Campbell River Project Water Use Plan

Upper and Lower Campbell Lake Fish Spawning Success Assessment

Implementation Year 8

Reference: JHTMON-3

JHTMON-3: Upper and Lower Campbell Lake Fish Spawning Success Assessment Year 8 Annual Monitoring Report

Study Period: 2021

Laich-Kwil-Tach Environmental Assessment Ltd. Partnership
Ecofish Research Ltd.

October 10, 2023

JHTMON-3: Upper and Lower Campbell Lake Fish Spawning Success Assessment

Year 8 Annual Monitoring Report

Prepared for:

BC Hydro Water License Requirements
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October 10, 2023

Prepared by:

Laich-Kwil-Tach Environmental Assessment Ltd. Partnership

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Title Page Photographs

Top left: Looking upstream at the Miller Creek snorkel start point.

Top right: Looking at UCR-LKGN01 set location.

Bottom left: Rainbow Trout observed in Thelwood Creek.

Bottom right: Looking downstream at the Thelwood Creek snorkel end point.

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EXECUTIVE SUMMARY

Water Use Plans (WUPs) were developed for all of BC Hydro's hydroelectric facilities through a consultative process and have implemented monitoring to address outstanding management questions. To address uncertainty around factors limiting fish abundance, terms of reference were provided for monitoring programs to assess whether fish benefits are being realized under the WUP operating regime and to evaluate whether limits to fish production could be improved by modifying operations in the future. The *Upper and Lower Campbell Lake Fish Spawning Success Assessment* (JHTMON-3) comprises one component of the wider effectiveness monitoring studies within the Campbell River WUP. The overall aim of JHTMON-3 is to test the assumption that recruitment of salmonids (trout and char) in Upper Campbell Reservoir (Upper Campbell Reservoir and Buttle Lake) and Lower Campbell Reservoir is limited by availability of Effective Spawning Habitat (ESH) (i.e., spawning habitat that remains 'suitable' for the duration of the spawning and following incubation periods). The three species of primary interest are Rainbow Trout, Cutthroat Trout and Dolly Varden. JHTMON-3 involves assessing the extent of spawning habitat both within and above the drawdown zone, evaluating overall habitat utilization and spawning success, and determining whether the area of effective spawning habitat is sufficient to allow the salmonid populations to fully seed the reservoirs. Results obtained thus far, particularly incubation tests and population modelling carried out during Year 5, suggest that recruitment of salmonids is influenced by availability of ESH, although not to the extent assumed during the development of the Water Use Plan. Continued monitoring of critical components of the JHTMON-3 monitoring program will inform conclusions for the final Year 10 report.

Effective Spawning Habitat Model Results

The ESH Performance Measure Model quantifies the amount of spawning habitat within the drawdown zone that is available to fish at the time of spawning but not subsequently inundated by rising reservoir levels during the egg incubation period. Because life histories and the timing of spawning and incubation vary among species, separate ESH models were run for Cutthroat Trout, Rainbow Trout and Dolly Varden.

ESH values for both Lower and Upper Campbell reservoirs were highly variable among years for all three species, particularly for Cutthroat Trout in the Upper Campbell Reservoir. ESH values calculated for 2021 in the Upper Campbell Reservoir for both Rainbow Trout and Cutthroat Trout were higher than in 2020; in the case of Cutthroat Trout the ESH value in 2021 was almost 7 times that in 2020, and almost double than the long-term average, whereas for Rainbow Trout the ESH value in 2021 was ~20% higher than in 2020 and ~30% lower than the long-term average. ESH values in 2021 corresponded with a seasonal drawdown in 2021 that was lower than average coupled with steadily increasing water levels through the incubation period.

Gill Netting Surveys

Gill netting surveys between August 23 and August 24, 2021 (8th year of gillnetting surveys) in Upper Campbell Reservoir resulted in the capture of 25 Cutthroat Trout, 173 Rainbow Trout, no Dolly Varden, one sculpin, and three Cutthroat Trout/Rainbow Trout hybrids. Note that the catch limit of 150 Rainbow Trout was exceeded in nine gillnet sets, and as consequence gillnets were not deployed at two sites. Catch per unit effort (CPUE) ranged from 0.085 to 0.212 fish/net hour for Cutthroat Trout and 0.25 to 2.52 fish/net hour for Rainbow Trout. Relative condition of Rainbow Trout age 5+ was lower than expected (0.93).

Species-specific inverse von Bertalanffy growth functions were developed during Year 5 and refined in subsequent years to assign ages of unaged fish, based on their fork length. These functions use all available data from the monitoring program (Years 1 to 8), and therefore will progressively improve as more data are collected through this monitoring program.

Cutthroat Trout were captured more often in sinking nets, suggesting a benthic lifestyle. Rainbow Trout were more abundant in floating gill nets, suggesting a pelagic lifestyle.

Snorkel Surveys

Snorkel surveys were undertaken in the Lower Campbell Reservoir during March and April 2021 (8th year of snorkel surveys), to target the Cutthroat Trout spawning period, and in the Buttle Lake and Upper Campbell Reservoir in June 2021, to target the Rainbow Trout spawning period. The survey results for Rainbow Trout were incorporated into the existing enumeration of adult spawning fish in the six tributaries of Buttle Lake and Upper Campbell Reservoir since 1990.

Snorkel surveys were undertaken at three tributaries of Lower Campbell Reservoir for adult Cutthroat Trout spawners in 2021. Miller Creek and Fry Creek were sampled on March 2, 2021; Greenstone River was sampled later due to colder water conditions (on April 19, 2021). Adult Cutthroat Trout were observed in Greenstone River (n = 20), one adult was observed in Miller Creek, and none in Fry Creek. However, Cutthroat Trout redds were observed in all three tributaries and were most abundant in Miller Creek (n = 172), followed by Fry Creek (n = 117) and Greenstone River (n = 12). One juvenile Cutthroat Trout was observed in Greenstone River during Spring snorkel surveys. The majority of adult Cutthroat observed were either brightly coloured, moderately coloured, or mid-spawn, indicating spawning activity at the time of the surveys.

Snorkel surveys targeting adult Rainbow Trout spawners were undertaken in tributaries to Buttle Lake and Upper Campbell Reservoir during low flow conditions from June 1 to 8, 2021. Rainbow Trout redds were recorded in all sampled tributaries except for Miller Creek. The highest number of redds was observed in Lower Elk River (1,210 redds), followed by Thelwood Creek (982 redds), and Upper Elk River (869 redds). The majority of adult Rainbow Trout observed were in moderately coloured condition or mid-spawning, and the highest numbers of adults were recorded in the Lower Elk River, Thelwood Creek, and Upper Elk River. Low numbers of adult Rainbow Trout were recorded in Henshaw Creek. Observed densities of Rainbow Trout were greatest in Wolf River

(960 fish/km), Thelwood Creek (640 fish/km), Lower Elk River (588 fish/km), and Philips Creek (440 fish/km). These patterns were similar to those observed during previous years of this monitoring program (2014-2020).

MON-3 Status of Objectives, Management Questions and Hypotheses after Year 8.

Study Objectives	Management Questions	Management Hypotheses	Year 8 (fiscal year 2021) Status
The aim of JHTMON-3 is to test the assumption that recruitment of salmonids (trout and char) in Upper and Lower Campbell reservoirs is limited by availability of ESH. The Monitor involves assessing the extent of spawning habitat both within and above the drawdown zone; evaluating overall habitat utilization and spawning success; and determining whether the area of ESH is sufficient to allow the salmonid populations to fully seed the reservoirs. Implementation of the WUP in the Upper and Lower Campbell Reservoirs is predicted to increase the area of ESH for both Cutthroat Trout and Rainbow Trout. Analysis of fish abundance and spawning success before and after the WUP implementation will test the assumption that salmonid recruitment is limited by availability of ESH.	Following implementation of the Campbell River WUP, does the population of Rainbow Trout, Cutthroat Trout and Dolly Varden in Upper and Lower Campbell reservoirs increase as a result of the expected gains in functional spawning habitat?	$H_0$1: Following implementation of the Campbell River WUP the abundance of adult trout does not change in Upper and Lower Campbell Reservoirs.	This was the 8th year of gillnetting and snorkel surveys. Data were collected as planned, from standardized snorkel surveys of spawning fish in tributaries, and gill netting of multiple cohorts in reservoirs. Gill net sampling could not proceed at two sites because the Rainbow Trout catch limit specified in the scientific fish collection permit was exceeded. This also occurred in Year 7 when catches were high. Results to date suggest that recruitment is positively correlated to effective spawning habitat, and therefore effects of reservoir inundation on embryo mortality may be strong enough to affect the dynamics of Cutthroat Trout in the Upper Campbell Reservoir.
	Are the trout populations in Upper and Lower Campbell reservoirs limited by the availability of ESH?	$H_0$2: Following implementation of the Campbell River WUP the abundance of adult trout in Upper and Lower Campbell Reservoirs is not correlated with ESH at the time of the cohort's emergence.	Preliminary results from population modelling indicate that the availability of ESH may be a limiting factor to recruitment of salmonids in the Upper Campbell Reservoir.
	Is the ESH performance measure a reliable measure of spawning habitat, and therefore	$H_0$3: The proportion of mature adults that spawn in the drawdown zones of Upper and Lower	Data on spawning habitat use were collected during Year 5 and integrated with information on spawning habitat

Study Objectives	Management Questions	Management Hypotheses	Year 8 (fiscal year 2021) Status
	useful in the present Monitor, as well as in future WUP investigations?	Campbell reservoirs is not biologically significant. $H_0$4: There is insufficient groundwater movement in areas of the drawdown zone suitable for trout spawning to replenish local oxygen supply and flush away metabolic waste.	availability collected during Year 4. The majority of spawning takes place in areas upstream of the drawdown zone but is highly variable among waterbodies. In some tributaries a considerable portion of spawning occurs within the drawdown zone. An experimental incubation test to assess mortality rate of eggs in relation to inundation by rising reservoir water elevation was carried out during Year 5. Hydrology and water quality data were also collected to support interpretation of the experimental results. Survival and hatch rates differed among streams and depths, from almost no effect of inundation to a substantial effect of inundation. Mortality rate was linked to stream conditions (i.e., groundwater exchange rate, surface water flow, and percentage of fines in the substrate). Thus far the main cause of mortality appears to be localized lack of oxygen.

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1. INTRODUCTION

1.1. Background to Water Use Planning

Water use planning exemplifies sustainable work in practice at BC Hydro. The goal is to provide a balance between the competing uses of water that include fish and wildlife, recreation, and power generation. Water Use Plans (WUPs) were developed for all of BC Hydro's hydroelectric facilities through a consultative process involving BC Hydro, local stakeholders, government agencies and First Nations. The framework for water use planning requires that a WUP be reviewed on a periodic basis and there may be monitoring to address outstanding management questions in the years following implementation of a WUP.

As the Campbell River Water Use Plan (BC Hydro 2012) process reached completion, a number of uncertainties remained with respect to the effects of BC Hydro operations on aquatic resources. A key question throughout the WUP process was "what limits fish abundance?" For example, are fish abundance and biomass limited by available habitat, food, environmental perturbations or ecological interactions? Answering this question is an important step to better understanding how human activities in the watershed affect fisheries, and in effectively managing water uses to protect and enhance aquatic resources. To address uncertainty in our understanding of the factors that limit fish abundance and biomass, monitoring programs were designed to assess whether fish benefits are being realized under the WUP operating regime and to evaluate whether limits to fish production could be improved by modifying operations in the future.

Salmonid (trout and char) recruitment (i.e., number of fish surviving to enter a particular life stage) is assumed to be limited by the availability of suitable spawning habitat. BC Hydro affects the amount of spawning habitat through reservoir filling and drawdown. The drawdown zone refers to the area within the elevation band of the reservoir between the high and low waterlines that is susceptible to becoming either inundated or exposed from water use operations. Each tributary draining directly into the reservoirs can be divided into an upstream section above the upper limit of the drawdown zone and a lower section within the drawdown zone. Observations suggest that some resident Rainbow Trout (*Oncorhynchus mykiss*) and Cutthroat Trout (*Oncorhynchus clarki*) spawn in tributaries and alluvial fans within the drawdown zone of Upper Campbell Lake and Buttle Lake Reservoir and Lower Campbell Lake Reservoir (Lough 2000). During the Campbell River WUP development, it was hypothesized that rising reservoir water levels during spring freshet inundate and thereby kill incubating eggs, limiting the area of ESH[1] for salmonids, and ultimately recruitment to populations in Upper Reservoir and the Lower Reservoir. The main premise for the impact hypothesis is that these fish typically dig their redds during late winter and spring when reservoir levels are low, and the redds are then susceptible to inundation from rising reservoir levels during the freshet period (Anon 2004). The absence of flowing water through a redd is thought to kill incubating embryos in the pre-eyed

[1] The term 'effective spawning habitat' refers to spawning habitat that remains 'suitable' for the duration of the spawning period and the ensuing incubation period.

stage because it prevents replenishment of oxygen and flushing of metabolic wastes at the egg-water interface.

The *Upper and Lower Campbell Lake Fish Spawning Success Assessment* (JHTMON-3) is one of a number of effectiveness monitoring studies within the Campbell River WUP. The objective of JHTMON-3 is to test salmonid recruitment (trout and char) in the Upper Campbell Reservoir (Upper Campbell Reservoir and Buttle Lake) and Lower Campbell Reservoir to help resource managers better understand the potential biological effects of BC Hydro operations. JHTMON-3 assesses the relationship between salmonid recruitment in the reservoirs and drawdown, specifically assessing whether population abundance of salmonids is limited by spawning habitat within the drawdown zone.

During the Campbell River WUP, an "ESH" Performance Measure (PM) was devised for trout spawners in the Upper Reservoir and the Lower Reservoir, which calculated the amount of spawning habitat inundated during the spawning and incubation period of different salmonid species. During the WUP, the ESH PM was used to evaluate reservoir operations by assuming that more spawning habitat would result in greater recruitment to Campbell River reservoirs and their tributaries. In essence, this PM assumed that recruitment of trout in the reservoirs is limited by functional spawning habitat. The aim of the JHTMON-3 monitoring study is to test this assumption.

1.2. BC Hydro Infrastructure, Operations, and Monitoring Context

1.2.1. Overview

The Campbell River WUP project area is complex and includes facilities and operations in the Campbell and Quinsam watersheds. The Upper and Lower Campbell reservoirs are located due west of the city of Campbell River on the east coast of Vancouver Island, British Columbia (Map 1). Details of BC Hydro's Campbell River infrastructure and operations are provided in the Campbell River System WUP (BC Hydro 2012).

1.2.2. Upper Campbell Reservoir

Buttle Lake and Upper Campbell Reservoir are effectively a single reservoir that is the largest in the Campbell River hydroelectric system. The largest tributaries are Thelwood Creek, entering the system at the south end of Buttle Lake, and the Elk River, which enters the west side of Upper Campbell Reservoir. Upper Campbell Reservoir is impounded by the Strathcona Dam, which was constructed between 1955 and 1958 and had a second generating unit installed in 1968. The dam also provides primary flow regulation for the Ladore and John Hart Dams, which are located downstream. Upper Campbell Reservoir's historical operational water elevation has been between 221.0 m and 210.0 m. The licensed storage for operations in Buttle Lake and Upper Campbell Lake Reservoir is 212.00 masl to 220.98 masl and 192.00 masl to 220.98 masl, respectively (BC Hydro 2012).

1.2.3. Lower Campbell Reservoir

Lower Campbell Reservoir is located 15 km east of Campbell River. It is located to the east, and at the outflow of, the Upper Campbell Reservoir (Map 1). Lower Campbell Reservoir is impounded by the Ladore Dam. The Ladore Dam was originally completed in 1949, and two generating units were added in 1957. The reservoir's historical operational water elevation has been between 178.3 masl and 174.0 masl, while the current storage licence limits for operation is 178.3 masl to 163.65 masl (BC Hydro 2012).

1.3. Historical Reservoir Elevations, and Implementation of the Interim Flow Management Strategy

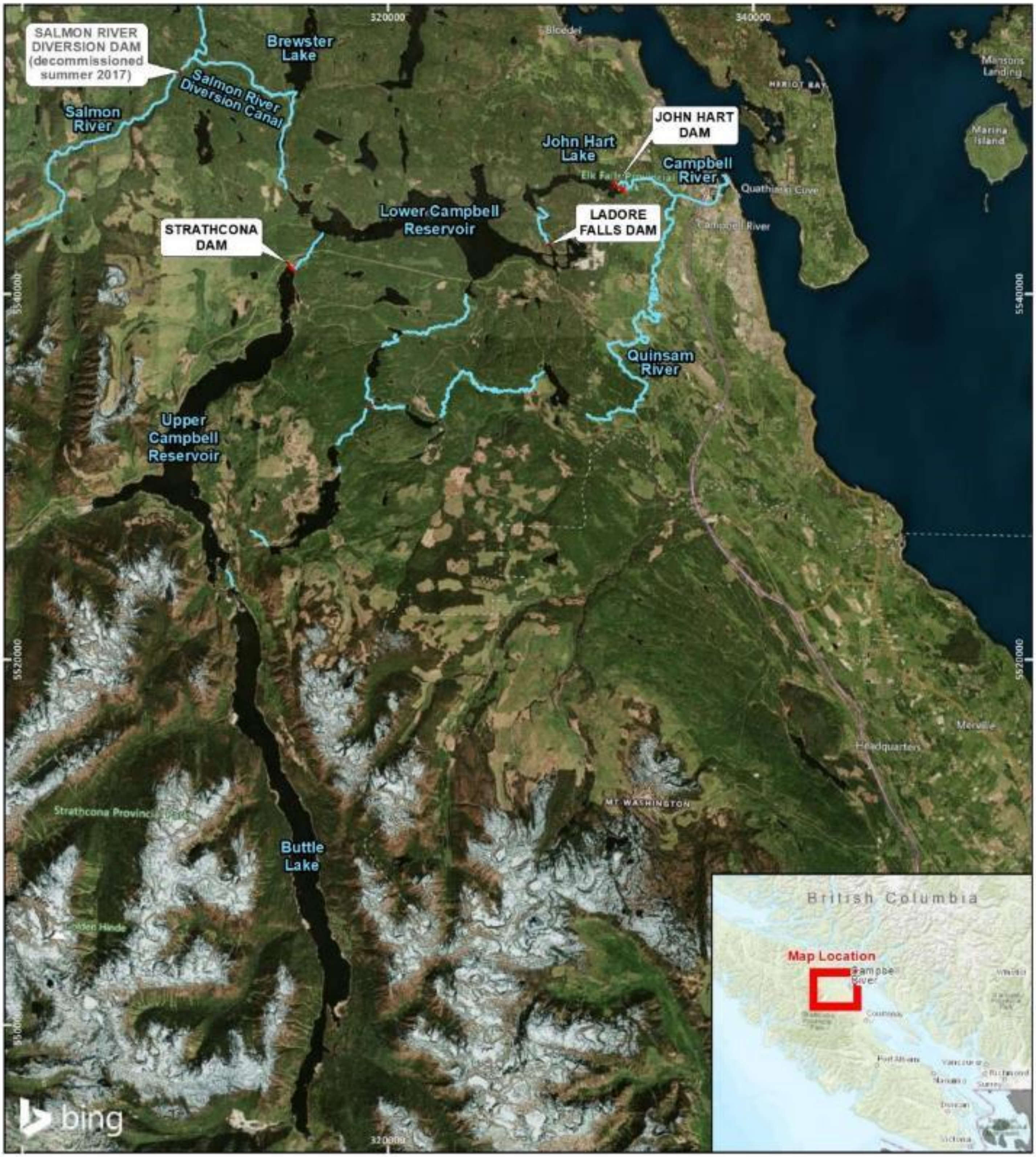
The Upper Campbell Reservoir experiences water level fluctuations of 4 to 10 m within years. (Figure 1). Fluctuations differ among years depending on hydrological conditions; however, in general, the reservoir is drawn down in late winter and early spring and recharges during late spring and early summer. A second drawdown typically occurs in late summer and early fall, prior to recharge due to fall rains. Seasonal changes are much less pronounced in Lower Campbell Reservoir, which is operated within a narrower range of elevations (Figure 2).

BC Hydro implemented an Interim Flow Management Strategy (IFMS) in October 1997, with the aim of balancing power generation with fisheries and wildlife habitat, shoreline conditions, flood control, and recreation interests. The IFMS was later replaced by the WUP, although impacts on reservoir elevations were minimal with respect to those outlined in the IFMS. Figure 1 and Figure 2 show the impact that the implementation of the IFMS had on elevations of the Upper and Lower Campbell Reservoirs. Following implementation of the IFMS, seasonality in elevation of the Upper Campbell Reservoir remained relatively stable, except for an increased duration of the period of high elevations during the summer, and a change in the seasonality of the elevation of the reservoirs in the spring, with a slightly longer period of low reservoir elevation and lower elevations. In general, the mean reservoir elevation was ~2m lower post-implementation of the IFMS, whereas the 10th and 90th quantiles of reservoir elevations were ~1m lower post-implementation of the IFMS (Figure 1). The implementation of the IFMS did not affect elevation of the Lower Campbell Reservoir (Figure 2).

1.4. Management Questions and Hypotheses

The overall objective of JHTMON-3 is to test the assumption that recruitment of salmonids (trout and char) in Upper and Lower Campbell reservoirs is limited by ESH. Testing this assumption was conducted by: 1) assessing the extent of spawning habitat both within and above the drawdown zone; 2) evaluating overall habitat utilization and spawning success; and 3) determining whether the area of functional spawning habitat is sufficient to allow the salmonid populations to fully seed the reservoirs. The three species of primary interest for the study are Rainbow Trout, Cutthroat Trout, and Dolly Varden (*Salvelinus malma*).

Project Overview



Legend
Dam

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

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NO.	DATE	REVISION	BY
1			
2			
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ECOFISH RESEARCH

Map 1

Path: M:\Projects-Active\1230_JHTMON\MXD\Overview\1230_JHT_ProjectOverview_3585_20200129.mxd

The JHTMON-3 monitoring program aims to address the following three management questions (BC Hydro 2015):

1. Following implementation of the Campbell River WUP, do the populations of Rainbow Trout, Cutthroat Trout, and Dolly Varden in the Upper Reservoir and Lower Reservoir increase as a result of the expected gains in functional spawning habitat?

And, by corollary:

2. Are the trout populations in Upper Reservoir and the Lower Reservoir limited by the availability of functional spawning habitat?
3. Is the ESH Performance Measure a reliable measure of spawning habitat, and therefore useful in the present monitoring study, as well as in future WUP investigations?

In addressing these questions, the monitoring study is designed to test the following four null hypotheses:

$H_0$1: Following implementation of the Campbell River WUP:

a. The abundance of adult trout does not change in Upper Reservoir.
b. The abundance of adult trout does not change in Lower Reservoir.

$H_0$2: Following implementation of the Campbell River WUP:

1. Abundance of adult trout in Upper Reservoir is not correlated with ESH at the time of the cohort's emergence.
2. Abundance of adult trout in Lower Reservoir is not correlated with ESH at the time of the cohort's emergence.

$H_0$3: The proportion of mature adults that spawn in the drawdown zones of Upper Reservoir and the Lower Reservoir is not biologically significant.

$H_0$4: There is insufficient groundwater movement in areas of the drawdown zone suitable for trout spawning to replenish local oxygen supply and flush away metabolic waste.

1.5. Scope of the JHTMON-3 Study

The current JHTMON-3 TOR proposes a 10-year study with the following study components:

1. Annual (Years 1-9) trap and gill net surveys of fish abundance and biomass in the reservoirs;
2. A two-year survey of spawning distribution in reservoir tributaries; and
3. A two-year detailed analysis of flow and incubation conditions within the drawdown zone of tributaries.

Methods for this multi-year study have changed in accordance with results from previous years. Results from the Year 1 studies (Hatfield *et al.* 2015) indicated that hydro-acoustic surveys provide coarse estimates of adult population, but do not yield age-specific abundances and therefore are not useful for assessing the effects of varying ESH values over time. Trap netting was found to be most effective at catching sculpin and stickleback, whereas gill nets are most effective at catching salmonids including Cutthroat Trout and Rainbow Trout. The additional sampling effort and cost associated with calibration of the gill net catches with trap net catches was determined to be not feasible. Trap net sampling was therefore discontinued for the 2016 (Year 3) monitoring program and only gill net sampling was continued.

The implemented Year 8 program followed the approach adopted for Years 3 to 8. Methods related to $H_0 1$ and $H_0 2$ in Year 8 involved:

1. Estimating fish abundance for salmonid species in Upper Campbell Reservoir, using sampling with gill nets.
2. Estimating abundance of spawning adfluvial trout (Cutthroat and Rainbow) using snorkel surveys in tributaries to Buttle Lake and Upper and Lower Campbell reservoirs.

Results from tests of null hypotheses $H_0 3$ and $H_0 4$ were presented in the JHTMON-3 Year 5 monitoring report (Buren *et al.* 2019). Briefly, results related to $H_0 3$ indicated that the majority of spawning takes place in areas upstream of the drawdown zone, but it is highly variable among waterbodies. In some tributaries a considerable portion of spawning occurs within the drawdown zone. Related to $H_0 4$, we carried out experimental incubation tests to assess mortality rate of eggs in relation to inundation. The incubation tests suggest that the modeling assumptions used during the WUP (i.e., reservoir inundation led to complete and instantaneous death of incubating Rainbow Trout embryos) were conservative and likely overestimated the effects of reservoir inundation. However, we observed high mortality of eggs at some sites, which provided some support to the assumption. These elevated mortality rates were tentatively linked to stream conditions (i.e., groundwater exchange rate, surface water flow, and percentage of fines in the substrate).

The work plan focuses most of the ESH investigative effort on Cutthroat Trout in Upper Campbell Reservoir because the potential population response is expected to be greatest due to the considerably larger drawdown (and therefore larger potential impact on egg mortality) and the general trend of rising water levels during the Cutthroat Trout incubation period (Figure 1). Any effect observed in Upper Campbell Reservoir is assumed to be transferable to Lower Campbell and John Hart reservoirs through application of the functional relationship developed for Upper Campbell Reservoir; however, the magnitude of response is expected to be less due to the more stable water levels in these two reservoirs (Figure 2). Additionally, it is advisable to focus on one reservoir rather than spread the same effort across two or more reservoirs, because this approach will improve the statistical strength of any relationship observed between ESH and fish CPUE.

We conducted a preliminary analysis of the relationship between ESH and fish population index for Cutthroat Trout in the Upper Campbell Reservoir for the Year 5 report, as proof of concept. Preliminary results suggest that effects of reservoir inundation on embryo mortality may be strong enough to affect the dynamics of Cutthroat Trout in the Upper Campbell Reservoir. Consistent with the terms of reference, this analysis will be updated for the Year 10 report, as ESH trends across fish age and abundance are anticipated to become more informative due to additional data from the ongoing monitoring.

Figure 1. Elevation of Upper Campbell Reservoir (recorded at Strathcona Dam), pre- and post-implementation of the Interim Flow Management Strategy. Grey lines represent elevations for individual years, blue lines represent mean elevations, red lines represent the 90th percentile elevations, green lines represent the 10th percentile elevations, and black line represent elevation in the current year. Timing of salmonid spawning and incubation periods are shown.

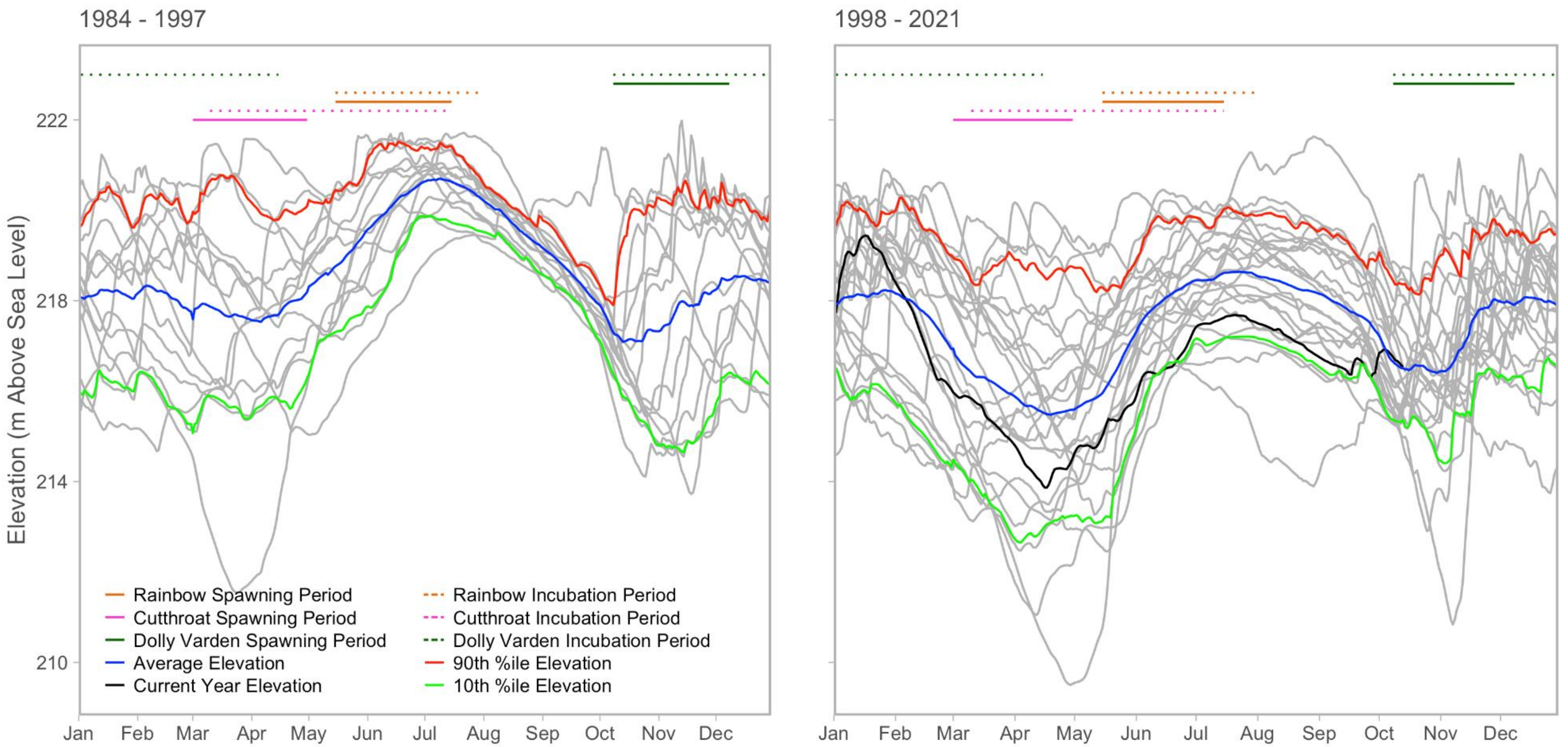
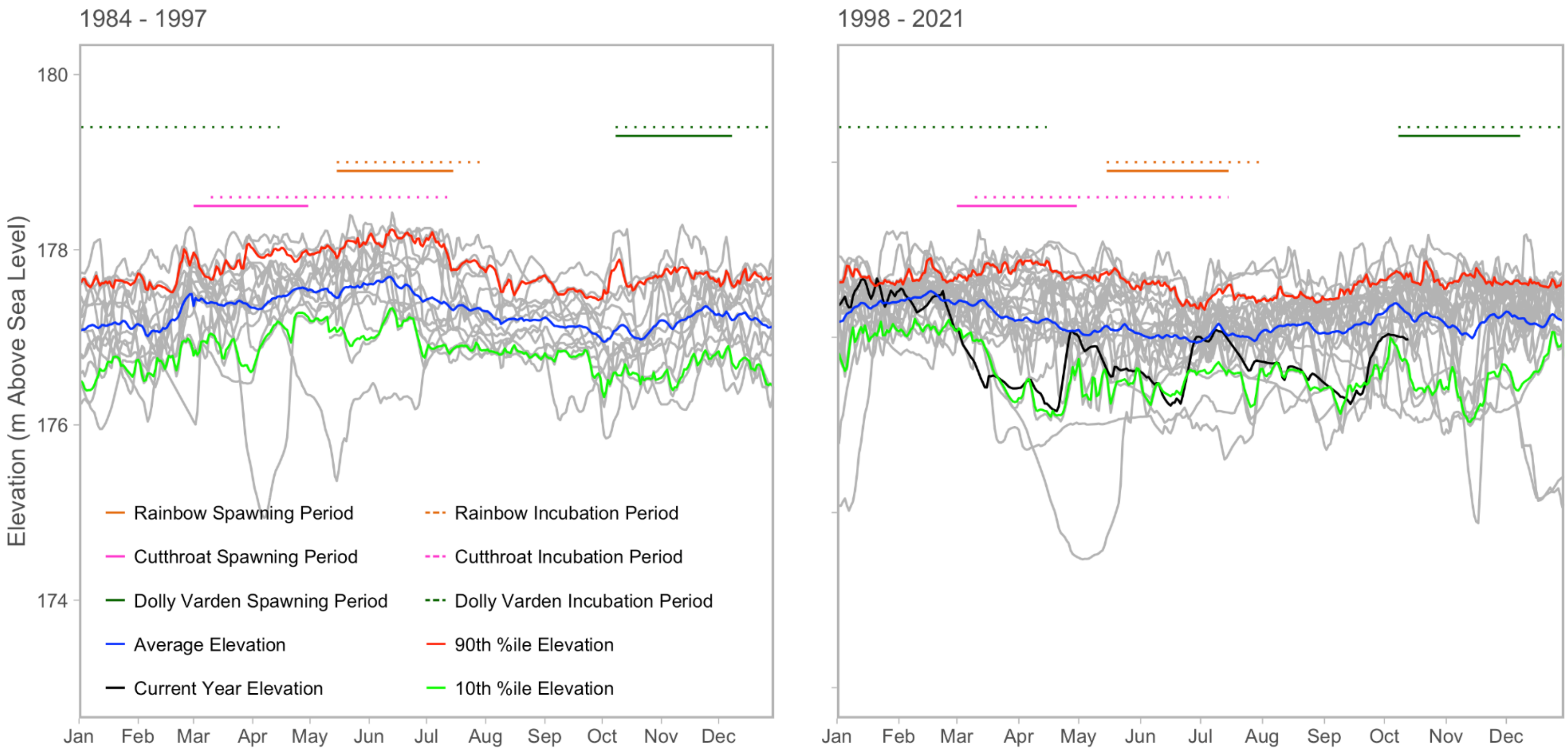


Figure 2. **Elevation of Lower Campbell Reservoir (recorded at Ladore Dam), pre- and post-implementation of the Interim Flow Management Strategy. Grey lines represent elevations for individual years, blue lines represent mean elevations, red lines represent the 90th percentile elevations, green lines represent the 10th percentile elevations, and black line represent elevation in the current year. Timing of salmonid spawning and incubation periods are shown.**



2. METHODS

2.1. Effective Spawning Habitat (ESH)

To quantify how reservoir elevations (and thus, spawning area available and area inundated during incubation) affect the success of spawning in tributary sections of the drawdown zones, an ESH performance measure was developed in the WUP (FTC 2003). The term "ESH" is used to refer to habitat that maintains its quality sufficiently to allow successful spawning and incubation. This performance measure is used to evaluate mortality of eggs following inundation, caused by accumulation of by-products of metabolism and insufficient oxygen replenishment. BC Hydro developed an ESH model to quantify ESH and to track the amount of habitat available for spawning that also receives sufficient flow during incubation periods (Leake, pers. comm. 2015).

The amount of spawning habitat for each day of spawning, and remaining habitat thereafter during incubation, was determined from reservoir-specific relationships between reservoir level and available spawning habitat (provided by BC Hydro, (Leake, pers. comm. 2015)) (Figure 3). Mean daily reservoir elevations for Strathcona Dam (Upper Campbell Reservoir) and Ladore Dam (Lower Campbell Reservoir) used in ESH modelling were provided by BC Hydro (Leake, pers. comm. 2015).

The incubation period was defined separately for the three species of interest, given their different life histories (Table 2); each species differs in the date of start and duration of incubation. Life history parameters were assumed to be constant across years. Incubation begins on the day of spawning and is assumed to last until a species-specific threshold in accumulated thermal units (ATU; i.e., daily accumulation of water temperature) is reached: 550 ATU for Cutthroat Trout, 600 ATU for Rainbow Trout, and 700 ATU for Dolly Varden (Table 2). Once this threshold is reached, eggs hatch. The metric Accumulated Thermal Units (ATU) was defined as the cumulative sum of daily average water temperature (Figure 4) (Leake, pers. comm. 2015). The ATU was tracked for each species during the corresponding incubation period and when the threshold ATU was reached (or on the incubation date end, whichever comes first), incubation was assumed to cease.

For each day of the incubation period, an effective spawning elevation was derived from the daily average reservoir elevation. If this elevation exceeded the reservoir elevation on the day of spawning by 25 cm for two consecutive days, then a portion of habitat was assumed to be lost. ESH area was determined from the effective spawning elevation and reservoir-specific relationships (Figure 3).

To obtain overall ESH, the daily ESH area was weighted by species-specific spawning intensities (Figure 5), to account for seasonality in the use of spawning habitat. Spawning intensities were assumed to be constant across years and follow a normal distribution with species-specific mean and standard deviations provided in Table 2. Standard deviation in mean spawning date was assumed to be equal to spawning duration divided by six.

Total annual ESH was calculated as the cumulative sum of the daily ESH during the spawning period. Similarly, total annual loss of effective habitat was calculated as the cumulative sum of the daily habitat loss during the spawning period.

The model is presented below as pseudo code. For each species, year, and day within the spawning period, the following steps were completed:

1. The mean daily reservoir elevation ("spawning elevation") was determined (data provided by BC Hydro).
2. The "effective spawning elevation" was set to the spawning elevation, the total ATU was set to the water temperature for the spawning day.
3. For each day of the incubation period:
    a. The reservoir elevation was compared to the effective spawning elevation;
    b. If the reservoir elevation exceeds effective spawning elevation by 25 cm for two consecutive days, then the effective spawning elevation was set to the reservoir elevation minus 25 cm; and
    c. The ATU for the incubation day was added to the total ATU.
4. At the end of incubation (when the total ATU meets the values in Table 1, or on the incubation end date in Table 1; whichever comes first) the ESH area was determined from the effective spawning elevation (Figure 3) (Leake, pers. comm. 2015).
5. ESH (area days, expressed as m^2d) was calculated by multiplying the ESH area by the spawning intensity, which was provided as a function of calendar date (Figure 5).
6. The initial spawning habitat was calculated by determining the habitat area for the spawning elevation and multiplying by the spawning intensity.
7. Loss of habitat was calculated by subtracting the ESH from the initial spawning habitat.

The above calculations were computed for each day of the spawning period and summed over each year to obtain total ESH and habitat loss.

Information pertaining to reservoir-specific relationship between reservoir elevation and available habitat (Figure 3), water temperature in the Upper and Lower Campbell Reservoirs (Figure 4), species-specific life histories (Figure 5 and Table 2), as well as mean daily reservoir elevations for Strathcona Dam (Upper Campbell Reservoir) and Ladore Dam (Lower Campbell Reservoir) used in ESH modelling were provided by BC Hydro.

Table 1. Spawning and incubation timing information used in the effective spawning habitat model for Cutthroat Trout, Rainbow Trout, and Dolly Varden (Leake, pers. comm. 2015).

Species	Period	Start	End	Peak	μ (days)	σ (days)	Duration (days)	Total ATUs for Fish
Cutthroat Trout	Spawning	01-Mar	30-Apr	22-Mar	22	10.2	61	550
	Incubation	01-Mar	15-Jul					
Rainbow Trout	Spawning	15-May	31-Jul	08-Jun	25	13	78	600
	Incubation	15-May	15-Aug					
Dolly Varden	Spawning	08-Oct	08-Dec	01-Nov	25	10.3	62	700
	Incubation	08-Oct	15-Apr					

$$\text{Spawning Intensity} = e^{-\left(\frac{(Day - Start\ Day + 1 - \mu)^2}{(2\sigma^2)}\right)/(\sigma\sqrt{2\pi})}$$

μ: Peak - Start Day + 1
σ: Duration/6

Figure 3. Relationships between spawning habitat within the drawdown zone and reservoir elevation for Upper Campbell Reservoir at Strathcona Dam (SCA) and Lower Campbell Reservoir at Ladore Dam (LDR). Additional spawning habitat above the drawdown zone is not accounted for in the model (Leake, pers. comm. 2015).

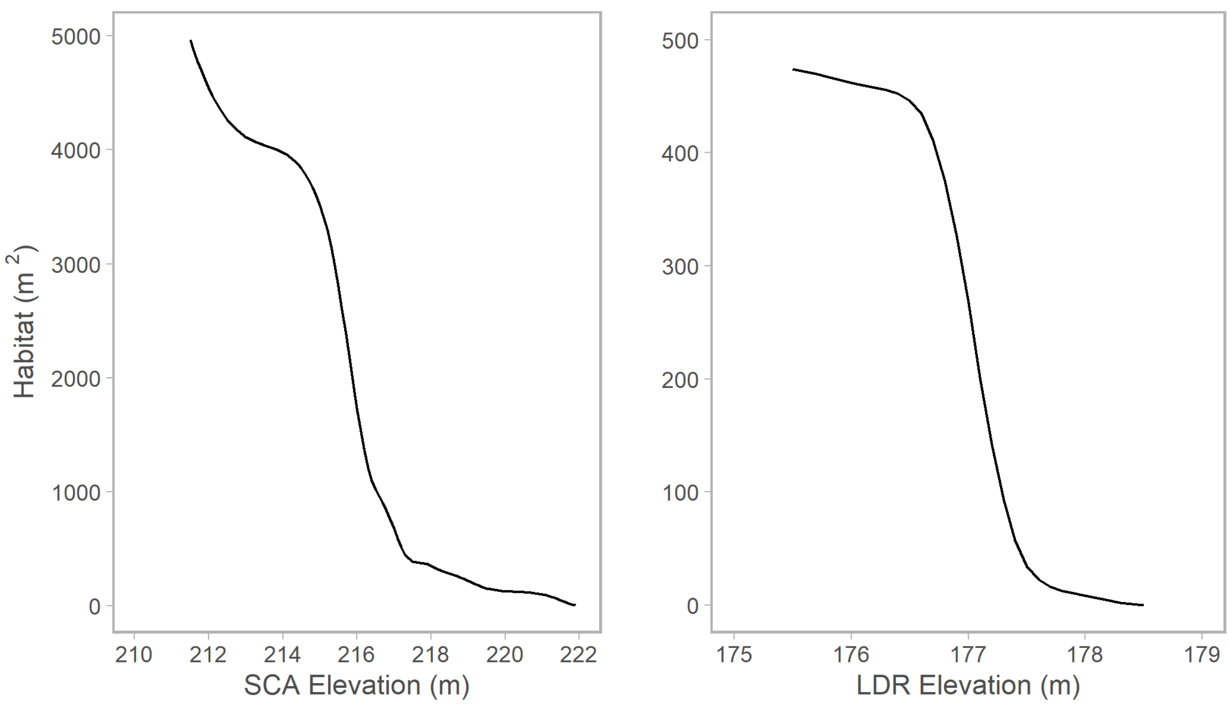


Figure 4. Water temperature trends used for effective spawning habitat model for Upper Campbell Reservoir at Strathcona Dam (SCA) and Lower Campbell Reservoir at Ladore Dam (LDR) (Leake, pers. comm. 2015).

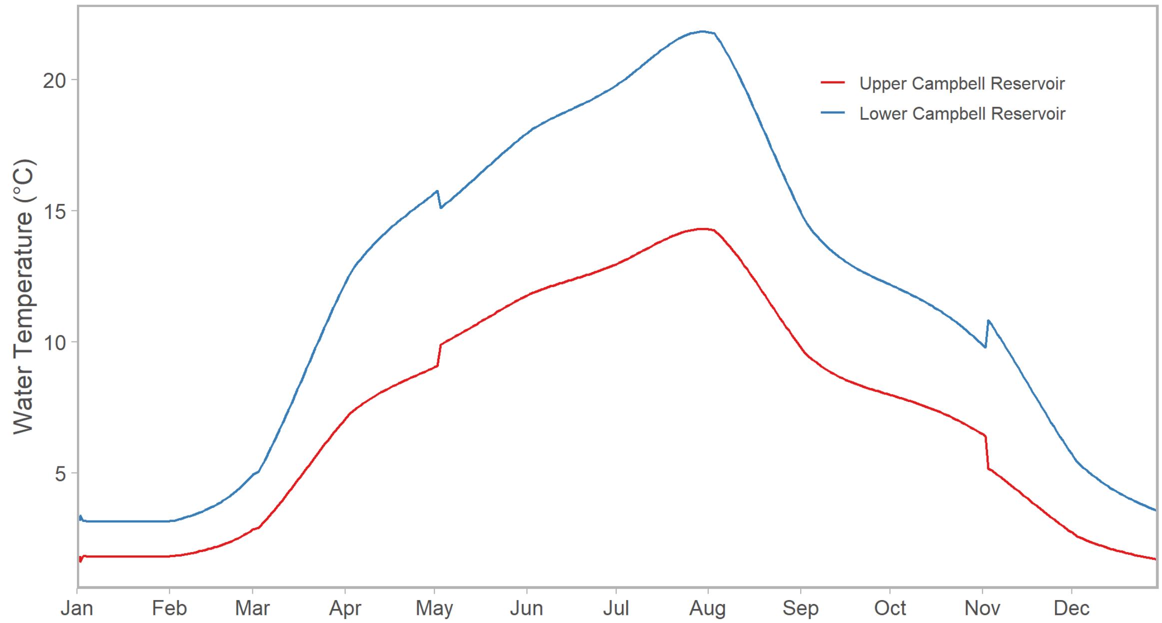
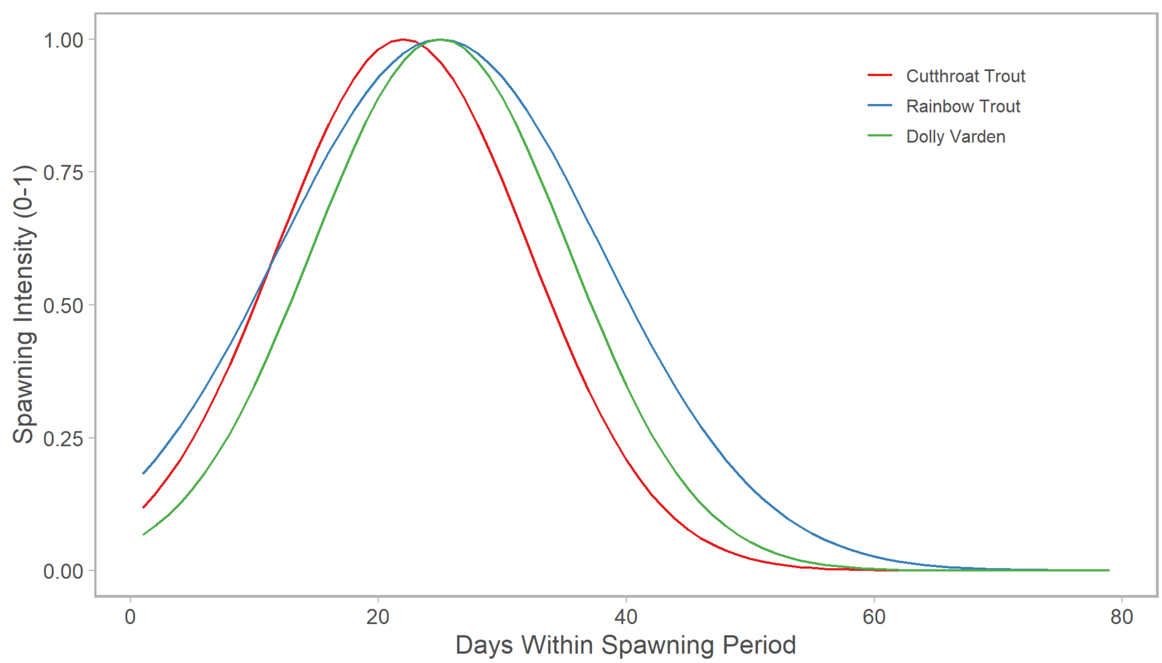


Figure 5. Timing of spawning intensity for Cutthroat Trout, Rainbow Trout, and Dolly Varden used in the effective spawning habitat model (Leake, pers. comm. 2015).



2.2. Population Index for Upper Campbell Reservoir

2.2.1. Field and Laboratory Work

2.2.1.1. Gill Netting

The study areas for JHTMON-3 are the Upper Campbell (including Buttle Lake) and Lower Campbell reservoirs and tributaries. Sample sites within the study areas were selected based on location within the drawdown zone and are presented in Map 2. Bathymetric maps were reviewed to identify sampling sites with suitable depth profiles. Site locations were selected in 2014 and the same locations were resampled in from 2015 to 2021.

The Year 8 gill netting surveys of Upper Campbell Reservoir were conducted using the same methods as Years 2 to 7 (2015-2020) studies. The gill netting sampling objective was to produce a fish abundance index by species and age. To maintain consistency, the same six sites as in previous years were sampled, and during similar dates (i.e., late summer, between August 23 and August 24, 2021) (Table 2). Both floating and sinking gill nets were used to target specific strata within the water column.

We made efforts to maintain similar effort throughout the monitoring program, and thus we aimed to deploy 12 overnight RISC nets sets in the Upper Campbell Reservoir. However, the catch limit of 150 Rainbow Trout was exceeded and therefore no nets were deployed at sites UCR-LNKG07 or UCR-LNKG08, resulting in 8 overnight RISC nets sets in the Upper Campbell Reservoir (Table 2). The catch and depth fished for each panel of each net was recorded. Nets were set perpendicular to shore with sinking nets set on the bed and floating nets set on the surface. RISC-standard gill nets were used (91.2 m long); the nets consist of six panels, each 15.2 m long and of different mesh sizes (25 mm, 76 mm, 51 mm, 89 mm, 38 mm, and 64 mm) strung together to form a 91.2 m long and 2.4 m deep net. Similarly, two Nordic nets have been deployed in the past at sites UCR-LKGN04 and UCR-LKGN07. Given the exceedance of the Rainbow Trout catch limit, the Nordic net at site UCR-LKGN07 was not deployed. Nordic nets were 13.0 m long by 1.8 m wide, with varying mesh sizes (12.5 mm, 19 mm, 16 mm, and 25 mm) sequenced to capture a range of size classes of fish.

When setting a net, the boat operator ensured the proper location and depth of the site using a GPS and depth sounder and positioned the net according to depth contours and wind conditions. The net was held in place with a net anchor at each end of the net. Nets were set overnight with soak times of 18 to 21 hours. Floating lights were attached to each net to mark their location overnight for boater safety. All fish captured from 80 mm to 150 mm for parr (with the exception of Miller Creek; 90 mm to 180 mm for parr), during gill netting were identified to species, weighed, and measured to the nearest mm (fork length) in the field. Scales and otoliths were taken from Rainbow Trout and Cutthroat Trout to allow for age classes to be assigned to both species.

Table 2. Sampling dates, site locations, and site conditions for Year 8 gill netting surveys on Upper Campbell Reservoir, August 2021.

Waterbody	Site	Sampling Date	UTM			Set #	Net Type	Net Position[1]	Net Length	Water Temp. (°C)	Turbidity[2]	Estimated Visibility (m)
			Zone	Easting	Northing							
Upper Campbell Reservoir	UCR-LKGN01	23-Aug-21	10U	314096	5539930	1	RISC	SK	91.2	20.6	C	8
		23-Aug-21	10U	314096	5539930	2	RISC	FL	91.2	20.6	C	8
	UCR-LKGN02	23-Aug-21	10U	314629	5537246	1	RISC	SK	91.2	21.0	C	8
		23-Aug-21	10U	314629	5537246	2	RISC	FL	91.2	21.0	C	8
	UCR-LKGN04	24-Aug-21	10U	308638	5533904	1	RISC	SK	91.2	21.4	C	8
		24-Aug-21	10U	308638	5533904	2	RISC	FL	91.2	21.4	C	8
		24-Aug-21	10U	308638	5533904	3	Nordic	SK	30.0	21.4	C	8
	UCR-LKGN06	24-Aug-21	10U	309419	5527967	1	RISC	SK	91.2	22.0	C	8
		24-Aug-21	10U	309419	5527967	2	RISC	FL	91.2	22.0	C	8

[1] SK - Sinking, FL - Floating

[2] C - Clear, L - Lightly turbid, M - Moderately turbid, T - Turbid

No Gill nets were deployed at sites UCR-LKGN07 or UCR-LKGN08 due to exceeding the catch limit of 150 Rainbow Trout

2.2.2. Data Analysis

2.2.2.1. Population Index

Catch Per Unit Effort

Catch per unit effort (CPUE) from gill netting, measured as fish caught per set-hour, was used as the metric of relative abundance in Upper Campbell Reservoir. CPUE was computed by individual net panel to estimate species relative abundance by 5 m depth intervals.

Individual Fish Analysis

Biological statistics computed for each species in the gill net catch include mean and standard deviation of length and weight, length-frequency and age distributions, weight-length regressions, and relative condition factor (K_r). To overcome limitations of dependencies of the condition factor on fish length, the relative condition factor (K_r) was calculated as:

$$K_r = \left(\frac{W}{\widehat{W}}\right)$$

where W is the weight of the fish in g, and $\hat{W}$ is the predicted body weight from a length-weight relationship (Le Cren 1951) (species-specific relationships shown in Figure 12 and Figure 15). If K_r is equal to 1, the fish is in average condition, if K_r is below 1 the fish is in condition lower than average, and if K_r is larger than 1 then the fish is in condition better than average.

Age distributions were calculated for trout only. Partially consumed individuals were excluded from analyses to ensure accuracy of fork length and/or weight measurements. Aging of fish by examination of the scales, and otoliths was undertaken by experienced Ecofish fisheries biologists, with the assistance of A-Tlegay staff. A subset of the samples was measured while the remainder of samples were stored in case additional samples are required. Aging protocols are provided in Appendix A.

Selection of the appropriate anatomical structure (scales, fin rays, or otoliths) to determine age of fish requires balancing precision and accuracy of the method with sample size limitations. Reading scales is easier, faster and cheaper, but less accurate than the other methods. Otoliths are more laborious and expensive to read but require lethal sampling. Fin rays are in between in terms of both accuracy and cost (e.g., Williamson and Macdonald 1997; Zymonas and McMahon 2009).

Assessments of the relative accuracy and feasibility of assigning age classes from the measured fork length was carried out during Years 4 and 5 of the monitoring programs (Bayly *et al.* 2018; Buren *et al.* 2019). Age breaks can be confidently assigned based on scale ages for younger age classes. However, it is challenging for older age classes given that growth plateaus and therefore the separation between age classes in an age-length plot becomes less distinct (Bayly *et al.* 2018). Assessment of the utility of fin rays to assign age revealed considerable variability, indicating they are of lower utility for accurate determination of age (Buren *et al.* 2019). Consequently, to maximise the information obtained given budgetary constraints reading of fin rays was discontinued for the Year 6 monitoring.

Stomach Content Analysis

Diets of Cutthroat Trout and Rainbow Trout were assessed in 2015, and 2017-2021, through the analysis of stomach contents of a subset of fish. Stomach contents were examined under a dissecting microscope, and classified in one of the following five categories: Fish, Plankton, Benthic, Terrestrial, and Other. The percent volume each category represented in the stomach contents was recorded.

Age Cohort Analysis

Age information obtained from the subsample of fish that were aged during the eight years of the monitoring project was used to assign ages to all Cutthroat Trout and Rainbow Trout caught. We fit species-specific length-at-age curves (Beverton 1954; Beverton and Holt 1957):

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

where:

- L_t is the expected or average length at age t;
- L_∞ is the asymptotic average length;
- K is the body growth rate coefficient (units are yr^{-1}); and
- t_0 is a modeling artifact that is said to represent the time or age when the average length was zero.

We computed non-parametric bootstrap estimates (n_{boot} = 10,000 iterations) 95% confidence intervals of the average length at age. We then carried out a form of inverse inference, where we estimate the age of unaged fish, given their length and the expected length at age. The lengths of fish age t are bounded by the upper confidence interval of the lengths of fish age t-1 and the upper confidence interval of fish of age length t.

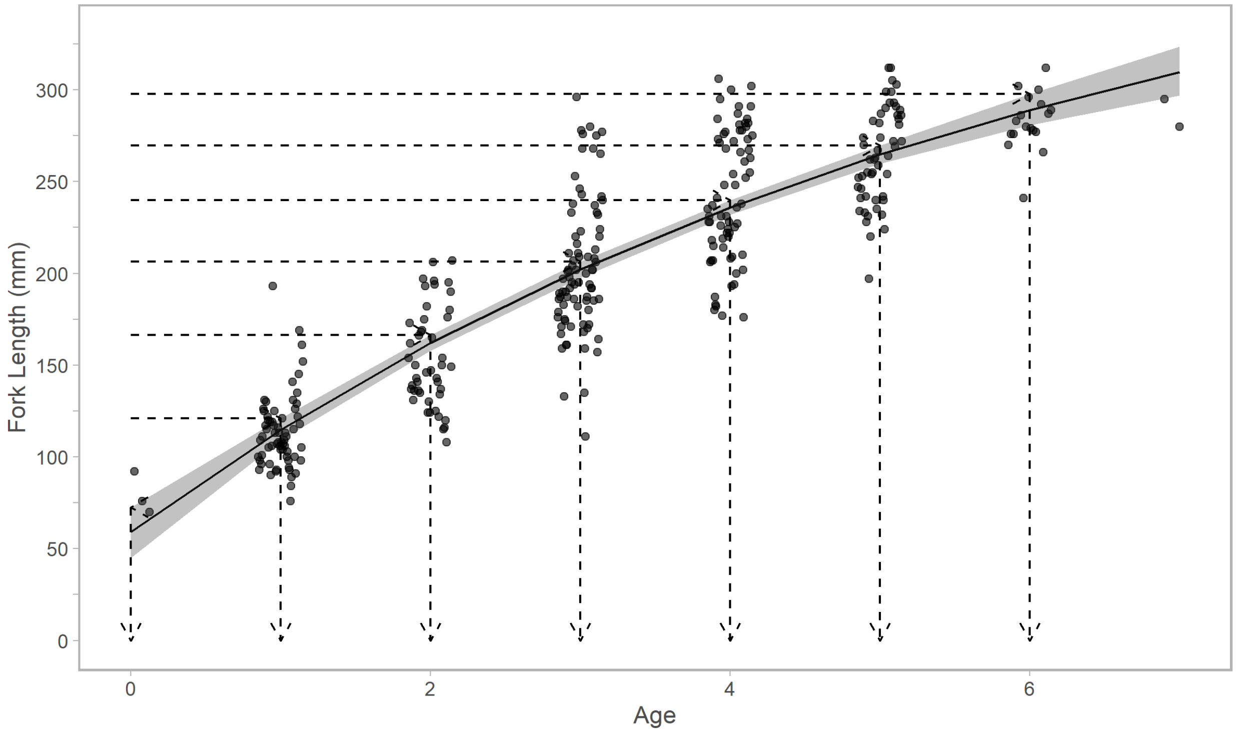
Rainbow Trout

A total of 342 scales, 37 fin rays, and 46 Rainbow Trout otoliths were read during Years 1 to 8 of the monitoring program (Table 3). This excludes fish that suffered total or partial damage (e.g., being partially consumed by crayfish) and therefore an accurate fork length could not be measured. Most aged fish were between the ages of 1+ and 6+, with only 6 fish aged as 0+ and 3 as 7+. Therefore, we grouped fish aged 6 and older into a cumulative age class ≥6+. Given the differences in sample sizes among hard structures (Table 3), we based the length at age curve for Rainbow Trout on ages read from scales (Figure 6).

Table 3. Sample size of aged Rainbow Trout structures, by age, during Years 1 to 8 of the monitoring program.

Species	Structure	Age	n
Rainbow Trout	Scales	0	6
		1	65
		2	46
		3	82
		4	70
		5	52
		6	18
		7	3
	Fin Rays	0	0
		1	0
		2	3
		3	11
		4	12
		5	8
		6	3
		7	0
		0	0
	Otoliths	1	0
		2	0
		3	2
		4	25
		5	13
		6	6
		7	0

Figure 6. Rainbow Trout length at age curve used for assigning age classes to fish of unknown age, based on their fork length.



Cutthroat Trout

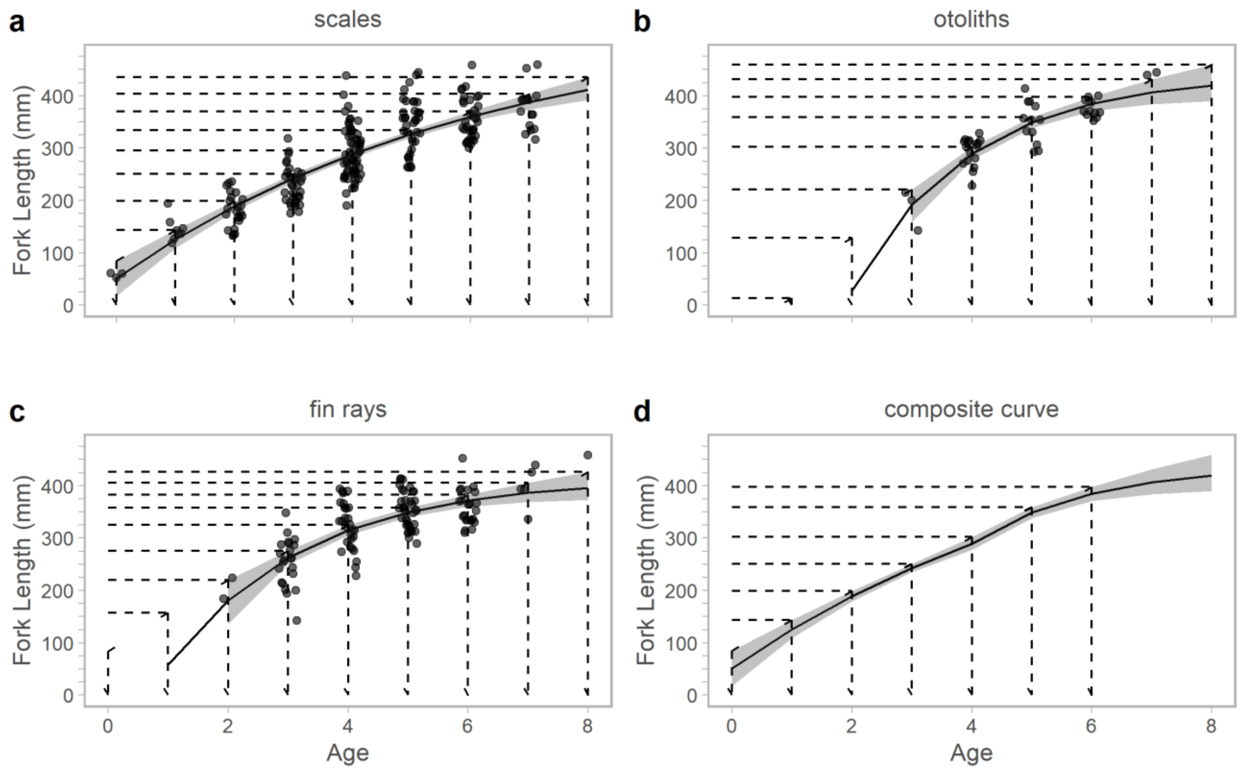
A total of 214 scales, 117 fin rays, and 45 Cutthroat Trout otoliths were read during Years 1 to 8 of the monitoring program (Table 4). This excludes fish that suffered total or partial damage due to e.g., being consumed by crayfish, and therefore an accurate fork length could not be measured. Most aged fish were between the ages of 1+ and 6+, with only 3 fish aged as 0+, 23 as 7+, and 1 as 8+. Therefore, we grouped fish aged 6 and older into a cumulative age class ≥6+.

The most accurate age readings are those based on otoliths (e.g., Hining *et al.* 2000; Stolarski and Hartman 2008). Thus, despite the relative smaller sample size we fit separate age at length curves by structure (Figure 7). All age readings carried out on otoliths were of relatively older fish (4+ and older). Hence, we created a composite curve, where the age breaks for young fish (3+ and younger) were obtained from scale data and age breaks for older fish (4+ and older) from otolith data (Figure 7d).

Table 4. Sample size of aged Cutthroat Trout structures, by age, during Years 1 to 8 of the monitoring program.

Species	Structure	Age	n
Cutthroat Trout	Scales	0	3
		1	8
		2	23
		3	33
		4	59
		5	37
		6	35
		7	16
		8	0
	Fin Rays	0	0
		1	0
		2	2
		3	22
		4	28
		5	35
		6	24
		7	5
		8	1
	Otoliths	0	0
		1	0
		2	0
		3	3
		4	17
		5	12
		6	11
		7	2
		8	0

Figure 7. Cutthroat Trout length at age curves, a) curve based on ages from scales, b) curve based on ages from otoliths, c) curve based on ages from fin rays, d) composite curve based on ages read on otoliths and scales. The composite curve was used for assigning age classes to fish of unknown age, based on their fork length.



2.3. <u>Snorkel Surveys of Spawners in Reservoir Tributaries</u>

Snorkel surveys of spawners and redds were undertaken in the lower reaches of the tributaries of Buttle Lake, Upper Campbell Reservoir, and Lower Campbell Reservoir during the Cutthroat Trout and Rainbow Trout spawning periods (Map 3). The tributaries were selected based on their reported spawning value for both trout species, and included seven survey reaches upstream of Buttle Lake and Upper Campbell Reservoir that have been surveyed historically since the early 1990s and were included in all previous years of the monitoring program. Snorkel surveys were undertaken in the following six tributaries of Buttle Lake and Upper Campbell Reservoir: Elk River (upper and lower reaches): Ralph Creek, Thelwood Creek, Wolf River, Phillips Creek, and Henshaw Creek (Table 5). In addition, snorkel surveys were undertaken in the following three tributaries of Lower Campbell Reservoir: Miller Creek, Fry Creek, and Greenstone River. Spring snorkel surveys were completed in tributaries of the Lower Campbell Reservoir in February and April to assess Cutthroat Trout spawning activity, and snorkel surveys of Upper Campbell Reservoir tributaries were completed in the late spring/early summer (June) to assess Rainbow Trout spawning.

On each survey date, individual stream sections were surveyed once by two experienced technicians swimming in pairs. To allow for comparison between years, the 2021 surveys followed standardized survey methods within each reach, as conducted during Years 1 to 7 (2014 to 2020) surveys, and historically by MFLNRO and BCCF (Pellett 2013). It is worth noting that Thelwood Creek (Buttle Lake) has undergone morphology changes during the time span covered by the JHTMON-3 monitoring project. We carried out snorkel surveys in such a manner as to maintain data consistency to enable temporal comparisons. A visual summary of morphological changes and surveyed reaches is provided in Appendix B. A number of variables were measured (Table 6) and photographs were taken of each site. Rainbow Trout was the target species for these historical surveys in Upper Campbell Reservoir tributaries and this focus was maintained for JHTMON-3 snorkel surveys to maximize comparability with historical records.

Similar to previous years, a fork length of 150 mm was designated as the boundary between juvenile and adult fish, based on the Provincial snorkel form template. The estimated fork lengths of juvenile fish ranged from 0 mm to 80 mm for fry, and from 80 mm to 150 mm for parr, during the 2021 surveys.

Surveys for the Cutthroat Trout spawning period were carried out in tributaries of the Lower Campbell Reservoir on March 2, 2021. Given the relatively cold conditions of Greenstone River compared to Miller and Fry Creeks, the survey of this river was delayed until April 19, 2021. Tributaries of Buttle Lake and Upper Campbell Reservoir were not sampled during the Cutthroat Trout spawning period, as described in Hatfield *et al.* (2016). Due to low Cutthroat Trout densities in the surveyed tributaries, redd counts were used to provide a reference for adult spawning effort.

Surveys for the Rainbow Trout spawning period were undertaken from June 1 to 8, 2021 in the tributaries of Buttle Lake and Upper Campbell Reservoir. Data recorded from the 2021 Rainbow Trout spawning surveys were compared to the Years 1 to 7 (2014 to 2020) dataset and available historical data for the Upper and Lower Campbell Reservoir. This historical record allows a quantitative comparison of abundance change over time, although it is noted that the data record is short, and sampling has not been undertaken during all years. Tributaries of Lower Campbell Reservoir were not surveyed during the Rainbow Trout spawning period (Hatfield *et al.* 2016).

Discharge measured in the Elk River at Water Survey of Canada gauge 08HD018 has historically been used as a reference to assess suitability for the Rainbow Trout snorkel surveys; based on the criterion that suitable survey conditions correspond to a discharge of $< 20\ m^3/s$ (Pellett 2013). This was also used for spring surveys, to determine suitable flows for access and visibility. Mean daily discharge at the gauge during the spring and summer survey dates were below this $< 20\ m^3/s$ guidance value; suggesting that conditions were acceptable for conducting snorkelling surveys.

Table 5. Snorkel survey reach details for Year 8 surveys.

Watershed	Stream	Survey Distance	Survey Start Location	Survey End Location
Upper Campbell	Upper Elk River	6.0	Drum Creek 200 m US confluence	HWY 28 take out/ put in
	Lower Elk River	5.4	HWY 28 take out/put in	Upper Campbell Lake
Buttle	Ralph River	0.9	50 m u/s Shepard Creek	Buttle Lake
	Thelwood Creek	2.5	Falls at powerhouse	Bridge at Buttle Lake
	Wolf River	0.3	Falls Pool	Buttle Lake
	Phillips Creek	0.3	300 m u/s lake	Buttle Lake
	Henshaw Creek	0.5	Cascades	Buttle Lake
Lower Campbell	Miller Creek	0.4	Cascades	Fry Lake
	Fry Creek	1.2	Barrier DS logging road	Lower Campbell Lake
	Greenstone River	2.4	~1.0km u/s of Bridge	Lower Campbell Lake

Table 6. Variables measured during the Year 7 snorkel surveys in the selected tributaries of Upper Campbell Reservoir, Buttle Lake, and Lower Campbell Reservoir. Note that both water and air temperatures for Ralph River, and the weather conditions for the Upper Campbell watershed were not recorded.

Variable	Unit/Classification
Weather	Conditions recorded
Water temperature	°C
Effective Visibility	Measured or estimated in meters
Fish size class	fry/parr/adults; 150-250mm, 251-350mm, 351-450mm, and >450mm
Fish species	Cutthroat Trout (CT)/Rainbow Trout (RB)/Dolly Varden (DV)
Fish condition	Bright/moderately coloured/mid-spawn/post-spawn/undetermined
Redd observations	Location/size/number/species

3. RESULTS

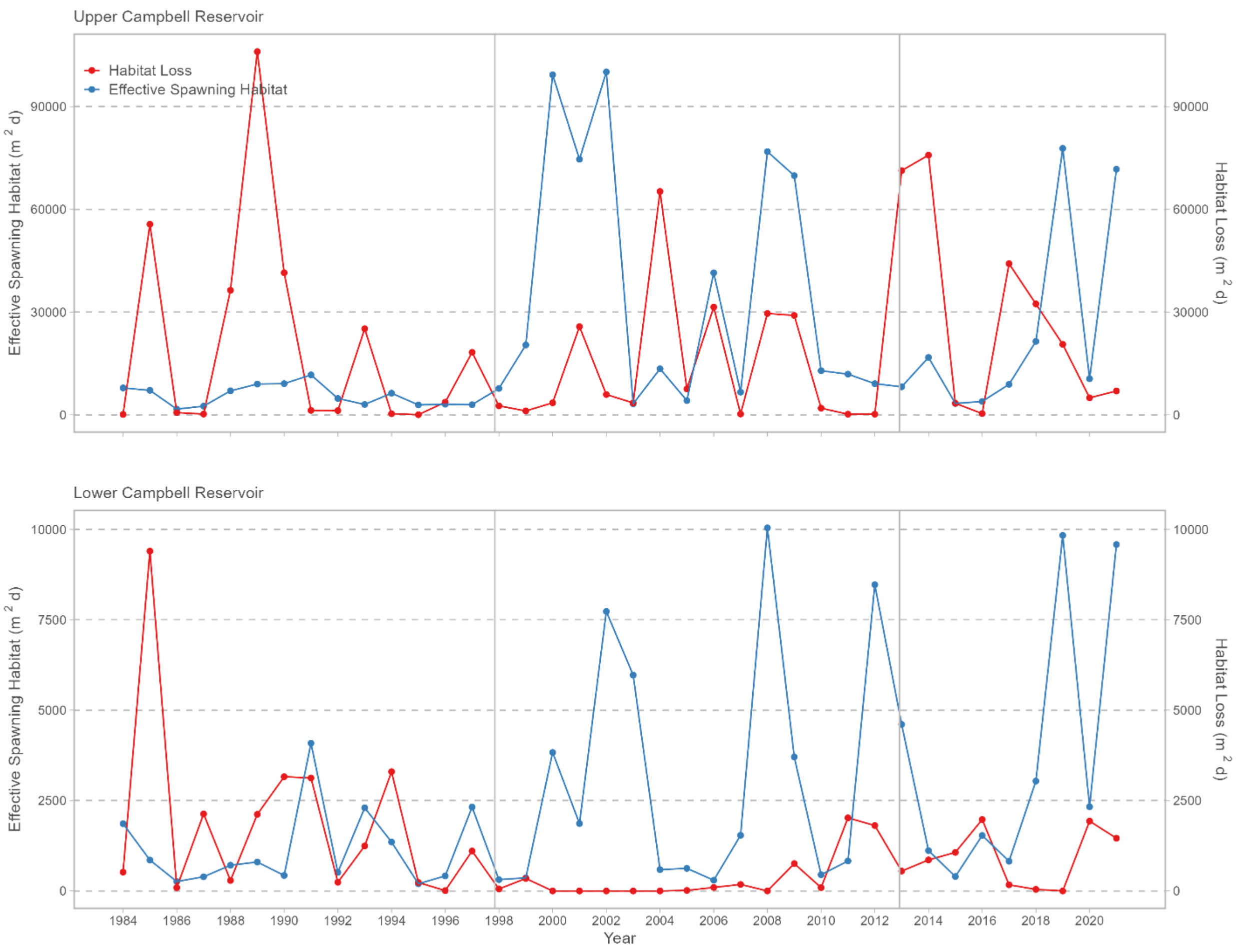
3.1. Effective Spawning Habitat (ESH)

3.1.1. Cutthroat Trout

ESH values for both Lower and Upper Campbell reservoirs were variable among years, with much greater variability in the Upper Campbell Reservoir ESH (range of 1,676 to 100,111 m^2d; mean = 22,455 m^2d) than the Lower Campbell Reservoir ESH (range of 198 to 10,043 m^2d; mean = 2,536 m^2d) (Figure 8). Following the implementation of the Interim Flow Management Strategy there were several years when ESH for Cutthroat Trout in the Upper Campbell Reservoir reached high levels (up to 100,000 m^2d). In 2021, the ESH for Cutthroat Trout in the Upper Campbell Reservoir was similar to that recorded prior to the implementation of the Interim Flow Management Strategy (10,528 m^2d). During this monitoring program (2014-2021), ESH in the Upper Campbell Reservoir was highest in 2019, followed by 2021 and 2018, whereas values observed during 2015-2017 were an order of magnitude lower (Figure 8).

ESH loss was calculated as the difference between ESH and initial spawning habitat during the spawning and incubation period. Oscillations in the water level of the Upper Campbell Reservoir are associated with ESH losses ranging from 44 to 106,046 m^2d (mean = 19,956 m^2d). ESH loss in the Upper Campbell Reservoir is variable and does not seem to have been affected by the implementation of the Interim Flow Management Strategy. During this monitoring program, the ESH loss was minimal during 2015 (3,371 m^2d) and 2016 (363 m^2d), and higher in 2014 (75,823 m^2d), 2017 (44,131 m^2d), 2018 (32,389 m^2d), and 2019 (20,579 m^2d). ESH loss was relatively low during 2021 (6,966 m^2d). Water levels in the Lower Campbell Reservoir are less variable, resulting in relatively minimal loss of ESH (range of 0 to 9,398 m^2d; mean = 1,063 m^2d; Figure 8).

Figure 8. Results of effective spawning habitat and loss of effective spawning habitat models for Cutthroat Trout from 1984 to 2021. Vertical lines denote dates of implementation of the Interim Flow Management Strategy (October 1997), and the Water Use Plan (November 2012). Note the different Y axes for the two reservoirs.



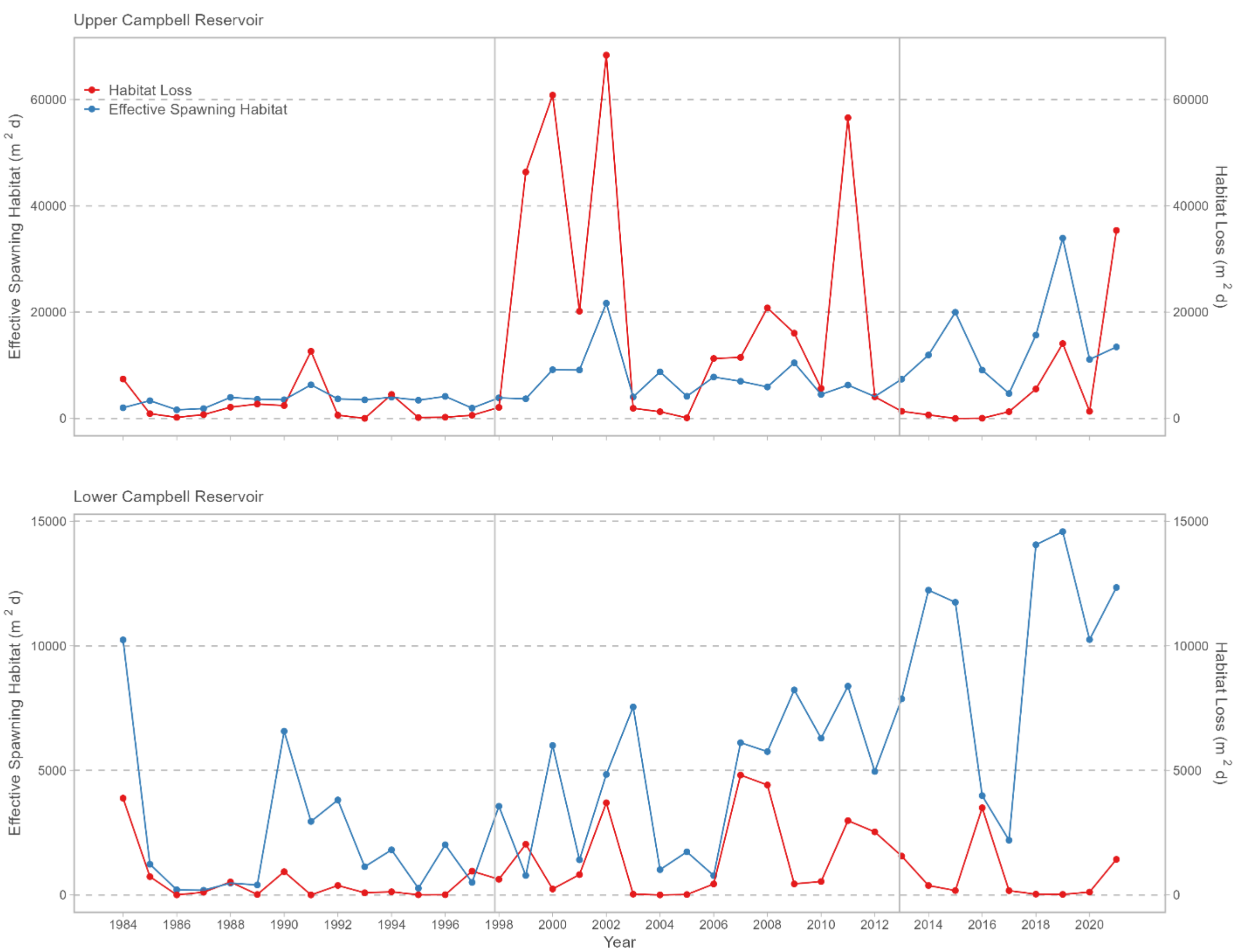
3.1.2. Rainbow Trout

ESH values for both Lower and Upper Campbell reservoirs were variable among years, with greater variability in the Upper Campbell Reservoir ESH (range of 1,619 to 33,919 m²d; mean = 7,491 m²d) than the Lower Campbell Reservoir ESH (range of 188 to 14,583 m²d; mean = 4,958 m²d). Following the implementation of the Interim Flow Management Strategy ESH increased more than two-fold in both reservoirs (Upper Campbell Reservoir: $mean_{pre\text{-}IFMS}$: 3,350 m²d, $mean_{post\text{-}IFMS}$: 9,906 m²d; Lower Campbell Reservoir: $mean_{pre\text{-}IFMS}$: 2,271 m²d, $mean_{post\text{-}IFMS}$: 6,526 m²d). ESH in both reservoirs during this monitoring program was high, reaching a peak in 2019, followed by 2018, 2021, 2014, 2015, and 2020. During 2016 and 2017 it was smaller, although it was at average or above average values (Figure 9).

Oscillations in the water level of the Upper Campbell Reservoir are associated with effective Rainbow Trout spawning habitat losses ranging from 0 to 68,352 m²d (mean = 11,100 m²d). Water levels in the Lower Campbell Reservoir are less variable, resulting in relatively minimal loss of ESH (range of 0 to 4,810 m²d; mean = 1,019 m²d) (Figure 9). It is noteworthy that ESH for Rainbow Trout in both reservoirs are completely in sync since at least 2007.

ESH loss in the Lower Campbell Reservoir does not seem to have been affected by the implementation of the Interim Flow Management Strategy. ESH loss habitat in the Lower Campbell Reservoir was highest immediately following the implementation of the IFMS, and was until recently positively associated with the ESH (i.e., there were large losses in years when ESH was high). During this monitoring program this pattern does not hold as ESH was high and habitat loss was very small (range: 0 – 14,083 m^2d) (Figure 9).

Figure 9. Results of effective spawning habitat and loss of effective spawning habitat models for Rainbow Trout from 1984 to 2021. Vertical lines denote dates of implementation of the Interim Flow Management Strategy (October 1997), and the Water Use Plan (November 2012). Note the different Y axes for the two reservoirs.

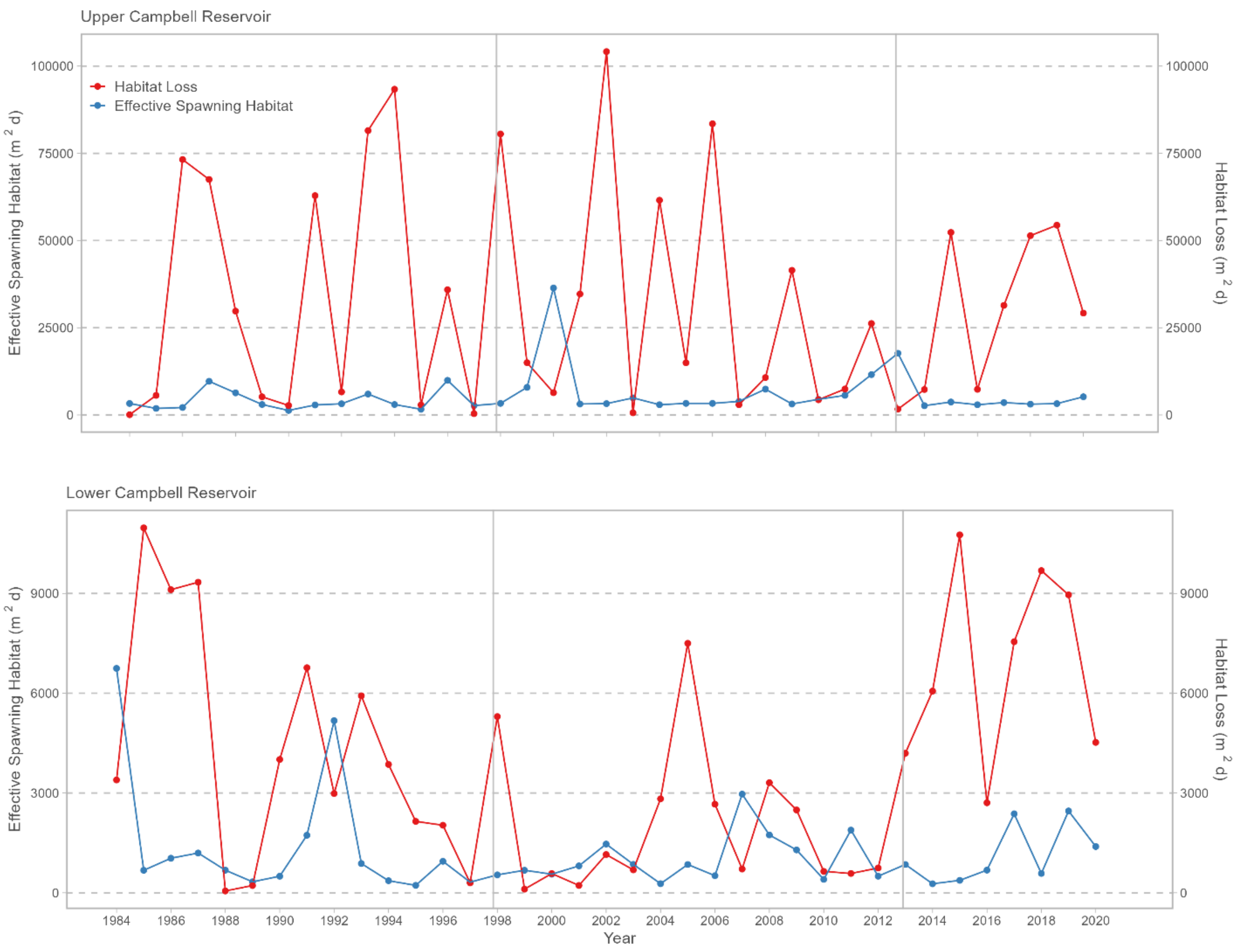


3.1.3. Dolly Varden

Given the timing of spawning and incubation of Dolly Varden (Figure 1) relative to reporting requirements, ESH metrics could only be calculated until 2020 (Figure 10). Effective habitat values for both Lower and Upper Campbell reservoirs were variable among years with much greater variability for the Upper Campbell Reservoir ESH (range of 1,295 to 36,389 m^2d; mean = 5,502 m^2d) than the Lower Campbell Reservoir ESH (range of 223 to 6,747 m^2d; mean = 1,219 m^2d) (Figure 10). The implementation of the Interim Flow Management Strategy does not seem to have affected the values of ESH for Dolly Varden, except for a couple of very high values in the Upper Campbell Reservoir in 2000 (36,389 m^2d) and 2013 (17,690 m^2d). ESH in the Upper Campbell Reservoir during this monitoring program (2014-2019) was consistently around 3,000 m^2d, while in the Lower Campbell Reservoir was low during 2014-2016 (~400 m^2d), increased an order of magnitude in 2017, dropped in 2018, increased again in 2019, and dropped again in 2020 (Figure 10).

Fluctuations in the water level of the Upper Campbell Reservoir are associated with relatively regular oscillations in losses of effective Dolly Varden spawning habitat ranging from 73 to 104,159 m^2d (mean = 32,356 m^2d). In contrast, there has been comparatively little change in effective Dolly Varden spawning habitat loss among years in Lower Campbell Reservoir (range of 55 to 10,973 m^2d; mean = 3,921 m^2d) (Figure 10). ESH loss in both reservoirs is variable and does not seem to have been affected by the implementation of the Interim Flow Management Strategy. During this monitoring program, the ESH loss was variable, reaching a peak of 54,408 m^2d in 2019 in the upper Campbell Reservoir and a low of 2,707 m^2d in 2016 in the Lower Campbell Reservoir (Figure 10).

Figure 10. Results of effective spawning habitat and loss of effective spawning habitat models for Dolly Varden from 1984 to 2020. Vertical lines denote dates of implementation of the Interim Flow Management Strategy (October 1997), and the Water Use Plan (November 2012). Note the different Y axes for the two reservoirs.



3.2. Population Index for Upper and Lower Campbell Reservoirs

3.2.1. Summary of Gillnet Sampling Results

Fish sampling from the six gill net monitoring sites recorded a total of 25 Cutthroat Trout, 173 Rainbow Trout, one Sculpin, three Cutthroat Trout/Rainbow Trout hybrids (Table 7). No Dolly Varden nor Threespine Stickleback were captured in 2021. Rainbow Trout had the greatest mean CPUE (1.06 fish/net hour), followed by Cutthroat Trout (0.143 fish/net hour). CPUE for Cutthroat Trout and Rainbow Trout varied among sites, with higher CPUE recorded at sites UCR-LKNG01 and UCR-LKNG06 (Table 7). CPUE for Rainbow Trout was at least two times higher than the CPUE for Cutthroat Trout at all sites (Table 7). Representative photographs and raw data collected during gillnet surveys are presented in Appendix C.

Table 7. Summary of gill net survey effort, catch statistics, and CPUE from the Upper Campbell Reservoir, August 2021.

Site	Sampling Date	# of Sets	Gill Netting Effort (hrs)	Gill Net Catch (# of Fish)					Gill Net CPUE (# of Fish / net hr)				
				CT	RB	DV	CC	CT/RB	CT	RB	DV	CC	CT/RB
UCR-LKGN01	23-Aug-21	2	42.5	9	21	0	0	0	0.212	0.494	0.000	0.000	0.000
UCR-LKGN02	23-Aug-21	2	42.3	5	41	0	0	0	0.118	0.969	0.000	0.000	0.000
UCR-LKGN04	24-Aug-21	3	59.0	5	15	0	1	2	0.085	0.254	0.000	0.017	0.034
UCR-LKGN06	24-Aug-21	2	38.1	6	96	0	0	1	0.158	2.520	0.000	0.000	0.026
	Total	**9**	**181.8**	**25.0**	**173.0**	**0.0**	**1.0**	**3.0**					
	Average		**45.5**	**6.3**	**43.3**	**0.0**	**0.3**	**0.8**	**0.143**	**1.060**	**0.000**	**0.004**	**0.015**
	SD		**9.2**	**1.9**	**36.9**	**0.0**	**0.5**	**1.0**	**0.055**	**1.018**	**0.000**	**0.008**	**0.018**

3.2.2. Cutthroat Trout

3.2.2.1. CPUE

Cutthroat Trout were caught at every gill net sampling site; however, CPUE was variable across gill netting sites as well as gill net depth. The sampling site CPUE ranged from 0.085 to 0.212 fish/net hour at the gill netting sites, with an overall mean CPUE of 0.143 fish/net hour (Table 7). CPUE in floating nets was zero fish/hr (Table 8). Cutthroat Trout were captured at 2.5 m or 7.5 m in sinking nets. CPUE was zero for floating nets and CPUE in sinking nets ranged from 0.041 to 0.051 fish/net hour (Table 8). These data suggest that Cutthroat Trout have a benthic-oriented distribution (as opposed to pelagic).

Table 8. CPUE (no. fish / hour) of all Cutthroat Trout based on gill net type and bottom depth. Catches from Nordic gill nets were not included in this analysis.

Net Type	CPUE (no. fish / hour)			
	Bottom Depth (m)			
	2.5	7.5	12.5	17.5
Floating	0	0	0	0
Sinking	0.051	0.041	0	0

Net depth for sinking nets is equal to bottom depth and 2.5 m for floating nets.

3.2.2.2. Individual Fish Analysis

A total of 12 Cutthroat Trout were captured during gill netting surveys in the Upper Campbell Reservoir and size of captured fish ranged from 202 to 374 mm (Figure 11). The weight of Cutthroat Trout caught in the Upper Campbell Reservoir followed an isometric growth curve (i.e., the exponent of the length-weight relationship is 3) (Figure 12).

Figure 11. **Length-frequency histogram for Cutthroat Trout (CT) captured during the gill-netting surveys on Upper Campbell Reservoir, 2021. Grey bars represent data collected during the eight years of monitoring, and black bars represent data collected during 2021.**

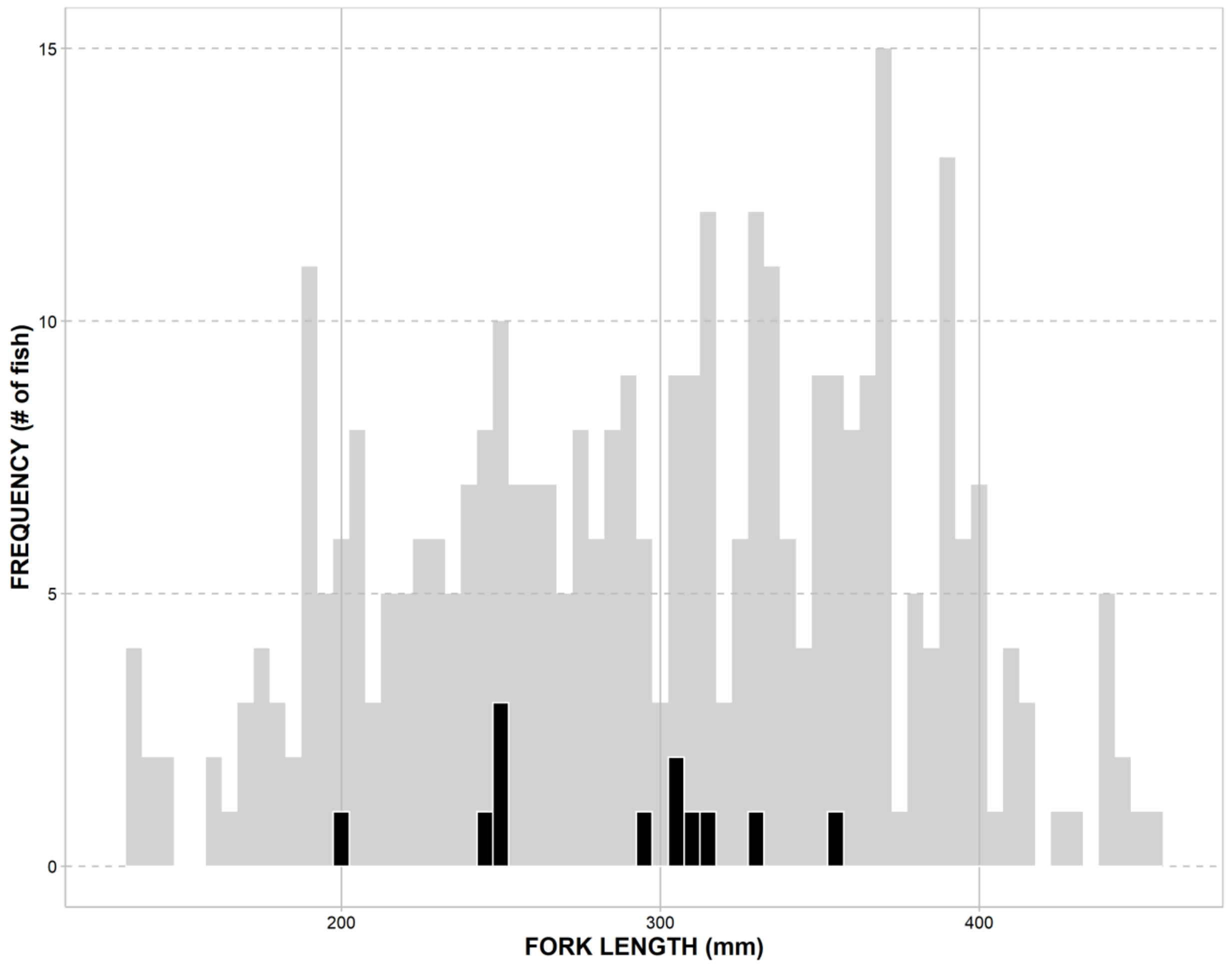
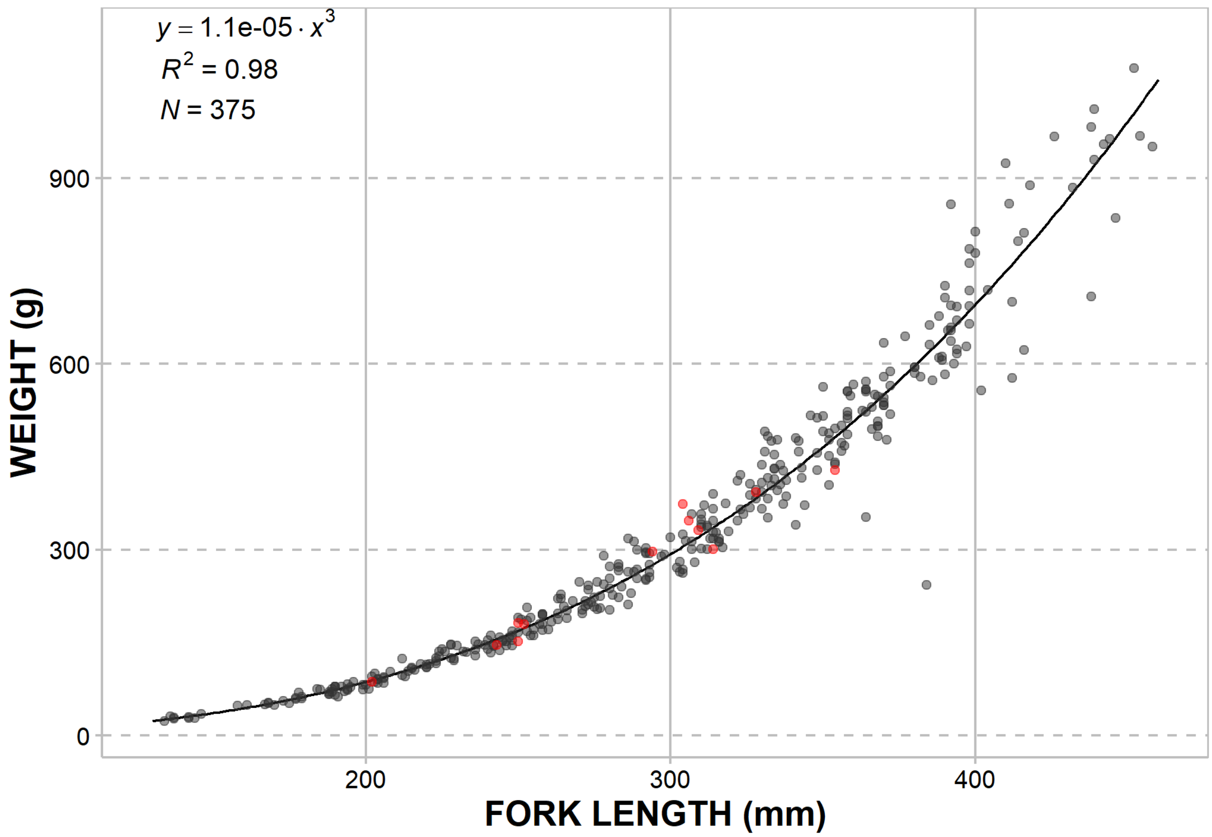


Figure 12. Length-weight relationship for Cutthroat Trout captured during gill net surveys in the Upper Campbell Reservoir, 2014-2021. Grey dots represent data collected during 2014-2020, and red dots represent data collected during 2021.



3.2.2.3. Stomach Content Analysis

A total of 153 Cutthroat Trout stomach contents were analysed (Table 9). During 2015 and 2017, Cutthroat Trout in the Upper Campbell Reservoir fed largely on fish (>75%), with some contribution of benthic and terrestrial prey (Table 9). The contribution of fish in the diet has diminished gradually during the span of the monitoring program, to ~45% during 2018 and 2019, to ~25% in 2020, and increased to ~61% in 2021. Consequently, the relative importance of benthic and terrestrial prey in the diet has increased from 2017 to 2020 but decreased in 2021 (Table 9).

Table 9. Diet analysis of Cutthroat Trout captured during gill net surveys in the Upper Campbell Reservoir, 2015, and 2017-2021. The data are presented as mean percent volume.

Predator Species	Year	Sample Size	Plankton	Fish	Benthic	Terrestrial	Other
Cutthroat Trout	2015	18	-	77.8	5.6	11.1	5.6
	2017	33	-	78.8	10.6	10.6	-
	2018	28	3.0	44.8	17.1	35.0	-
	2019	35	-	48.6	23.0	27.0	1.4
	2020	18	2.8	23.9	42.2	31.1	-
	2021	21	-	61.4	31.4	7.1	-

3.2.2.4. Age Cohort Analysis

The age of Cutthroat Trout caught in gill nets in Year 8 (n: 12 fish) ranged in age from 3+ to 5+, concentrated in the older age classes (Table 10). Mean relative condition of Cutthroat Trout of all ages was good; the mean K was close to 1 for all ages (Table 10), and there were no big departures from the expected weight from the length-weight relationship (Figure 12).

The CPUE of fish ages 5+ and 3+ were the highest recorded; 0.071 and 0.033 fish/net hour, respectively. CPUE for the other ages were 0.016 fish/net hour. No 0+, 1+, and 2+ age fish were caught (Table 11).

Table 10. Summary of fork length, weight, and relative condition of Cutthroat Trout captured during gill netting surveys in Upper Campbell Reservoir, 2021, excluding partially consumed fish (n = 13 fish).

Age	Fork Length (mm)				Weight (g)				Relative Condition (K_r)			
	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max
0+	0	-	-	-	0	-	-	-	0	-	-	-
1+	0	-	-	-	0	-	-	-	0	-	-	-
2+	0	-	-	-	0	-	-	-	0	-	-	-
3+	4	236.3	202.0	250.0	4	141.6	86.5	181.9	4	0.97	0.90	1.08
4+	2	273.0	252.0	294.0	2	238.7	180.3	297.0	2	1.06	1.04	1.08
5+	6	319.2	304.0	354.0	6	362.3	301.0	428.0	6	1.04	0.89	1.23
≥6+	0	-	-	-	0	-	-	-	0	-	-	-

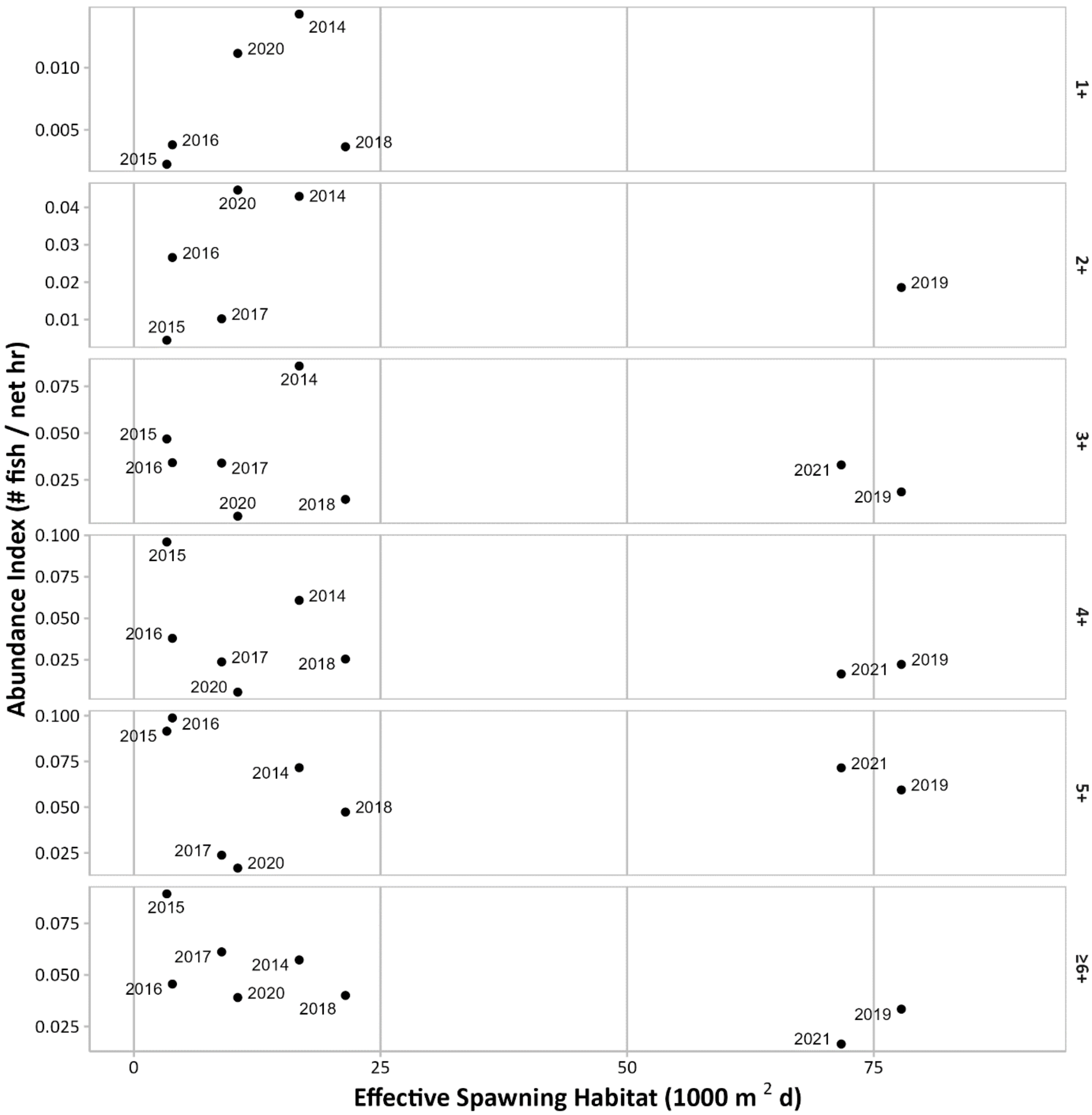
Table 11. CPUE of Cutthroat Trout age cohorts captured during gill netting surveys in Upper Campbell Reservoir, 2021.

Age	Number of Fish Caught	CPUE # of Fish/net hr)
0+	0	0.000
1+	0	0.000
2+	0	0.000
3+	6	0.033
4+	3	0.016
5+	13	0.071
≥6+	3	0.016

3.2.2.5. Comparison of Abundance Index to Effective Spawning Habitat

There is no clear relationship between age-specific abundance indices of Cutthroat Trout and ESH in the Upper Campbell Reservoir (Figure 13). There are substantial inter annual differences in CPUE; the largest values of CPUE were recorded for age 5+ fish in 2016 (0.102 fish/net hr), 4+, 5+ fish and 6+ fish in 2015 (0.096, 0.094, and 0.087 fish/net hr, respectively), with age-specific CPUE values in the last four years reduced substantially, particularly in 2021. In contrast, the values of ESH were high during 2008 and 2009 (~70,000 m^2d), dropping an order of magnitude in 2010 and remaining relatively stable until 2018 when it increased to around ~20,000 m^2d, saw a further increase in 2019 to values similar to those observed a decade ago (77,797 m^2d), dropping again in 2020, and then further increased again to 71,706 m^2d in 2021.

Figure 13. Cutthroat Trout abundance index in relation to Effective Spawning Habitat values of the Upper Campbell Reservoir for each age cohort.



3.2.3. Rainbow Trout

3.2.3.1. CPUE

Rainbow Trout were caught at every sampling site; however, CPUE was variable across gill netting sites and gill net depth. The sampling site CPUE ranged from 0.25 to 2.52 fish/net hour at the gill netting sites, with an overall mean CPUE of 1.06 fish/net hour (Table 7).

All Rainbow Trout were captured at 7.5 m and 12.5 m depths in floating nets, whereas no Rainbow Trout were caught in the deepest sinking or floating net (17.5 m). Adult Rainbow Trout were captured at 2.5 m depth in floating nets whereas adult Rainbow Trout were captured at 7.5 m in sinking nets. CPUE was generally higher for floating nets than for sinking nets (Table 12). There is no clear pattern of varying CPUE with depth for either floating or sinking nets (Table 12). These data suggest that Rainbow Trout are distributed primarily in open (i.e., pelagic) water.

Table 12. CPUE (no. fish / hour) of a) all Rainbow Trout and b) adult Rainbow Trout (>150 mm) based on gill net type and bottom depth. Catches from Nordic gill nets were not included in this analysis.

a) All Rainbow Trout

Net Type	CPUE (no. fish / hour)			
	Bottom Depth (m)			
	2.5	7.5	12.5	17.5
Floating	0	0.051	0.051	0
Sinking	0.051	0	0.010	0

Net depth for sinking nets is equal to bottom depth and 2.5 m for floating nets.

b) Adult Rainbow Trout

Net Type	CPUE (no. fish / hour)			
	Bottom Depth (m)			
	2.5	7.5	12.5	17.5
Floating	0.034	0.051	0.051	0
Sinking	0	0.010	0	0

Net depth for sinking nets is equal to bottom depth and 2.5 m for floating nets.

3.2.3.2. Individual Fish Analysis

A total of 154 Rainbow Trout were captured during gill netting surveys ranging from sizes of 91 to 302 mm (Figure 14). The length frequency distribution of all Rainbow Trout caught in the Upper Campbell Reservoir had 4 modes at around 110 mm, 195 mm, 235 mm, and 275 mm (Figure 14). Length of fish caught during Year 8 coincides with the modes of the fish caught during the 8 years of the monitoring. The weight of Rainbow Trout caught in the Upper Campbell Reservoir during the length of the monitoring program (2014-2021) followed an allometric growth curve, with an exponent of 2.8 (Figure 15).

Figure 14. Length-frequency histogram for Rainbow Trout captured during the gill-netting surveys on Upper Campbell Reservoir, 2021. Grey bars represent data collected during the eight years of monitoring, and black bars represent data collected during 2021.

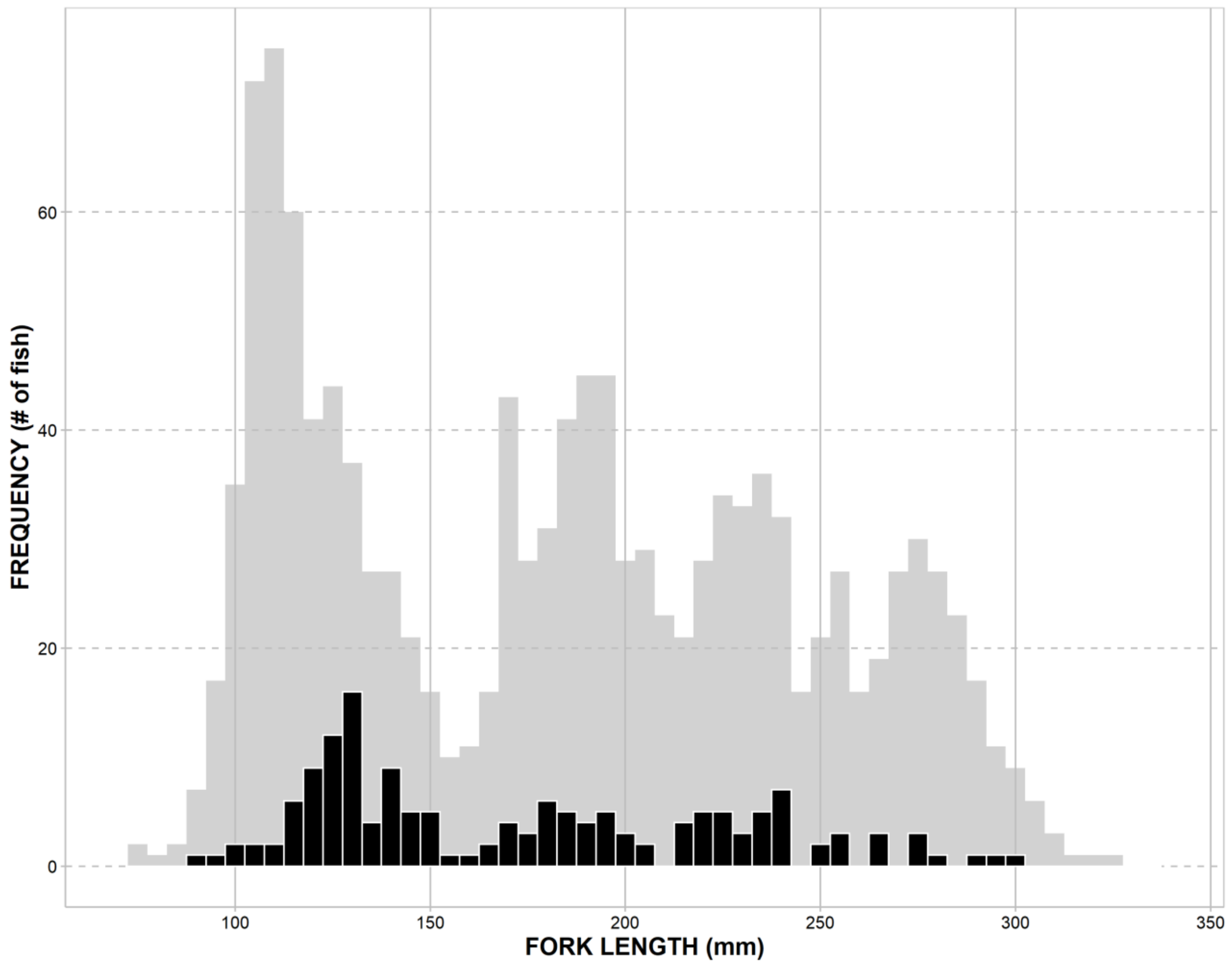
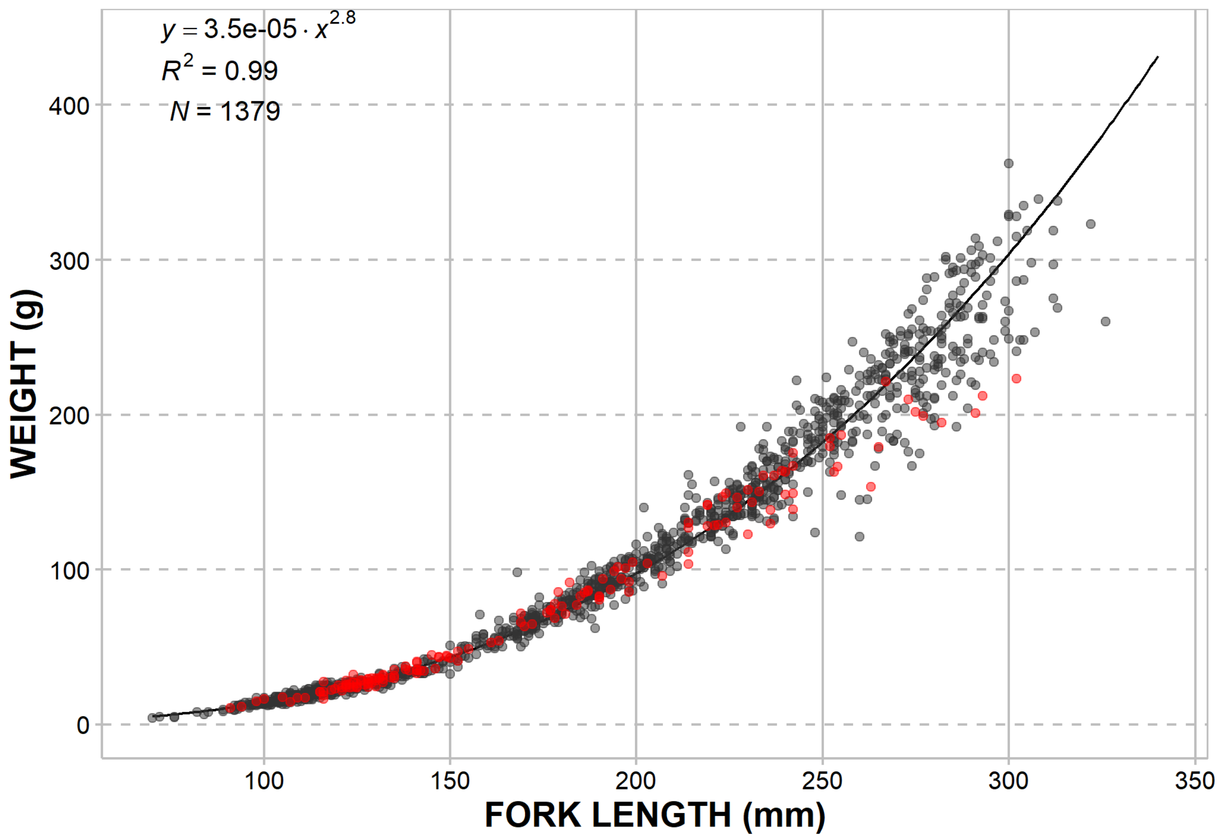


Figure 15. Length-weight relationship for Rainbow Trout captured during gill net surveys in the Upper Campbell Reservoir, 2014-2021. Grey dots represent data collected during 2014-2020, and red dots represent data collected during 2021.



3.2.3.3. Stomach Content Analysis

A total of 529 Rainbow Trout were analysed for stomach contents; with a large proportion of the effort concentrated during 2018-2021 (Table 13). Rainbow Trout in the Upper Campbell Reservoir varied over time; in 2015 it was dominated by benthic prey, during 2017-2019 was largely dominated by terrestrial prey, in 2020 was dominated by planktonic prey, and in 2021 was evenly split between terrestrial prey and plankton prey.

Table 13. Diet analysis of Rainbow Trout captured during gill net surveys in the Upper Campbell Reservoir, 2015, and 2017-2021. The data are presented as mean percent volume.

Predator Species	Year	Sample Size	Plankton	Fish	Benthic	Terrestrial	Other
Rainbow Trout	2015	8	25.0	-	75.0	-	-
	2017	59	31.4	-	1.7	66.9	-
	2018	102	33.2	-	0.2	66.5	-
	2019	108	18.5	-	-	81.5	-
	2020	119	71.3	0.8	-	27.9	-
	2021	133	47.0	-	-	53.0	-

3.2.3.4. Age Cohort Analysis

The age of Rainbow Trout caught in gill nets in Year 8 ranged in age from 1+ to 5+ (Table 14). Most fish captured during Year 8 gill netting were between ages 2+ and 4+ (Table 14). Mean relative condition of Rainbow Trout was close to 1 for all ages (Table 14), except age 5+ fish whose mean relative condition was low (0.93). The low condition of older fish is noticeable as lower than expected weights in the length-weight relationship for fish larger than ~250 mm (Figure 15). Further analysis of trends in relative condition of adult Rainbow Trout may be warranted for the Year 9 report.

There was a decreasing trend of relative abundance of Rainbow Trout with age; the relative abundance of younger fish was quite low this year and it generally decreased with age with some variability around the overall trend (Table 15). No age 0+ fish were caught.

Table 14. Summary of fork length, weight, and relative condition of Rainbow Trout captured during gill netting surveys in Upper Campbell Reservoir, 2021, excluding partially consumed fish (n = 19).

Age	Fork Length (mm)				Weight (g)				Relative Condition (K_r)			
	n	Mean	Min	Max	n	Mean	Min	Max	n	Mean	Min	Max
0+	0	-	-	-	0	-	-	-	0	-	-	-
1+	17	109.8	91.0	120.0	17	18.5	10.5	27.5	17	1.01	0.77	1.30
2+	60	134.4	121.0	163.0	59	32.5	21.9	53.9	59	1.00	0.84	1.25
3+	32	184.9	167.0	203.0	31	83.2	63.1	104.6	31	1.05	0.90	1.23
4+	24	224.8	207.0	239.0	24	136.2	95.7	163.7	24	1.01	0.84	1.13
5+	14	250.6	240.0	267.0	14	169.7	138.7	221.5	14	0.93	0.73	1.06
≥6+	0	-	-	-	0	-	-	-	0	-	-	-

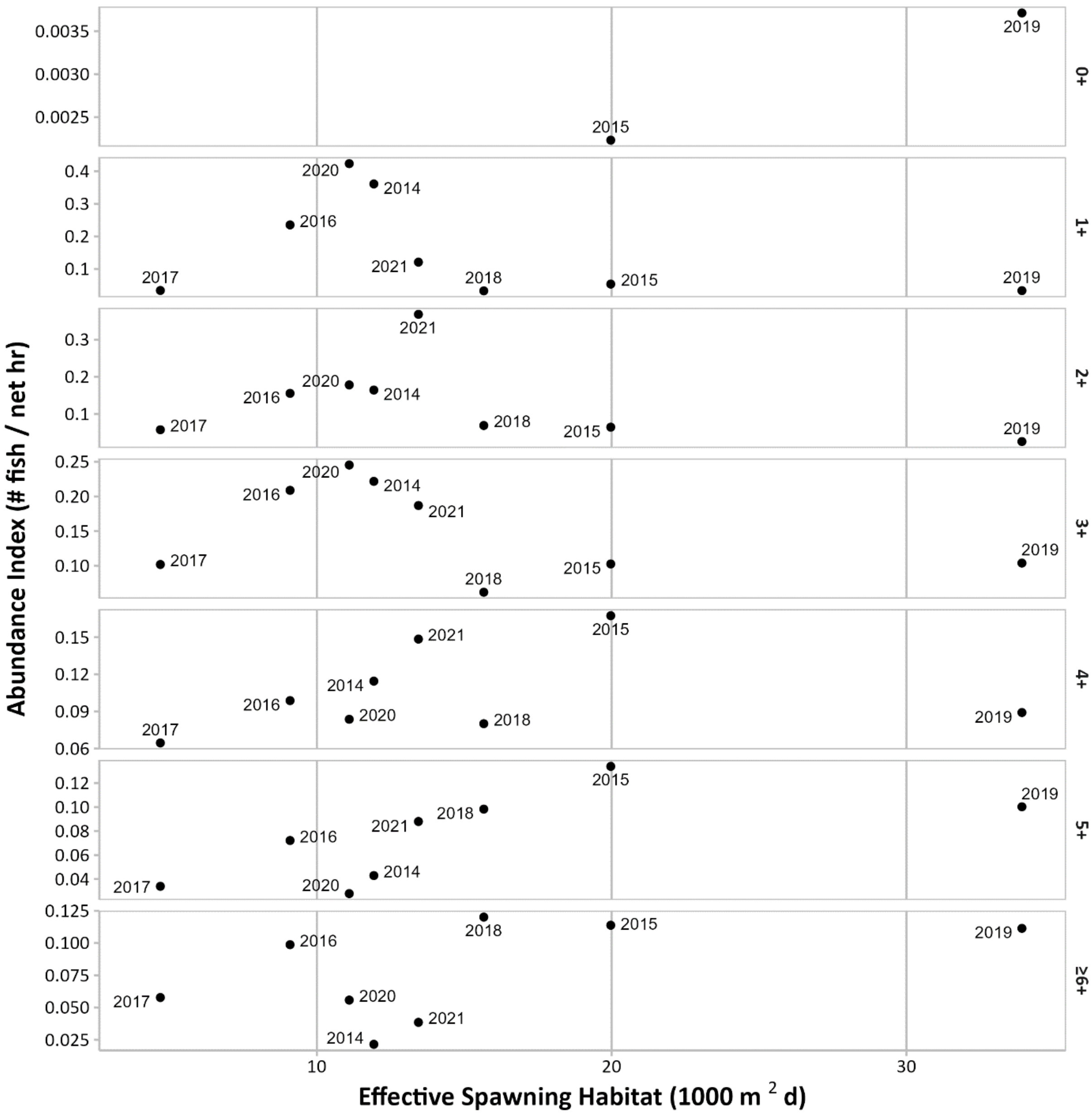
Table 15. CPUE (fish / net hour) of Rainbow Trout age cohorts captured during gill netting surveys in Upper Campbell Reservoir, 2021.

Age	Number of Fish Caught	CPUE (# of Fish/net hr)
0+	0	0.000
1+	22	0.121
2+	67	0.368
3+	34	0.187
4+	27	0.148
5+	16	0.088
≥6+	7	0.038

3.2.3.5. Comparison of Abundance Index to Effective Spawning Habitat

There is no clear relationship between age-specific abundance indices of young (1+ to 3+) Rainbow Trout and the ESH in the Upper Campbell Reservoir (Figure 16). However, the age-specific abundance indices of 4+ to 6+ fish are positively correlated to the ESH in the Upper Campbell Reservoir (Figure 16). There is substantial inter annual differences in CPUE; the largest values of CPUE were recorded in 2020 and 2021; age 1+ (0.396 fish/net hr) and age 3+ (0.24 fish/net hr) in 2020, and age 2+ (0.368 fish/net hr) in 2021. The values of ESH during this monitoring project (2014-2021) were variable; they initially increased from ~10,000 m^2d to ~20,000 m^2d in 2015, then decreased to a low in 2017 of ~5,000 m^2d, increased through 2019 to a maximum of ~35,000 m^2d, decreased again in 2020 to ~10,000 m^2d. and increased in 2021 to ~13,000 m^2d (Figure 16).

Figure 16. Rainbow Trout abundance index in relation to Effective Spawning Habitat values of the Upper Campbell Reservoir for each age cohort.



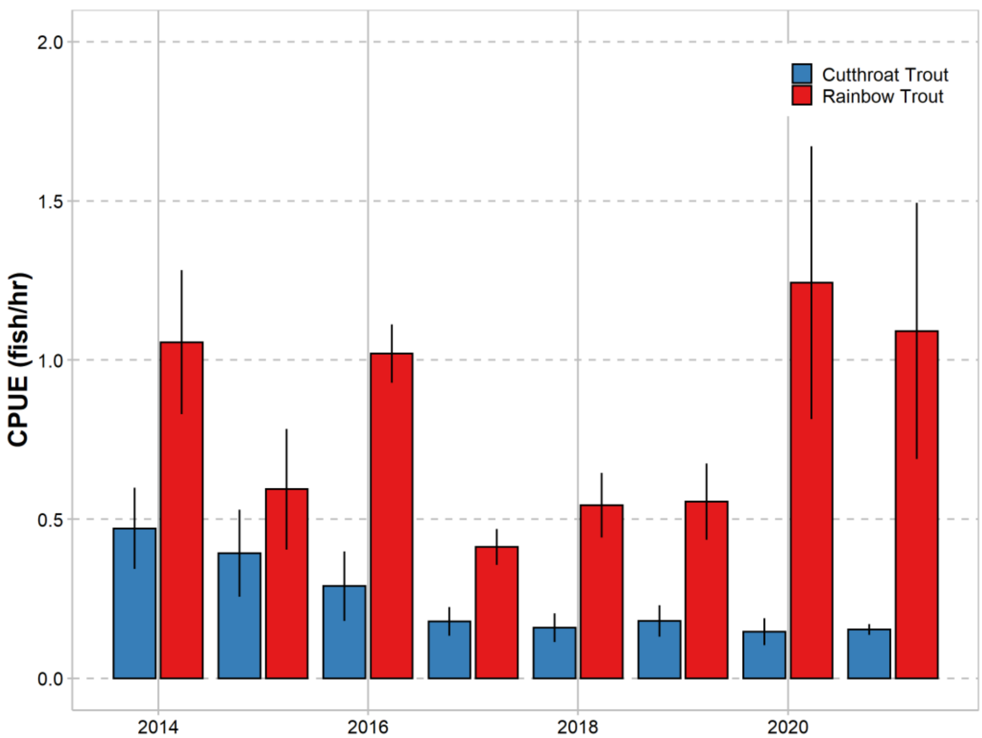
3.2.4. Historical Comparison

In this section, we provide brief summaries of historical gill net catch data for Cutthroat and Rainbow Trout for both species for the Upper Campbell Reservoir overall, and by sample site for each species separately.

3.2.4.1. Upper Campbell Reservoir

Sampling results from Year 1 to Year 8 (2014 to 2021) suggest that mean Cutthroat Trout CPUE is in a declining trend, while average Rainbow Trout CPUE is highly variable and seems to be increasing since 2017 (Figure 17) in the Upper Campbell Reservoir. Cutthroat Trout CPUE has declined since Year 1. It is worth noting that Year 8 CPUE for Cutthroat Trout (0.14 fish/net hour) was the lowest on record since 2014. Year 4 (2017) had the lowest CPUE for Rainbow Trout since program initiation in 2014. Rainbow Trout CPUE has shown an increasing trend since Year 4, reaching the maximum observed CPUE in Year 7 (1.25 fish/net hour) and remaining high in Year 8 (1.06 fish/net hour).

Figure 17. Comparison of Cutthroat and Rainbow Trout CPUE from littoral gill net surveys in the Upper Campbell Reservoir among the eight years of this program to date (2014-2021). The bars represent the annual mean CPUE, and the vertical error bars represent +/- SE.

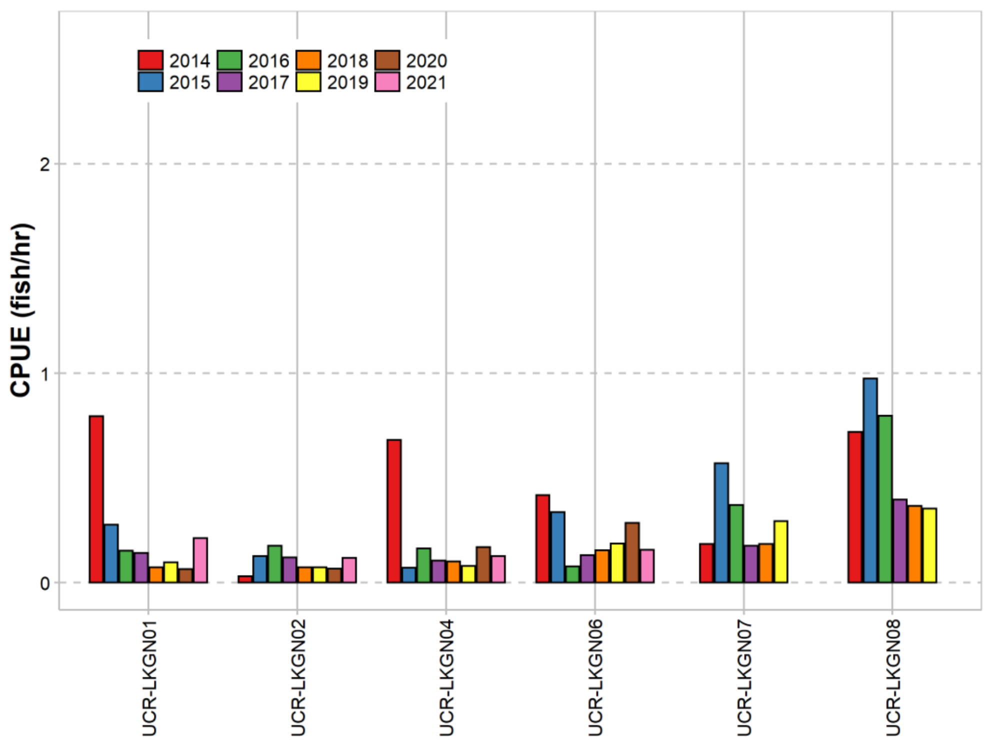


Cutthroat Trout

Results from the Year 8 Population Index are comparable to past years (Figure 18). UCR-LKGN02 had consistently lower Cutthroat Trout CPUE compared to the other sites.

Cutthroat Trout had a consistent preference for some sites over others, but trends for Cutthroat Trout CPUE are not apparent within sampling sites or across years. In fact, the only site with a consistent trend across all sampling years is UCR-LKGN01, for which CPUE has decreased annually since 2014, although it increased in 2021. However, there seems to be an increasing trend over time in site UCR-LKNG06 since 2016, although it decreased in 2021. Compared to previous years, CPUE values remained similar across sites. Assuming CPUE is an indication of habitat preference, it would appear that habitat at UCR-LKGN08 is preferred over that at the other sites (although no gill nets were deployed at the site in the last wo years along with UCR-LKGN07 due to exceeding Rainbow Trout catch limit, see Section 2.2.1.1), while UCR-LKGN02 and UCR-LKGN04 are less-preferred sites.

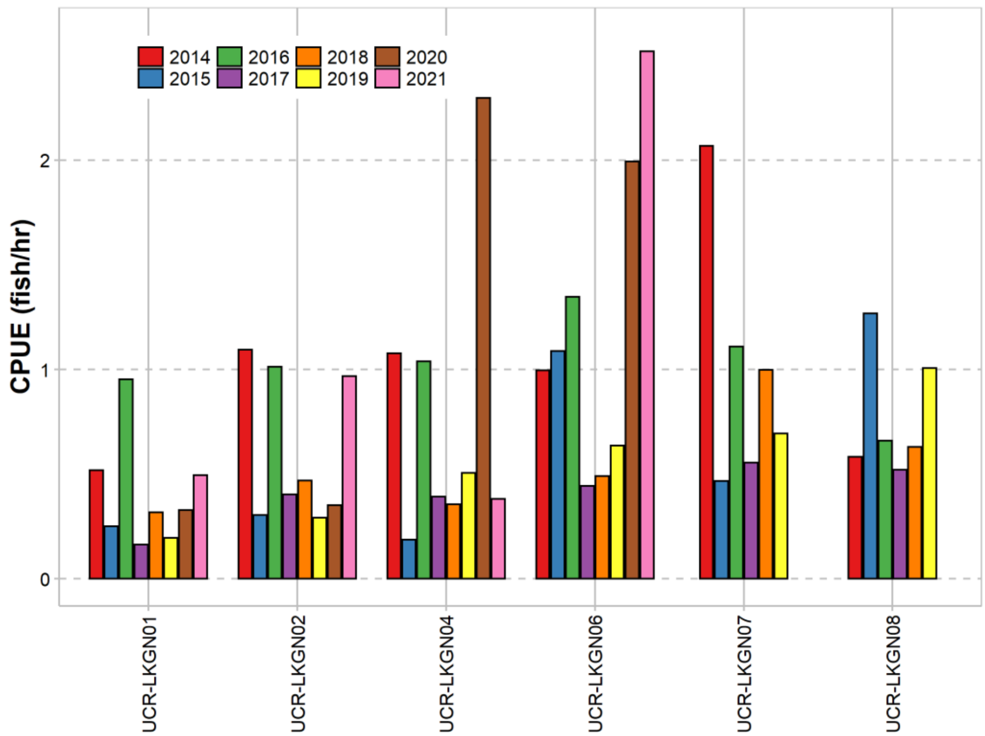
Figure 18. Comparison of Cutthroat Trout CPUE from littoral RISC gill net surveys by sample site among the seven years of this program to date (2014-2021).



Rainbow Trout

There is no consistent trend in CPUE results for Rainbow Trout among the sampling sites or across sampling years (Figure 19). Across most sites, CPUE was highest in 2014 and 2016. The CPUE in 2020 increased largely in sites UCR-LKNG04 and UCR-LKNG06, to the maximum levels observed (2.3 fish/hr and 2 fish/hr, respectively). The CPUE in 2021 reached the maximum level observed in site UCR-LKGN06 (2.5 fish/hr) (Figure 19).

Figure 19. Comparison of Rainbow Trout CPUE from littoral RISC gill net surveys by sample site among the eight years of this program to date (2014-2021).



3.3. Snorkel Survey of Spawners in Reservoir Tributaries

3.3.1. Survey Conditions

Details of survey locations, dates, effort, and conditions are presented for spring (Table 16) and summer surveys (Table 17). All parameters (discharge, visibility, and temperature) during the spring surveys were influenced by seasonal freshet and precipitation with varying effective visibility from 3 m in March to 6 m in April and with temperatures ranging between 2.0°C and 2.8°C (Table 16). Relative to the spring, increased water temperature and visibility was experienced during summer surveys (Table 17). Representative photographs collected during snorkel surveys are presented in Appendix D.

Table 16. Sampling effort and conditions for Year 8 snorkel surveys in tributaries of the Lower Campbell Reservoir during spring surveys in 2021. Survey distances for Fry and Miller Creek are from LKT (2015) and Greenstone River survey distances are based on satellite images.

Watershed	Stream	Survey Distance (km)	Date	Survey Duration (hrs)	Total Effort (hrs)	Water Temp. (°C)	Air Temp (°C)	Estimated Visibility (m)	Mean Daily Discharge (m^3/s)[1]	Weather
Lower Campbell	Fry Creek	1.2	02-Mar-21	0.8	1.5	2.8	4.0	5.0	3.5	Partly Cloudy
	Greenstone River	2.4	19-Apr-21	1.5	3.1	2.0	10.0	6.0	22.3	Partly Cloudy/Dry/None in 24 hours/Light Breeze
	Miller Creek	0.4	02-Mar-21	1.9	3.7	2.5	5.0	3.0	3.5	Partly Cloudy

[1] Data from the Gauge 08HD018 form Government of Canada Wateroffice site

Table 17. Sampling effort and conditions for Year 8 snorkel surveys during summer 2021. Survey distances are from LKT (2015). Note that both water and air temperature for Ralph River were not recorded.

Watershed	Stream	Survey Distance (km)	Date	Survey Duration (hrs)	Total Effort (hrs)	Water Temp. (°C)	Air Temp (°C)	Estimated Visibility (m)	Mean Daily Discharge (m^3/s)[1]	Weather[1]
Buttle Lake	Henshaw Creek	0.5	01-Jun-21	0.6	1.1	5.5	11.0	5.0	24.5	Sunny/Dry/None in 24 hours/Calm
	Phillips Creek	0.3	02-Jun-21	0.4	0.8	5.0	12.0	5.0	24.8	Sunny/Dry/None in 24 hours/Light Breeze
	Ralph River	0.9	01-Jun-21	0.3	0.6	n/a	n/a	5.0	24.5	Sunny/Dry/None in 24 hours/Calm
	Thelwood Creek	2.5	03-Jun-21	0.8	1.7	7.0	10.0	5.0	22.0	Partly Cloudy/Dry/None in 24 hours/Light Breeze
	Wolf River	0.3	02-Jun-21	0.4	0.9	6.5	16.0	5.0	24.8	Sunny/Dry/None in 24 hours/Light Breeze
Upper Campbell	Lower Elk River	5.4	08-Jun-21	1.9	3.8	NA	NA	6.0	9.8	Partly Cloudy/Dry/None in 24 hours/Light Breeze
	Upper Elk River	6.0	08-Jun-21	1.0	2.0	5.0	12.0	6.0	9.8	Partly Cloudy/Dry/None in 24 hours/Light Breeze

[1] Data from the Gauge 08HD018 form Government of Canada Wateroffice site.

3.3.2. Survey Results

3.3.2.1. Cutthroat Trout

Year 8 snorkel survey data for the Cutthroat Trout spring spawning period are summarized below (Table 18). Redds observed between late February and April were assumed to be Cutthroat Trout redds, even in cases where no fish were observed. Please refer to Section 3.3.3 for a comparison with historical snorkel counts.

Snorkel surveys for spawning Cutthroat Trout were conducted in tributaries of the Lower Campbell River in March and April 2021. During these Lower Campbell River snorkel surveys most adult Cutthroat Trout were observed in Greenstone River, and only one adult fish in Miller Creek; however, redds were observed in all three tributaries of Lower Campbell Reservoir (Table 18).

Densities of Cutthroat Trout were low in all tributaries (this reflects the low CPUE recorded in the gillnet sampling), reaching maximum of only 4.4 fish/km in Thelwood Creek (Figure 20). It is noteworthy the decrease in density of Cutthroat Trout in Wolf River where the density recorded in 2019 was >60 fish/km, whereas it was only 3.3 fish/km in 2021. The majority of adult Cutthroat observed in 2021 were either bright (*n* = 46) or moderately coloured (*n* = 6) (Figure 21). Fish in mid-spawn condition were only observed in Greenstone River (n = 13, Figure 21).

Table 18. Cutthroat Trout counts during 2021 snorkel surveys in the tributaries of Upper and Lower Campbell Reservoirs and Buttle Lake.

Watershed	Month	Waterbody	Date	Cutthroat Trout Observations (# of fish)[1]							Redds[2]
				Total	Fry	Parr	151-250	251-350	351-450	450+	
Buttle Lake	June	Henshaw Creek	01-Jun-21	2	0	0	2	0	0	0	n/a
		Phillips Creek	02-Jun-21	2	0	0	0	2	0	0	n/a
		Ralph River	01-Jun-21	1	0	0	0	1	0	0	n/a
		Thelwood Creek	03-Jun-21	11	0	0	2	8	1	0	n/a
		Wolf River	02-Jun-21	1	0	0	0	1	0	0	n/a
Lower Campbell	March	Fry Creek	02-Mar-21	0	0	0	0	0	0	0	117
		Miller Creek	02-Mar-21	1	0	0	0	1	0	0	172
	April	Greenstone River	19-Apr-21	21	0	1	7	12	1	0	12
Upper Campbell	June	Lower Elk River	08-Jun-21	25	0	0	10	15	0	0	n/a
		Upper Elk River	08-Jun-21	4	1	0	0	3	0	0	n/a

[1] Fry = <80 mm fork length, Parr = 81-150 mm fork length, All others are categorized as mm fork length

[2] All redds observed in March and April are assumed to be Cutthroat Trout redds. Redds observed in June are assumed to be Rainbow Trout. "n/a" reflects no sampling for redds since sampling occurred outside of spawning period.

Figure 20. Cutthroat Trout observed density (fish/km; all life stages) during Year 8 snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir.

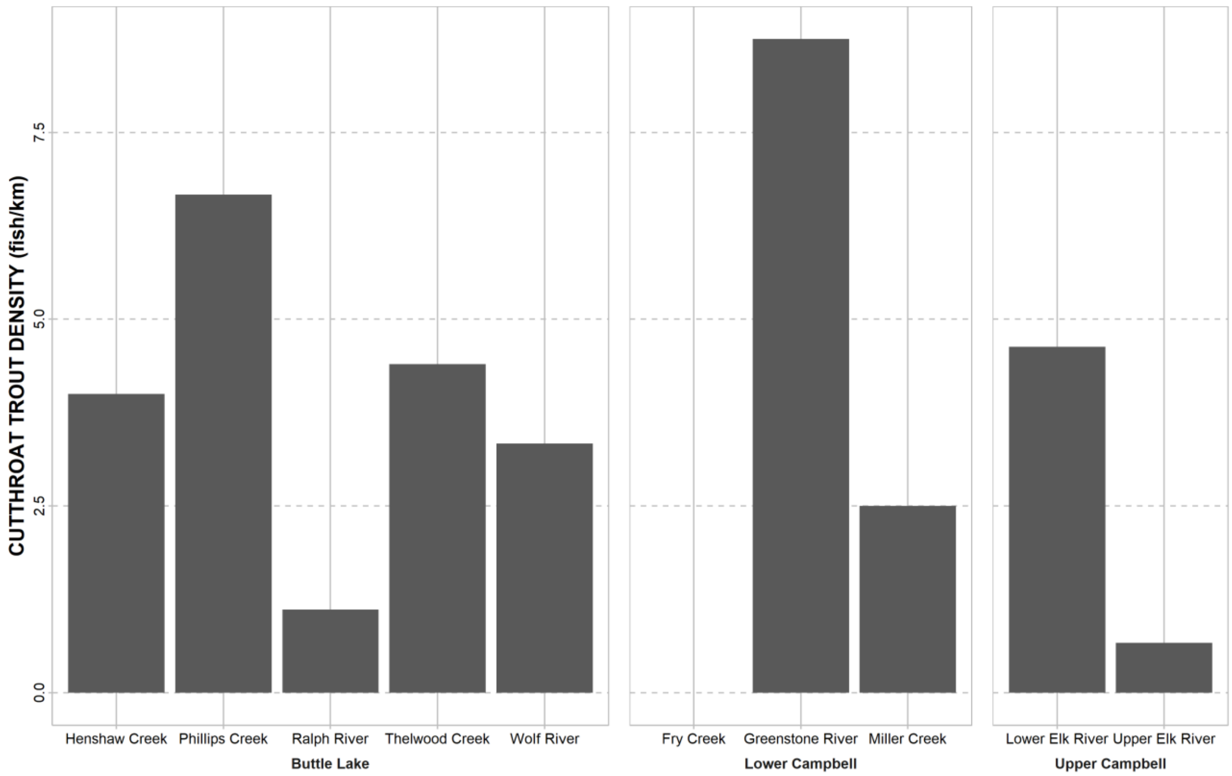
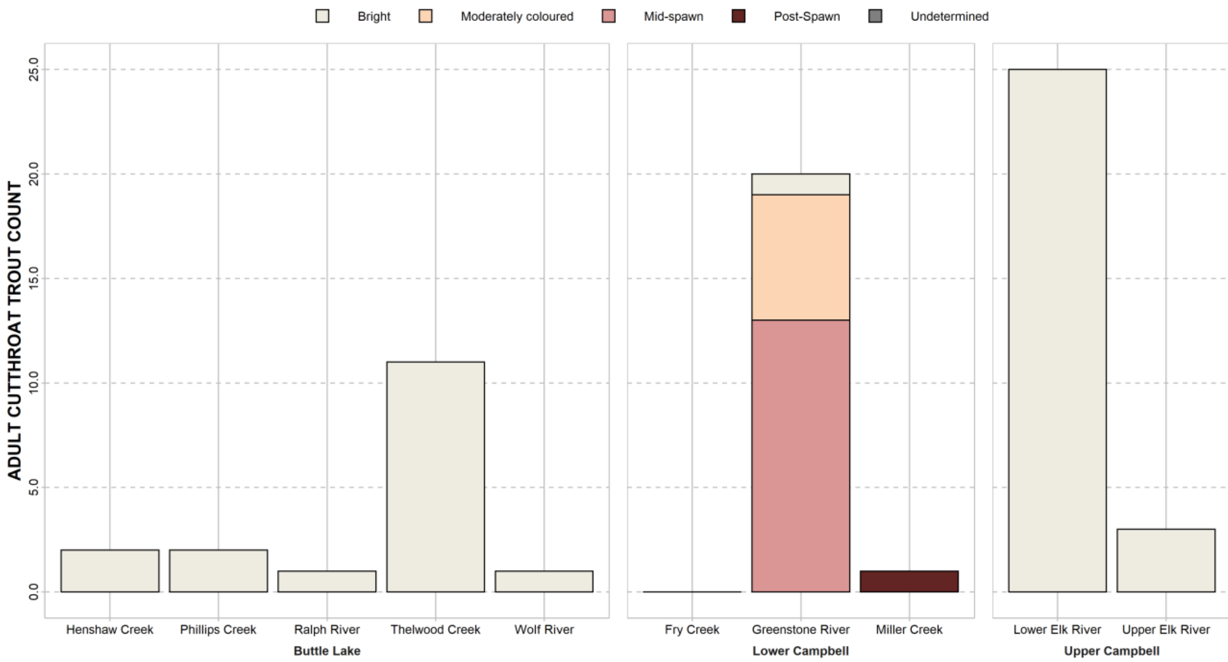


Figure 21. Counts of adult Cutthroat Trout observed during Year 8 snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir, by condition classes.



3.3.2.2. Rainbow Trout

Rainbow Trout redds were recorded in all surveyed tributaries of Upper Campbell and Buttle Lake (Table 19). The highest number of redds was observed in Lower Elk River (1,210 redds), followed by Thelwood Creek (982 redds), and Upper Elk River (869 redds). The total number of Rainbow Trout redds recorded in the Elk River in Year 8 (2,079) was higher than last year (Year 7: 1,819, Year 6: 2,379, Year 5: 2,110, Year 4: 1,087, Year 3: 1833, Year 2: 1846) (Buren *et al.* 2019, 2021; Bayly *et al.* 2018; Smyth and Hatfield 2017; Hatfield *et al.* 2016). The number of Rainbow Trout redds recorded in Thelwood Creek in Year 8 (982) were lower than in previous years, except for Year 4 (Year 7: 1,088, Year 6: 1,782, Year 5: 1,519, Year 4: 576, Year 3: 1,217, Year 2: 1,441) (Buren *et al.* 2019, 2021; Bayly *et al.* 2018; Smyth and Hatfield 2017; Hatfield *et al.* 2016)[2]. Redds were observed during snorkel surveys in tributaries of the Lower Campbell Reservoir in February and April; however, they are assumed to have been excavated by Cutthroat Trout. Please refer to Section 3.3.3 for a comparison with historical snorkel counts.

[2] Redd counts were not consistently recorded for all survey reaches in Year 1, hence no comparison is made with Year 1 data here.

Total Rainbow Trout density per km of stream (juvenile and adult fish combined) varied considerably among stream reaches, with observed densities greatest in Wolf River (960 fish/km), Thelwood Creek (640 fish/km), Lower Elk River (588 fish/km), and Philips Creek (440 fish/km) (Figure 22). When interpreting these results, note that variability in channel width hinders direct comparison of this metric between tributaries.

Adult Rainbow Trout counts were much higher than Cutthroat Trout consistently throughout the monitoring program, which may have been a result of effective survey timing in relation to Rainbow Trout spawning, or due to differences in the number of spawners between the species. Highest count numbers of adult Rainbow Trout observations were recorded from lower Elk River (3,173 fish); Thelwood Creek (1,601 fish); and upper Elk River (1,526 fish) (Figure 23). These watercourses also correspond to the highest counts from previous years.

The majority of the observed Rainbow Trout were of moderately coloured (37.0%), or in mid-spawn (35.7%) condition, suggesting that these surveys occurred during spawning (Figure 23). Low numbers of fish in post-spawn condition were observed, representing only 11.8% (n = 803) across all waterbodies (Figure 23).

Table 19. Rainbow Trout counts during 2021 snorkel surveys in the tributaries of Upper and Lower Campbell Reservoirs and Buttle Lake.

Watershed	Month	Waterbody	Date	Rainbow Trout Observations (# of fish)[1]							Redds[2]
				Total	Fry	Parr	151-250	251-350	351-450	450+	
Buttle Lake	June	Henshaw Creek	01-Jun-21	112	0	1	15	96	0	0	46
		Phillips Creek	02-Jun-21	132	0	7	32	93	0	0	15
		Ralph River	01-Jun-21	258	0	0	64	194	0	0	107
		Thelwood Creek	03-Jun-21	1601	0	0	731	870	0	0	982
		Wolf River	02-Jun-21	288	0	4	88	196	0	0	245
Lower Campbell	March	Miller Creek	02-Mar-21	2	0	0	0	2	0	0	n/a
	June	Lower Elk River	08-Jun-21	3173	0	13	2423	737	0	0	1210
Upper Campbell	June	Upper Elk River	08-Jun-21	1526	0	44	496	986	0	0	869

[1] Fry = <80 mm fork length, Parr = 81-150 mm fork length, All others are categorized as mm fork length

[2] All redds observed in June are assumed to be Rainbow Trout redds

"n/a" reflects no sampling for redds since sampling occurred outside of spawning period

Figure 22. Rainbow Trout observed density (fish/km; all life stages) during Year 8 summer snorkel in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir. Rainbow Trout observed incidentally during snorkel surveys for Cutthroat Trout in the Lower Campbell Reservoir are not included.

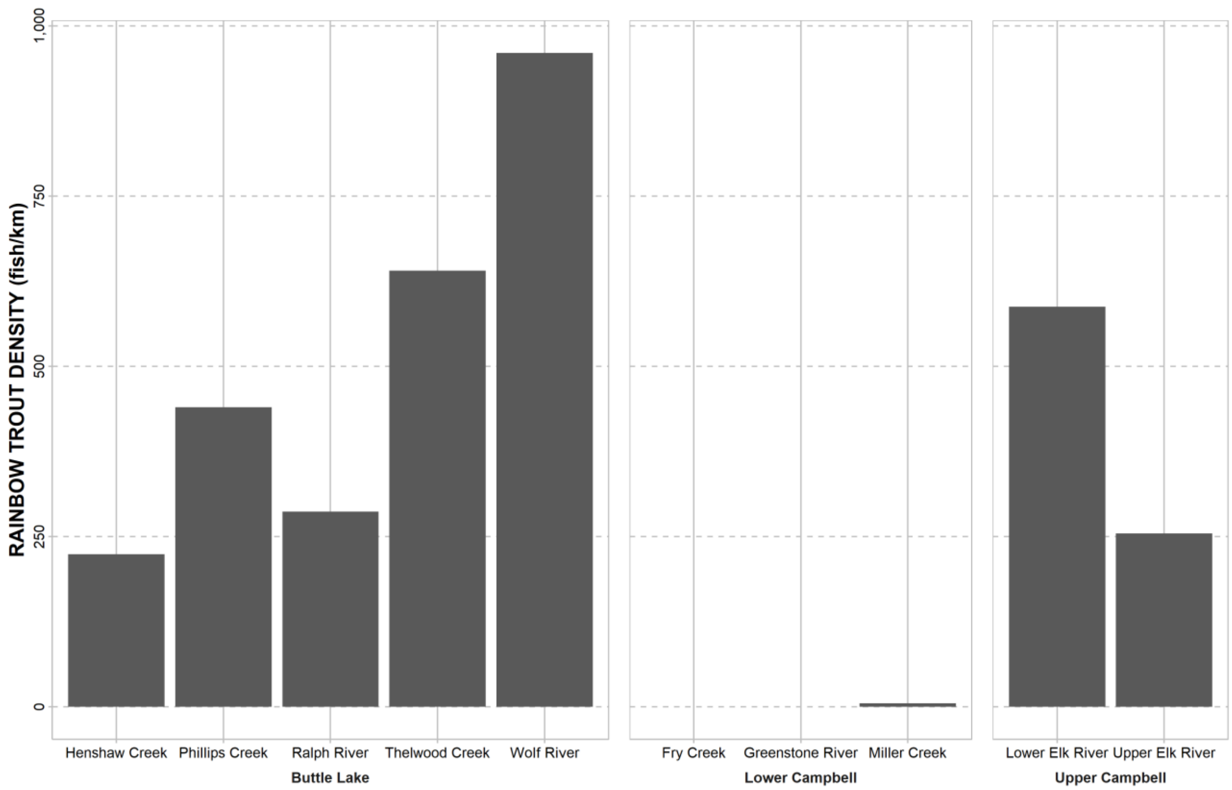
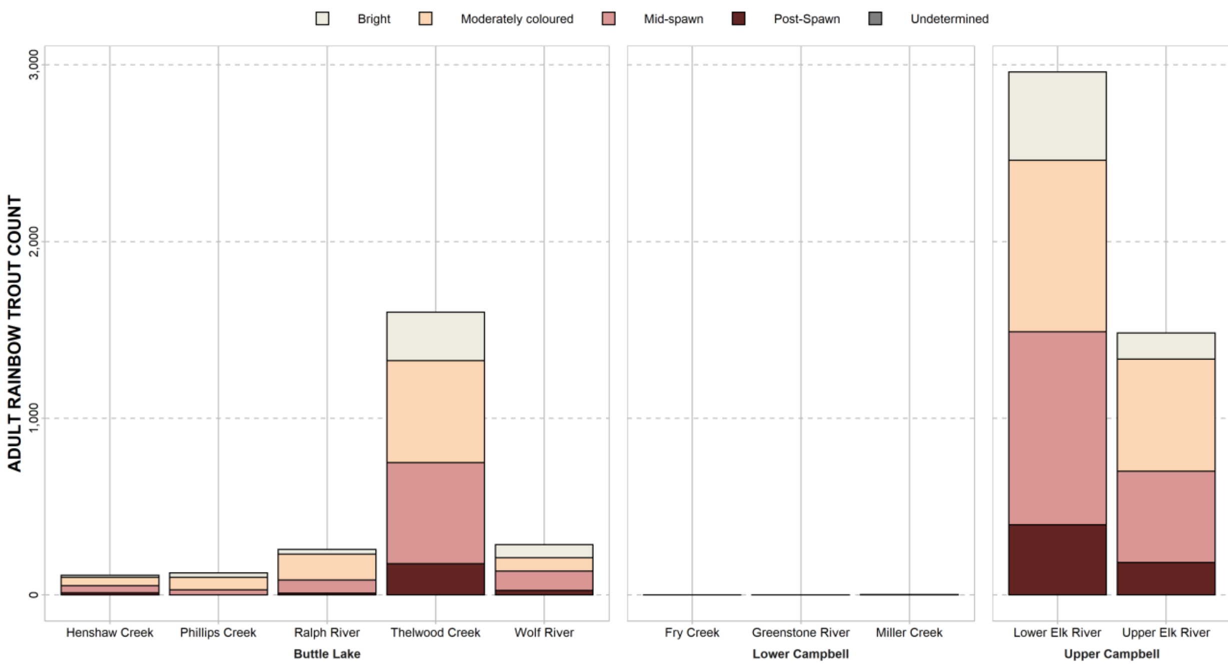


Figure 23. Counts of adult Rainbow Trout observed during Year 8 summer snorkel surveys in the tributaries of Upper Campbell Reservoir and Buttle Lake, by condition classes. Rainbow Trout observed incidentally during snorkel surveys for Cutthroat Trout in Lower Campbell Reservoir are not included.



3.3.2.3. Dolly Varden and Unidentified Salmonids

The numbers of adult Dolly Varden observed were much lower than the number of observed Cutthroat or Rainbow trout consistently through the monitoring program. This reflects the timing of the surveys, which targeted Cutthroat Trout and Rainbow Trout spawning during the late winter/spring and summer, respectively. Snorkel surveys targeting the Dolly Varden spawning period (October to early December) were not undertaken and are outside the scope of this monitoring program; therefore, all observations of Dolly Varden are classified as incidental.

No Dolly Varden parr were observed during summer surveys (Table 20). The greatest number of adult Dolly Varden were observed in Henshaw Creek (8 fish) which was the highest number recorded through the 8 years of monitoring (Year 2: 4, Year 4: 3, Year 7: 1) (Buren *et al.* 2021; Bayly *et al.* 2018; Hatfield *et al.* 2016). Consequently, the density of Henshaw Creek Dolly Varden (16 fish/km) was the highest through the 8 years of monitoring (Figure 24). Densities observed in other streams were 6.7 fish/km (Wolf River) or below and were comparable to those recorded previously.

Figure 24. Dolly Varden observed density (fish/ km) from 2021 summer snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir.

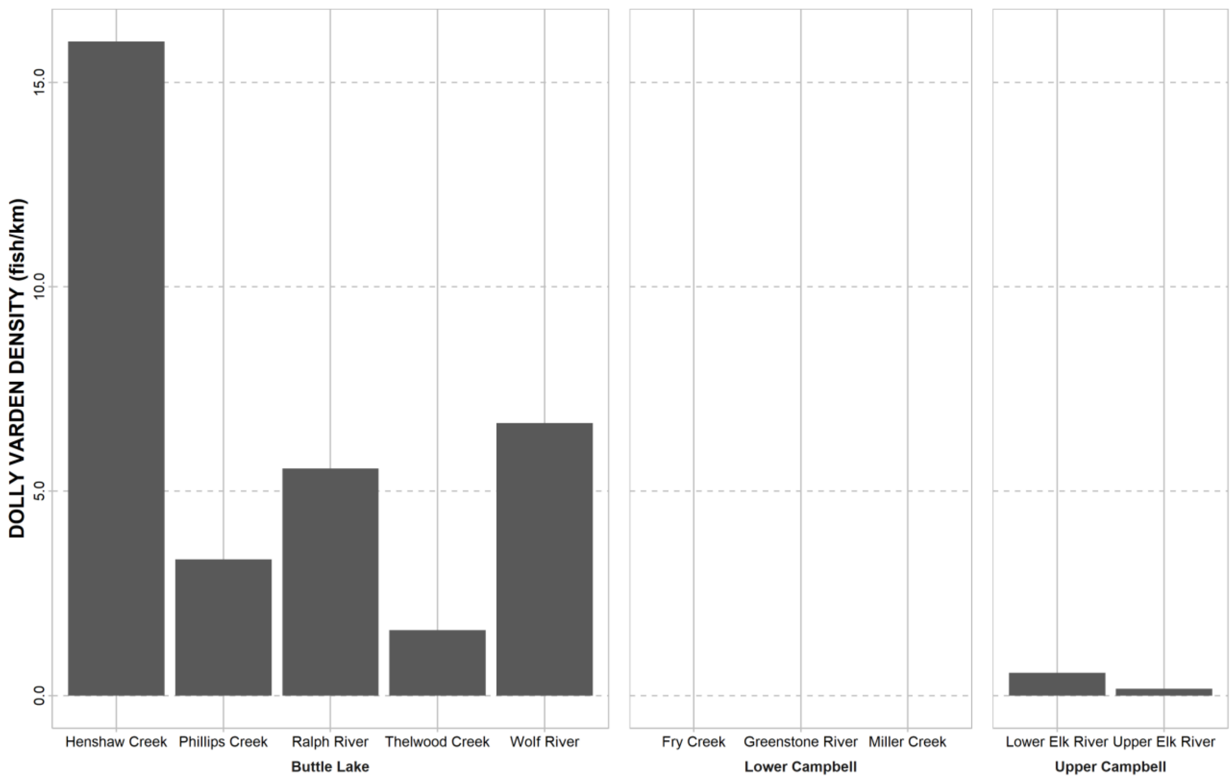


Table 20. Dolly Varden population counts (incidental) from 2021 snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir.

Watershed	Month	Waterbody	Date	Dolly Varden Observations (# of fish)[1]							Redds[2]
				Total	Fry	Parr	151-250	251-350	351-450	450+	
Buttle Lake	June	Henshaw Creek	01-Jun-21	8	0	0	8	0	0	0	n/a
		Phillips Creek	02-Jun-21	1	0	0	0	1	0	0	n/a
		Ralph River	01-Jun-21	5	0	0	1	4	0	0	n/a
		Thelwood Creek	03-Jun-21	4	0	0	3	1	0	0	n/a
		Wolf River	02-Jun-21	2	0	0	0	2	0	0	n/a
Upper Campbell	June	Lower Elk River	08-Jun-21	3	0	0	3	0	0	0	n/a
	June	Upper Elk River	08-Jun-21	1	0	0	1	0	0	0	n/a

[1] Fry = <80 mm fork length, Parr = 81-150 mm fork length, All others are categorized as mm fork length

"n/a" reflects no sampling for redds since sampling occurred outside of spawning period

3.3.3. Comparison with Historical Data

3.3.3.1. Overview

Snorkel surveys targeting the Rainbow Trout spawning period have been undertaken to enumerate adult spawning fish in the six tributaries of Buttle Lake and Upper Campbell Reservoir since 1990. In recent years, prior to 2014, these surveys were completed by BCCF with funding from BC Hydro (Pellett 2013). The frequency of snorkel surveys prior to 2014 has not been consistent from year to year for several of the tributaries. The size limit used to define "adult" fish during historical surveys is not known, with the exception of Fry Creek (fork length > 100 mm). Fish count data for the six tributaries that are part of this monitoring program (data for the survey reaches in the upper and lower Elk River are presented separately) are presented in Table 21; of the three species enumerated, counts have historically been highest for Rainbow Trout, which was also true for the June 2021 surveys.

Regular annual snorkel surveys were not undertaken in the three sampled tributaries of Lower Campbell Reservoir, and no historical data are available for Miller Creek (Strathcona Dam tailrace); however, surveys were undertaken in Fry Creek in 2003 and 2004 and were re-commenced as part of the JHTMON-3 monitoring program in 2014 (Pellett 2013). These historical data are derived from surveys undertaken across a range of months and are thus presented separately in Table 22; note that only one fish has been recorded since 2014.

Table 21. Summary of adult fish count snorkel survey data in six tributaries of Upper Campbell Reservoir and Buttle Lake that were surveyed (1990–2021). Historical data (prior to 2014) were provided by BCCF (Pellett 2013).

Watershed[1]	Waterbody	Species[2]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Upper Campbell[3]	Upper Elk	RB	n/a	436	1,475	487	960	542	370	n/a	n/a	n/a	n/a	428	168	337	728	n/a
		CT	n/a	8	7	0	19	11	1	n/a	n/a	n/a	n/a	3	2	0	5	n/a
		DV	n/a	0	5	0	0	2	n/a	n/a	n/a	1	n/a	6	0	0	0	n/a
	Lower Elk	RB	823	1,134	1,087	1,194	1,411	773	1,044	n/a	n/a	n/a	n/a	1,089	1,184	1,259	1,784	n/a
		CT	7	16	11	1	26	2	8	n/a	n/a	n/a	n/a	3	2	1	3	n/a
		DV	0	0	4	0	13	0	n/a	n/a	n/a	0	n/a	6	2	1	2	n/a
Buttle	Ralph	RB	n/a	300	1,300	965	2,100	n/a	n/a	n/a	2,620	n/a	1,175	420	724	532	910	n/a
		CT	n/a	0	0	4	0	n/a	n/a	n/a	2	n/a	2	0	0	2	10	n/a
		DV	n/a	10	10	4	4	n/a	n/a	n/a	30	n/a	8	0	3	0	17	n/a
	Thelwood	RB	n/a	1,000	2,500	3,220	3,975	n/a	2,300	n/a	n/a	4,915	2,840	2,501	3,374	3,032	2,590	n/a
		CT	n/a	200	15	88	347	n/a	53	n/a	n/a	141	53	441	34	64	20	n/a
		DV	n/a	225	1	0	30	n/a	2	n/a	n/a	28	0	0	8	3	6	n/a
	Wolf	RB	n/a	n/a	n/a	n/a	n/a	800	n/a	n/a	n/a	450	n/a	361	228	170	576	335
		CT	n/a	n/a	n/a	n/a	n/a	2	n/a	n/a	n/a	1	n/a	3	0	0	0	0
		DV	n/a	n/a	n/a	n/a	n/a	30	n/a	n/a	n/a	12	n/a	4	0	30	41	23
	Phillips	RB	n/a	n/a	750	n/a	n/a	800	n/a	n/a	n/a	500	148	132	111	65	109	94
		CT	n/a	n/a	0	n/a	n/a	6	n/a	n/a	n/a	2	0	6	0	5	1	0
		DV	n/a	n/a	20	n/a	n/a	50	n/a	n/a	n/a	10	1	16	1	5	0	11
	Henshaw	RB	n/a	98	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4	24	7	78	n/a
		CT	n/a	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0	0	0	n/a
		DV	n/a	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0	0	2	n/a

Watershed[1]	Waterbody	Species[2]	2006	2007	2008	2009	2010	2011	2012	2013	2013	2014	2015	2016	2017	2018	2019	2020	2021
Upper Campbell[3]	Upper Elk	RB	1,586	1,066	1,562	1,847	1,445	n/a	716	551	877	1,147	764	900	1,304	1,164	1,534	2,093	1,482
		CT	4	0	2	5	10	n/a	11	10	8	2	3	2	21	13	4	14	3
		DV	6	1	1	1	2	n/a	1	0	1	1	1	0	0	0	0	1	1
	Lower Elk	RB	5,340	4,862	5,630	2,501	3,919	n/a	3,980	1,537	1,204	1,742	886	2,104	2,774	2,541	2,112	3,645	3,160
		CT	3	3	11	4	20	n/a	5	5	7	2	4	6	11	19	23	10	25
		DV	9	2	0	2	1	n/a	0	1	0	0	1	2	0	2	1	0	3
Buttle	Ralph	RB	650	690	1,103	1,181	708	n/a	479	536		835	407	419	421	647	785	1,038	258
		CT	2	0	2	0	0	n/a	1	2		1	0	3	8	5	6	2	1
		DV	4	56	0	9	4	n/a	0	13		4	1	3	4	5	3	3	5
	Thelwood	RB	3,105	3,921	4,408	4,128	4,892	1,123	3,748	4,104		2,567	800	1,110	1,633	1,571	1,850	2,639	1,601
		CT	25	10	12	4	17	32	26	15		0	11	11	14	28	19	22	11
		DV	24	6	4	9	5	2	0	0		0	7	8	3	8	6	2	4
	Wolf	RB	n/a	n/a	1,250	1,210	1,590	140	192	666		384	410	345	327	625	844	760	284
		CT	n/a	n/a	6	1	0	0	2	3		3	0	10	26	12	19	2	1
		DV	n/a	n/a	25	90	90	30	5	18		30	25	5	51	29	11	13	2
	Phillips	RB	n/a	n/a	162	624	540	106	145	191		223	157	153	79	93	188	236	125
		CT	n/a	n/a	1	0	0	0	2	0		2	0	0	1	2	3	2	2
		DV	n/a	n/a	3	4	40	21	3	8		18	0	0	0	3	0	3	1
	Henshaw	RB	5	42	24	93	27	n/a	8	37		26	29	44	17	26	77	96	111
		CT	0	0	1	0	0	n/a	0	0		0	0	0	3	1	3	1	2
		DV	0	0	0	0	0	n/a	0	0		0	0	0	0	0	0	0	8

[1] Historical data for Fry Creek (Lower Campbell Reservoir) are presented separately.

[2] RB - Rainbow Trout, CT - Cutthroat Trout, and DV - Dolly Varden.

[3] Elk River reaches were sampled on June 11 and June 12, 2013. Both values are presented.

"n/a" indicate that surveys were not undertaken.

Table 22. Historical adult fish count data for Fry Creek, from survey dates 2003, 2004, 2014-2021. Data collected in 2003 and 2004 were provided by BCCF (Pellett 2013).

Waterbody	Year	Month	Fish Count[1,2]		
			RB	CT	DV
Fry Creek	2003	February	0	18	0
		March	0	287	0
		April	0	9	0
		May	48	573	1
		June	20	3	0
		October	0	140	0
	2004	February	0	15	0
		April	0	3	0
		May	0	185	14
	2014	June	0	0	0
	2015	June	1	0	0
	2016	March	0	0	0
	2017	March	0	0	0
	2018	March	0	0	0
	2019	March	0	0	0
	2020	February	0	0	0
	2021	March	0	0	0

[1] Fish counts for 2003 and 2004 include fish ≥ 100 mm and fish counts from 2014 onwards include fish ≥ 150 mm

[2] RB - Rainbow Trout, CT - Cutthroat Trout, and DV - Dolly Varden

3.3.3.2. Cutthroat Trout

The data presented here for June 2021 are from Rainbow Trout spawning surveys, so any trends in Cutthroat Trout should be interpreted cautiously. Adult Cutthroat Trout counts in 2021 (ranging from 1 to 25 fish) are generally consistent with historical observations for the period 1990 to 2016 (Table 21). Noteworthy are Thelwood Creek, where an order of magnitude decrease was recorded in 2002, and counts have remained low since, Lower Elk River where there is an increasing trend in the number of Cutthroat Trout since 2014 except the year 2020. In Wolf River we observed the largest decrease in number of fish, from 19 in 2019 to only 1 in 2021.

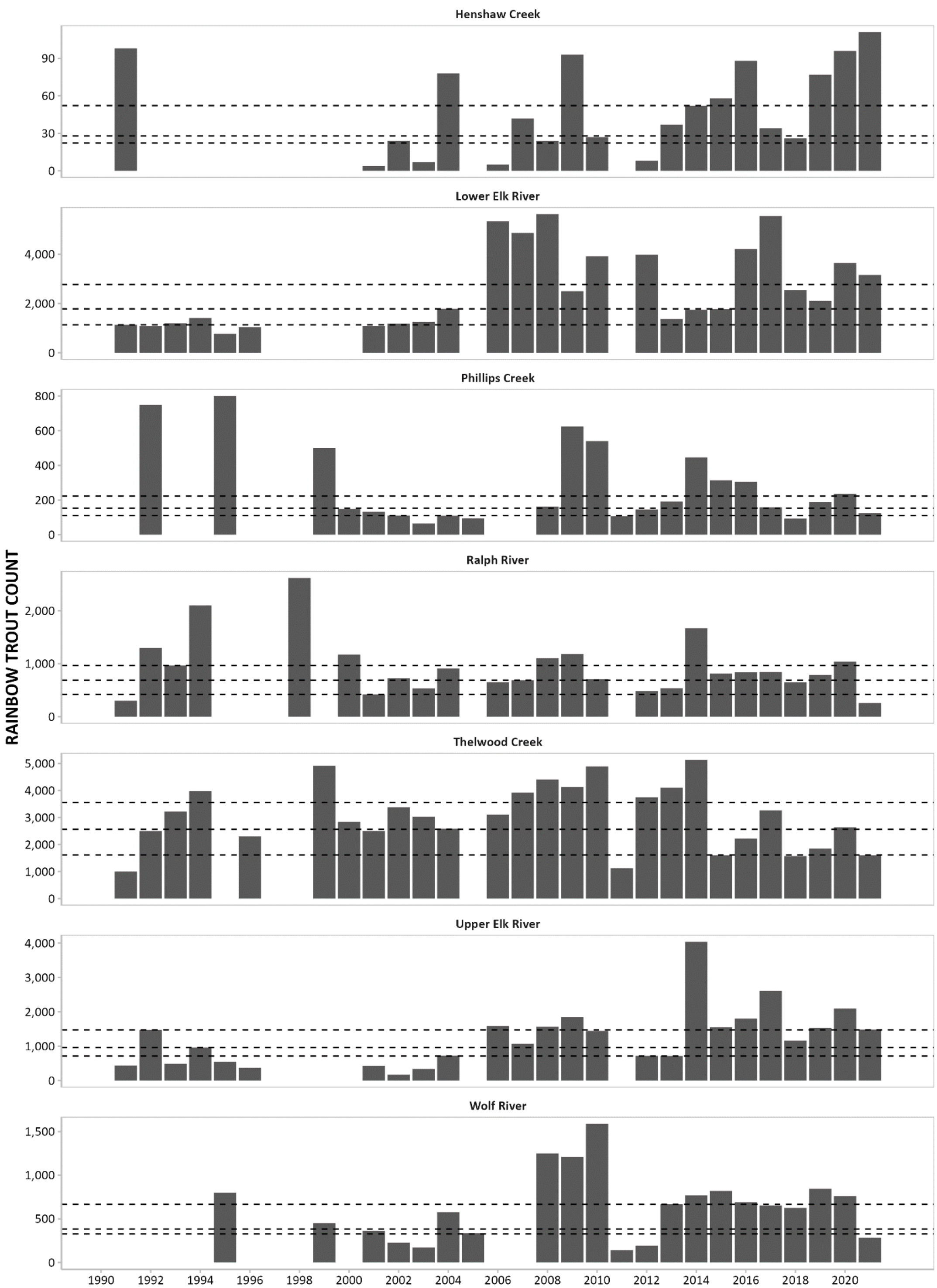
In Fry Creek, comparable survey data for March are only available in 2003 when 287 Cutthroat Trout were observed, and in the 2016-2021 period no fish were observed (Table 22). However, as mentioned in Section 3.3.2.1, surveys were likely conducted following 2021 Cutthroat Trout spawning which means that the 2021 counts are not an accurate measure of the spawner abundances in Fry Creek.

3.3.3.3. Rainbow Trout

There is high variability in adult Rainbow Trout counts among years for individual tributaries, and no clear trends across the entire time series (Table 21, Figure 25). There is an increasing trend during the last four years in a tributary: Henshaw Creek (Figure 25). Although there is no clear temporal trend, the counts of adult Rainbow Trout are synchronous among streams.

Counts of Rainbow Trout in 2021 were above the 75th percentile in three of the streams surveyed: Henshaw Creek, Upper Elk River, and Lower Elk River, at or above the 25th percentile in one stream: Philips Creek, and below the 25th percentile in three streams: Ralph River, Thelwood Creek, and Wolf River (Figure 25). No adult Rainbow Trout were recorded in Fry Creek in June 2021; however, this was comparable to sampling results from spring surveys in previous years (Table 22).

Figure 25. Adult Rainbow Trout counts in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir (1990-2021). Dotted horizontal lines represent 25th, 50th and 75th quantiles. Not all waterbodies were surveyed all years. Historical data (prior to 2014) were provided by BCCF (Pellett 2013).



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3.3.3.4. Dolly Varden

The data presented here are from surveys completed during the month of June which targeted Rainbow Trout spawning, so any trends in Dolly Varden should be interpreted cautiously. The 2021 adult Dolly Varden counts were low (range = 1 to 8), similar in magnitude to the results of the surveys carried out since 2014, broadly comparable with historical surveys, although the count in Wolf River continued the decreasing trend previously recorded (Table 21). Of the seven survey reaches in Buttle Lake and Upper Campbell Reservoir, the 2021 adult Dolly Varden counts were in line with the median values for the majority of tributaries (Table 21), but was substantially below the historical median value for Wolf River (2021, *n* = 2; historical range = 0 to 90; median = 25). No adult Dolly Varden were counted in Fry Creek in 2021, consistent with the previous surveys conducted in the month of February (Table 22).

4. DISCUSSION

4.1. Overview

The overall objective of JHTMON-3 is to test the assumption that recruitment of salmonids (trout and char) in Upper and Lower Campbell reservoirs is limited by availability of ESH. Results obtained thus far, particularly incubation tests and population modelling carried out during Year 5, suggest that recruitment of salmonids is influenced by availability of ESH, although not to the extent assumed during the development of the Water Use Plan. The following sections highlight the main conclusions for each component of the study conducted in Year 8.

4.2. Effective Spawning Habitat (ESH)

The Year 8 ESH study builds on results from previous years and was successful in providing an improved understanding of trends in the habitat loss metric and ESH metric for the two target species, Cutthroat Trout and Rainbow Trout, as well as for Dolly Varden. For the three species considered in this study, ESH was variable among years, with much greater variability in the Upper Campbell Reservoir. In 2021, the ESH for Cutthroat Trout and Rainbow Trout in Upper Campbell Reservoir were among the highest recorded during this monitoring program, and corresponded with a seasonal drawdown that was lower than average coupled with steadily increasing water levels through the incubation period (Figure 1). Based on preliminary results from the statistical catch-at-age model (Buren *et al.* 2019), the large estimates of ESH recorded in 2021 may potentially result in an increase in the abundance of age 1+ fish in 2022.

4.3. Population Index for Upper and Lower Campbell Reservoirs

The Year 8 sampling results (2021) provide an eighth year of data on population abundance, recruitment, and effective spawning metrics. The results allow for the preliminary determination of an abundance index for each age cohort for both trout species. This approach will be built upon in the next 2 years to develop abundance measures for individual ages and test the management hypotheses described in Section 1.4.

There are substantial inter-annual differences in age-specific CPUE of Cutthroat Trout and Rainbow Trout. CPUE of Cutthroat Trout aged ≥6+ in 2021 were among the lowest recorded during this monitoring program, whereas CPUE of Cutthroat Trout aged 5+ were above their age-specific average CPUEs. CPUE of young Rainbow Trout aged 2+ were the largest recorded during this monitoring program. Relative condition of Rainbow Trout age 5+ was lower than expected. Further analysis of trends in relative condition of adult Rainbow Trout may be warranted for the Year 9 report.

4.4. Snorkel Survey of Spawners in Reservoir Tributaries

Snorkel surveys were completed in five tributaries to Buttle Lake, one tributary to Upper Campbell Reservoir, and three tributaries to Lower Campbell Reservoir during the Year 8 surveys in 2021. Spring snorkel surveys carried out in March and April targeted the Cutthroat Trout spawning period in the tributaries of Lower Campbell Reservoir. Few Cutthroat Trout were recorded during the spring snorkel surveys; however, several redds were identified, attributed to early Cutthroat Trout spawning.

Linear densities (i.e., fish / m of stream length) of Rainbow Trout were the highest densities recorded during this monitoring program in most waterbodies, whereas linear densities of Cutthroat Trout and Dolly Varden were below average densities recorded during this monitoring program in most waterbodies.

The numbers of Rainbow Trout redds recorded in 2021 in the Upper Campbell Reservoir were lower than the waterbody-specific averages recorded during this monitoring program, and the number of redds recorded in Buttle Lake tributaries were generally higher than their corresponding waterbody-specific averages, reaching maximum recorded in Thelwood Creek and Wolf River. The number of Cutthroat Trout redds recorded in 2021 in Miller Creek was the highest recorded during this monitoring program, whereas the number of Cutthroat Trout redds recorded in Greenstone River was below the average of the number of redds recorded in that waterbody during this monitoring program.

The snorkel survey results for spawning Rainbow Trout in tributaries of Buttle Lake and Upper Campbell Reservoir identified counts above historical median averages in three streams: Henshaw Creek, Lower Elk River, and Upper Elk River, and similar to historical median averages in the remaining streams. No adult Rainbow Trout were recorded in Fry Creek (tributary to Lower Campbell Reservoir) during 2021, representing low count numbers that matched the previous reference number of zero Rainbow Trout observed in 2004, 2014, and 2016-2020.

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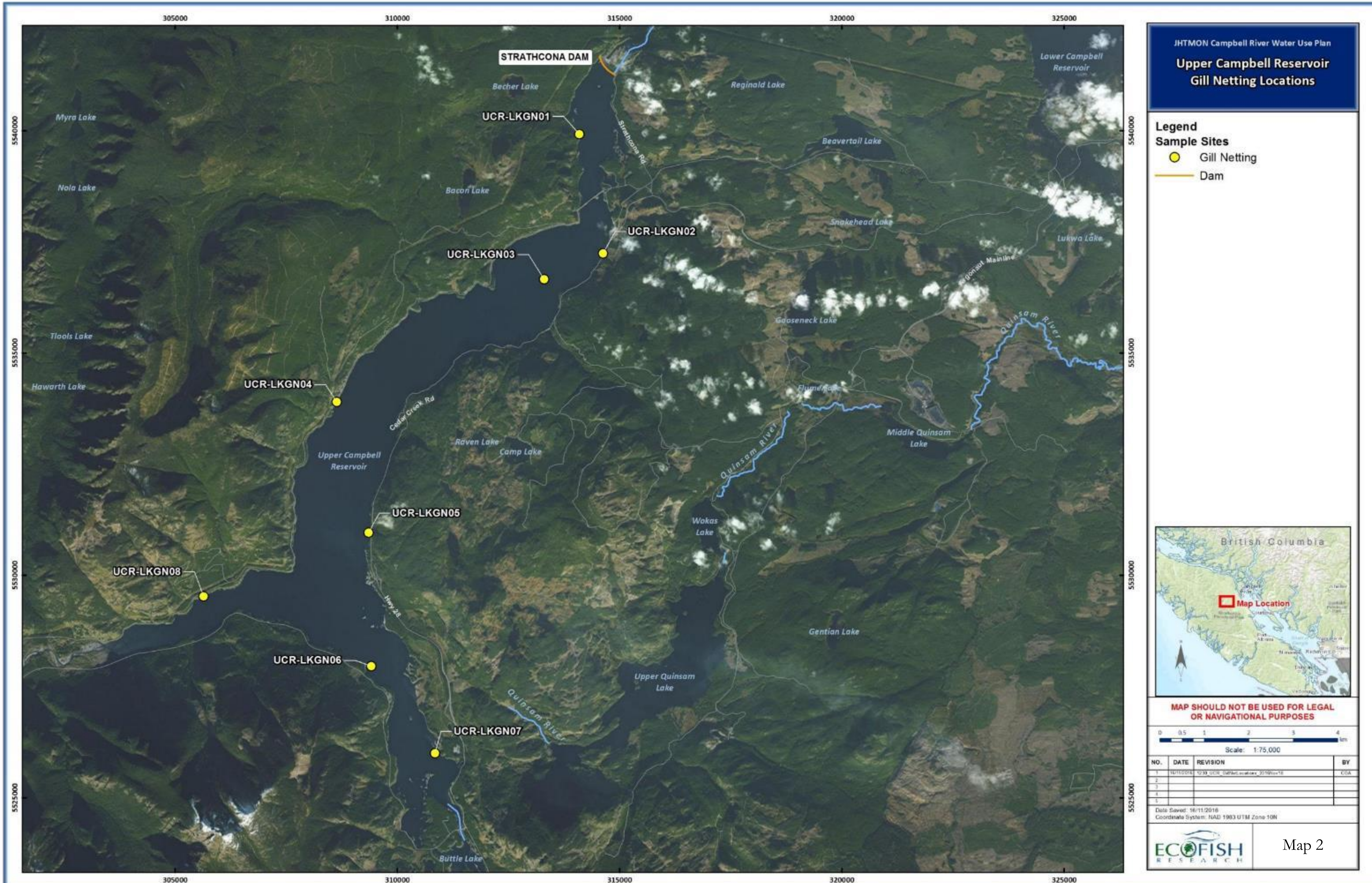
PROJECT MAPS



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APPENDICES

Appendix A. Aging Structure Collection and Reading Protocol - 2021

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1. BACKGROUND

Fish scales, fin rays, otoliths, and other bony structures are commonly collected during fish sampling programs to determine fish age. Scales and fin rays can be collected without harming fish, while the fish must be killed to remove otoliths and other bony structures. Ideally, aging structures are collected from a representative sample of each size class and species during sampling programs. For a more complete discussion of the collection and preparation of aging structures see BC Resource Inventory Standards Committee Fish Collection Methods and Standards (RISC 1997) and Sjolund (1974).

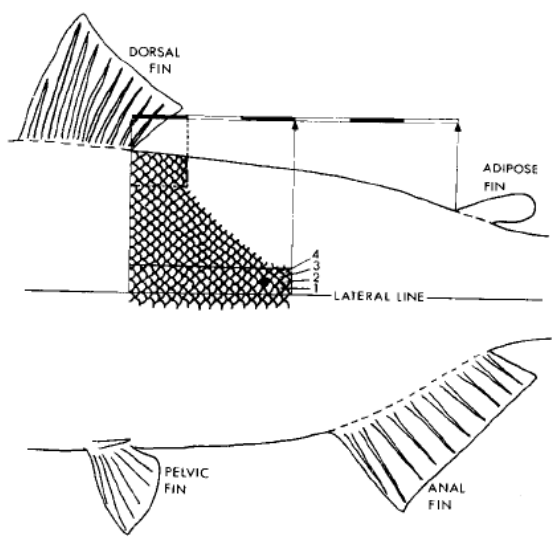
2. METHODS

2.1. Sample Collection and Preparation

2.1.1. Scales

The method for collecting scales depends on the size of the fish that is being sampled. For small and juvenile fish a few scales are scraped off with a scalpel from the area described in Figure 1. For larger fish tweezers are used to pull individual scales off the fish from the area described in Figure 1. The scales from the scalpel are smeared or placed onto a microscope slide, taking care to spread the scales out and avoid them overlapping. A second slide is placed over the scale to sandwich it between the two slides and the slides are taped together with scotch tape. Each sample is labelled and placed within a labelled scale envelope. Scale samples are stored in a plastic container that is specific to each project file, inside a locked metal filing cabinet.

Figure 1. The preferred area for removing scales from a fish (outlined in black) (Sjolund 1974).



2.1.2. Fin Ray

Fin ray samples can be taken from either the pectoral or pelvic fins. Ecofish standard procedure is to remove the left pectoral fin ray unless it is damaged; in that case remove the right pectoral fin. If the fish is large (>150 mm) one fin can be taken. If the fish is smaller (<150 mm) two or three of the longest rays should be removed from the fin by clipping them off near the base of the fin and peeling the fin ray back. Fin rays should be placed in labelled scale envelopes and stored in a dry location, locked inside a metal filing cabinet in an Ecofish office, separated and labeled by project.

2.1.3. Otoliths and Other Bony Structures

Otoliths are generally considered the best structure to accurately age fish because they do not undergo resorption at the same rate as scales or even fin rays and are easy to interpret but the fish must be dead to collect them. Fish are typically euthanized by overdosing in anesthetic. Once dead, the structures are removed by dissecting the fish as per the methods outlined in Section 6 of the BC Resource Inventory Standards Committee Fish Collection Methods and Standards (RISC 1997). Bony structures are stored dry in 5.0 ml plastic vials in labelled scale envelopes or in a solution of glycerin and water in labelled vials. Each otolith should be kept in a separate vial.

2.1.4. Sample Archiving

For each sample, a minimum of three scales, two fin ray sections, or one otolith section, are photographed from each individual fish using a digital camera and a compound microscope. The two photographs should be representative of the sample and not display any significant deformity or damage. Photographs are stored on the Ecofish Research Ltd. network in the appropriate Project folder, and all sample slides and structures are archived in a locked metal cabinet.

2.1.5. Aging

Fish age is determined by examining the structures for winter annuli. The winter annuli in scales is characterized by the noticeably tighter spacing of growth rings (circuli) that are formed during winter growth. In fin rays, otoliths and other bony structures, winter annuli are apparent as thin translucent bands. An example of each of these structures is given in Figure 2 (from Bilton and Jenkinson 1969). Fish age is given as counts of winter annuli. Juveniles that emerged in the same year that they were collected and have not gone through a winter are classified as 0+; fish that exhibit one winter annulus are classified as 1+; and so on. Damaged structures that cannot be accurately aged are recorded as 'damaged'.

Aging of fish samples is conducted by a minimum of two qualified technicians, one primary ager and one QA technician. Each technician ages the samples independently using only sampling date and biological data (length or weight) for the fish. The QA technician records the ages of the scales and compares these ages to the first agers' results entered into EcoDAT. Where ages for a single sample are different between technicians and an age cannot be agreed upon, the sample will be reviewed by a senior biologist.

Figure 2. **Example of sockeye and chum salmon scales, otoliths, and fin rays (from Bilton and Jenkinson 1969).**

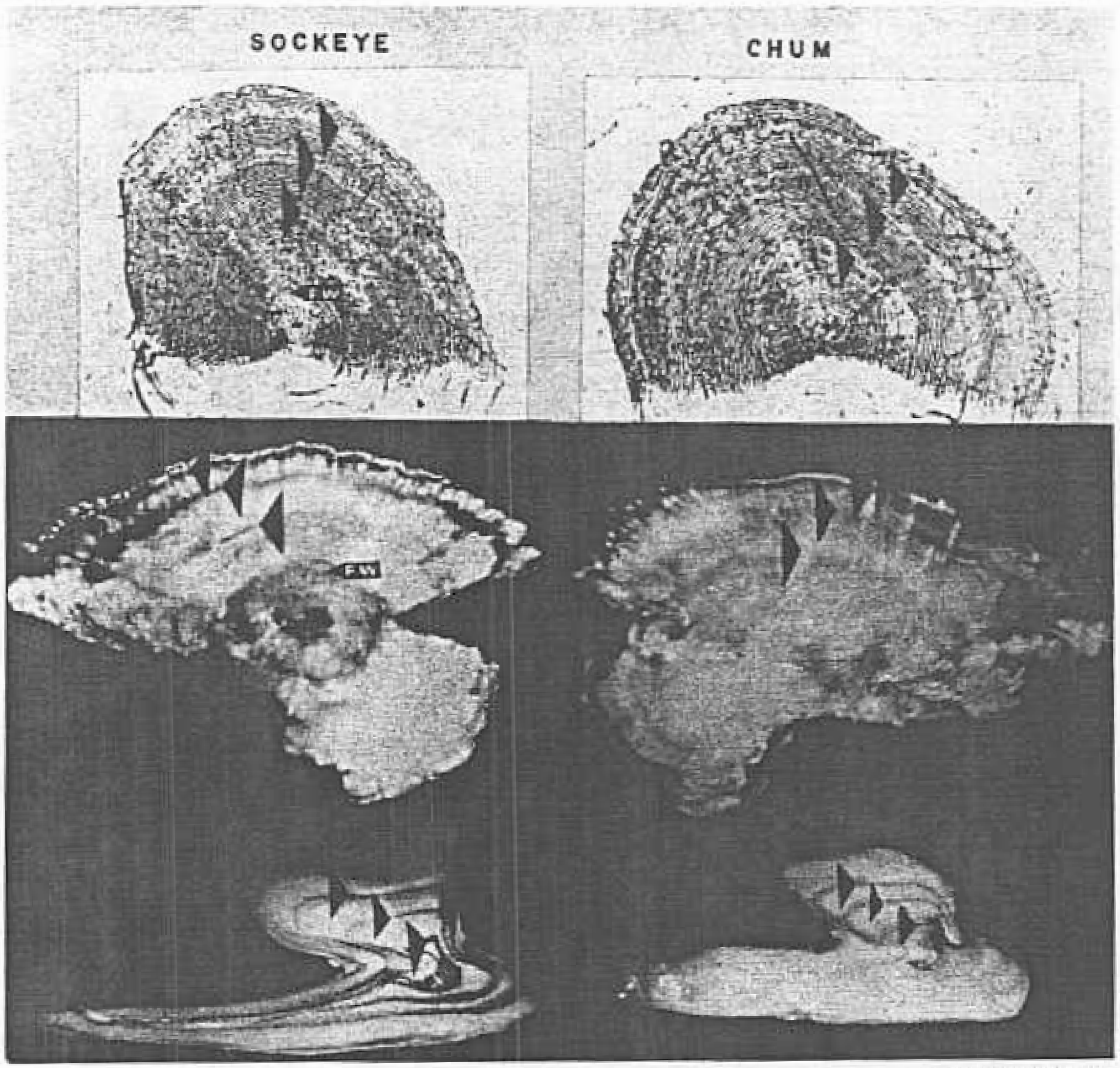


FIG. 4. Scale, otolith, and fin ray from a 1.3 sockeye and a 0.3 chum salmon: FW indicates freshwater annulus; arrows indicate ocean annuli.

Bilton and Jenkinson — J. Fish. Res. Bd. Canada

REFERENCES

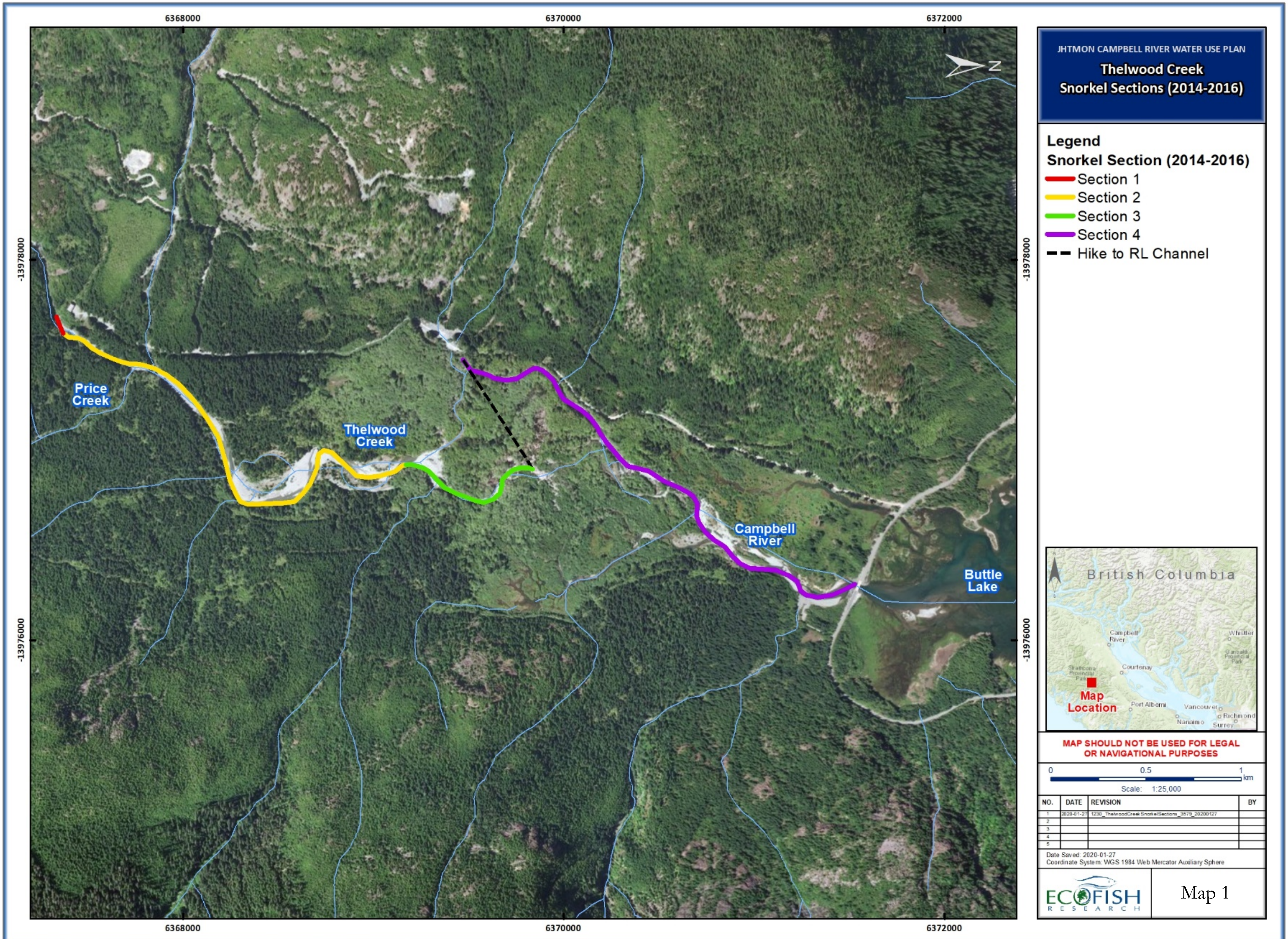
Bilton, H.T., and D.W. Jenkinson. 1969. Age determination of sockeye (*Oncorhynchus nerka*) and chum (*O. keta*) salmon from examination of pectoral fin rays. J Fish Res Board Can 26:1199-1203.

RISC (BC Resource Inventory Committee). 1997. Fish Collection Methods and Standards. Version 4. Prepared by the BC Ministry of Fisheries, Fisheries Inventory Section, for the Resources Inventory Committee.

Sjolund, W.R. 1974. Collection and preparation of scales, otoliths and fin rays for fish age determination. Fisheries Technical Circular No. 12. British Columbia Fish and Wildlife Branch. 22 pp.

Appendix B. Thelwood Creek Geomorphological Changes (2014-2016, 2017-2018, 2019, and 2020- 2021)

LIST OF MAPS



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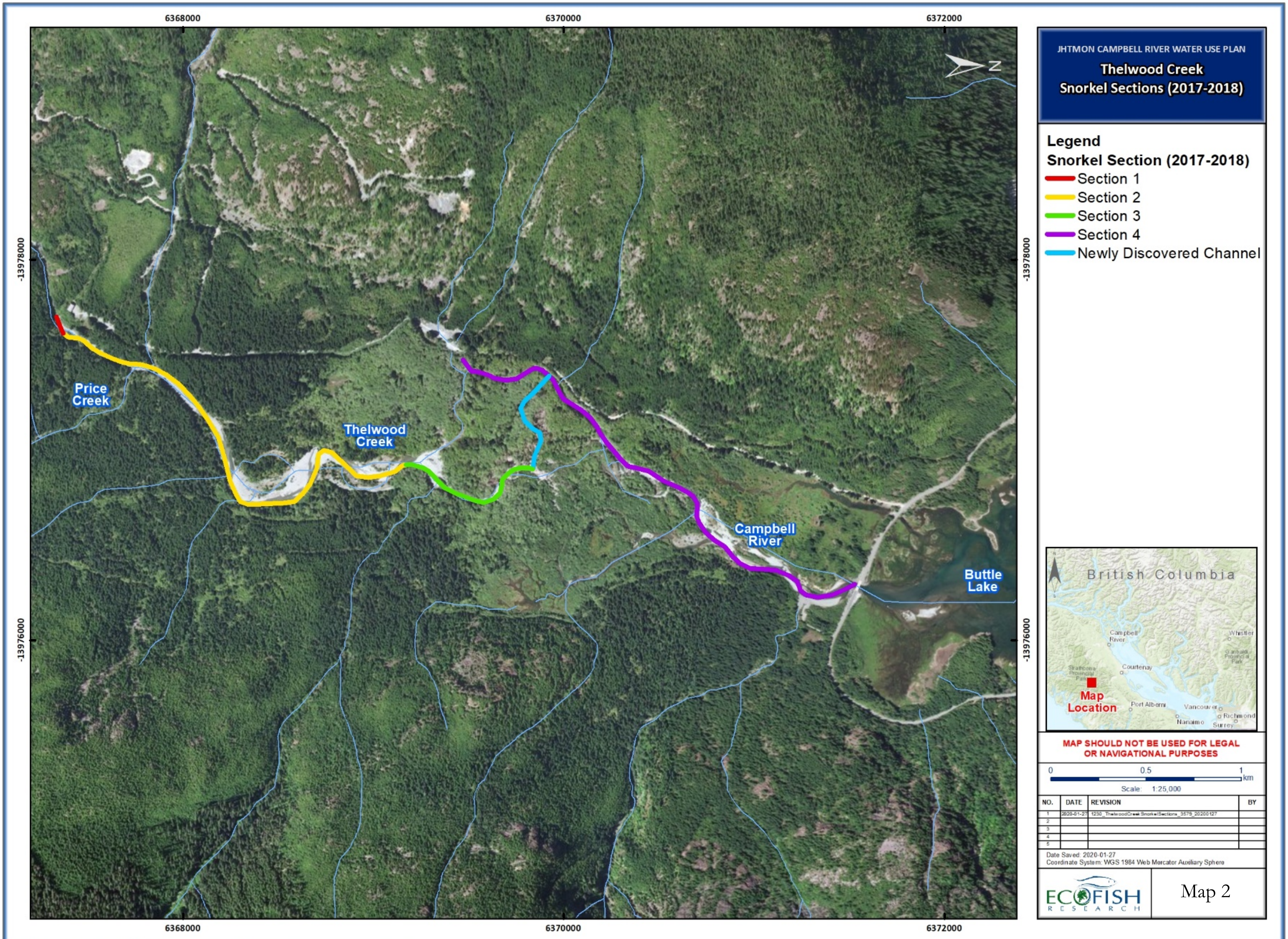

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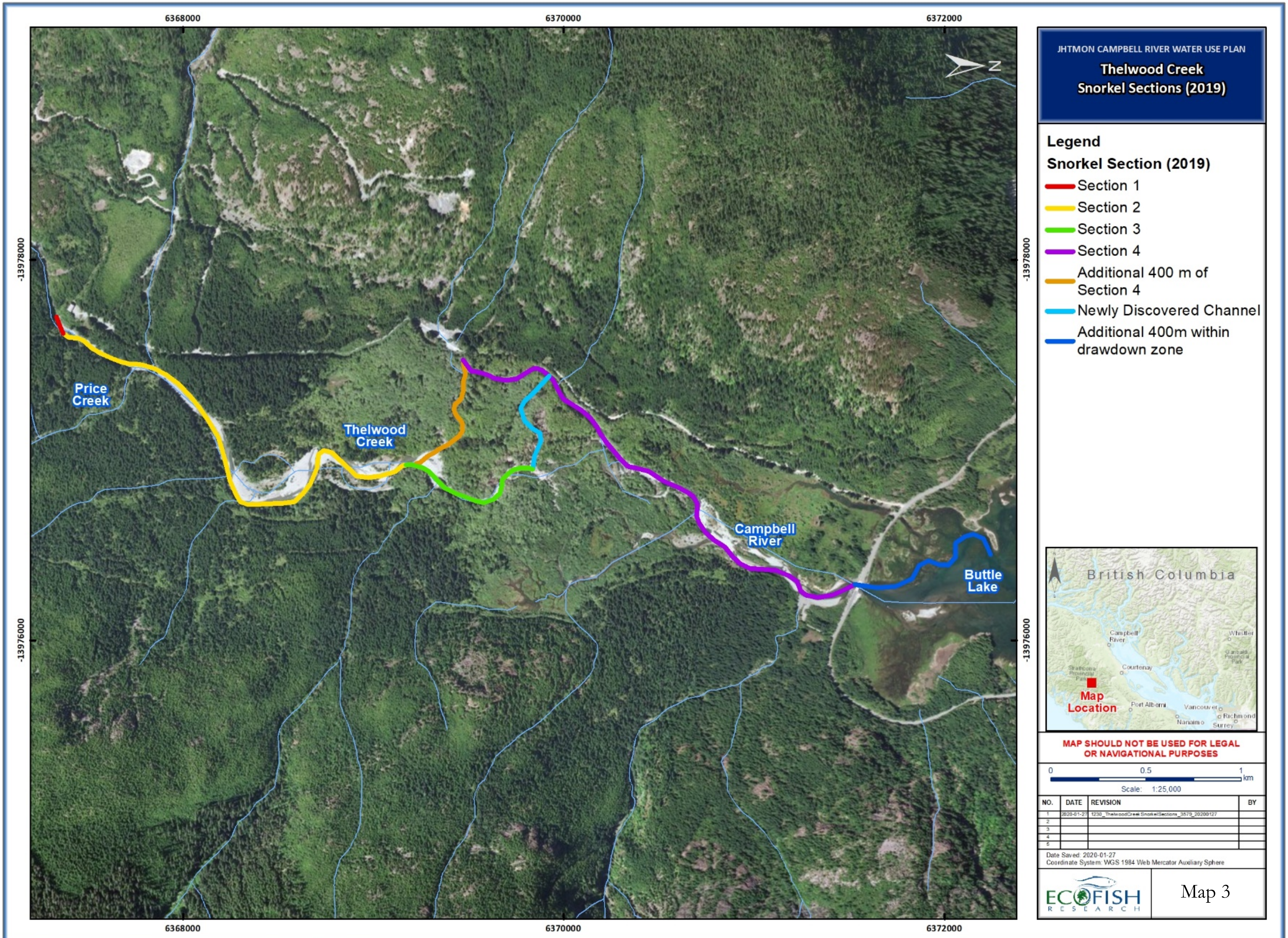

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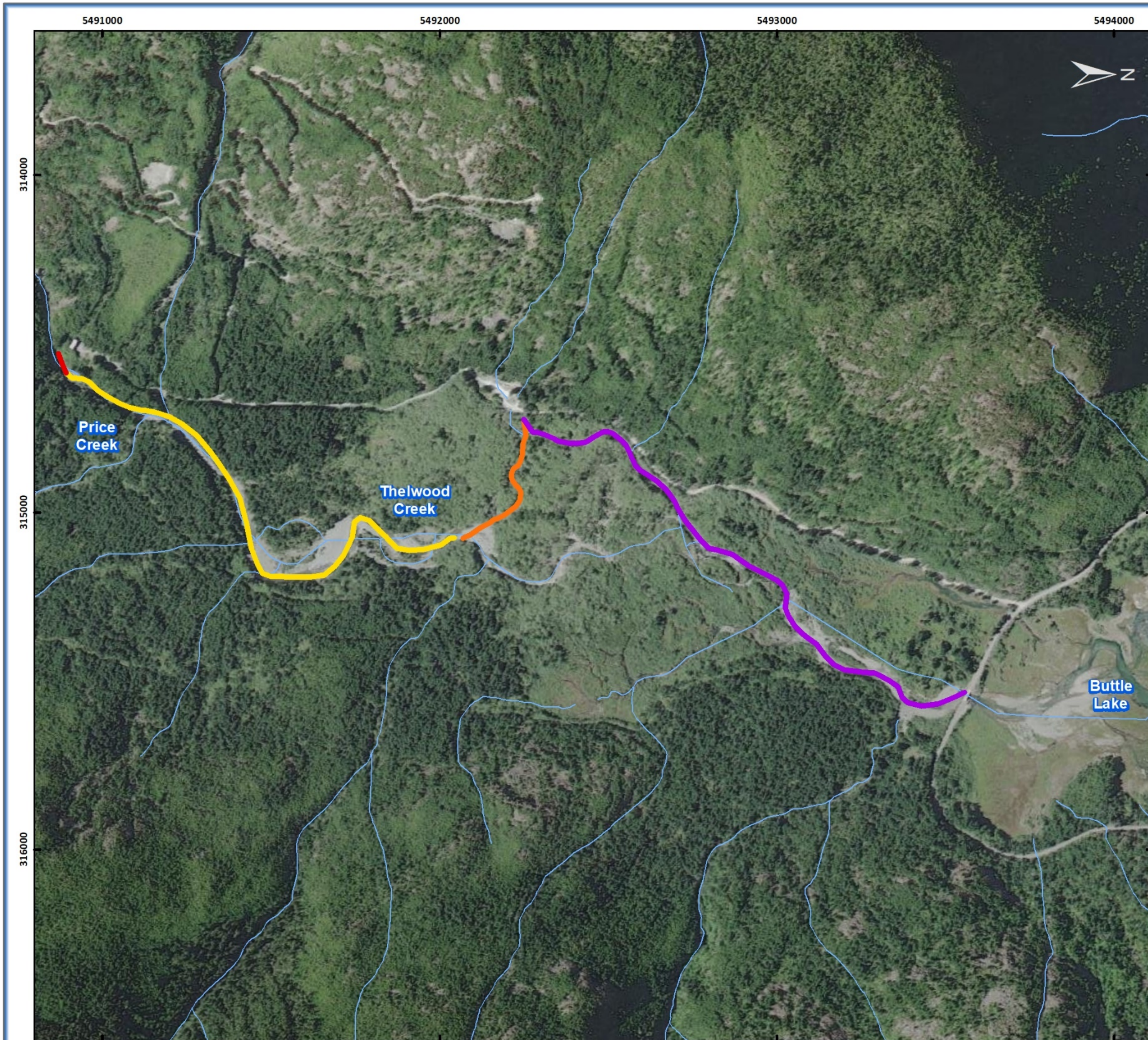
JHTMON CAMPBELL RIVER WATER USE PLAN

Thelwood Creek Snorkel Sections (2020-2021)



Legend

Snorkel Section (2020-2021)

- Section 1
- Section 2
- Section 4
- Additional 400 m of Section 4

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 0.25 0.5 km

Scale: 1:16,000

NO.	DATE	REVISION	BY
1	2022-04-01	1230_ThelwoodCreekSnorkelSections_4921_20220401	BAM
2			
3			
4			
5			

Date Saved: 2022-04-01
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 4

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Appendix C. Gill Net Capture Data and Representative Photographs - 2021

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LIST OF FIGURES

Table 1. Raw fish data from gill net sampling.

Waterbody	Waypoint/Site Name	Date	Net Type	Set #	Panel #	Species[1]	Measured Length (mm)	Weight (g)	K	Sex	Sexual Maturity (I, M, UNK)	Age Sample Type	Age Sample Number	Age Sample Type 2	Age Sample Number 2	DNA Sample Type	DNA Sample Number
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	4	NFC											
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	3	RB	233	144.0	1.14	M	M	SC	01				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	3	CT	338	422.0	1.09	F	M	SC	02	OT	02		
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	1	RB	141	32.7	1.17		I	SC	03				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	1	RB	131	29.7	1.32		I	SC	04				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	1	RB	128	30.8	1.47		I	SC	05				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	6	CT	297	323.0	1.23	F	M	SC	06	OT	06		
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	6	CT	304	374.0	1.33	F	M	SC	07	OT	07		
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	2	CT	252	180.3	1.13	F	I	SC	08				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	2	CT	356	527.0	1.17	M	M	SC	09	OT	09		
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	2	RB	231	143.3	1.16	F	M	SC	10				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	2	RB	273	209.8	1.03	M	M	SC	11	OT	11		
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	2	RB	248	153.0	1.00	F	M	SC	12				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	2	RB	230	151.6	1.25	M	I	SC	13				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	2	RB	216	120.3	1.19	M	I	SC	14				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	2	RB	137	26.5	1.03		I						
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	172	64.8	1.27		I	SC	16				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	224	129.6	1.15		I	SC	17				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	178	68.6	1.22		I	SC	18				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	176	72.1	1.32		I	SC	19				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	214	111.1	1.13	F	M	SC	20				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	CT	250	151.9	0.97	F	I	SC	21				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	182	91.7	1.52	F	I	SC	22				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	190	80.4	1.17	M	I	SC	23				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	198	85.3	1.10	M	I						
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	224	149.3	1.33	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	219	141.8	1.35		UNK	SC	26				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB	234	160.7	1.25		UNK	SC	27				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	SK	1	5	RB/CT	296	275.9	1.06	M	I	SC	28	OT	28	FC	28
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	2	NFC											
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	4	NFC											
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	6	NFC											
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	147	43.3	1.36		UNK	SC	01				

[1]NFC- No fish caught, RB- Rainbow Trout, CT- Cutthroat Trout, CC- Sculpin, RB/CT- Rainbow/Cutthroat Trout

Table 2. Continued.

Waterbody	Waypoint/Site Name	Date	Net Type	Set #	Panel #	Species[1]	Measured Length (mm)	Weight (g)	K	Sex	Sexual Maturity (I, M, UNK)	Age Sample Type	Age Sample Number	Age Sample Type 2	Age Sample Number 2	DNA Sample Type	DNA Sample Number
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	131	29.7	1.32			SC	02				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	142	34.7	1.21			SC	03				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	135	31.2	1.27								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	132	29.0	1.26								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	132	31.5	1.37								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	115	21.0	1.38			SC	07				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	129	29.8	1.39								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	149	44.2	1.34								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	152	40.9	1.16			SC	10				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	139	34.6	1.29			SC	11				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	122	25.0	1.38								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	116	18.6	1.19								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	120	25.1	1.45								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	132	32.0	1.39								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	150	43.0	1.27			SC	16				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	130	29.7	1.35								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	122	28.1	1.55			SC	18				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	116	21.0	1.35								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	128	29.5	1.41								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	119	22.7	1.35								
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Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	125	24.3	1.24								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	143	34.5	1.18			SC	24				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	128	25.9	1.24								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	130	24.5	1.12								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	115	21.0	1.38								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	125	26.4	1.35								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	111	17.2	1.26								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	138	37.5	1.43			SC	30				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	107	14.5	1.18								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	125	23.8	1.22								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	132	27.0	1.17								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	116	16.4	1.05								

[1]NFC- No fish caught, RB- Rainbow Trout, CT- Cutthroat Trout, CC- Sculpin, RB/CT- Rainbow/Cutthroat Trout

Table 3. Continued.

Waterbody	Waypoint/Site Name	Date	Net Type	Set #	Panel #	Species[1]	Measured Length (mm)	Weight (g)	K	Sex	Sexual Maturity (I, M, UNK)	Age Sample Type	Age Sample Number	Age Sample Type 2	Age Sample Number 2	DNA Sample Type	DNA Sample Number
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	130	28.4	1.29			SC	35				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	100	16.2	1.62			SC	36				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	134	30.2	1.26								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	138	35.6	1.35								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	126	27.7	1.38								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	128	24.1	1.15								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	121	23.8	1.34								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	109	17.2	1.33								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	111										
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	123										
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	94	11.4	1.37								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	123	26.1	1.40								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	116										
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	127	25.5	1.24								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	126	28.7	1.43			SC	49				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	138	29.4	1.12								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	124	27.0	1.42			SC	51				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	141	35.0	1.25								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	135	29.8	1.21			SC	53				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	147	43.5	1.37			SC	54				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	124										
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	124	24.0	1.26								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	1	RB	121	21.9	1.24								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	5	RB	167										
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	5	RB	171	75.5	1.51								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	5	RB	194	93.7	1.28								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	5	RB	141	40.7	1.45								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	5	RB	164										
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	5	RB	214	130.5	1.33	M	M	SC	63				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	5	RB	195	101.4	1.37			SC	64				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	5	RB	222	129.0	1.18	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	219	127.9	1.22								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	214	127.0	1.30								

[1]NFC- No fish caught, RB- Rainbow Trout, CT- Cutthroat Trout, CC- Sculpin, RB/CT- Rainbow/Cutthroat Trout

Table 4. Continued.

Waterbody	Waypoint/Site Name	Date	Net Type	Set #	Panel #	Species[1]	Measured Length (mm)	Weight (g)	K	Sex	Sexual Maturity (I, M, UNK)	Age Sample Type	Age Sample Number	Age Sample Type 2	Age Sample Number 2	DNA Sample Type	DNA Sample Number
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	170	63.1	1.28								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	227	146.5	1.25								
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	237	160.5	1.21	F	M	SC	70				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	236	138.3	1.05	F	M	SC	71				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	233	150.2	1.19	F	M	SC	72				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	227	140.0	1.20	F	I	SC	73				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	223	147.0	1.33	M	I	SC	74				
Upper Campbell Reservoir	UCR-LKGN06	2021-08-24	FL	2	3	RB	268	168.7	0.88	F	M	SC	75	OT	75		
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	4	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	6	CT	345	501.0	1.22	M	M	SC	01	OT	01		
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	6	CT	335				UNK	SC	02	OT	02		
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	6	CT	210	96.0	1.04	M	I	SC	03				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	5	RB	240	148.3	1.07		UNK	SC	04				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	5	CT	202	86.5	1.05	M	I	SC	05				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	5	CC	126	20.6	1.03								
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	3	RB/CT	230	130.5	1.07	M	I	SC	07			FC	07
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	3	RB/CT	249	164.4	1.06	M	I	SC	08			FC	08
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	2	CT	361	530.0	1.13	F	M	SC	09	OT	09		
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	1	RB	123	23.7	1.27		I	SC	10				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	1	RB	91	10.5	1.39		I	SC	11				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	1	RB	129	26.7	1.24		I	SC	12				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	1	1	RB	128	26.8	1.28		I	SC	13				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	3	1	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	3	2	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	3	3	RB	80				UNK						
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	3	4	RB	128	28.1	1.34		I	SC	02				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	SK	3	4	RB	135	35.0	1.42		I	SC	03				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	2	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	4	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	6	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	1	RB	122	25.7	1.42		I	SC	01				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	1	RB	124	31.9	1.67		I	SC	02				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	1	RB	141	34.6	1.23		I	SC	03				

[1]NFC- No fish caught, RB- Rainbow Trout, CT- Cutthroat Trout, CC- Sculpin, RB/CT- Rainbow/Cutthroat Trout

Table 5. Continued.

Waterbody	Waypoint/Site Name	Date	Net Type	Set #	Panel #	Species[1]	Measured Length (mm)	Weight (g)	K	Sex	Sexual Maturity (I, M, UNK)	Age Sample Type	Age Sample Number	Age Sample Type 2	Age Sample Number 2	DNA Sample Type	DNA Sample Number
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	1	RB	138	35.4	1.35		I	SC	04				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	5	RB	145	44.8	1.47		I	SC	05				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	3	RB	242	138.7	0.98	M	I	SC	06				
Upper Campbell Reservoir	UCR-LKGN04	2021-08-24	FL	2	3	RB	242	175.4	1.24	F	M	SC	07				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	2	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	4	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	6	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	214	103.6	1.06	F	M	SC	01				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	203	103.7	1.24	M	M	SC	02				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	169	65.8	1.36	M	I	SC	03				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	181	71.3	1.20	M	I	SC	04				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	191	93.8	1.35	M	I	SC	05				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	180	76.1	1.30	F	I	SC	06				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	186	84.9	1.32	M	M	SC	07				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	230	122.5	1.01		UNK	SC	08				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	190	82.6	1.20		UNK	SC	09				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	187	85.9	1.31	F	I	SC	10				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	193	87.0	1.21		UNK	SC	11				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	177	73.4	1.32	M	I	SC	12				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	190	81.9	1.19	M	M	SC	13				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	199	104.6	1.33	M	M	SC	14				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	184	77.0	1.24		UNK	SC	15				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	169	71.5	1.48	M	I	SC	16				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	149	43.7	1.32		UNK	SC	17				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	178	77.7	1.38		UNK	SC	18				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	179	85.3	1.49		UNK	SC	19				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	187	86.7	1.33	F	M	SC	20				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	5	RB	224	130.2	1.16	M	M	SC	21				

[1]NFC- No fish caught, RB- Rainbow Trout, CT- Cutthroat Trout, CC- Sculpin, RB/CT- Rainbow/Cutthroat Trout

Table 6. Continued.

Waterbody	Waypoint/Site Name	Date	Net Type	Set #	Panel #	Species[1]	Measured Length (mm)	Weight (g)	K	Sex	Sexual Maturity (I, M, UNK)	Age Sample Type	Age Sample Number	Age Sample Type 2	Age Sample Number 2	DNA Sample Type	DNA Sample Number
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	118	22.0	1.34		I	SC	22				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	141	39.8	1.42		I	SC	23				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	155	48.5	1.30		I	SC	24				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	146	36.0	1.16		I	SC	25				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	128	29.2	1.39		I	SC	26				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	122	24.0	1.32		I	SC	27				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	112	17.8	1.27		I	SC	28				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	98	14.7	1.56		I	SC	29				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	105	17.6	1.52		I	SC	30				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	1	RB	96	11.8	1.33		I						
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	3	RB	253	162.9	1.01	F	M	SC	32				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	3	RB	282	194.8	0.87	M	M	SC	33	OT	33		
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	3	RB	265	179.2	0.96		UNK	SC	34	OT	34		
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	3	RB	254	166.5	1.02		UNK	SC	35				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	SK	1	3	RB	197	100.8	1.32	M	I	SC	36				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	1	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	2	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	4	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	6	CT	340	447.0	1.14	F	M	SC	01	OT	01		
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	6	CT	374	593.0	1.13	M	M	SC	02	OT	02		
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	3	CT	306	347.0	1.21	F	M	SC	03	OT	03		
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	5	CT	309	331.0	1.12	F	M	SC	04	OT	04		
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	5	CT	294	297.0	1.17	F	I	SC	05	OT	05		
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	5	RB	219	141.5	1.35		UNK	SC	06				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	5	RB	194	98.7	1.35		UNK	SC	07				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	5	RB	196	93.9	1.25		UNK	SC	08				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	5	RB	185	82.8	1.31		UNK	SC	09				
Upper Campbell Reservoir	UCR-LKGN02	2021-08-23	FL	2	5	RB	177	73.8	1.33		UNK	SC	10				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	1	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	2	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	4	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	6	CT	328	393.0	1.11	F	M	SC	01	OT	01		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	6	CT	324	344.0	1.01	F	M	SC	02	OT	02		

[1]NFC- No fish caught, RB- Rainbow Trout, CT- Cutthroat Trout, CC- Sculpin, RB/CT- Rainbow/Cutthroat Trout

Table 7. Continued.

Waterbody	Waypoint/Site Name	Date	Net Type	Set #	Panel #	Species[1]	Measured Length (mm)	Weight (g)	K	Sex	Sexual Maturity (I, M, UNK)	Age Sample Type	Age Sample Number	Age Sample Type 2	Age Sample Number 2	DNA Sample Type	DNA Sample Number
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	6	CT	360			F	M			OT	03		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	CT	314	301.0	0.97	F	M	SC	04	OT	04		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	CT	331	377.0	1.04	F	M	SC	05	OT	05		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	CT	243	146.0	1.02	F	I	SC	06				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	CT	354	428.0	0.96	F	M	SC	07	OT	07		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	CT	250	181.9	1.16	F	I	SC	08				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	RB	267	221.5	1.16	M	M	SC	09	OT	09		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	RB	242	166.9	1.18	F	M	SC	10				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	RB	207	95.7	1.08	M	I	SC	11				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	3	RB	255	186.6	1.13	F	M	SC	12				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	5	CT	230	116.3	0.96	M	I	SC	13				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	5	RB	161	52.8	1.27	M	I	SC	14				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	5	RB	152	47.1	1.34	M	I	SC	15				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	5	RB	263	153.3	0.84	F	M	SC	16	OT	16		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	5	RB	252	184.7	1.15	M	M	SC	17				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	SK	1	5	RB	239	163.7	1.20			SC	18				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	1	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	2	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	4	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	6	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	291	201.0	0.82	F	M	SC	01	OT	01		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	302	223.4	0.81		UNK	SC	02	OT	02		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	293	212.0	0.84	F	M	SC	03	OT	03		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	277	199.2	0.94	F	M	SC	04	OT	04		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	275	201.6	0.97	F	M	SC	05	OT	05		
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	240	162.9	1.18	F	M	SC	06				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	221	128.6	1.19	M	I	SC	07				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	252	179.3	1.12	M	M	SC	08				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	3	RB	242	149.0	1.05		UNK	SC	09				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	5	RB	236	129.4	0.98		UNK	SC	10				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	5	RB	198	91.8	1.18	F	I	SC	11				
Upper Campbell Reservoir	UCR-LKGN01	2021-08-23	FL	2	5	RB	163	53.9	1.24		I	SC	12				

[1]NFC- No fish caught, RB- Rainbow Trout, CT- Cutthroat Trout, CC- Sculpin, RB/CT- Rainbow/Cutthroat Trout

Figure 1. Example of typical gill net gear deployment location (UCR-LKGN01) during 2021 gill net surveys.

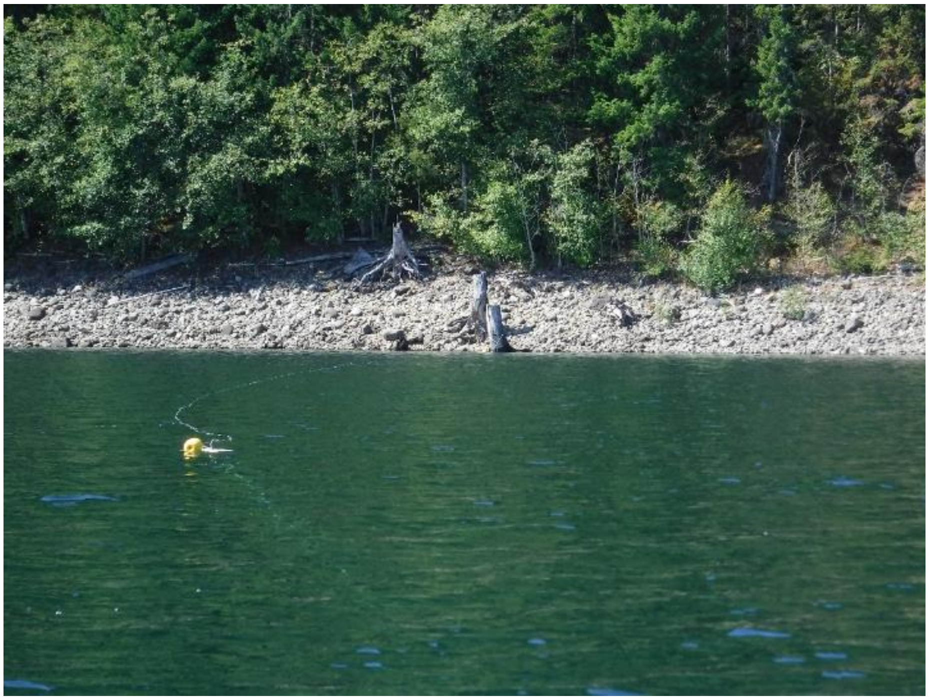

Figure 2. Example of typical gill net gear deployment location (UCR-LKGN04) during 2021 gill net surveys.

Figure 3. 309 mm Cutthroat Trout captured at UCR-LKGN02 on August 23, 2021.

Figure 4. 328 mm Cutthroat Trout captured at UCR-LKGN01 on August 23, 2021.

Figure 5. 338 mm Cutthroat Trout captured at UCR-LKGN06 on August 24, 2021.

Figure 6. 340 mm Cutthroat Trout captured at UCR-LKGN02 on August 23, 2021.

Figure 7. 345 mm Cutthroat Trout captured at UCR-LKGN04 on August 24, 2021.

Figure 8. 356 mm Cutthroat Trout captured at UCR-LKGN06 on August 24, 2021.

Figure 9. 122 mm Rainbow Trout captured at UCR-LKGN04 on August 24, 2021.

Figure 10. 191 mm Rainbow Trout captured at UCR-LKGN02 on August 23, 2021.

Figure 11. 219mm Rainbow Trout captured at UCR-LKGN06 on August 24, 2021.

Figure 12. 234 mm Rainbow Trout captured at UCR-LKGN06 on August 24, 2021.

Figure 13. 242 mm Rainbow Trout captured at UCR-LKGN04 on August 24, 2021.

Figure 14. 267 mm Rainbow Trout captured at UCR-LKGN01 on August 23, 2021.

Appendix D. Snorkel Survey Observations and Representative Photographs - 2021

LIST OF FIGURES

Figure 1. Looking downstream at Greenstone River snorkel start on April 19, 2021.

Figure 2. Looking downstream at Greenstone River snorkel end on April 19, 2021.

Figure 3. Uneyed egg observed at Greenstone River on April 19, 2021.

Figure 4. Trout eggs observed on boulder at Greenstone River on April 19, 2021.

Figure 5. Looking downstream at Miller Creek snorkel start on March 2, 2021.

Figure 6. Looking upstream at Miller Creek snorkel end on March 2, 2021.

Figure 7. Looking downstream at Fry Creek snorkel start on March 2, 2021.

Figure 8. Looking upstream at Fry Creek snorkel end on March 2, 2021.

Figure 9. Cutthroat Trout alevin observed at Fry Creek on March 2, 2021.

Figure 10. Uneyed eggs observed at Fry Creek on March 2, 2021.

Figure 11. Looking downstream at Ralph River snorkel start on June 1, 2021.

Figure 12. Looking upstream at Ralph River snorkel end on June 1, 2021.

Figure 13. Looking downstream at Henshaw Creek snorkel start on June 1, 2021.

Figure 14. Looking upstream at Henshaw Creeks snorkel end on June 1, 2021.

Figure 15. Looking downstream at Wolf River snorkel start on June 2, 2021.

Figure 16. Looking upstream at Wolf River snorkel end on June 2, 2021.

Figure 17. Looking downstream at Phillips Creek snorkel start on June 2, 2021.

Figure 18. Looking upstream at Phillips Creek snorkel end on June 2, 2021.

Figure 19. Looking downstream at Elk River upper section snorkel start on June 8, 2021.

Figure 20. Looking upstream at Elk River upper section snorkel end on June 8, 2021.

Figure 21. Uneyed eggs observed at Elk River upper section snorkel on June 8, 2021.

Figure 22. Redds observed at Elk River upper section snorkel on June 8, 2021.

Figure 23. Looking downstream at Elk River lower section snorkel start on June 8, 2021.

Figure 24. Looking upstream at Elk River lower section snorkel end on June 8, 2021.

Figure 25. Looking downstream at Thelwood Creek snorkel start on June 3, 2021.

Figure 26. Looking upstream at Thelwood Creek snorkel end on June 3, 2021.