributaries can lose connectivity when reservoir levels are <713 m before the onset of freshet, although primary spawning tributaries have not been affected during the spawning period. **H_5: Rejected**. 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 then put further data collection for these parameters on hold to make budget room for additional tributary fish sampling sessions per year. See the Year 6 report for more details.
	4. Is there a relationship between the minimum reservoir elevation and the relative productivity of fish populations? **H_2:** The annual abundance index for rainbow trout is independent of minimum reservoir elevations observed over the period of monitoring. **H_{2a}:** The annual abundance index for Age-1 rainbow trout is independent of a minimum reservoir elevation effect (sampling year minus 1). **H_{2b}:** The annual abundance index for Age-2 rainbow trout is independent of a minimum reservoir elevation effect (sampling year minus 2). **H_3:** The annual abundance index for rainbow trout is independent of maximum reservoir elevations observed over the period of monitoring. **H_{3a}:** The annual abundance index for Age-1 rainbow trout is independent of a maximum reservoir elevation effect (sampling year minus 1). **H_{3b}:** The annual abundance index for Age-2 rainbow trout is independent of a maximum reservoir elevation effect (sampling year minus 2).	• We undertook to address this MQ by correlating the annual abundance index of rainbow trout (total and age-specific CPUEs) with minimum and maximum reservoir elevations. Year 9 (2021) 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 3.16 (Section 3.6) and Figure F1 (Appendix F). • For minimum reservoir levels, there was a slight correlation with total fish abundance although it was weak (R^2= 0.14). Notably, 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 the *maximum* reservoir levels and total fish abundance (R^2= 0.86) which reflects the positive effect of lower maximum reservoir elevations associated with modified operations. To some extent, annual minimum and maximum reservoir elevations are not independent because the reservoir tended to be drawn lower in the spring during years with a lower target maximum. • Relative to the correlation between maximum reservoir level and the *total* rainbow trout abundance index (CPUE; Figure 3.16), the age-specific correlations (for Age-1 and Age-2 fish) were weaker (see Figure F1 in Appendix F). This is likely because, even though recruitment and overall abundance has increased under modified operations, the population seems to have hit an upper abundance limit (due to various fish production and survival bottlenecks, see responses to MQs #2 and #3, above). As such, increased recruitment and survival of one cohort, which tends to track across years, appears to limit the recruitment and survival of subsequent cohorts due to intra-specific competition. The abundance index of each age class tends to reverberate up and down within the total abundance limit as a result. **H_2, H_{2a}, H_{2b}: Likely Confirmed** based on the relatively weak correlations (i.e., R^2= 0.14 for total abundance; R^2= 0.15 for Age-1 abundance; and R^2= 0.45 for Age-2 abundance) between annual total and age-specific CPUEs coupled with *minimum* reservoir elevation values for the period of monitoring to-date (2013 to 2021). Refer to Figure 3.10, Table 3.19, Figure 3.16 (Section 3.6) and Figure F1 (Appendix F).

Primary Objectives	Management Questions and Study Hypotheses	Year 9 (2021) Results To-Date
		H_3, H_{3a}, H_{3b}: Rejected for *total* abundance based on the relatively strong correlation (R^2= 0.86) with maximum reservoir elevation values for the period of monitoring to-date (2013 to 2021), but **likely Confirmed** for *age-specific* CPUEs for the reasons stated in the points above. Refer to Figure 3.10, Table 3.19, Figure 3.16 (Section 3.6) and Figure F1 (Appendix F).
	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. • 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. • 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). • Depending on inflows in a given year, a*ny* operation that reduces the maximum fill elevation in Downton Reservoir is likely to impact instream flow conditions in the Middle Bridge River as more flow must be passed through La Joie Dam to offset the reduced storage in the reservoir. The lost storage from a reduced maximum elevation cannot be fully offset by a lower minimum elevation. This effect (reduced storage and higher flow conveyance in the Middle Bridge River and elsewhere in the system downstream) has been observed under modified operations. • The compilation of annual fish abundance index, biological characteristics data, and key habitat factors data for all years of the monitoring program have been useful for addressing this MQ; however, it may also require BC Hydro flow modelling for the Middle Bridge River and inflows to Downton Reservoir, which is outside the scope of this program.

Table of Contents

1. Introduction

1.1. Background

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

Given the scope of these data gaps and the schedule of the BRG WUP it was not possible to conduct the required studies within the time available before WUP-based operational decisions needed to be made. As such, these decisions were based upon an extensive amount of qualitative judgment about which habitat and operations-related factors were most important in the regulation of fish population abundance and distribution in Downton Reservoir. To resolve these data gaps and better inform reservoir operating strategies, the Consultative Committee recommended a long term monitoring study to obtain more comprehensive information on local habitats and fish populations. A set of management questions related to fisheries management goals and associated hypotheses regarding potential fish population responses to the selected WUP operations were also defined to provide direction for the study.

The Bridge River Power Development Water Use Plan was accepted by the provincial Comptroller of Water Rights in March 2011. Terms of Reference (ToR) for the Downton Reservoir Fish Habitat and Population Monitoring program were developed and approved by late 2012, and field data collection activities were initiated in 2013. Under the WUP, monitoring for this program is scheduled to continue annually until 2022. Data collection for Year 9 of this proposed 10-year study was completed in 2021.

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).

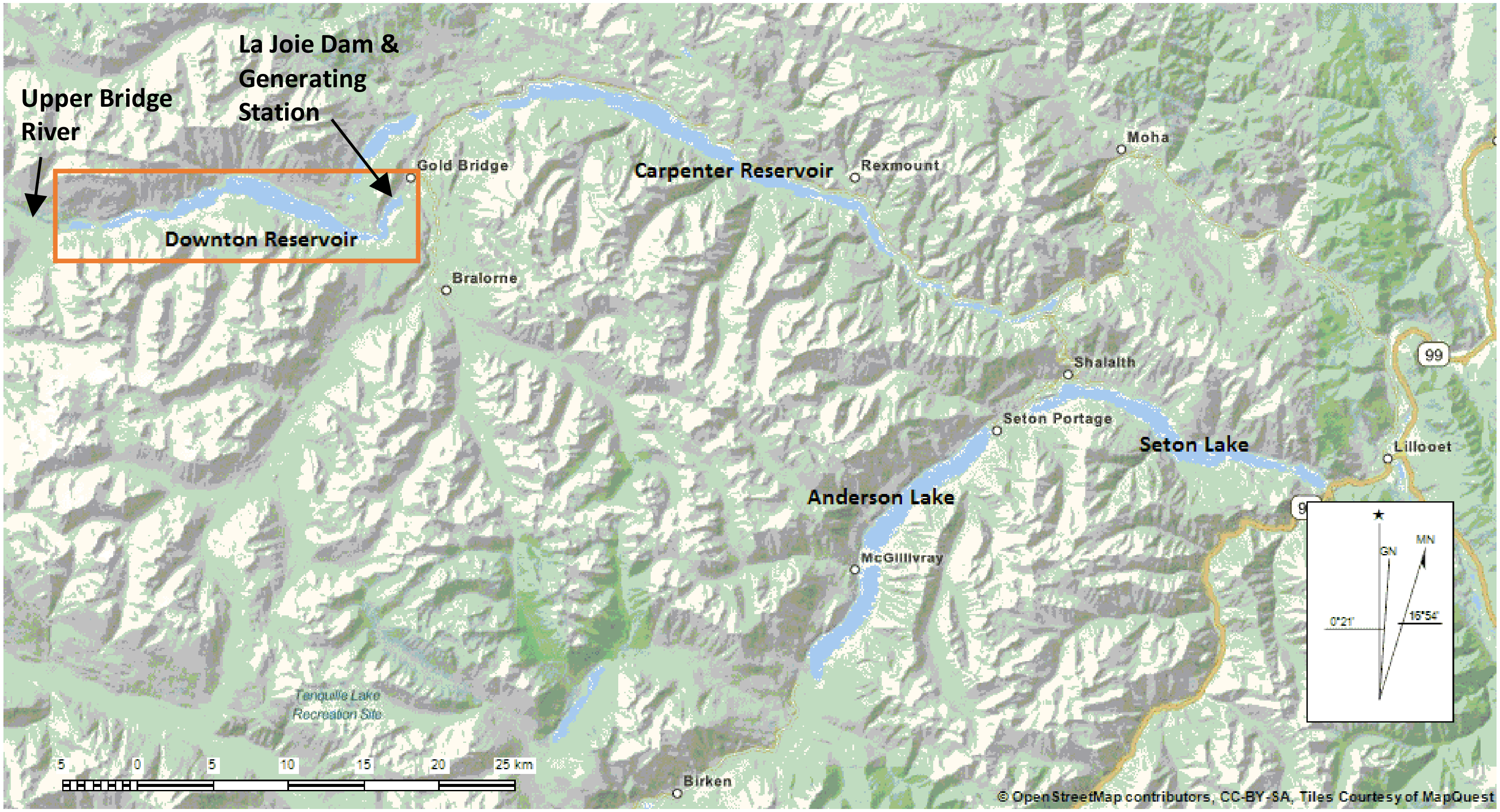

Figure 1.1 Bridge River and Seton River watersheds. The extent of the BRGMON-7 study area, which includes all of Downton Reservoir and tributaries between the Upper Bridge River inflow and La Joie Dam, is outlined by the orange rectangle.

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), Year 8 (2020) and Year 9 (2021). 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 9 (2021) 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)	9 (2021)[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 9 (2021) 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 May/June, a summer session was completed in September, and a fall session was completed in October 2021. 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 9 (2021) 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 (2021) represents monitoring year 9. The general schedule of field sampling activities is presented in Table 1.2.

Table 1.2 Year 9 (2021) Schedule of Field Sampling Sessions and Activities.

Field Sampling Activities	Dates (2021)
Temperature logger deployment & retrieval	4 May; 10 Jun; 21 Jul; 2 Sep; 14 Oct
Tributary Access Surveys	26 May; 9 Jun
Tributary Spawner Surveys	26 May to 28 Jul (weekly)
Tributary Fish Sampling	Spring: 31 May to 2 Jun Summer: 1 to 3 Sep Fall: 13 to 14 Oct
Fish Population Index Survey	3 to 10 Jun

2. Methods

The general approach to this monitoring program has been 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) was 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 has indicated 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 were 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 4 May, checked and downloaded on 10 June, 21 July and 2 September, and retrieved for the end of the monitoring period on 14 October, 2021. The locations of the temperature array and other loggers in the study area are shown on Figure 2.1.

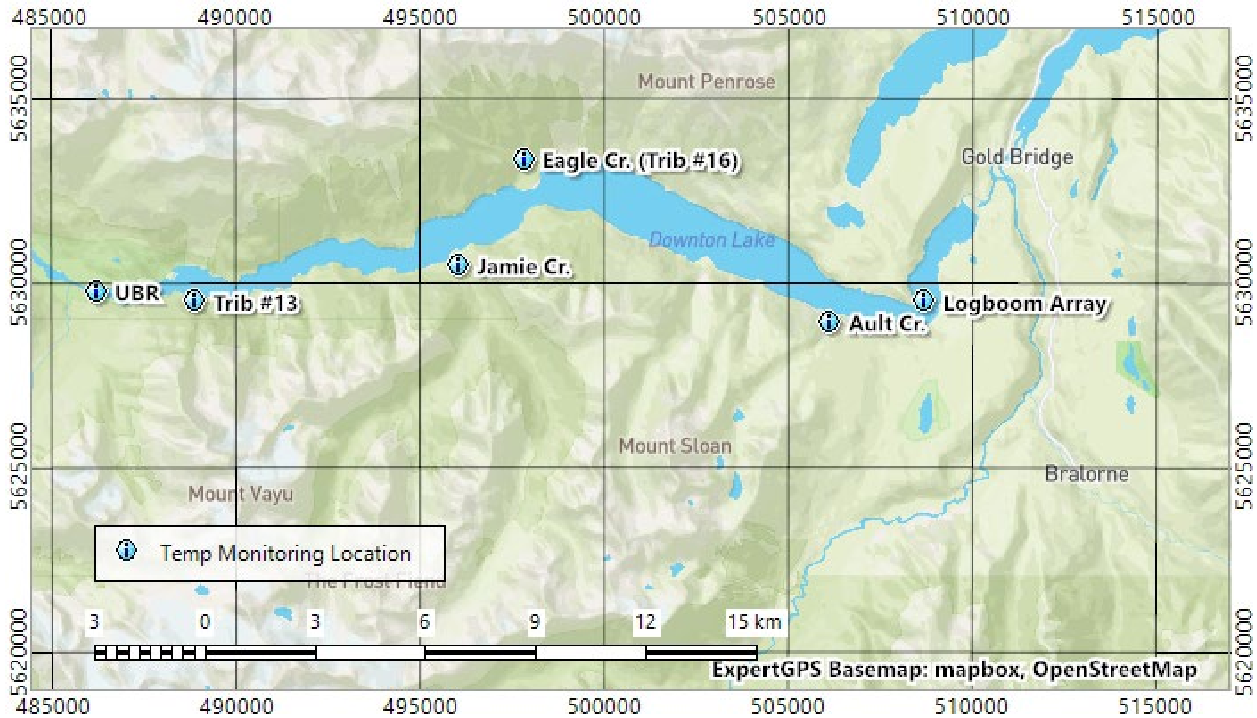

Figure 2.1 Locations of the tributary temperature loggers and the Downton Reservoir logboom temperature array.

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. Maximum 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 continuing since then, 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 has needed 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, and several years since that time) when reservoir elevations were <711 m and creek flows were low (i.e., pre-freshet; see Photo A10 in Appendix A). In these instances, 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).

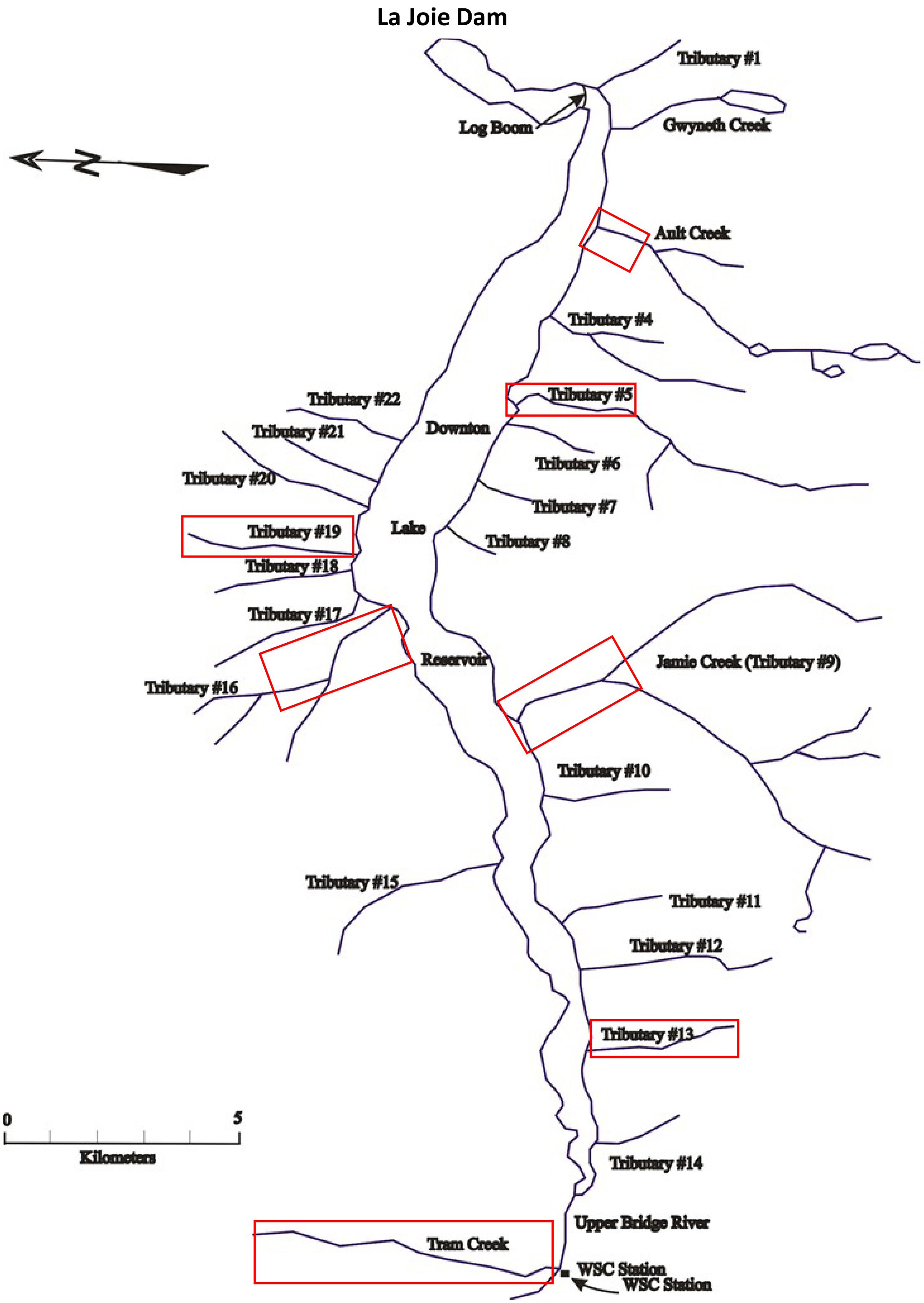

Figure 2.2 Downton Reservoir and the relative location of tributaries. Streams that have been monitored for this program (i.e., tributary access surveys, spawner surveys, and tributary fish sampling) are outlined in red.

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 6-8 (2018 to 2020), stream length was again measured for each assessed tributary during the spawner surveys in Year 9 (2021). 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, 2020 and 2021 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 2021, 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 2019a), 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., falls on Ault Creek), or the stream channel was too overgrown with dense vegetation cover to be sampled effectively (i.e., Paul Creek). In total, 12 tributary sites were sampled in spring (drawdown zone n= 6; upland n= 6), 15 sites were sampled in summer (drawdown zone n= 7; upland n= 8), and 9 sites were sampled in fall (drawdown zone n= 4; upland n= 5). During the spring session, Eagle Creek (upland and drawdown) couldn't be accessed because the reservoir elevation was too low to get there by boat and Tram Creek was inaccessible because the tramway (for crossing the UBR) was out of service for maintenance. Paul Cr, Trib. #19 and Eagle Cr were inaccessible during the fall session due to wood debris accumulation and erosion at the boat launch caused by the higher (>734 m) reservoir levels in 2021, which prevented us from launching the boat.

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 Type XII or 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., to check for 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 8 (2015 – 2020), the index survey in Year 9 (2021) 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 9 (2021) followed a stratified design as described in previous monitoring reports for Year 1 (Sneep 2015), Year 3 (Sneep 2018b), Year 4 (Sneep 2018a), and Year 5 (Sneep 2019b). 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 2019a); 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). Fewer sites were accessible in the west zone during Year 9 (2021) due to slightly lower reservoir elevations at the time of the survey (relative to previous years). As a result, a smaller proportion of sites were sampled in the west zone (*n*= 14) than in the mid and east zones (*n*= 22 and 25, respectively).

The sample timing for the fish index survey in Year 9 (2021) was 3 to 10 June. 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, two key ones of interest for tracking an annual recruitment index were Age 1 and 2 fish which primarily reside in the reservoir year-round. Catches for these fish should not be affected by migrations or potential changes in spawn timing across the study period.

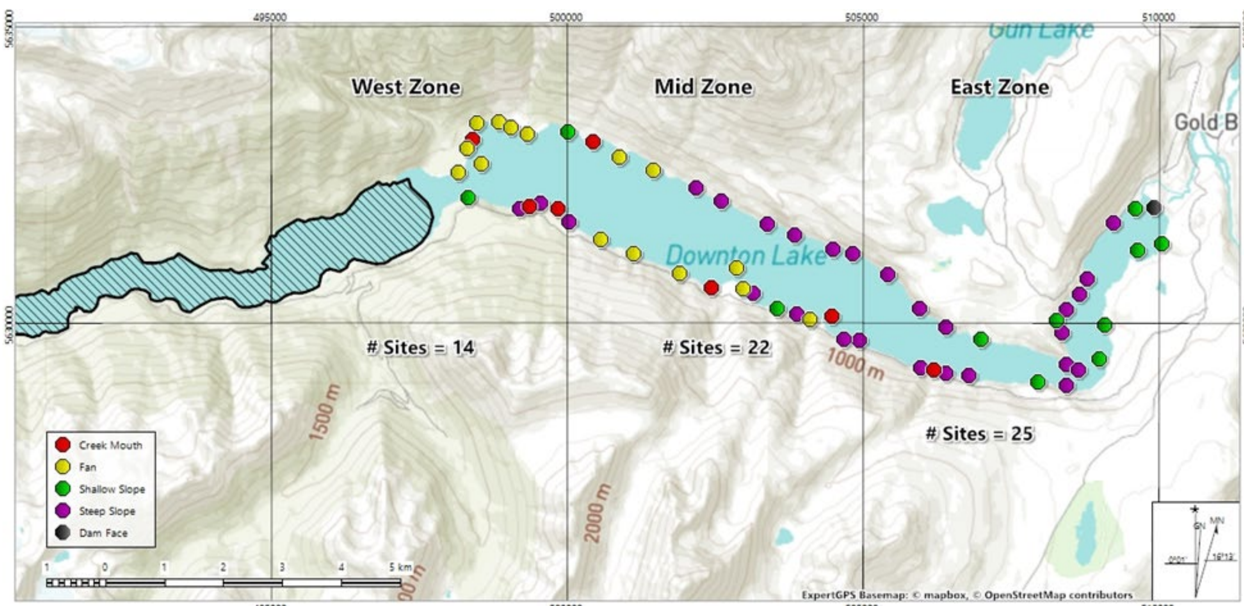

Figure 2.3 The three longitudinal zones (west, mid, and east) and the distribution of sites for the fish population index survey conducted from 3 to 10 June 2021 (between 717 m and 719 m reservoir elevation). Note: The hashed-out area represents the dewatered portion of the reservoir basin at the time of the survey.

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

Boat electrofishing was conducted at night. At each site, the boat was maneuvered to a pre-designated starting point (GPS coordinate) along the reservoir perimeter from which a section of edge habitat was electrofished. The following boat EF settings were used: Electrofisher = Smith-Root 5.0 GPP; Voltage Range = High (50 – 1000 V); % of Power = 20% to 80%; Output = ca. 3 to 5 amps; DC Current Mode; Frequency = 60 DC pulses/sec. A total of 61 sites were sampled in 2021 (creek mouth *n*= 7; fan *n*= 15; shallow *n*= 11; steep *n*= 28) covering 17,230 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 5-9 (2017–2021) Downton Reservoir fish population index surveys to assess the incidence of fish mortality and tag loss 24-hours post-capture.

As part of the analyses of the fish population index survey data, we also calculated annual growth curves based on the median size (from the forklength data) of each age class (determined by scale ageing – see Section 2.6). We used Akaike Information Criterion (AIC) and Schwarz Criterion (SC) scores to distinguish among a set of possible models describing the relationship between fish size and age in the program Growth II (Henderson and Seaby 2006). The 4-parameter Logistic model was selected based on the closeness of fit of the points to the model and the number of parameters used by the model (reflected as the lowest AIC and SC scores), and because it allows for a non-zero lower asymptote. The 4-parameter logistic growth equation is as follows:

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

Where:

L_t is Length at Age $_t$;
α is the lower asymptote
L_∞ is the upper asymptote;
k is the growth rate; and
δ is a shape parameter that determines the steepness of the rising curve.

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

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

Where:

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

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

2.6. Laboratory Analysis

Following a period of air drying, 203 rainbow trout scale samples were mounted by St'at'imc Eco-Resources technicians (Christina Shaw and Cliff Leslie) 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 195 of the mounted samples (8 were noted as un-readable due to poor condition or too much scale regeneration) 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 2021 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 SER technicians (Christina Shaw and Cliff Leslie). 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 8 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 2021, which are illustrated in Figure 3.1. Daily surface elevations for monitoring years 1 to 8 (2013 to 2020; coloured according to “N2-2P” and “Modified Operations” regimes) are also included for reference.

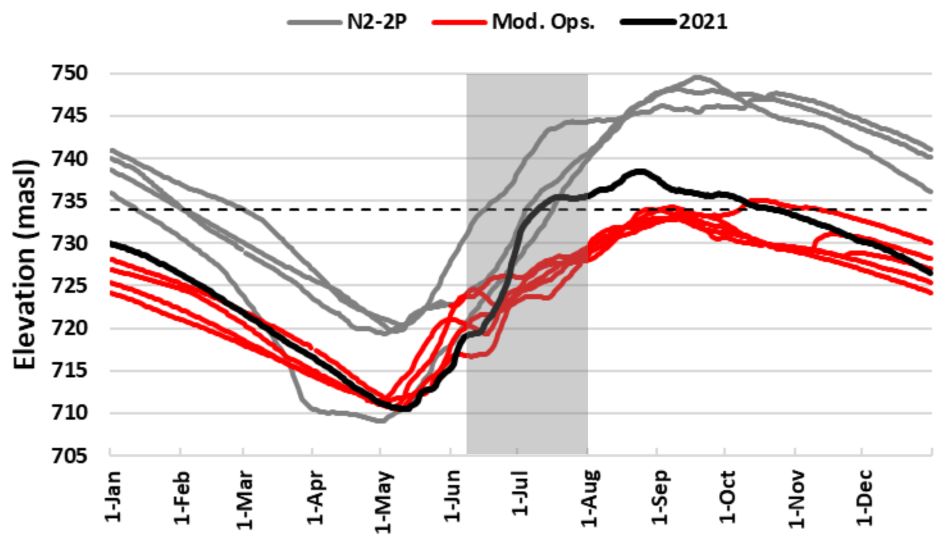

Figure 3.1 Daily surface elevations in Downton Reservoir showing years under “Normal” N2-2P Operations (2013-2015) vs. Modified Operations (2016-2021). The current year (2021) is shown as a black line for reference. The shaded area represents the observed rainbow trout spawning period. The horizontal dashed line indicates the *target* modified maximum fill elevation (i.e., 734 m).

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 (generally 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 have been 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.

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, 8 and 9 (2017 to 2021); however, maximum elevations in 2021 (i.e., 738.49 m; Figure 3.1) exceeded the target by nearly 4.5 m due to higher inflows that year. Surface elevations at the start of the rainbow trout migration and spawning period in 2021 were on par with other modified operations years (i.e., ~720 m) but a period of particularly high inflows (resulting from record high ambient temperatures) occurred in late June and early July 2021 and are reflected by the steep increase in reservoir levels shown for that period in Figure 3.1. As a result, the reservoir had filled ~7 m higher by the end of the spawning period in late July relative to the other modified operations years.

Outside of this period, reservoir operation in winter, spring and fall 2021 followed a generally similar trajectory as the other modified operations years. At the start of 2021, reservoir elevation was 730.0 m as it was drawing down from the 2020 maximum fill level of 735.1 m. The mean drawdown and fill rates for the reservoir were -12 cm/day and +29 cm/day, respectively (Table 3.1). Lowest reservoir elevation (i.e., 710.5 m) occurred from 10 to 12 May, and summer full pool elevations occurred across the month of August 2021 (max. = 738.5 m from 23 to 26 August). The reservoir had been drawn down to 726.5 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 9 (2013 to 2021). 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)	719.7	749.5	29.8	-15	-21	+23	+73
2 (2014)	709.0	748.2	39.2	-20	-80	+31	+81
3 (2015)	720.4	747.0	26.6	-14	-30	+33	+58
N2-2P Averages	**716.4**	**748.3**	**31.9**	**-16**	**-44**	**+29**	**+71**
4 (2016)	719.4	733.9	14.6	-14	-28	+12	+55
5 (2017)	711.5	733.5	22.0	-9	-29	+17	+69
6 (2018)	711.3	733.0	22.7	-10	-22	+19	+67
7 (2019)	710.7	733.5	22.8	-9	-17	+17	+73
8 (2020)	710.4	735.1	24.7	-10	-22	+16	+83
9 (2021)	710.5	738.5	28.0	-12	-24	+29	+102
Mod. Ops. Averages	**710.9**	**734.7**	**23.8**	**-11**	**-24**	**+18**	**+75**

[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 28 m in 2021, which was higher than the other modified operations years mostly due to the difference in maximum elevation (i.e., 3.4 to 5.5 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 2021 minimum elevation (710.5 m) was most similar to 2014 (709.0 m), 2017 (711.5 m), 2018 (711.3 m), 2019 (710.7 m) and 2020 (710.4 m), and ~8 to 9 m lower than the other study years. The mean drawdown rate (-12 cm/day) was similar to the other modified operations years (i.e., 2016-2020), whereas the mean fill rate (+29 cm/day) was on par with the normal operations years (2013-2015) due to the rapid filling in June.

The change from normal maximum fill elevation of 749.81 m to 734.00 m (target) 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 has provided ample contrast for assessing the fish population response across the period of monitoring. However, the limited number of 'normal' N2-2P operations years monitored 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 2021) are provided in Appendix B (Figures B1 and B2).

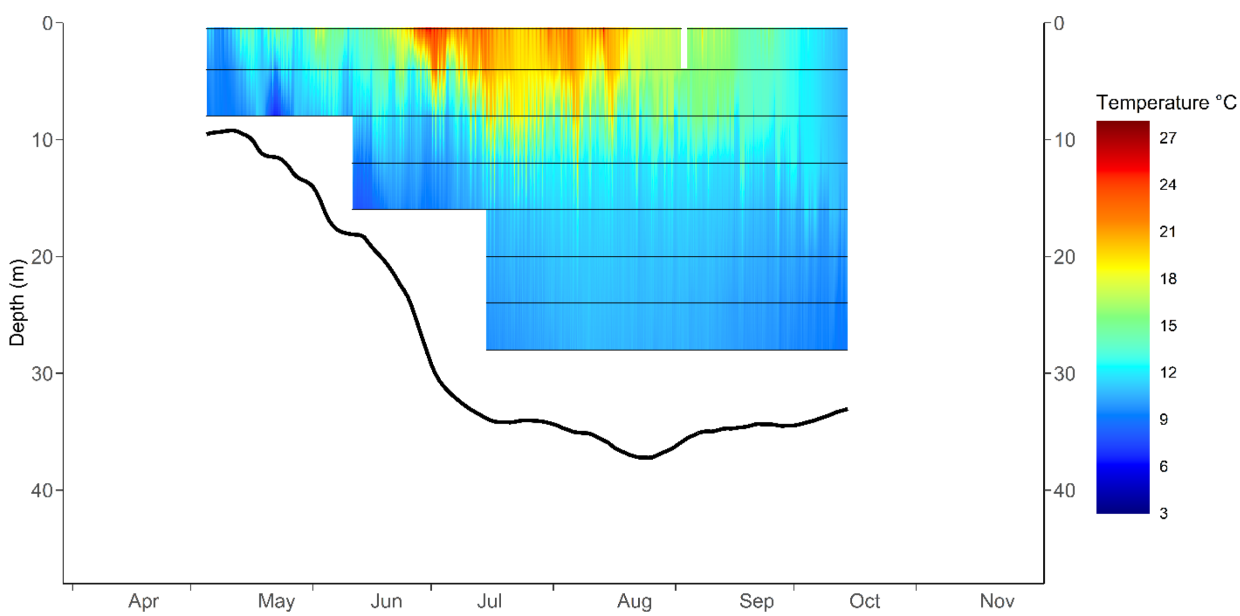

Figure 3.2 Water temperature profile recorded in Downton Reservoir at the log boom (see Figure 2.1 for location) from May to October 2021. The horizontal lines indicate the measurement depths. Temperatures between those depths were linearly interpolated. The solid black line references the reservoir 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 9 (2021), mean daily surface temperatures increased from 9.7°C to 16.7°C across the month of May, and then decreased to 13.5°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 spiked across the remainder of June, peaked at 25.0°C on 30 June (the highest recorded to-date), and then gradually cooled to 10.6°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 7.8°C and 11.8°C, throughout the monitored period. Other than a higher peak surface temperature in 2021, and widely variable surface temperatures during the snow melt period in June and the first half of July, the temperature patterns described for 2021 were generally similar to those reported for previous years (Figure 3.3; Appendix B, Figure B1; Sneep 2022).

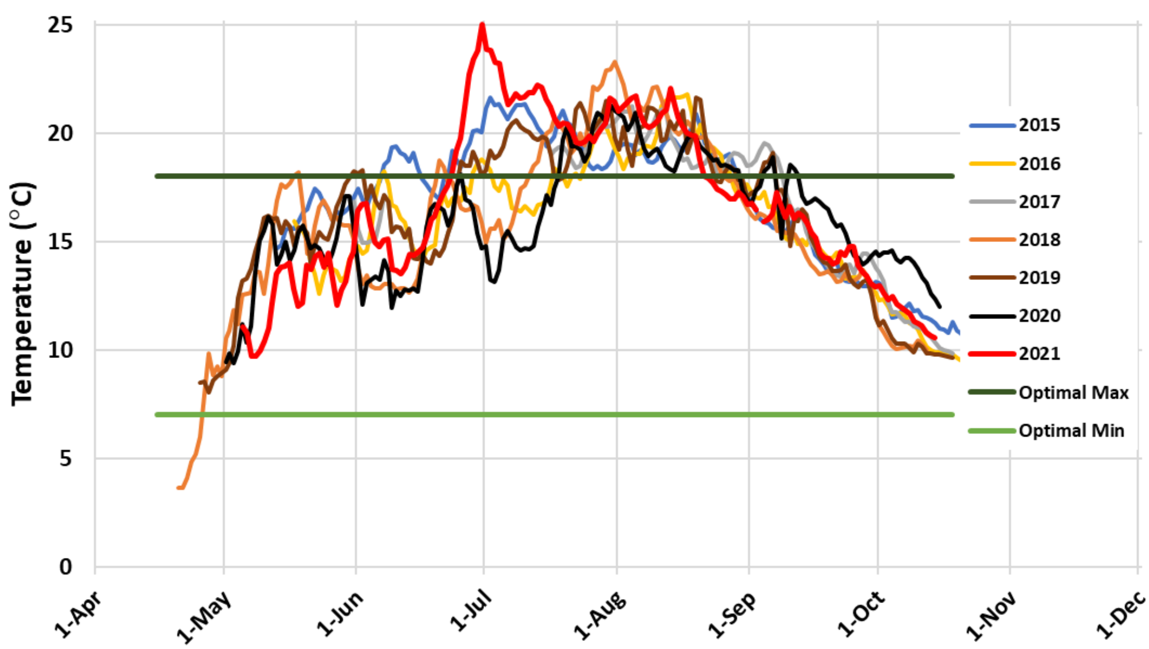

Figure 3.3 Mean daily reservoir surface temperatures during the April to October monitoring period by study year (2015 to 2021). The light and dark green horizontal lines bracket the preferred temperature range for key life history stages of rainbow trout (McPhail 2007).

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., typically 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 8.6°C (in the UBR) to 14.4°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 much of 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. 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).

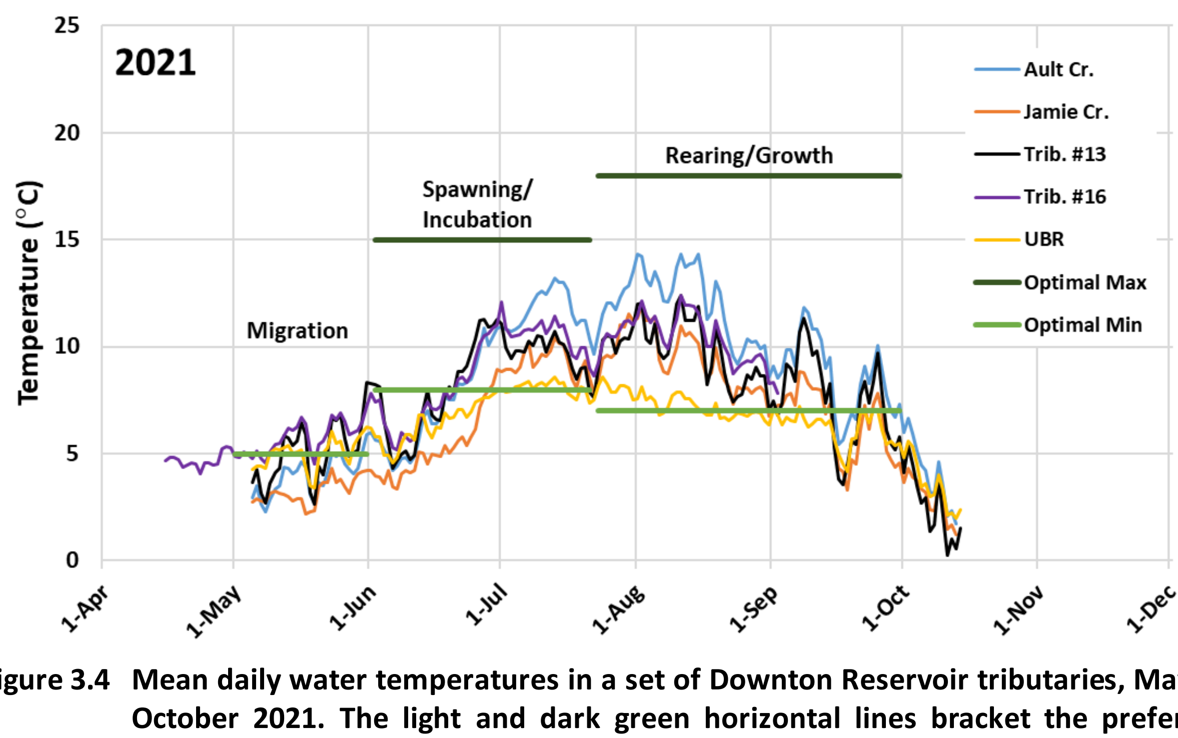

Figure 3.4 Mean daily water temperatures in a set of Downton Reservoir tributaries, May to October 2021. The light and dark green horizontal lines bracket the preferred temperature range for key life history stages of rainbow trout (McPhail 2007).

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 9 (2021) 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 seven years available to-date, mean temperatures in the known spawning creeks (e.g., Tribs. #13 and #16) varied by up to 2°C during both the Pre-Spawn/Migration and Spawning/Incubation periods among years. 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 2022). 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, 2020 or 2021 (according to the creek) so far, but were generally quite similar among years (means varied by 0.1°C to 1.3°C).

Table 3.2 Mean Water Temperatures in Downton Reservoir tributaries by Season/Life History Period (for rainbow trout) among the available study years.

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	-
	2021	5.1	7.1	6.9	6.7
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
	2021	3.4	6.9	8.2	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	-
	2021	5.5	8.6	8.8	8.3
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	-
	2021	6.1	8.9	10.4	9.0
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
	2021	4.3	9.0	10.6	9.2

[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.

Continued…

Table 3.2 (Continued). Mean Water Temperatures at the surface of Downton Reservoir by Season/Life History Period (for rainbow trout) among the available study years.

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
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
	2021	13.5	19.0	17.8	17.7

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

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 (2015 to 2021). 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. Peak emergence timing in 2021 was shifted earlier by 1-2 weeks relative to previous years, likely due to the more rapid warm up of creek temperatures at the end of June related to record high ambient temperatures. However, the predicted start and end timing in 2021 was not substantially different than other years.

The emergence timing 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 or beginning of September in 2017, 2019, 2020 and 2021 (see Section 3.5 and Sneep 2022). The incubation period has ranged from a minimum of 46 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 typically varying by only 1 to 8 days between years (2021 being an exception as noted above).

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., end of August or beginning of September) were still available in the sampled creeks during the fall session (i.e., mid October) and ranged from 22 to 55 mm by that time (see Section 3.5).

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)
	2021	25 Jul (56)	9 Aug (48)	8 Sep (50)
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)
	2021	24 Jul (55)	7 Aug (46)	5 Sep (47)

[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 9 (2021) were conducted on 26 May and 9 June, to target the rainbow trout spawner migration period. Reservoir elevations on these dates were ~714 m and ~719 m, respectively. Across the duration of the rainbow trout spawning period, the reservoir filled from 716 m in early June to 735 m by the end of July (i.e., an elevational increase of 19 m). The creeks visited in Year 9 (2021) included: Ault Creek, Paul Creek, Cathy Creek, Jamie Creek, Trib. #10, Trib. #13, Eagle Creek and Trib. #19 (Table 3.4; refer to Figure 2.2 for the location of each creek).

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 (2021 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 (Eagle Cr)	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 26-May-21	TRUE [c]	TRUE	TRUE	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 16-Jun-20	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
719 m	9-Jun-21	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
720 m	24-May-18 15-Jun-18	TRUE	TRUE	TRUE	FALSE [d]	TRUE	TRUE	TRUE	TRUE
721 m	6-May-15	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
722 m	18-May-16 23-Jun-17	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
729 m	4-Jun-15	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE

[a] Reservoir longitudinal zone as described in Section 2.5.
[b] "-" means the tributary access could not be assessed on this survey date due to avalanche hazard 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 when surveyed on 15 May 2019. The creek was more fully connected when it was surveyed at this elevation on 26 May 2021.
[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 9 (2021) minimum elevation of 710.5 m (on 11 May) was within the range of minimum elevations observed in Year 2 (2014; 709.0 m), Year 6 (2018; 711.3 m), Year 7 (2019; 710.7 m) and Year 8 (2020; 710.4 m), when Ault Creek was observed flowing to ground before reaching the reservoir edge (see Photo A10 in Appendix A). This was again observed in 2021 when Ault Creek was visited on 4 May for temperature logger installation and reservoir elevation was 711 m. However, each of the dates when potential access issues were observed (8 May 2014, 19 April 2018, 24 April 2019, 30 April 2020, and 4 May 2021) 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 by the start of the spawning surveys and beyond during 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 (i.e., <714 m) to further corroborate this finding. 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 to 9 (2019-2021). 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 target (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 any of the survey dates during the monitoring years to-date.

3.4. Tributary Spawner Surveys

In Year 9 (2021), weekly spawner surveys were conducted across a 9-week period from 26 May to 28 July. A consistent set of repeat surveys were conducted in Trib. #13, Jamie Creek, Cathy Creek (Trib. #5), and Ault Creek throughout the 2021 spawning period. Eagle Creek (Trib. #16), Trib. #19 and Tram Creek could not be monitored consistently in Year 9 due to access issues (e.g., low reservoir elevation or access blockages). As shown in Table 3.5, in-water visibility conditions in 2021 were variable among surveys. They were rated fair or poor on several survey dates (see Section 2.3 for definition of these qualitative terms) due to the effects of freshet flows on visibility conditions in the creeks. Discharges changed from low to very high (related to a spate of very hot weather in June and early July) and then to moderate across the monitored period. Reduced visibility conditions are known to affect the efficacy of the streamwalk spawner count method and this was a factor in at least some creeks on 7 of 9 surveys in 2021. As such, peak counts likely represented minimum estimates for this year.

Based on the 2021 weekly counts, spawners first started arriving in identified spawning streams at the beginning of June (Table 3.5). This was on par with the arrival timing noted in previous years (Sneep 2022; Sneep 2020; Sneep 2019a). Peak timing in 2021 was on 23 June which was the last survey before the large run-off event at the end of June that washed out the Bridge-Main FSR and altered the stream channel on some creeks (most notably Trib. #13). A sudden drop in spawner counts occurred after this period, but the latest spawners were observed on the 21 July survey. As in previous years, this temporal distribution represented an approx. 8- to 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 9 (2021). Cell colour reflects visibility conditions for each survey (good = green; fair = yellow; poor = red).

Week	2021 Survey Dates	Ault Cr. [a]	Cathy Creek			Jamie Creek			Trib. #13		
		n [b]	*n*	DS %	US %	*n*	DS %	US %	*n*	DS %	US %
1	26 May	0	0			0			0		
2	02 Jun	2	1	100%		1	100%		1	100%	
3	16 Jun	-	0			2	100%		2	100%	
4	23 Jun	21	6	100%		7	100%		15	87%	13%
5	30 Jun[c,d]	0	0			0			-		
6	07 Jul	0	0			0			2		100%
7	14 Jul[d]	0	3	100%		0			-		
8	21 Jul	0	0			0			6	83%	17%
9	28 Jul	0	0			0			0		
Peak *n* & Total %		**21**	**6**	**100%**	**0%**	**7**	**100%**	**0%**	**15**	**81%**	**19%**

[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.

[c] Extremely poor visibility conditions on 30 Jun survey. Creeks were in very high flow condition due to spate of record high air temperatures which also affected counts on subsequent surveys in 2021.

[d] Could not access Trib. #13 on this survey date due to road washouts on the 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 19-73 spawners from Years 2 to 8 (annual max. *n*= 50, 19, 57, 30, 33 and 73 for 2014, 2015, 2016, 2018, 2019 and 2020, respectively). The peak count in Year 9 (2021; *n*= 15) was the lowest 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 Years 8 or 9 (2020 or 2021) 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.

For assessing any potential trend in overall spawner counts we fitted a regression for all data points across monitoring years (excluding Year 1 since the surveys were conducted by a different contractor that year). The regression line was nearly flat (slope = -0.02) with a very low R^2 value (0.000004). This result was either indicative of no change overall across the period of monitoring or reflects that the method was ineffective for detecting a change (e.g., because counts were uncalibrated by a method such as mark-resight which can help account for changes in visibility conditions and different observers among surveys and years).

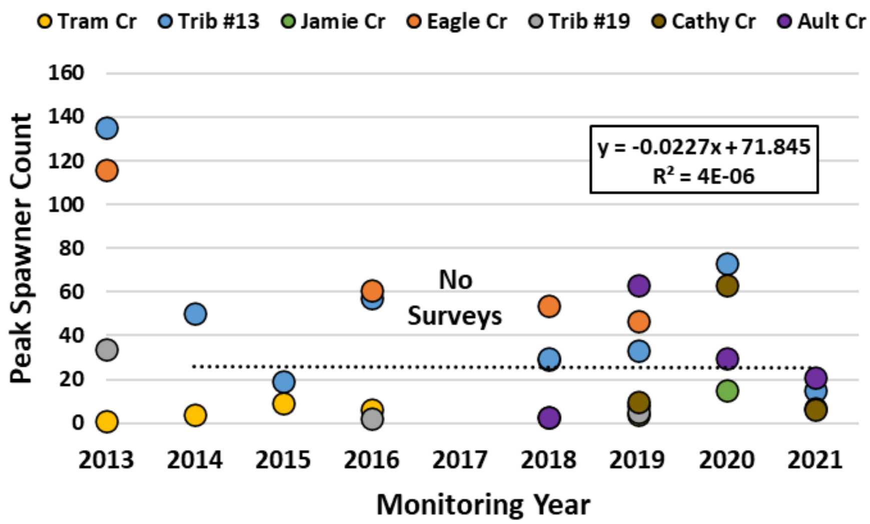

Figure 3.5 Peak spawner counts (coloured dots) in surveyed tributaries for BRGMON-7 monitoring years 1 to 9 (2013 to 2021) and regression (dotted line) for all counts among years (excluding 2013 which were done by a different contractor). Note: Spawner counts were not conducted in Year 5 (2017) – see 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 9 (2021) 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 Years 8 and 9 (2020 and 2021). In Ault Creek, the peak counts from 2019 to 2021 were 63, 30 and 21 spawners, respectively. The 2019, 2020 and 2021 peak counts in Cathy Creek were 10, 63 and 6 spawners, 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 from 2018 to 2021 (by the BRGMON-7 program). The number of observed spawners was consistently low (annual max. *n*= 2-15) during each of those years, and Jamie Creek was generally characterized by fair or poor visibility conditions for all surveys. As noted above, the general trend of spawner observations among years has remained relatively stable since 2014 with certain creeks (i.e., Eagle Creek and Trib. #13) remaining dominant spawning tributaries 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 2021 proportions suggested a mean of ~93% used the drawdown zone vs. 7% in the upland, overall. Actual proportions for each 2021 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, 8 and 9 (2018-2021) (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 2021) these values were 719.0 m and 728.7 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 163.8 m (or 43%) under modified operations. For steeper streams, such as Ault Creek, the total drawdown stream length was reduced by an average of 126.8 m (or 83%) under normal operations versus an average of 111.4 m (or 57%) 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.

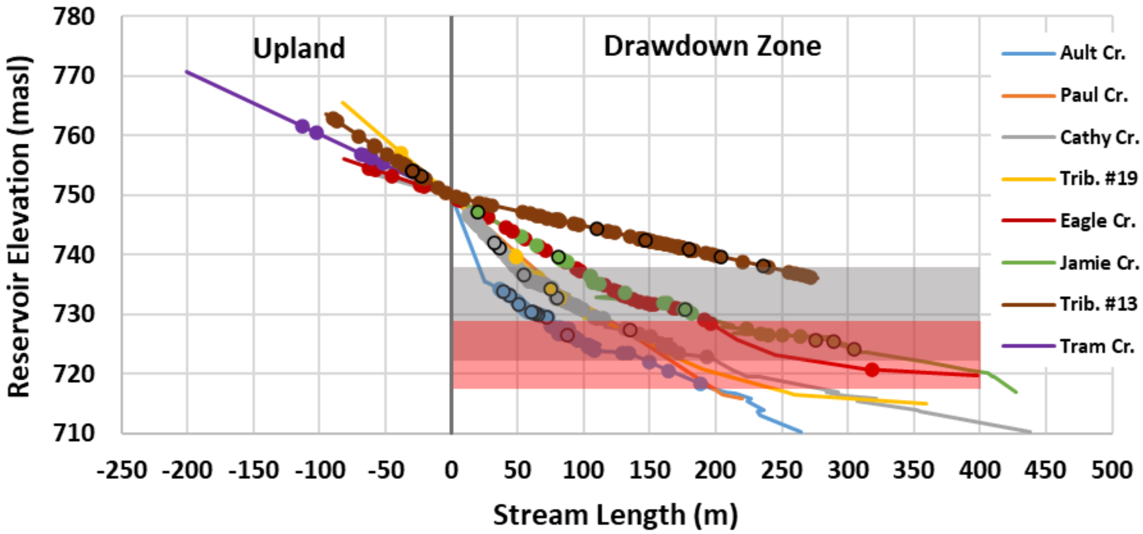

Figure 3.6 Distribution of rainbow trout spawner observations (dots) along the longitudinal sections (lines) of each surveyed tributary to Downton Reservoir from Year 7 to 9 (2019 to 2021). Year 9 spawner observations are outlined in black. The vertical grey line represents the top of the drawdown zone (value of 0 on the x-axis). The colour-shaded areas represent the minimum and maximum reservoir elevation ranges during the rainbow trout spawning period for "Normal" (N2-2P; grey) and Modified (red) operations. The overlap is represented by the darker red area.

Table 3.6 Minimum and maximum 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	
		Min	Max	Diff.	Eagle Cr.	Ault Cr.
1 (2013)	21 May to 15 Jul	722.3	736.9	14.6	63%	81%
2 (2014)	22 May to 15 Jul	714.6	733.5	18.9	68%	85%
3 (2015)	4 Jun to 17 Jul	729.2	743.5	14.3	74%	84%
Normal Operations Averages		**722.0**	**738.0**	**16.0**	**68%**	**83%**
4 (2016)	19 May to 20 Jul	722.1	725.2	3.1	20%	29%
5 (2017)	1 Jun to 20 Jul [a]	718.0	727.7	9.7	49%	58%
6 (2018)	5 Jun to 25 Jul	719.4	728.0	8.6	50%	58%
7 (2019)	4 Jun to 23 Jul [b]	723.2	728.5	5.3	20%	45%
8 (2020)	28 May to 22 Jul	715.4	727.3	11.9	49%	65%
9 (2021)	2 Jun to 21 Jul	715.9	735.5	19.6	72%	89%
Modified Operations Averages		**719.0**	**728.7**	**9.7**	**43%**	**57%**

[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, 2020 and 2021 (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 2019-2021). Under modified operations, these percentages were reduced to 15% and 30%, 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	Min. Reservoir Elevation (m)	Max. Reservoir Elevation (m)		% Inundated [b]	
		Spawning	Incubation	Spawning	Incubation
1 (2013)	722.3	736.9	745.8	44%	82%
2 (2014)	714.6	733.5	745.6	31%	81%
3 (2015)	729.2	743.5	745.4	66%	69%
Normal Operations Averages				**47%**	**77%**
4 (2016)	722.1	725.2	732.6	2%	28%
5 (2017)	717.9	727.7	731.2	10%	23%
6 (2018)	719.4	728.0	732.0	11%	26%
7 (2019)	723.2	728.5	731.8	10%	25%
8 (2020)	715.4	727.3	732.1	9%	27%
9 (2021)	715.9	735.5	736.3	51%	51%
Modified Operations Averages				**15%**	**30%**

[a] Based on spawner observations documented in 2019 - 2021. 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 2021). 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.

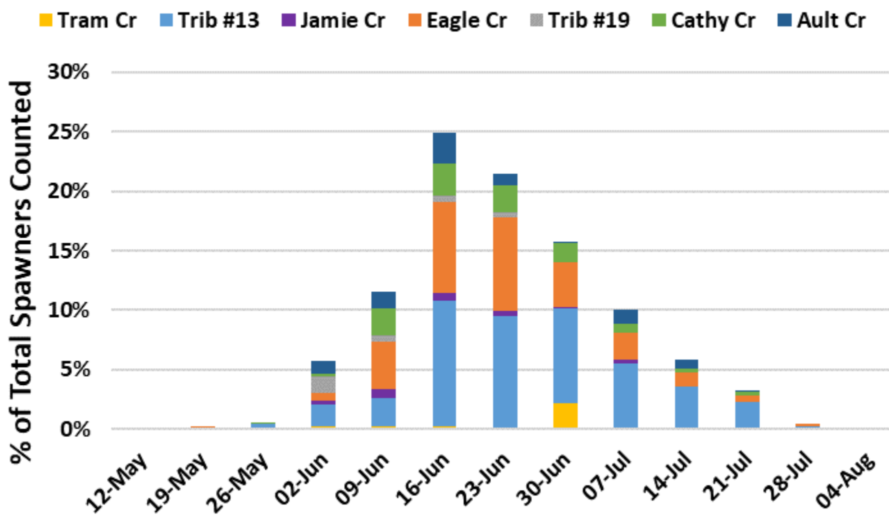

Figure 3.7 % Contribution of weekly spawner counts to the total across the monitoring period, all study years combined. Relative proportions by tributary are included. Dates on the x-axis are typical or representative of the weekly spawner survey interval; however, actual dates have varied slightly (+/- 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 (31 May to 2 Jun; *n*= 12 sites), summer (1-3 Sep; *n*= 15 sites), and fall (13-14 Oct; *n*= 9 sites) in 2021, 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 Years 7 & 8 (2019, 2020; spring, summer and fall) (Sneep 2022). Water clarity varied from good to fair and poor among tributaries during each seasonal survey (as noted in Table 3.8). As in all previous years, the visibility was chronically poor at the Upper Bridge River sites, and either fair or poor in Jamie Creek. However, visibility was also generally poorer at more creeks than usual during the spring session in 2021 due to the onset of snow melt and high flows.

As noted in past reports, fish presence and abundance differed among tributaries, and elevation zones within tributaries, during each season. In 2021, total catch-per-unit-effort (CPUE) was lowest in spring (2.8 ±1.1 fish/100 m), highest in summer (16.0 ±5.1 fish/100 m), and moderate in fall (4.1 ±2.5 fish/100 m). 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 2021, the highest CPUE values were in the drawdown and upland zones of Eagle Creek (56.7 fish/100 m in each zone), in Tram Creek (upland; 36.7 fish/100 m), and the drawdown zone of Cathy Creek (29.0 fish/100 m) during the summer session. Highest CPUEs in spring and fall were in the drawdown zone of Trib. #13 in both cases (13.3 and 23.3 fish/100 m, respectively). Also, a greater number of tributaries had higher CPUE values in summer: catches at 7 of 15 sites (47%) were >10 fish/100 m, whereas this was the case at only 1 of 9 sites (11%) in fall and and 1 of 12 sites (8%) in spring. Note: this percentage (and total CPUE) in fall 2021 would likely have been higher, but access issues precluded sampling at several sites that have had moderate or high catches in fall during previous years (i.e., Eagle Creek, Trib. #19, Paul Creek, and Tram Creek).

Typically, the creeks with the highest catches have been documented as spawning tributaries for Downton Reservoir rainbow trout. For example: catches in Eagle Creek, typically one of the primary spawning tributaries (see Section 3.4), were substantially higher than in any other creek during summer when the new year class of fry was available. Catches of young-of-year fry in Tram, Cathy, Paul and Ault creeks in early September 2021 also confirmed use of these tributaries for spawning and corroborated the predicted emergence timing window provided in Table 3.3.

Table 3.8 Summary of backpack EF effort and catch in Downton Reservoir tributaries during spring, summer and fall 2021. All captured fish were rainbow trout. Cell colour reflects visibility conditions for each survey (good = green; fair = yellow; poor = red).

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	193	2	6.7
	Mid	Paul Cr.	Drawdown	30	226	0	0.0
		Cathy Cr.	Drawdown	30	198	0	0.0
			Upland	30	174	0	0.0
		Trib. #19	Drawdown	30	297	1	3.3
			Upland	30	232	0	0.0
	West	Jamie Cr.	Drawdown	30	212	1	3.3
			Upland	30	179	0	0.0
		Trib. #13	Drawdown	30	271	4	13.3
			Upland	30	198	1	3.3
		UBR-1	Upland	30	254	1	3.3
		UBR-2	Upland	30	195	0	0.0
Spring Totals				**360**	**2,629**	**10**	**2.8 (SE ±1.1)**
Summer	East	Ault Cr.	Drawdown	8		2	23.8
	Mid	Paul Cr.	Drawdown	30		2	6.7
		Cathy Cr.	Drawdown	21		6	29.0
			Upland	30		2	6.7
		Trib. #19	Drawdown	30		0	0.0
			Upland	30		0	0.0
	West	Eagle Cr.	Drawdown	30		17	56.7
			Upland	30		17	56.7
		Jamie Cr.	Drawdown	30		0	0.0
			Upland	30		0	0.0
		Trib. #13	Drawdown	30		2	6.7
			Upland	30		3	10.0
		Tram Cr.	Upland	30		11	36.7
		UBR-1	Upland	30		4	13.3
		UBR-2	Upland	30		1	3.3
Summer Totals				**419**	**N/A**	**67**	**16.0 (SE ±5.1)**
Fall [b]	East	Ault Cr.	Drawdown	17		0	0.0
	Mid	Cathy Cr.	Drawdown	17		1	5.9
			Upland	30		1	3.3
	West	Jamie Cr.	Drawdown	30		0	0.0
			Upland	30		0	0.0
		Trib. #13	Drawdown	30		7	23.3
			Upland	30		1	3.3
		UBR-1	Upland	30		0	0.0
		UBR-2	Upland	30		0	0.0
Fall Totals				**244**	**N/A**	**10**	**4.1 (SE ±2.5)**

[a] Sampling could not be conducted in Eagle Cr. or Tram Cr. during the spring session in 2021 because they were inaccessible.

[b] Paul Cr, Trib. #19 and Eagle Cr were inaccessible during the fall session due to wood debris accumulation and erosion at the boat launch caused by the higher (>734 m) reservoir levels in 2021.

Thirty-six fish from the tributary catch in 2021 were a tag-able size (≥80 mm): 33 were newly marked with PIT tags, and two were recaptures (Table 3.9). Both of the recaptured fish were caught in the same stream 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 were 42 days (spanning adjacent seasons in the same year) and 685 days (spanning different years).

Table 3.9 Summary of rainbow trout recaptures during tributary fish sampling in monitoring Year 9 (2021).

Tag Code	Original Capture Data				Recapture Data				Days-at-Large
	Season	Date	Trib.	Zone	Season	Date	Trib.	Zone	
980028	Summer	17 Oct 2019	Cathy Cr.	Drawdown	Summer	1 Sep 2021	Cathy Cr.	Upland	685
561140	Summer	2 Sep 2021	Trib. #13	Drawdown	Fall	14 Oct 2021	Trib. #13	Drawdown	42

The ages of captured fish ranged from Age-0+ to Age-4 in both spring and summer, and from Age-0+ to Age-3 in fall (Table 3.10; Figure 3.8). Three fish in Trib. #13, two fish in Ault Creek, one fish in Trib. 19, and one fish in Jamie Creek (all ranging in age from 1 to 4) captured during the spring sampling in 2021 were sexually mature and in some stage of pre-spawning condition (4 males, 3 females; 4 green, 1 gravid, 2 ripe). The remainder of the fish sampled in each season were assessed as either sexually immature (*n*= 72) or mature (*n*= 8) based on size or age, but were not in spawn-ready condition at the time of sampling.

The new year class of recently emerged fry made up the bulk of the catch in both summer and fall (i.e., *n*= 39 or 58%, and *n*= 6 or 60%, 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). Fish older than Age-0+ collectively comprised a smaller proportion of catches in the tributaries.

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 2021.

Age	Season	n	Forklength (mm)		CPUE (fish/m)·100
			Min.	Max.	
0	Spring	2	39	76	0.5
	Summer	39	21	35[a]	10.7
	Fall	6	22	43[a]	2.1
1	Spring	2	112	139	0.5
	Summer	12	59	105	2.8
	Fall	2	92	102	0.7
2	Spring	2	187	210	0.7
	Summer	11	109	177	2.6
	Fall	1	176	176	0.4
3	Spring	2	220	270	0.7
	Summer	4	181	272	1.0
	Fall	1	262	262	0.3
4	Spring	2	270	280	0.5
	Summer	1	278	278	0.2
	Fall	0			0.0

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

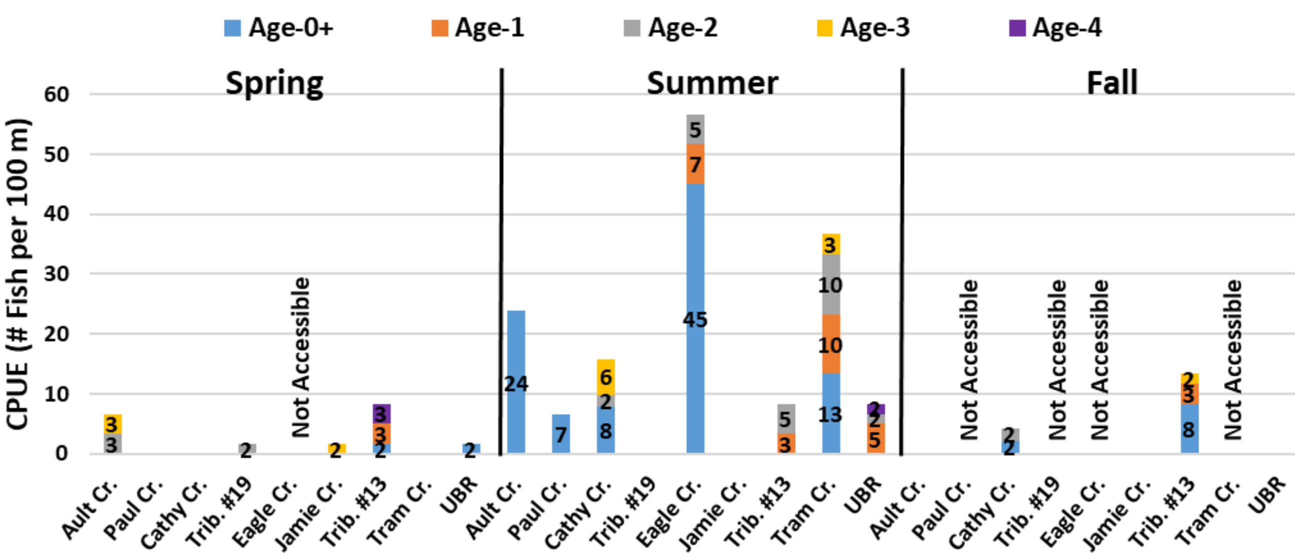

Figure 3.8 Catch-per-unit effort (fish/100 m) by age class for each sampled tributary based on the results of backpack electrofishing surveys in spring, summer and fall 2021.

A summary of average CPUE in the tributaries by year for each season is shown in Figure 3.9. As is apparent from this figure, lowest CPUEs have routinely occurred during spring, highest CPUEs have most typically occurred in summer (with a few exceptions when sample timing preceded the end of the emergence period), and moderate to high CPUEs have occurred during fall among the available years to-date.

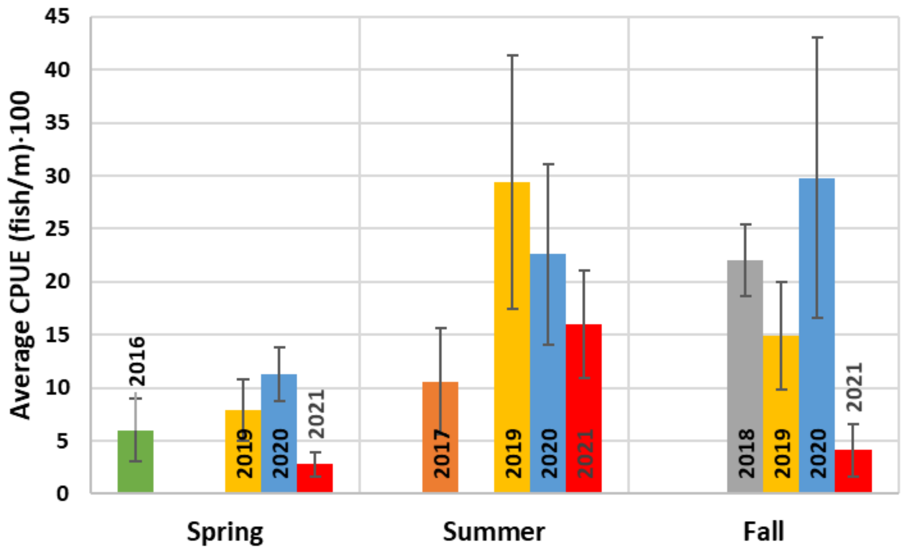

Figure 3.9 Mean catch-per-unit effort (fish/100 m) for spring, summer, and fall by year (all tributaries combined) based on the results of backpack electrofishing surveys.

3.6. Fish Population Index Survey

A total of 1,527 fish were captured by boat electrofishing during the annual fish index survey in Year 9, conducted between 3 and 10 June 2021 when reservoir elevations were filling between 717 and 719 m. Sixty-one sites were sampled, including 7 creek mouths, 15 fans, 11 shallow shorelines, and 28 steep shorelines (Table 3.11). The total shoreline distance sampled was 17.2 km, or ~46% of the total reservoir perimeter at the mean survey elevation (~718 m). All captured fish were rainbow trout.

In total, 1,089 rainbow trout were newly marked with PIT tags. Fish that were too small (<80 mm fork length) or in poor condition when processed, were not tagged. Twenty-two tagged fish were recaptured during the Boat EF survey in 2021; 9 were within-session recaptures and 13 were recaptures of fish originally tagged between 2018 and 2020 (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 9 boat electrofishing index survey in June 2021.

Metric	Units	Habitat Type			
		Cr. Mouth	**Fan**	**Shallow**	**Steep**
Sites	#	7	15	11	28
Effort	total seconds	1,546	9,899	6,511	17,429
	total meters	325	4,905	2,878	9,122
Catch	# of fish	107	287	447	686
	# of fish marked	96	249	275	469
	# of recaptures	4	1	5	12
CPUE	fish/sec·100 (±SE)	6.9 (±1.0)	3.0 (±0.5)	7.3 (±1.3)	4.2 (±0.6)
		4.8 (±0.4)			
	fish/meter·100 (±SE)	34.7 (±5.8)	5.9 (±1.0)	16.0 (±2.8)	7.7 (±0.8)
		11.9 (±1.5)			

2021 catch-per-unit-effort (CPUE) values (by shoreline length), were greatest at creek mouths, followed by shallow shorelines, and then by steep shorelines and fans, although the differences between the latter two were not as large. Mean CPUE values (for all types combined) were: 4.8 (SE 0.4) fish/100 sec of electrofishing; or 11.9 (SE 1.5) fish/100 m of shoreline length, which were very similar to the values reported in 2018 to 2020, and higher than the values for all prior years (2013-2017) (Table 3.12). Including consideration of the standard error, the 2018 to 2021 CPUE values represented a significant increase in fish abundance in the reservoir, whereas differences among previous years (2015-2017) were not significant. Until the end of this monitoring program, 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 and reservoir operating regimes (see Figure 3.10, 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 for monitoring years 1 to 9, including averages for the "Normal" (N2-2P) vs. Modified Operations periods.

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)
N2-2P Average	**18.9** (±2.4)	**8.1** (±0.7)	**8.5** (±1.0)	**5.5** (±0.5)	**8.5** (±0.6)
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)
9 (2021)	34.7 (±5.8)	5.9 (±1.0)	16.0 (±2.8)	7.7 (±0.8)	**11.9** (±1.5)
Mod. Ops Average	**35.2** (±3.8)	**7.5** (±0.5)	**13.2** (±1.5)	**7.8** (±0.6)	**12.5** (±0.9)

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

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 5, 6, 8 and 9 (2017, 2018, 2020 and 2021). Differences between shallow slopes and fans were within the margin of error in Years 3 and 7 (2015 and 2019). The value for steep habitats was higher than for fans in Years 6 and 9 (2018 and 2021), but otherwise was the lowest among the available habitat types in every other year. 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 3.10. In Year 9 (2021), the CPUE for Age-1 fish (4.6 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 (3.4 fish/100 m) was the highest value for that age class documented to-date (i.e., range between 0.7 and 3.4 fish/100 m among years). The CPUE for Age-3 fish in 2021 was also very strong at 2.4 fish/100 m, second only to the 2020 value of 3.4 fish/100 m for this age class (range between 1.0 and 3.4 fish/100 m among years). The Age-4 CPUE in 2021 (0.9 fish/100 m) was at the low end of the range (0.6 to 2.7 fish/100 m) for this age class among years. The generally 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 6 years (see Figure 3.1 in Section 3.1). Both of these factors have contributed to the higher overall CPUE values in recent years.

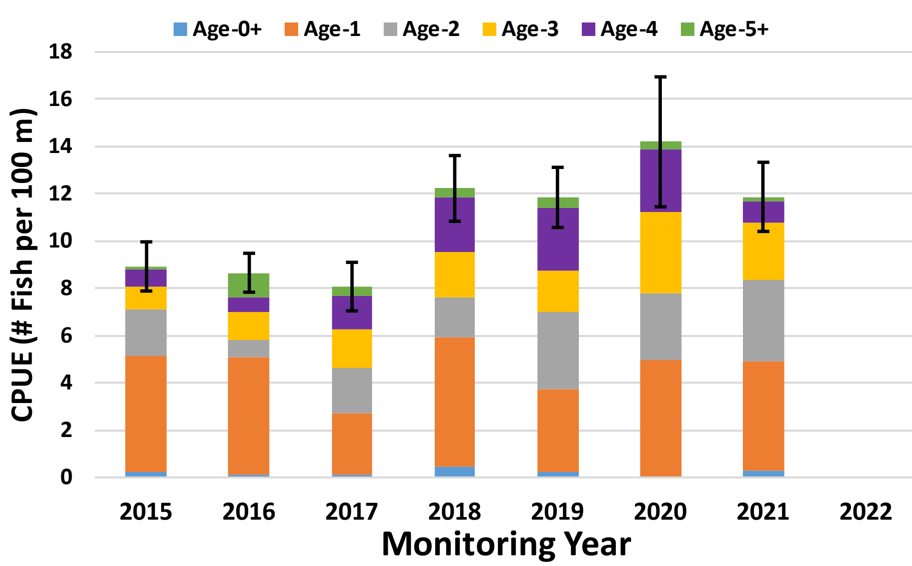

Figure 3.10 Catch-per-unit-effort summary by age class for each monitoring year from 2015 (Year 3) to 2022 (Year 10). Currently only data up to 2021 were available for this report. Year 1 (2013) & 2 (2014) results have not been included due to incompatibility of sampling approach in those years with 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) every year. 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 age-specific 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 3.14 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 9 (2021), the highest mean CPUE was documented in the west zone of the reservoir (14.1 ±3.5 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 and in many cases the error margins among zones have overlapped.

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)
2021		14.1 (±3.5)	9.0 (±2.2)	13.2 (±2.2)

[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 4 of the 1,527 captured fish (or <1%) in Year 9 (2021) 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 124 fish (~8% of the 2021 catch) were held for approx. 24 hours after sampling, then re-evaluated for condition and tag loss, and then released. In total, 124 of the held fish (or 100%) were alive after 24 hours and were noted to be in vigorous condition upon release. The delayed mortality results in Years 5 to 8 (2017 to 2020) were all similarly low (i.e., 0%, 1%, 3% and 2% mortality, respectively). Tag loss was noted for 1 of the held individuals (0.8%) in 2017, and 0 individuals in 2018–2021, for a combined tag loss rate of 0.2%.

Recaptures of Tagged Fish

A total of nine fish that were marked with PIT tags were recaptured at different sites within the same session in Year 9 (2021; Table 3.14). Seven of these fish had moved a short distance (i.e., <1 km), while the other two had moved more substantial distances (1.9 and 2.0 km) across varying periods (i.e., from within the same night up to 3 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 9 (2021).

Tag Code	Original Capture Data			Recapture Data			Dist. (km)
	Date	Zone	Habitat[a]	Date	Zone	Habitat[a]	
229469	6-Jun-21	East	ST	7-Jun-21	East	ST	0.3
125846	10-Jun-21	East	SH	10-Jun-21	East	ST	0.5
229421	6-Jun-21	East	ST	9-Jun-21	East	ST	0.5
229100	10-Jun-21	East	SH	10-Jun-21	East	ST	0.6
229687	7-Jun-21	East	SH	9-Jun-21	East	ST	0.7
229218	4-Jun-21	Mid	FN	5-Jun-21	Mid	ST	0.8
229141	4-Jun-21	Mid	CM	5-Jun-21	Mid	ST	0.8
229697	7-Jun-21	East	SH	10-Jun-21	East	ST	1.9
229318	5-Jun-21	East	ST	7-Jun-21	East	SH	2.0

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

In addition to the within-session recaptures, there were 13 between-year recaptures in Year 9 (2021). Original capture and recapture information for these fish is summarized in Table 3.15. Six of the thirteen between-year recaptures were initially captured in 2020 (i.e., were at-large for ~1 year). Five of the between-year recaptures were originally tagged in 2019 (~2 years at large), and two were from 2018 (~3 years at large; one of which had also been recaptured in 2019). As with the within-session recaptured fish, the locations for each capture event were varying distances apart (i.e., ranging from 0.2 to 9.2 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 2020 and 2021): Three fish (forklengths = 82, 119 and 126 mm) were assessed as Age-1 based on scale ageing analysis (see section below) when initially captured, and were 203, 197 and 180 mm forklength, respectively, when recaptured a year later (at Age-2). This represented a growth range of 56 to 127 mm in one year for this cohort of fish. Another three fish (forklengths = 155, 185 and 193 mm) were assessed as Age-2 when initially captured, and were 246, 250 and 223 mm a year later (at Age-3), representing 31 to 94 mm of annual growth.

For fish captured and recaptured more than one year apart: Three fish captured in 2019 at Age-1 were recaptured in 2021 at Age-3 and had grown an average of between 60 and 75 mm/yr across those two years. Two fish captured in 2019 at Age-3 were recaptured in 2021 at Age-5 and had each grown an average of 12 mm/yr across those years. Two fish captured in 2018 at Age-1 were recaptured in 2021 at Age-4 and had grown an average of 55 and 63 mm/yr during that period. 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 9 (2021). 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)		
316990	08-Jun-18	East	125	09-Jun-21	West	315	9.2	63
317427 [b]	03-Jun-18	West	90	03-Jun-21	Mid	254	2.8	55
316206	07-Jun-19	West	290	08-Jun-21	West	315	0.7	12
316354	07-Jun-19	West	218	09-Jun-21	West	242	2.0	12
560105	09-Jun-19	Mid	98	09-Jun-21	West	249	1.5	75
560252	10-Jun-19	East	90	06-Jun-21	Mid	232	2.3	71
560561	12-Jun-19	East	91	07-Jun-21	East	210	1.5	60
621821	19-Jun-20	Mid	155	07-Jun-21	East	246	3.2	94
621907	19-Jun-20	Mid	193	06-Jun-21	East	223	4.0	31
621909	20-Jun-20	Mid	82	03-Jun-21	Mid	203	1.9	127
621181	22-Jun-20	East	126	07-Jun-21	East	180	1.7	56
621347	22-Jun-20	East	185	07-Jun-21	East	250	1.5	68
561248	24-Jun-20	West	119	09-Jun-21	West	197	0.2	81

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

[b] This fish had previously been recaptured on 11-Jun-19 (~1 year at large) at 4.0 km from it's original capture location in the West zone when it was 210 mm and 105 g.

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

A length-frequency histogram for rainbow trout captured by boat electrofishing in Year 9 (2021) is presented in Figure 3.11. The coloured bars in this figure represent the contribution of the different age classes as determined by analysis of 195 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.

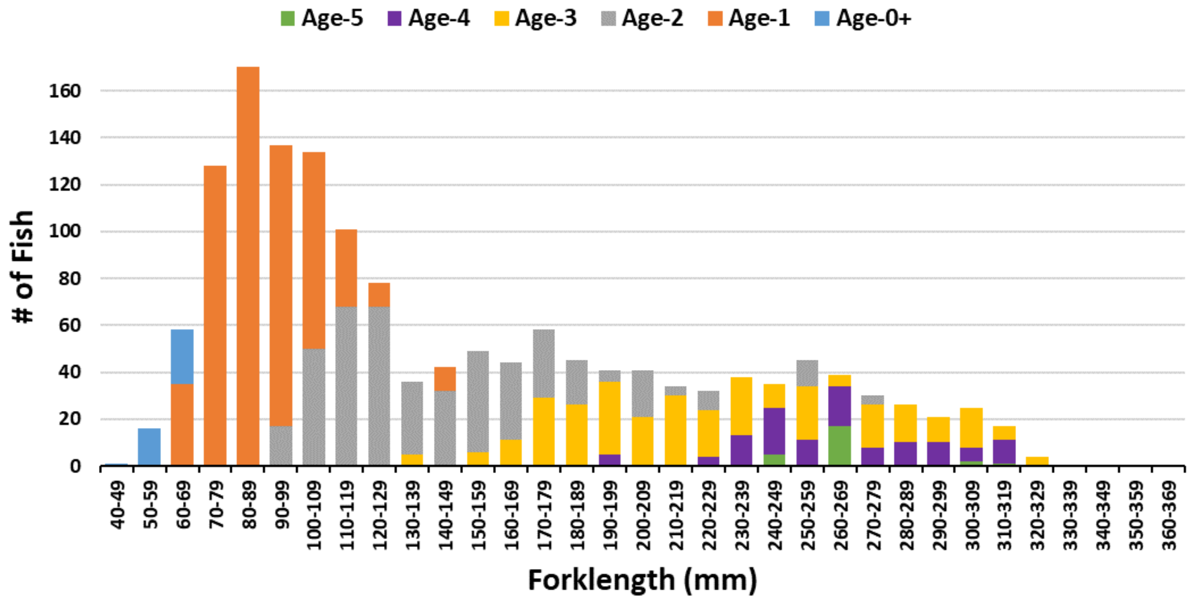

Figure 3.11 Length-frequency histogram for rainbow trout captured during the fish population index survey in Downton Reservoir, 3 to 10 June 2021. Size ranges for each available age class are shown.

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 2021 (Table 3.16). Differences in the median sizes in 2021 were: 27 mm between Age-0 and Age-1, 45 mm between Age-1 and Age-2, 87 mm between Age-2 and Age-3; 42 mm between Age-3 and Age-4, and 3 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 2022), and the 2021 median sizes were among the lowest for Age-1 to Age-4 fish (similar to 2019) of 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 9 (2021).

Age	*n* [a]	Forklength (mm)		
		Minimum	Median	Maximum
0+	40	46	**60**	65
1	592	65	**87**	146
2	442	98	**132**	278
3	314	133	**219**	328
4	114	196	**261**	315
5	25	244	**264**	315

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

We also computed growth curves using the 4-parameter logistic model (as explained in Section 2.5) based on the median forklength and weight values for each age class for the 2013 to 2021 data sets to assess differences in growth among years and reservoir operational regimes based on this standardized approach (Figure 3.12; 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 six years of data for the Modified Operations period (i.e., 2016-2021).

The median forklengths for the oldest fish in the sample (i.e., Ages 5 and 6) suggested 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-2 and Age-4 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, 2016 and 2020; reduced in 2017 and 2018; and lowest in 2019 and 2021.

Despite these changes noted among years, the differences in growth based on median forklength were minimal between the N2-2P and Modified Operations periods (Figure 3.12 top). The median forklengths for the Mod. Ops. period were slightly lower for each age class, particularly the younger fish (i.e., Age-0+, Age-1 and Age-2); however, the error margins for older fish (i.e., >Age-2) overlapped substantially, suggesting these differences were not statistically significant. The differences in growth based on median weight also tended to be lower for the Mod. Ops period (Figure 3.12 bottom); however, the trend among age classes was the opposite: error margins for the younger fish (≤Age-3) overlapped substantially, whereas differences among operating regimes for older fish (>Age-3) were larger. Based on these results, the growth of rainbow trout in the reservoir under Modified Operations was the same or only slightly lower (based on forklength) than N2-2P operations, but growth based on weight diminished as fish got older during the Mod. Ops. period.

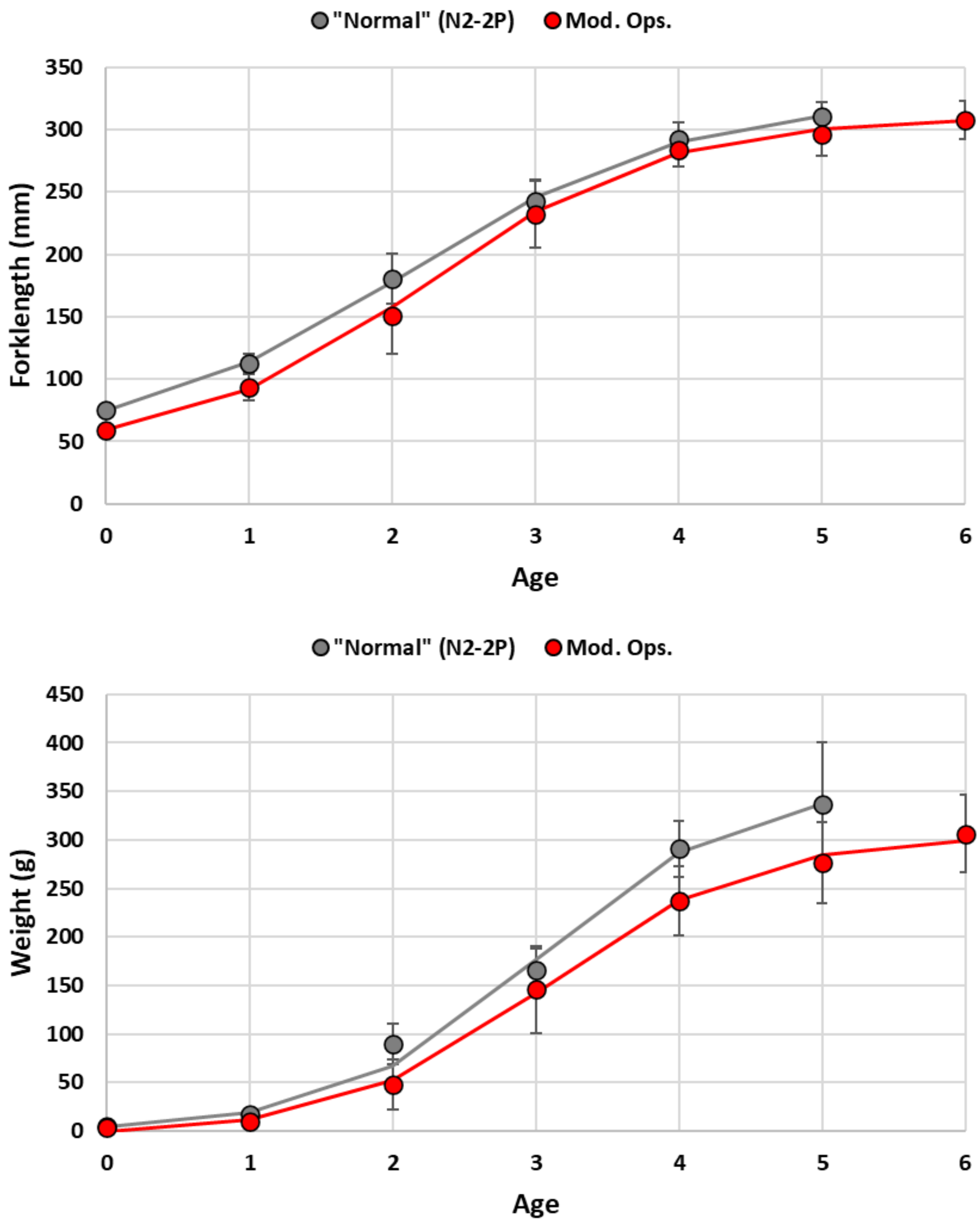

Figure 3.12 Median (± SE) forklengths (top) and weights (bottom) with 4-parameter Logistic growth curves for rainbow trout captured during the annual fish population index survey in Downton Reservoir during "Normal" (N2-2P; 2013-2015) and Modified Operations (2016-2021) periods. Curves for each of the 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 2013-2021; Figure 3.13; 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.

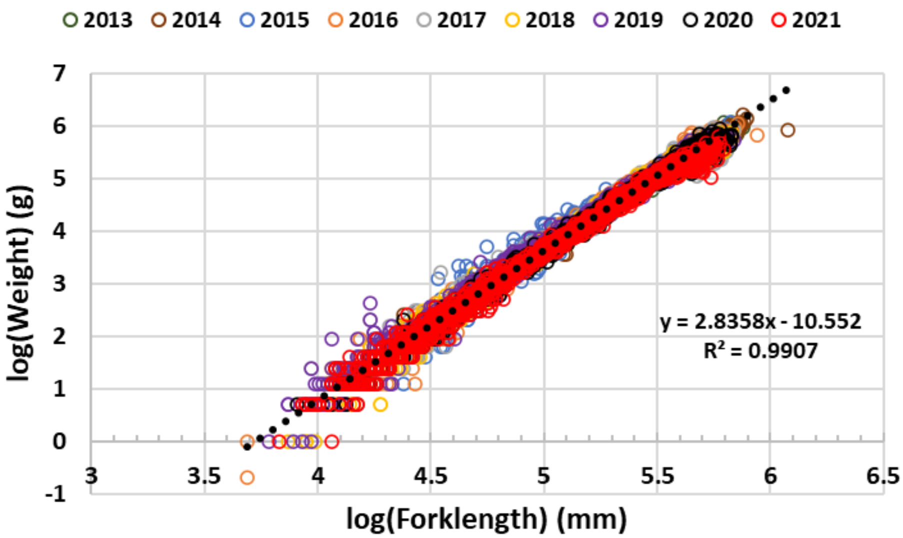

Figure 3.13 Log-transformed length-weight relationships for Downton Reservoir rainbow trout in Years 1 to 9 (2013 to 2021). Open circles are the individual data points (colour-coded by year) and the dotted line represents the overall regression (all years combined). See Table 3.17 for the sample size, 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
9 (2021)	1,439	2.82	-10.54	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 3.14). Condition factor generally declines as fish age and this was apparent during both operational regimes in Downton Reservoir; however, the timing of when the decline started was slightly different among them. During the N2-2P years (2013-2015) Fulton's K values were highest for Age-1, declined steadily from Age-2 to Age-4, and then stabilized between Age-4 and Age-5. Under Modified Operations (2016-2021), mean Fulton's K values were equivalent to the N2-2P period for Age-1 and Age-3 to Age-5, but were higher for Age-2, reflecting a later decline in condition factor with age compared to the N2-2P results.

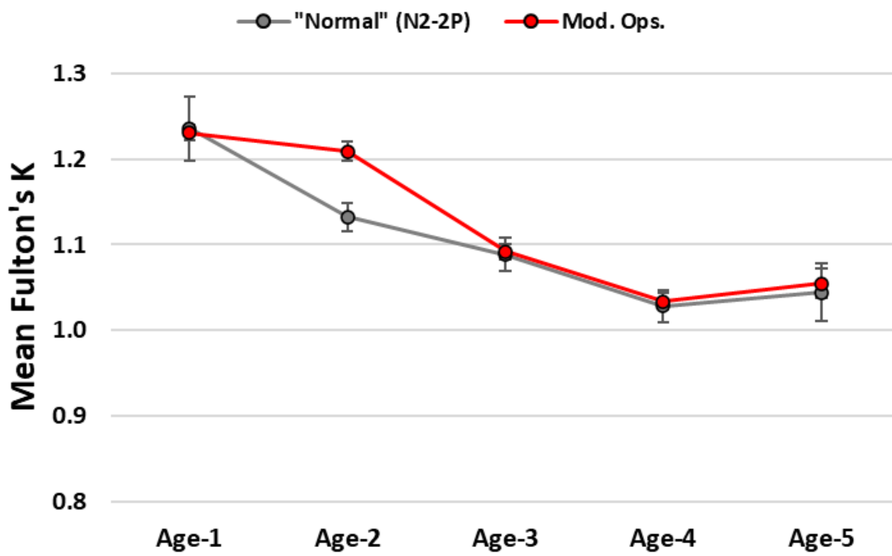

Figure 3.14 Mean condition factor (± SE) by age class during "Normal" (N2-2P; 2013-2015) and Modified Operations (2016-2021) periods for rainbow trout in Downton Reservoir based on fish sampled during the annual fish population indexing survey between late May and late June each year.

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 is apparent in Figure 3.12, 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 some 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 = purple; 2021 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	**261 (-5)**	114
2017	**62**	59	**79 (+17)**	492	**185 (+106)**	285	**219 (+34)**	314		
2018	**53**	29	**100 (+47)**	495	**132 (+32)**	442				
2019	**-**	0	**87 (+29)[a]**	592						
2020	**60**	40								

[a] This growth value is an estimate (based on average Age-0+ size for the Mod. Ops. years) since there were no Age-0+ fish in the 2020 catch (i.e., recruitment year 2019 + 1).

The assignment of ages also allowed for the comparison of CPUE for each age class by habitat type (Figure 3.15). 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 9 (2021), catch rates of Age-1 fish were highest and nearly equivalent in shallow slopes and at creek mouths, and lowest on fans and steep-sloped shorelines. Age-2 fish were most prevalent on shallow slopes, followed by creek mouths, steep shorelines and then fans. As in past years, older fish (Age-3 and -4) were most prevalent at creek mouths and at much lower densities in the other habitat types. The abundance index of Age-5 fish was low in each habitat type.

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. Previously, we reported on increased catch rates of Age-1 fish in Year 6 (2018) (Sneep 2019b), followed by increased catch rates of Age-2 fish in Year 7 (2019) (Sneep 2020) and Age-3 fish in Year 8 (2020) (Sneep 2022), suggesting that improved recruitment had occurred starting in 2016 (when this cohort incubated and emerged) and had tracked through for this cohort in subsequent years. However, the strength of this cohort did not follow through to Age-4 fish in Year 9. Instead, the catch rates for Age-1, -2 and -3 fish in 2021 were all strong suggesting the possible establishment of a new equilibrium in abundance among age classes this year and further affirming that conducive rearing conditions have persisted through the modified operations years to-date. The prevalence of Age-1 and Age-2 fish along shallow shorelines, steep shorelines and fans relative to the older age classes in these habitats 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.

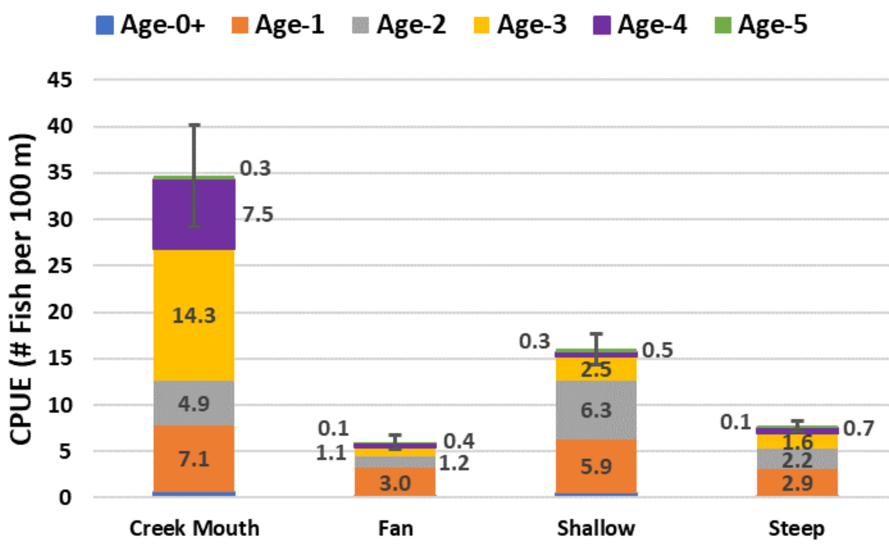

Figure 3.15 Catch-per-unit-effort (fish/100 m) by age class for each habitat type in Downton Reservoir based on the results of the boat electrofishing survey in Year 9, 3 to 10 June 2021.

The relative contribution of each age class to the catch in 2021, compared to 2015-2020 is shown in Table 3.19. The CPUE values and percent contributions for Age-0+, Age-1 and Age-2 fish in 2021 (i.e., 2020, 2019 and 2018 recruits) were at or above the average for the modified operations period, whereas Age-3, Age-4 and Age-5 were below the mod. ops. average. On the other hand the 2021 CPUE values for all of the age classes except Age-4 fish were at or above the averages for the N2-2P period. In terms of a comparison of the operational regimes, the average CPUE values for Age-0+, Age-1 and Age-5 fish were equivalent between the N2-2P and Mod. Ops. periods, whereas the average CPUE values for Age-2, Age-3 and Age-4 fish were all higher under the Mod. Ops. regime. 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.

Table 3.19 Comparison of catch-per-unit-effort (fish/100 m) by age class for monitoring years 3 to 9 (2015-2021), which spanned the periods of "Normal" (N2-2P) and Modified Operations. The percent contribution of each age class to the yearly total is provided in brackets and totals for each year and operational period are provided.

Study Year	CPUE – fish/100 m (% contribution) by Age							
	Age-0+	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	All (SE)
3 (2015)	0.3 (3%)	4.9 (55%)	2.0 (22%)	1.0 (11%)	0.7 (8%)	0.1 (1%)	-	**8.9 (±1.0)**
4 (2016)	0.1 (1%)	5.0 (58%)	0.7 (8%)	1.2 (14%)	0.6 (7%)	0.8 (9%)	0.2 (3%)	**8.7 (±0.8)**
5 (2017)	0.1 (1%)	2.6 (32%)	1.9 (23%)	1.6 (20%)	1.4 (18%)	0.2 (3%)	0.1 (2%)	**8.1 (±1.0)**
"Normal" (N2-2P)	**0.1 (2%)**	**3.9 (49%)**	**1.4 (18%)**	**1.4 (15%)**	**1.3 (11%)**	**0.5 (5%)**	**0.1 (1%)**	**8.5 (±0.6)**
6 (2018)	0.4 (4%)	5.5 (45%)	1.7 (14%)	1.9 (16%)	2.3 (19%)	0.4 (3%)	-	**12.2 (±1.4)**
7 (2019)	0.2 (2%)	3.5 (29%)	3.3 (28%)	1.8 (15%)	2.7 (22%)	0.5 (4%)	-	**11.8 (±1.3)**
8 (2020)	-	5.0 (35%)	2.8 (20%)	3.4 (24%)	2.7 (19%)	0.3 (2%)	-	**14.2 (±2.7)**
9 (2021)	0.3 (3%)	4.6 (39%)	3.4 (29%)	2.4 (21%)	0.9 (7%)	0.2 (2%)	-	**11.9 (±1.5)**
Mod. Ops.	**0.3 (2%)**	**4.0 (38%)**	**2.6 (22%)**	**3.3 (18%)**	**3.2 (17%)**	**0.4 (2%)**	**-**	**12.5 (±0.9)**

To that end, we also compared year-specific CPUEs according to reservoir operating levels among years (Figure 3.16). Total CPUE (for all age classes combined) was plotted against annual maximum reservoir elevations (upper plot) and annual minimums (lower plot). For minimum reservoir levels, there was a slight correlation with total fish abundance although it was weak (R^2= 0.14). The relationship between the maximum reservoir levels and total fish abundance was stronger (R^2= 0.86), which reflected the positive effect of lower maximum reservoir elevations associated with modified operations. This effect is also supported by the results of other monitoring components as well (e.g., spawner distributions according to elevation in the creeks). It is also important to note that, to some extent, annual minimum and maximum reservoir elevations are not independent because the reservoir tended to be drawn lower (or more consistently low) in the spring during years with a lower target maximum. As such, the slight trend noted for minimum reservoir elevations may actually be linked to the maximum reservoir elevation effect.

We also endeavoured to plot age-specific CPUE (for Age-1 and Age-2 fish) against minimum and maximum reservoir elevations to highlight any potential effects on recruitment and the younger age classes (Figure F1 in Appendix F). 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.

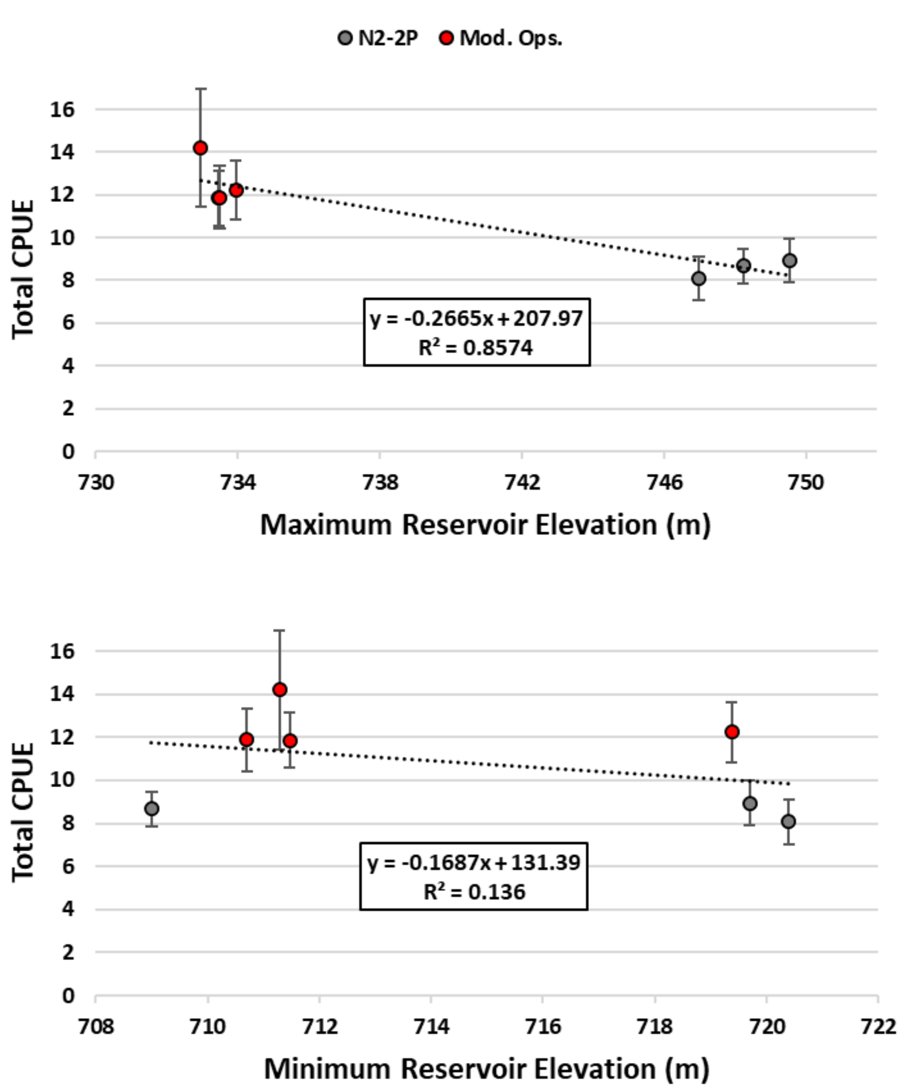

Figure 3.16 Plots of total annual CPUE for Downton Reservoir rainbow trout (all age classes combined) against maximum reservoir elevations (upper plot) and minimum reservoir elevations (lower plot).

Relative to the correlation between maximum reservoir level and the total rainbow trout abundance index (CPUE; Figure 3.16), the age-specific correlations (for Age-1 and Age-2 fish) were weaker (Figure F1 in Appendix F). This is likely because, even though recruitment and overall abundance has increased under modified operations, the population seems to have hit an upper abundance limit (due to various fish production and survival bottlenecks). As such, increased recruitment and survival of one cohort, which has tended to track across years, appears to limit the recruitment and survival of subsequent cohorts due to intra-specific competition. The abundance index of each age class tends to reverberate up and down within the total abundance limit as a result.

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 9 (2021), the Age-0+ rainbow trout were recruited in 2020, the Age-1 fish were recruited in 2019, and the Age-2 fish were recruited in 2018.

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	
2021	2022		

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 9), 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 2018-2021) 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 further characterize any changes among years.

A higher proportion of trout (≥70% under each operational regime) 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 6-9 (2018- 2021) 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 peak emergence timing among study years has been minimal to-date, generally varying by only 1-8 days (see Table 3.3 in Section 3.2). However, the modelled timing in Year 9 (2021) was a bit of an exception: it was predicted to be approx. 2 weeks earlier than usual due to a spate of record high ambient temperatures (i.e., the "heat dome") in late June and early July (i.e., early in the incubation period) that year. The predicted timing each year was also generally confirmed by the sampling of recently emerged fry in late August or early September: in 2017 (CPUE = 9 fish/100 m; forklength range = 23 to 33 mm), 2019 (CPUE = 22 fish/100 m; forklength range = 20 to 46 mm), 2020 (CPUE = 11 fish/100 m; forklength range = 20 to 35 mm), and 2021 (CPUE = 11 fish/100 m; forklength range = 21 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), 2020 (CPUE = 18 fish/100 m; forklength range = 22 to 55 mm), and 2021 (CPUE = 2 fish/100 m; forklength range = 22 to 43 mm). Note: mean Age-0+ CPUE in fall 2021 was lower likely because access issues precluded sampling in several key spawning tributaries that year.

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, 2019 and 2021 (due to a high contribution of Age-1 and Age-2 recruits in those years). 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 and weight for each age class in each year, suggest that growth based on forklength has not measurably changed (differences among operating regimes are within error margins), whereas growth based on weight has slowed slightly for the older age classes since initiation of modified operations in 2016, likely due to competition for food resources by the increased densities of younger recruits. However, condition factor has actually been unaffected, other than for Age-2 fish (which was higher under modified operations) 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 has reached that target in more years than under N2-2P. In the six years of modified operations to-date, minimum elevations were 719.38, 711.47, 711.29, 710.71, 710.42, and 710.48 m, and maximum fill elevations were 733.99, 733.46, 732.96, 733.49, 735.05 and 738.49 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 3 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 the strength of comparisons between N2-2P and modified operations, 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., 2018-2021 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 three years based on N2-2P recruitment available when sampling methods and effort were consistent with subsequent years). This difference was primarily due to increased catches of Age 1 fish in 2018; Age 2 and Age 4 fish in 2019; Age 2, Age 3 and Age 4 fish in 2020, and Age 2 and Age 3 fish in 2021. CPUEs for Age-2 to Age-4 fish have increased since 2016 when they were at or near their lowest. It seems reasonable 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 increased contribution of Age-1 fish in 2018 (that recruited in 2016), and generally increasing abundance of older fish (ages 2-4) since 2016 may be related to the modified operation of the reservoir (particularly the reduced maximum fill elevation that has occurred during the spawning period), which was implemented starting in 2016 and continued through to 2021.

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 and Age 3 and 4 fish between 2020 and 2021 despite strong recruitment to the other age classes in those years (see Table 3.19). Furthermore, despite the increased densities of fish up to and including Age 4 for 4 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. As such, increased recruitment and survival of one cohort, which has tended to track across years, appears to limit the recruitment and survival of subsequent cohorts due to intra-specific competition. The abundance index of each age class tends to reverberate up and down within the total abundance limit as a result, until a new balance among age classes is re-established.

While the 10th and final year of data collection has not yet been completed, these conclusions are supported by multiple years of replicate data at this point. They will be further informed by results from the final year of monitoring in 2022 when they are available. The current results have confirmed 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 is essential for ultimately linking the observed patterns and trends in abundance to specific operational characteristics across the entire 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 rejected at this stage of the program. The 2018 to 2021 results consistently showed that the annual abundance index *increased* for fish that recruited under modified operations (starting in 2016) relative to those that recruited before. However, reduced abundance of Age-1 fish from 2018 to 2019, Age-2 fish from 2019 to 2020, and Age-3 fish from 2020 to 2021 (i.e., a cohort that recruited under modified operations) suggests that the population may have hit a total abundance ceiling that alternately favours certain age classes over others until a new equilibrium among age classes is established. The finer balancing among fish Age 1 to 3 in Year 9 (2021) may be an early indication that a new equilibrium under modified operations conditions is being established.

This program has established an effective method for tracking this information (Fish Population Index Survey) that is being successfully implemented and there are currently 7 years of comparable abundance index data points available at this point (3 years of recruitment under normal operations and 4 years under modified operations; refer to sections 2.5 and 3.6) with 1 year yet-to-be completed before the end of the currently prescribed monitoring period.

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 to 9 (2019-2021) 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 varies 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 anecdotally observed). Based on tributary fish sampling results to-date, recaptures of tagged fish (*n*= 6 in 2019; *n*= 4 in 2020; *n*= 2 in 2021) 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 or early September; 2021 CPUE = 16.0 ±5.1 fish/100 m) and fall (i.e., mid October; 2021 CPUE = 4.1 ±2.5 fish/100 m) related to the presence of newly or recently emerged fry during those months. As noted earlier, mean CPUE in fall 2021 was lower than usual for that season likely because access issues precluded sampling in several key spawning/fish-bearing tributaries that year.

However, the abundance of fish in the creeks was diminished in spring (i.e., late May or early June; 2021 CPUE = 2.8 ±1.1 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). 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) and Year 9 (2021) – 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 final year of the program (see Section 5 – Recommendations). This approach has helped to address the additional variability in fish abundance or use between the seasons that was 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, 2020 and 2021) 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 9 (2018-2021) 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 163.8 m (or 43%) 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 126.8 m (or 83%) under normal operations versus an average of 111.4 m (or 57%) 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 2021), 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 three years of data collection for this component available to-date, the majority of spawners in the drawdown zone used the section between approx. 730 m and 746 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). These data have contributed 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 7 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. 2022), 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 (including shallow slopes, steep 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 one of the habitat types associated with the lowest catch rates of fish during the annual index survey. These habitat surveys also indicated that there was no significant loss of any habitat type that has been 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)). Any potential correlation between the observed changes in the fish abundance index among years and fish “access” to different substrate size distributions or interstitial depths within the reservoir basin has not been explicitly analyzed. If this is even possible with the data available, it 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 densities of rainbow trout at creek mouths reflect 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 confirmed at this stage; however, the additional data characterizing the specific spawning distribution within the drawdown portion of the selected tributaries from Year 10 (2022) will also be useful to further support this conclusion.

Data collection to support this began in Year 7 (2019) and is proposed to continue again next year (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 tended to start at a lower elevation and filled less across the rainbow trout spawning period than it did under normal operations and spawners have been observed in these creeks during the four most recent years (2018-2021). 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.

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 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 (70% of observations under N2-2P; 82% under mod. ops.), relative to the upland zone (30% under N2-2P; 18% under mod. ops.) (Appendix C, Table C1). Among selected tributaries, spawners were distributed throughout the drawdown zone, but were particularly concentrated between 730 m and 746 m (Appendix C, Table C2). While some tributaries are used minimally, or not at all, the drawdown zone of Tribs. #13 and Eagle Creek (as two key examples) have been used extensively and consistently. There is also evidence of spawning distribution expansion into the drawdown zone portion of Ault and Cathy creeks where they were not previously observed during normal (N2-2P) operations years (as described above).

The secondary null hypothesis (H_{4b}), which states**:** "*Operation of the reservoir restricts fish access to tributaries limiting the productivity of fish populations*" is rejected at this point. Evidence to-date suggests that connectivity of some tributaries may be cut off when reservoir levels are <713 m during April or May before the onset of freshet (due to creeks flowing to ground), but these effects have not yet been observed during the spawning period or on the primary spawning tributaries. 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. A final round of tributary access surveys is planned for Year 10, such that access scores in Table 3.4 can be populated for any remaining reservoir operation and inflow scenarios that may not yet have been observed during the rainbow trout pre-spawning migration period.

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. Differences in the distribution and quantity of the shoreline habitat types (mostly due to a reduction of steep habitats at the lowest elevations), substrate composition and interstitial spaces were observed among the selected reservoir elevations. 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 more detailed information and the rationale for rejecting this hypothesis at this stage.

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 9 (2021) 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 somewhat weak relationship may exist between the minimum reservoir levels during a given year and the abundance index of rainbow trout associated with those years (suggesting a slight positive effect of lower minimum reservoir elevations, at least to the levels implemented within the monitoring years to-date); however, the results could also be consistent with an inference of "*no effect*" based on the slope (-0.17) and R^2 value (0.14; see the lower plot of Figure 3.16 in Section 3.6).

On the other hand, any effect of minimum elevations may actually be a reflection of another related factor which is not captured by this management question but does appear to have stronger support at this point: The relationship between *maximum* reservoir elevation and the associated annual abundance index of rainbow trout (upper plot on Figure 3.16). As indicated previously, minimum and maximum elevations were related because during modified operations when the maximum reservoir elevation target was reduced (from 749.81 m to 734.00 m), the reservoir also tended to be drawn lower (or more consistently low) in order to meet the reduced fill target. Lower minimum and maximum elevations also typically translate to lower reservoir elevations during the rainbow trout spawning and incubation period (from mid-May to the end of July) which is a critical period for recruiting the new year class and improving the productivity of the population.

Based on the total annual rainbow trout CPUE data up to Year 9 (2021), the slope (-0.27) and R^2 (0.86) values for the negative correlation between CPUE and maximum reservoir elevations were stronger than the correlation with minimum elevations. 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). 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), and the Year 9 (2021) results showed renewed strength of the Age-1 and Age-2 cohorts with reduced abundance of Age-4 fish. 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.

Presently there are not very strong or consistent correlations between minimum and maximum reservoir levels and the annual CPUEs for particular age classes on their own (i.e,. specifically Age-1 and Age-2 fish; see Appendix F, Figure F1) , or at least there are not strong enough signals to differentiate potential relationships from an inference of "*no effect*". For these two age classes, we looked at the effect of annual minimum and maximum reservoir elevations *during the spawning period*, as well as absolute minimum and maximum elevations experienced within the year prior to sampling (top-left, top right, lower-left and lower-right plots on Figure F1, respectively). The likely reason why the age-specific correlations are weaker than for all age classes combined is as stated above: the population as a whole has increased under modified operations characterized by lower maximum and more consistently low minimum elevations; however, the strength of individual age classes reverberates up and down within the overall size limitation of the population due to other bottlenecks (e.g., food availability and intra-specific competition).

The primary or secondary hypotheses that pertain to this management question are as follows:

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).

Based on the years monitored to-date, which have provided an ample degree of operational contrast (i.e., varying minimum and maximum levels, and fill and drawdown rates), hypotheses H_2, H_{2a}, and H_{2b} can likely be confirmed at this point based on the relatively weak correlations (i.e., R^2= 0.14 for total abundance; R^2= 0.15 for Age-1 abundance; and R^2= 0.45 for Age-2 abundance) between annual total and age-specific CPUEs coupled with minimum reservoir elevation values for the period of monitoring to-date (2013 to 2021). On the other hand, hypothesis H_3 can likely be rejected for total abundance based on the relatively strong correlation (R^2= 0.86) with maximum reservoir elevation values for the period of monitoring to-date (2013 to 2021), but hypotheses H_{3a} and H_{3b} can likely be confirmed for age-specific CPUEs for the reasons stated in the paragraphs above. Refer to Figure 3.16 (Section 3.6) and Figure F1 (Appendix F) for the relevant analysis results.

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 tributary length above the *modified* maximum reservoir levels. The increased CPUE indexes for Age-1 fish in 2018, Age-2 fish in 2019, Age-3 fish in 2020 (i.e., the first cohort that recruited under the lower modified operations levels), and then Age-1 and Age-2 fish in 2021 seem to support this (see Section 3.6). Observed increases in Age-2 to Age-4 CPUEs during the modified operations years in general 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 have also become apparent.

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.

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, prior to the WUP Order Review. 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) of this program, and additional work to characterize spawning distribution within the drawdown zone more specifically (initiated in Year 7 (2019)), could provide such inputs (refer to analysis results in Figure 3.6; Table 3.6; Table 3.7; and Appendix C, Table C1 and C2).

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

Recommendations pertaining to specific monitoring components or methods for the 10th and final year of monitoring in 2022 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) per year and collecting more specific data on spawner locations within the drawdown zone of the tributaries as was done in Years 8 and 9 (see more on these recommendations in the following bullets).
- 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. As in other recent years, 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).

- 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.

6. References

Anderson, R.O. and R.M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447–482 in B.R. Murphy and D.W. Willis, eds. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

BC Hydro. January 2015. Addendum to BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring Terms of Reference. Prepared for the BC Comptroller of Water Rights.

BC Hydro. January 2012. Bridge-Seton Water Use Plan – Monitoring Program Terms of Reference. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring. Prepared for the BC Comptroller of Water Rights.

BC Hydro. 2011. Bridge River Power Development Water Use Plan. Revised for Acceptance for the Comptroller of Water Rights. March 17, 2011.

B.C. Ministry of Environment, Lands and Parks. 1997. Fish Collection Methods and Standards – Version 4.0. Prepared by the Fish Inventory Unit for the Aquatic Ecosystems Task Force, Resource Inventory Committee.

Finstad, A.G., S. Einum, T. Forseth, and O. Ugedal. 2007. Shelter availability affects behaviour, size-dependent and mean growth of juvenile Atlantic salmon. *Freshwater Biology* **52,** 1710–1718. Doi: 10.1111/j.1365-2427.2007.01799.x

Henderson, P.A. and R.M. Seaby. 2006. *Growth II*. Pisces Conservation Ltd., Lymington, England.

Jensen, J.O.T., McLean, W.E., Jensen, M.E., Sweeten, T., and Damon, W. 2009. WinSIRP version 2.0 User Manual: Microsoft Windows®-based salmonid incubation and rearing programs, designed for Microsoft Excel®. Can. Tech. Rep. Fish. Aquat. Sci. 2839: vii + 49p.

Kondolf, G.M., and M.G. Wolman. 1993. The sizes of salmonid spawning gravels. *Water Resources Research*, **30**, 7, (2275-2285).

Korman, J., J. Schick and A. Clark. 2010. Cheakamus River Steelhead Juvenile and Adult Abundance Monitoring; Implementation Year 2. Reference CMSMON-3. Report prepared for BC Hydro and the Deputy Comptroller of Water Rights, February 2010.

McPhail, J.D. 2007. The Freshwater Fishes of British Columbia. The University of Alberta Press, Edmonton, Alberta, Canada. ISBN 978-0-88864-467-1.

Perrin, C., N. Swain, M. Hocking, P. Dinn, T. Hatfield and A. Marriner. 2016. JHTMON4: Upper and Lower Campbell Reservoirs Littoral Productivity Assessment Year 1 Annual Monitoring Report. Draft V2. Consultant's report prepared for BC Hydro by Laich-Kwil-Tach Environmental Assessment Ltd. Partnership, Limnotek Research and Development Inc. and Ecofish Research Ltd., July 15, 2016.

Putt, A., D. Ramos-Espinoza and C. White. 2019. Implementation Year 6 (October 2017-September 2018): Carpenter Reservoir and Middle Bridge River Fish Habitat and Population Monitoring. Reference: BRGMON-4. Report prepared for St'at'imc Eco-Resources by Instream Fisheries Research.

Sneep, J. and S. Hall 2012. Lower Bridge River Aquatic Monitoring – Year 2011 Data Report. Prepared for BC Hydro and the Deputy Comptroller of Water Rights, August 2012.

Sneep, J. 2015. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, 2013 and 2014 Results. Annual Data Report prepared for St'at'imc Eco-Resources and BC Hydro.

Sneep, J., C. Perrin, and J. Korman. 2022. BRGMON-1 Lower Bridge River Aquatic Monitoring, Year 10 (2021) Results. Report prepared for St'at'imc Eco-Resources and BC Hydro. April 2022.

Sneep, J. 2022. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 8 (2020) Results. Annual Data Report prepared for St'at'imc Eco-Resources and BC Hydro.

Sneep, J. 2020. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 7 (2019) Results. Annual Data Report prepared for St'at'imc Eco-Resources and BC Hydro.

Sneep, J. 2019a. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 6 (2018) Results. Annual Data Report prepared for St'at'imc Eco-Resources and BC Hydro.

Sneep, J. 2019b. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 5 (2017) Results. Annual Data Report prepared for St'at'imc Eco-Resources and BC Hydro.

Sneep, J. 2018a. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 4 (2016) Results. Annual Data Report prepared for St'at'imc Eco-Resources and BC Hydro.

Sneep, J. 2018b. BRGMON-7 Downton Reservoir Fish Habitat and Population Monitoring, Year 3 (2015) Results. Annual Data Report prepared for St'at'imc Eco-Resources and BC Hydro.

Ward, B.R., and P.A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River Steelhead trout (*Salmo gairdneri*) and the relationship to smolt size. Canadian Journal of Fisheries and Aquatic Sciences 45:1110 1122.

Wentworth, C.K. 1922. A Scale of Grade and Class Terms for Clastic Sediments. *Journal of Geology*, 30: 377-392.

White, C., D. Ramos-Espinoza, M. Chung, K. Cooke, S. Lingard, A. Putt and G. Pool. 2021. Lower Bridge River Adult Salmon and Steelhead Enumeration – Implementation Year 8 (2019). Reference: BRGMON-3. Report prepared for St'at'imc Eco-Resources by Instream Fisheries Research.

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 710.8 m on 5 May, 2021.

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

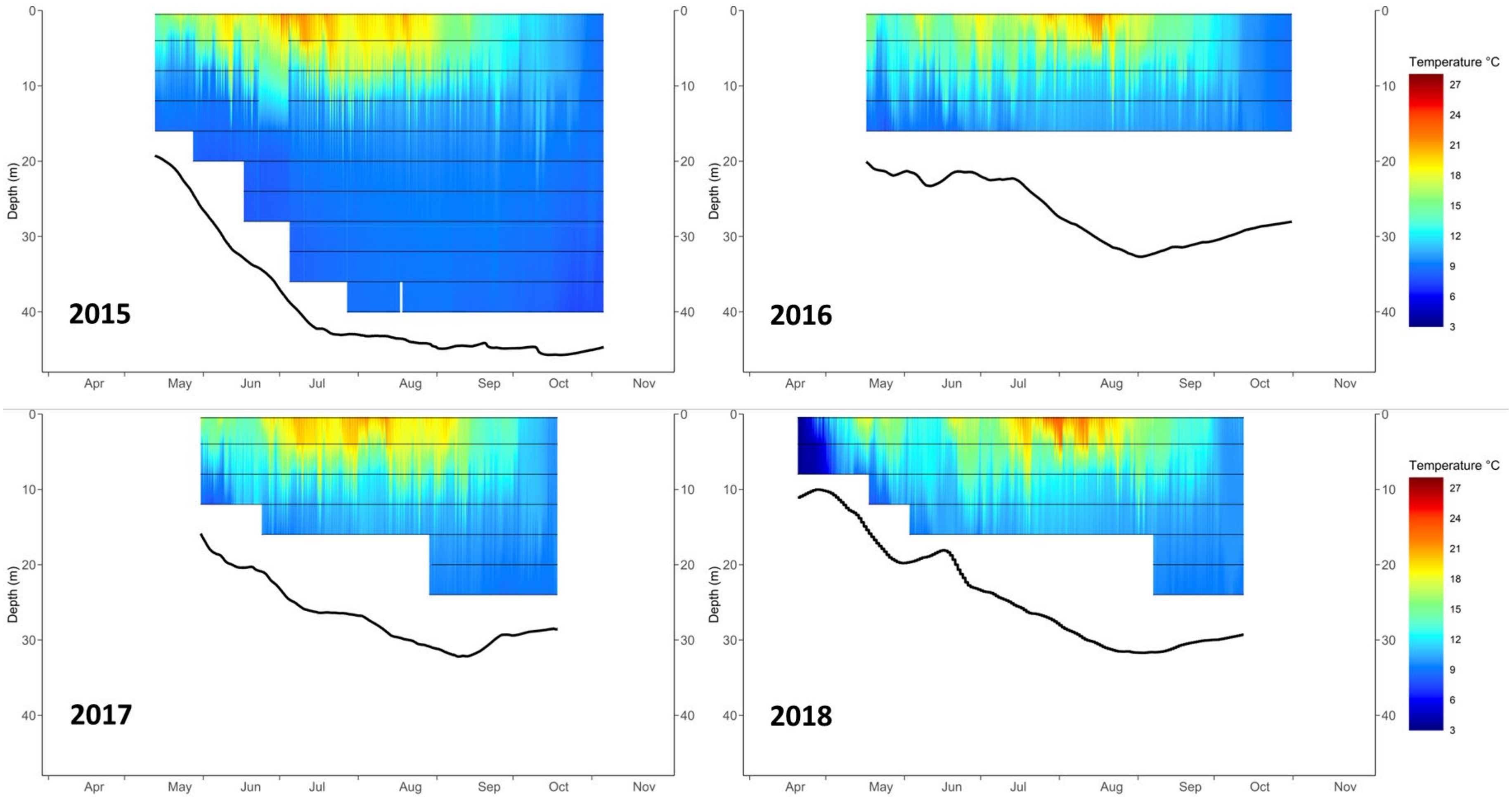

Figure B1 Water temperature profiles recorded in Downton Reservoir at the log boom (see Figure 2.1 for location), April to November 2015 (upper left), 2016 (upper right), 2017 (lower left), and 2018 (lower right). The horizontal lines indicate the measurement depths. Temperatures between those depths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

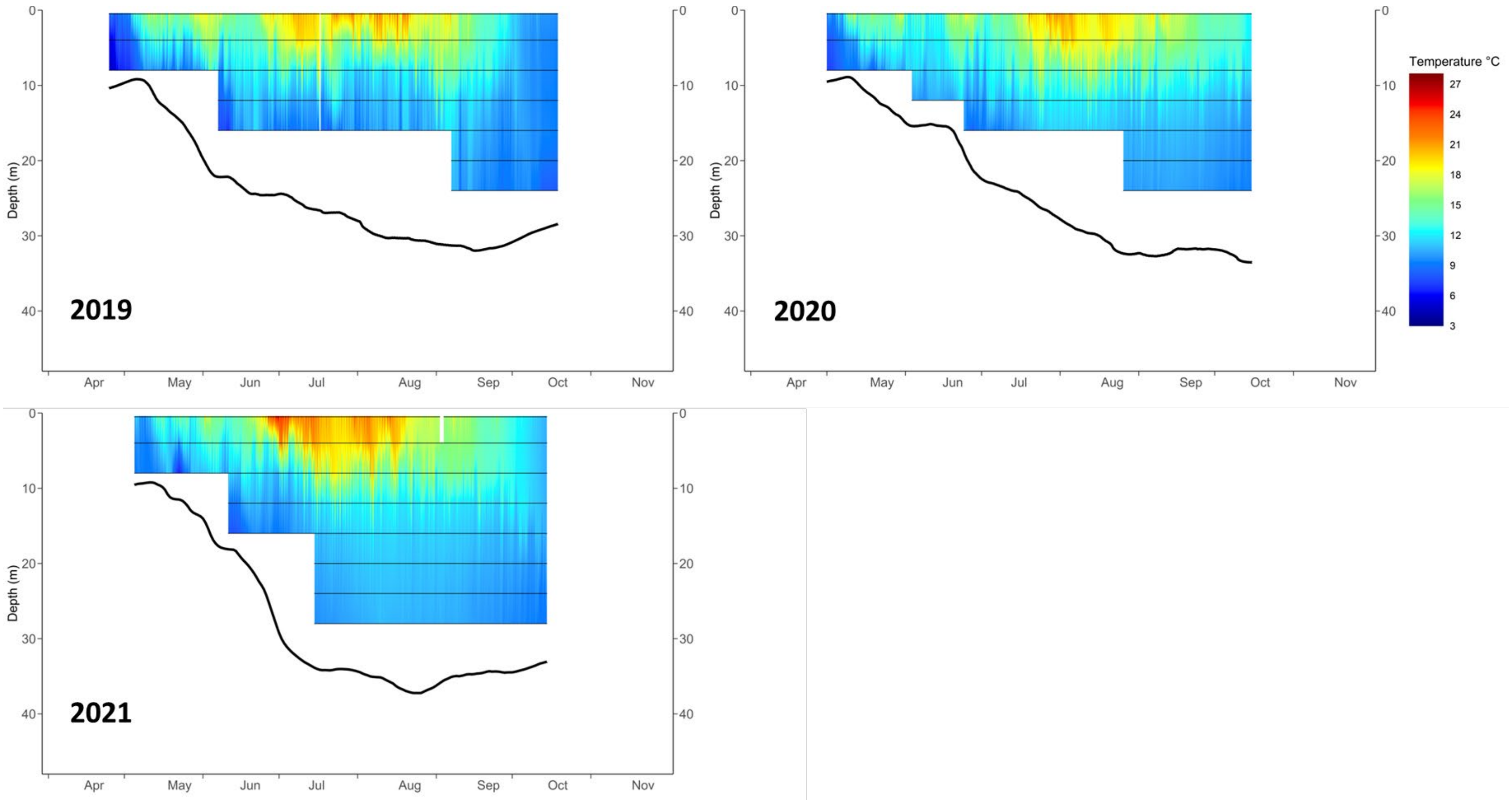

Figure B1 Cont. **Water temperature profiles recorded in Downton Reservoir at the log boom (see Figure 2.1 for location), April to November 2019 (upper left), 2020 (upper right), and 2021 (lower left). The horizontal lines indicate the measurement depths. Temperatures between those depths were linearly interpolated. The solid black lines reference the reservoir depths at the log boom.**

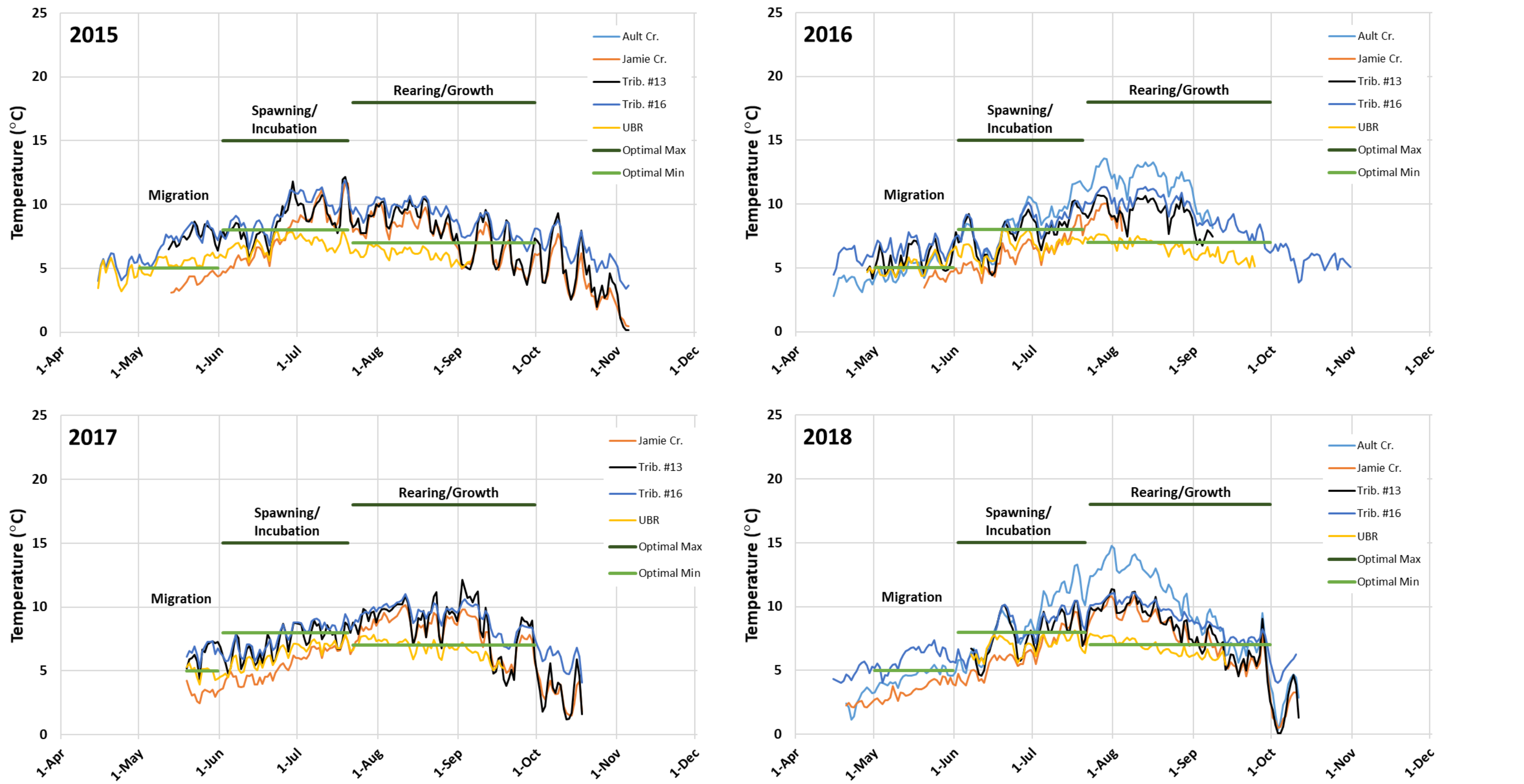

Figure B2 **Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to October 2015 (upper left), 2016 (upper right), 2017 (lower left), and 2018 (lower right). The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages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

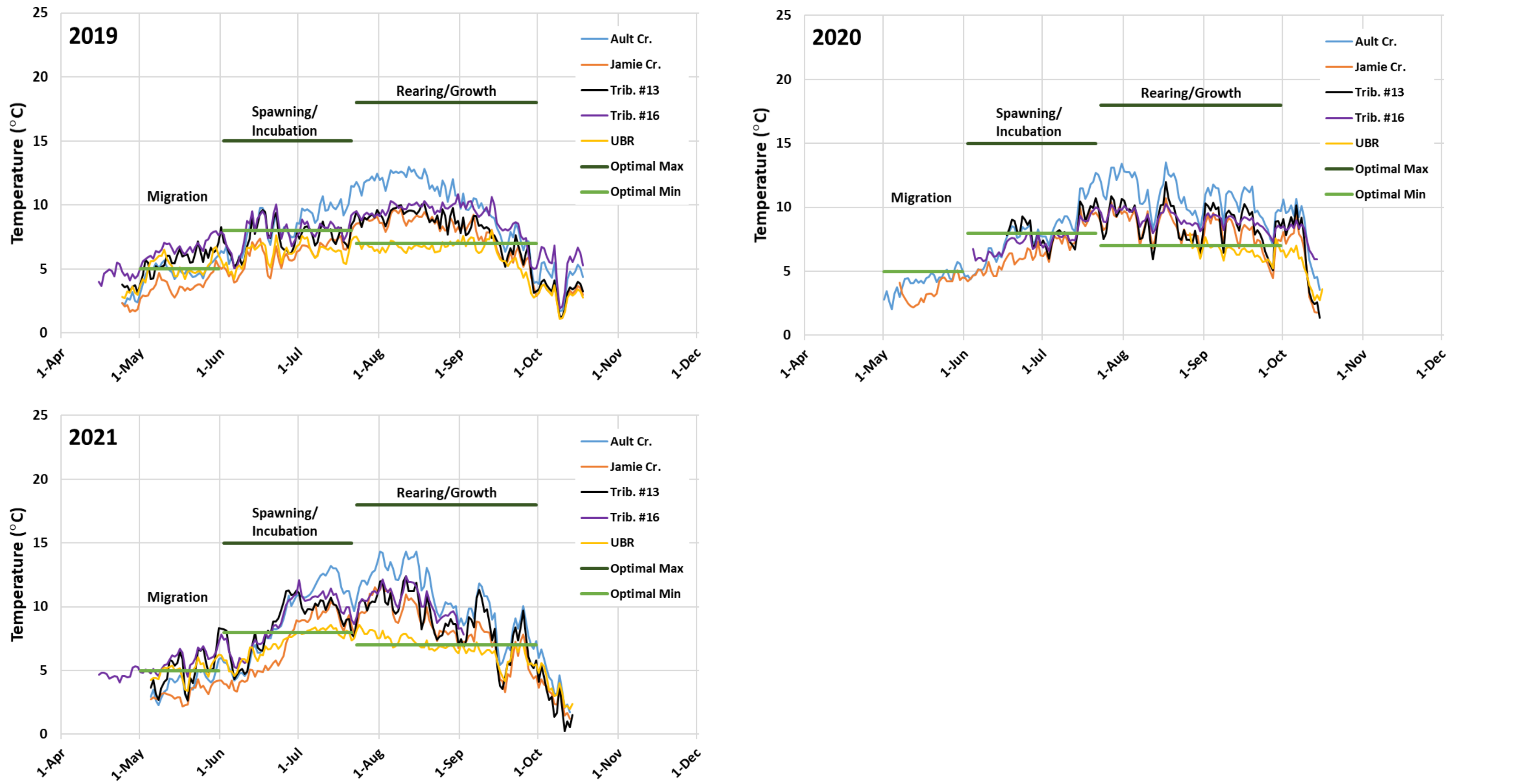

Figure B2 Cont. **Mean daily water temperatures in a set of select Downton Reservoir tributaries, April to October 2019 (upper left), 2020 (upper right), and 2021 (lower left). The light and dark green horizontal lines bracket the preferred temperature ranges for key life history stages of rainbow trout (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%
9 (2021)	93%	7%
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]	9%	34%	0%	25%	100%	**14%**
749.81	100%	100%	91%	66%	100%	75%	NA [a]	**86%**
746	100%	97%	91%	61%	99%	71%		**83%**
742	100%	81%	91%	55%	94%	54%		**72%**
738	100%	61%	73%	47%	81%	18%		**50%**
734	99%	32%	55%	39%	70%	NA [a]		**33%**
730	55%	19%		8%	33%			**18%**
726	18%	6%		2%	9%			**5%**
722	2%	1%		2%				**1%**
718					NA [a]			
714			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 (2019-2021)

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
316990	08-Jun-18	East	125	09-Jun-21	West	315	9.2	63
317427 [b]	03-Jun-18	West	90	03-Jun-21	Mid	254	2.8	55
316206	07-Jun-19	West	290	08-Jun-21	West	315	0.7	12
316354	07-Jun-19	West	218	09-Jun-21	West	242	2.0	12
560105	09-Jun-19	Mid	98	09-Jun-21	West	249	1.5	75

[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 (2019-2021).

[b] This fish was also recaptured on 11-Jun-19 (~1 year at large) at 4.0 km from it's original capture location in the West zone when it was 210 mm and 105 g.

Continued…

Tag Code[a]	Original Capture Data			Recapture Data			Dist (km)	Growth (mm/yr)
	Date	Zone	FL (mm)	Date	Zone	FL (mm)		
560252	10-Jun-19	East	90	06-Jun-21	Mid	232	2.3	71
560561	12-Jun-19	East	91	07-Jun-21	East	210	1.5	60
980028	17-Oct-19	Mid	120	01-Sep-21	Mid	181	0.1	33
621821	19-Jun-20	Mid	155	07-Jun-21	East	246	3.2	94
621907	19-Jun-20	Mid	193	06-Jun-21	East	223	4.0	31
621909	20-Jun-20	Mid	82	03-Jun-21	Mid	203	1.9	127
621181	22-Jun-20	East	126	07-Jun-21	East	180	1.7	56
621347	22-Jun-20	East	185	07-Jun-21	East	250	1.5	68
561248	24-Jun-20	West	119	09-Jun-21	West	197	0.2	81

[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 (2019-2021).

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

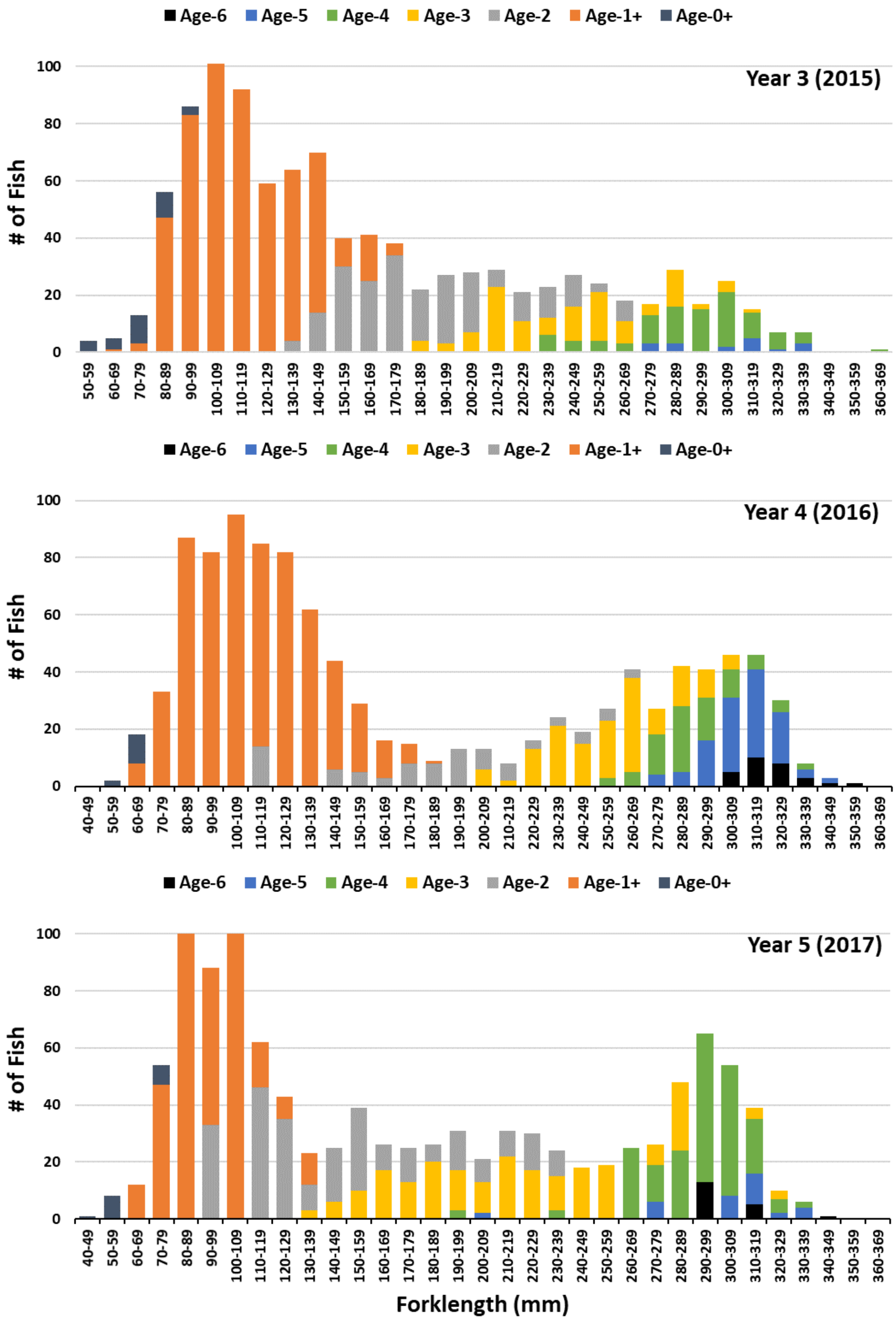

Figure E1 **Length-frequency histograms for each study year showing the distribution of age classes for rainbow trout in Downton Reservoir in late May to early June. Note: results for years 1 and 2 are not included due to different sampling approach in those years.**

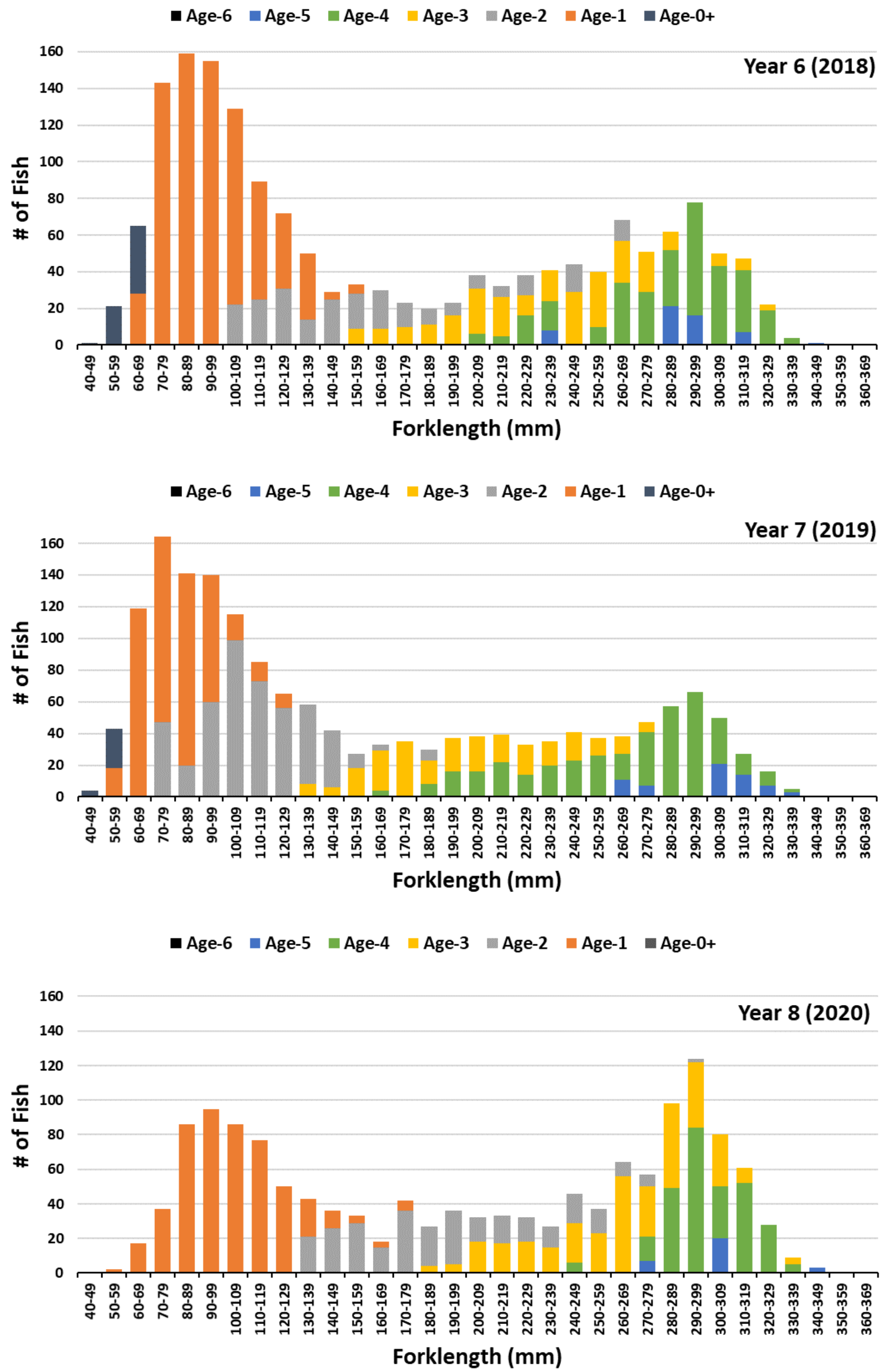

Figure E1 Continued (see description on previous page).

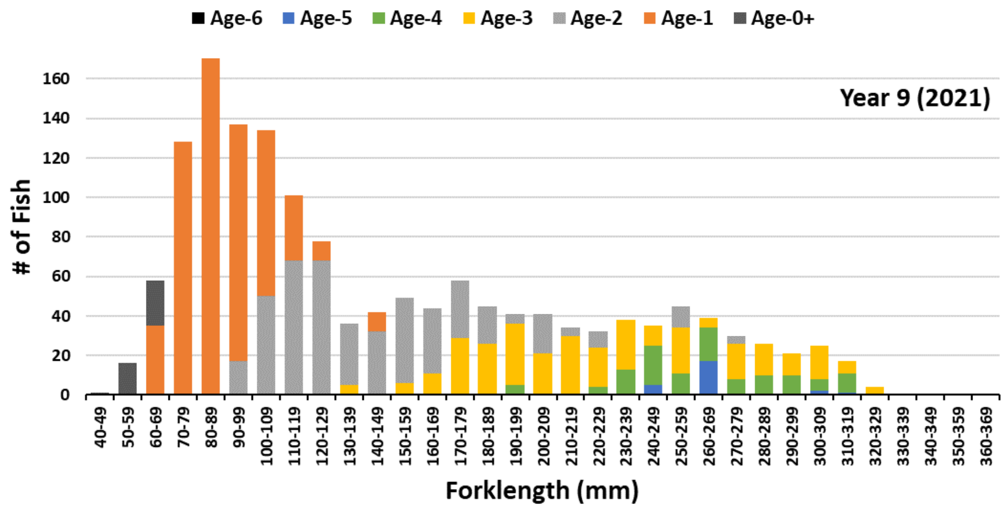

Figure E1 Concluded (see description on previous page).

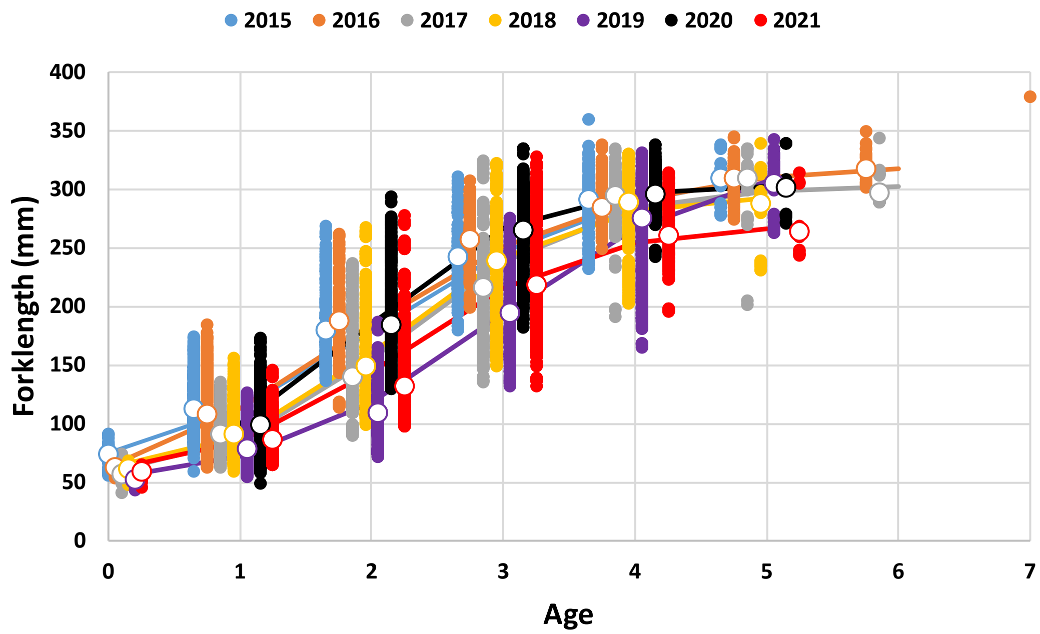

Figure E2 Size-at-age plot for rainbow trout captured during the annual fish population index survey, Years 3 to 8 (2015 to 2021). The lines represent the year-specific 4-parameter Logistic growth curves based on the median size values (open circles) for each available age class in Downton Reservoir. The individual length data points for each age class are also shown (filled circles).

Appendix F – Annual Age-1 and Age-2 CPUE vs. minimum and maximum reservoir elevations

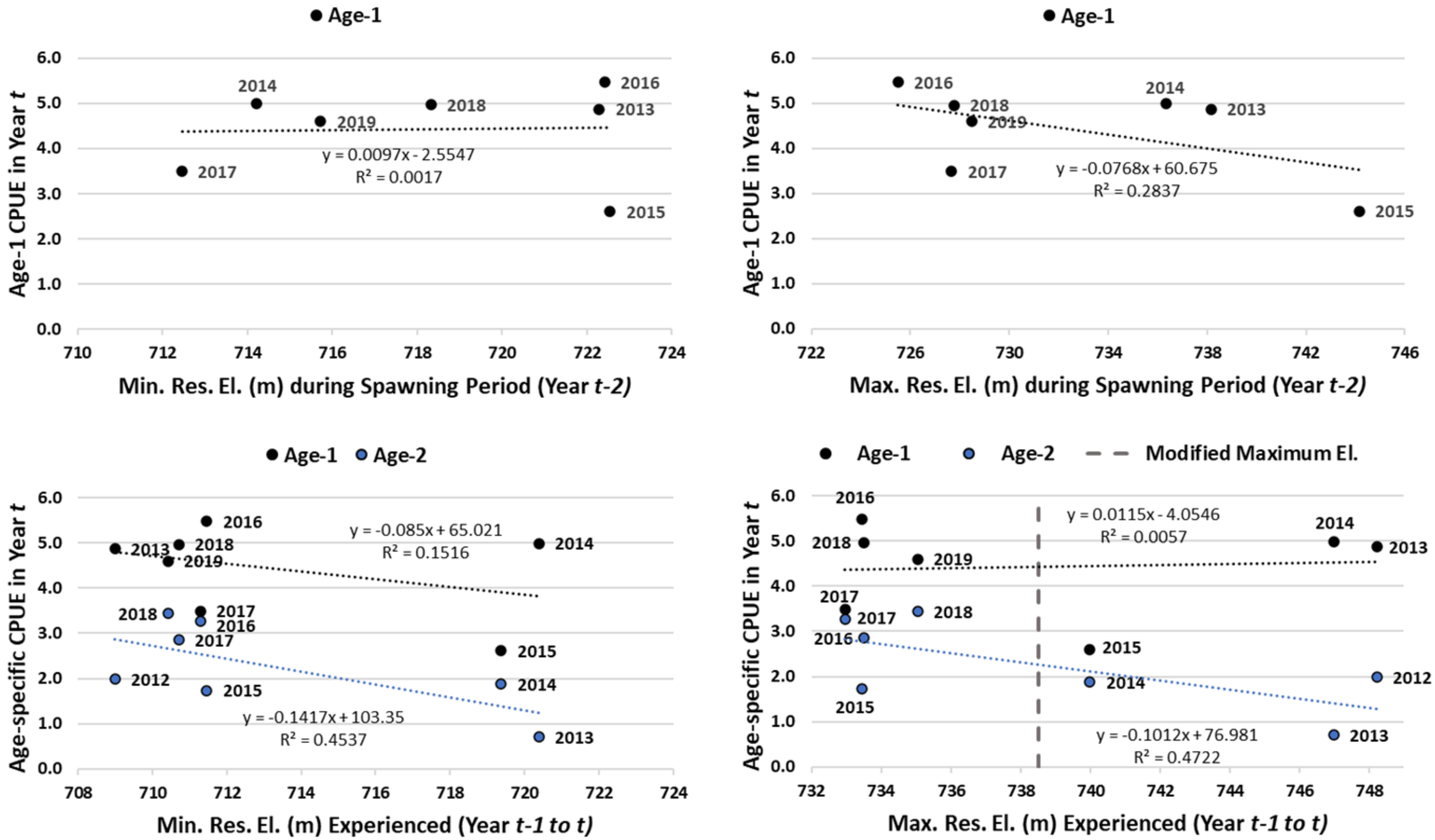

Figure F1 Plots of annual age-specific CPUE for Age-1 fish against minimum and maximum reservoir elevations during the spawning period in their recruitment year (*t-2*; upper panels); and Age-1 and Age-2 CPUEs against the minimum and maximum reservoir levels experienced in the previous year (*t-1* to *t*; lower panels). Labels next to each data point indicate the *recruitment* year (i.e., not the sampling year).