Campbell River Project Water Use Plan

Upper and Lower Campbell Lake Fish Spawning Success Assessment

Implementation Year 9

Reference: JHTMON-3

JHTMON-3: Upper and Lower Campbell Lake Fish Spawning Success Assessment Year 9 Annual Monitoring Report

Study Period: 2022

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 9 Annual Monitoring Report

Prepared for:

BC Hydro Water License Requirements
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Prepared by:

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Title Page Photographs

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

Top right: Looking downstream at large log jam observed on Thelwood Creek.

Bottom left: Looking at UCR-LKGN04 floating net set location.

Bottom right: Rainbow Trout observed during the Elk River snorkel survey.

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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 2022 in the Upper Campbell Reservoir for both Rainbow Trout and Cutthroat Trout were lower than in 2021 but higher than 2020. In the case of Cutthroat Trout, the ESH value in 2022 was ~30% lower than 2021 but two times higher than the long-term average. For Rainbow Trout the ESH value in 2022 was ~50% lower than 2021 and similar to the long-term average. ESH values in 2022 corresponded with a seasonal drawdown in 2022 that was lower than average coupled with steadily increasing water levels through the incubation period.

Gill Netting Surveys

The 9th year of gill netting surveys was conducted in the Upper Campbell Reservoir between August 15 and 16, 2022. A total of six sites were sampled resulting in captures of 28 Cutthroat Trout, 144 Rainbow Trout, no Dolly Varden, two sculpin, and four Cutthroat Trout/Rainbow Trout hybrids. Gill nets were not deployed at two sites as catches were nearing the fish collection permit limit of 150 Rainbow Trout. Catch per unit effort (CPUE) ranged from 0.059 to 0.33 fish/net hour for Cutthroat Trout and 0.26 to 2.85 fish/net hour for Rainbow Trout.

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 9), 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 targeting the Cutthroat Trout spawning period were conducted on Miller Creek and Fry Creek on March 7, 2022 and Greenstone River on April 19, 2022 due to colder water conditions. Two adult Cutthroat Trout were observed in Greenstone River, one adult was observed in Miller Creek, and none in Fry Creek. Cutthroat Trout redds were observed in all three tributaries and were most abundant in Miller Creek (n = 233), followed by Fry Creek (n = 107) and Greenstone River (n = 43). No juvenile Cutthroat Trout were observed during Spring snorkel surveys. The majority of adult Cutthroat observed were in post-spawn condition, indicating most spawning had already occurred by the time of the surveys.

Snorkel surveys targeting the Rainbow Trout spawning period were conducted in tributaries of Buttle Lake and Upper Campbell Reservoir during low flow conditions between June 1 to 9, 2022. Rainbow Trout redds were recorded in all sampled tributaries. The highest number of redds was observed in Lower Elk River (518 redds), followed by Thelwood Creek (336 redds), and Upper Elk River (311 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 (1,657 fish/km), Thelwood Creek (643 fish/km), Lower Elk River (390 fish/km), and Ralph River (296 fish/km). These patterns were similar to those observed during previous years of this monitoring program (2014-2021).

MON-3 Status of Objectives, Management Questions and Hypotheses after Year 9.

Study Objectives	Management Questions	Management Hypotheses	Year 9 (fiscal year 2022) 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.	Data were collected using the same methods as previous years and consisted of standardized snorkel surveys in the tributaries as previous years and gill netting in the Upper Campbell Reservoir. Gill nets were not deployed at two sites in Year 9 as catches were nearing limits specified in the scientific fish collection permit. Catch limit exceedances occurred in Year 7 and 8 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 the Cutthroat Trout population in the Upper Campbell Reservoir.

Study Objectives	Management Questions	Management Hypotheses	Year 9 (fiscal year 2022) Status
	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 useful in the present Monitor, as well as in future WUP investigations?	$H_0$3: The proportion of mature adults that spawn in the drawdown zones of Upper and Lower 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.	Data on spawning habitat use were collected during Year 5 and integrated with information on spawning habitat availability collected during Year 4. 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. 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, several 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 clarkii*) 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 the 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

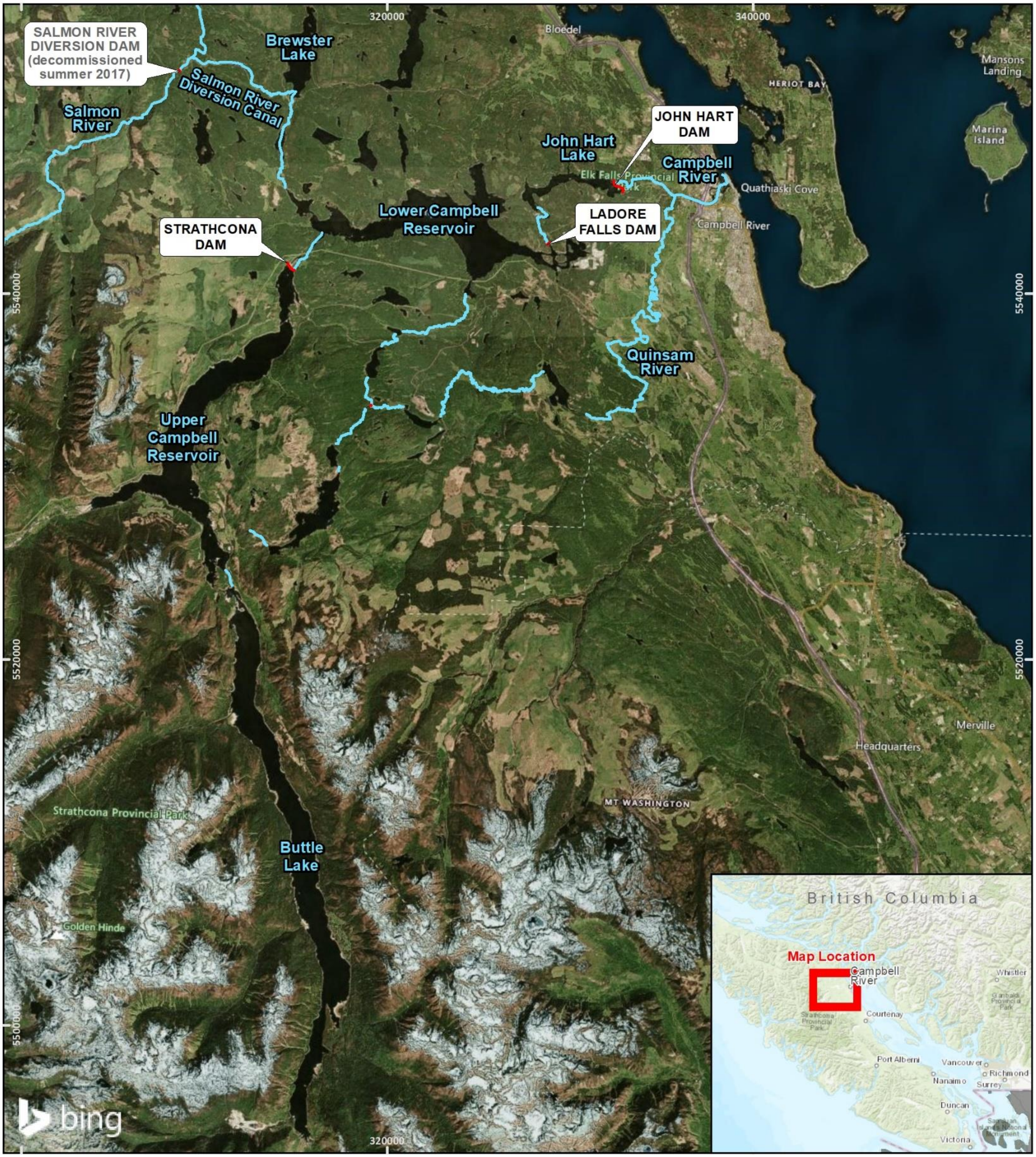
The Upper Campbell Reservoir experiences water level fluctuations of 4 to 10 m within years. (Figure 1). Fluctuations differ among years depending on hydrological conditions; however, in general, the reservoir is drawn down in late winter and early spring and recharges during late spring and early summer. 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 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 10^{th} and 90^{th} 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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ECOFISH RESEARCH

Map 1

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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:

a. Abundance of adult trout in Upper Reservoir is not correlated with ESH at the time of the cohort's emergence.
b. 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 Terms of Reference (TOR) developed for JHTMON-3, which was revised in 2015, proposes a 10-year study with the following study components (BC Hydro 2015):

1. Reservoir fish surveys in Upper and Lower Campbell reservoirs, using gill netting (10 years of data collection).
2. Spawner surveys in tributaries of Upper and Lower Campbell reservoirs using snorkel survey methods (10 years of data collection).
3. Detailed redd surveys to assess spawner distributions in tributaries of Upper and Lower Campbell reservoirs (2 years of data collection).

4. Studies to investigate incubation conditions in inundated portions of tributaries of Upper and Lower Campbell reservoirs (1 year of data collection).

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 9 program followed the approach adopted for Years 3 to 8. Methods related to $H_0$1 and $H_0$2 in Year 9 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 carried out 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 ongoing monitoring.

Figure 1. Elevation of Upper Campbell Reservoir (recorded at Strathcona Dam), pre- and post-implementation of the Interim Flow Management Strategy in October 1997. 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. The timing of salmonid spawning and incubation periods are shown.

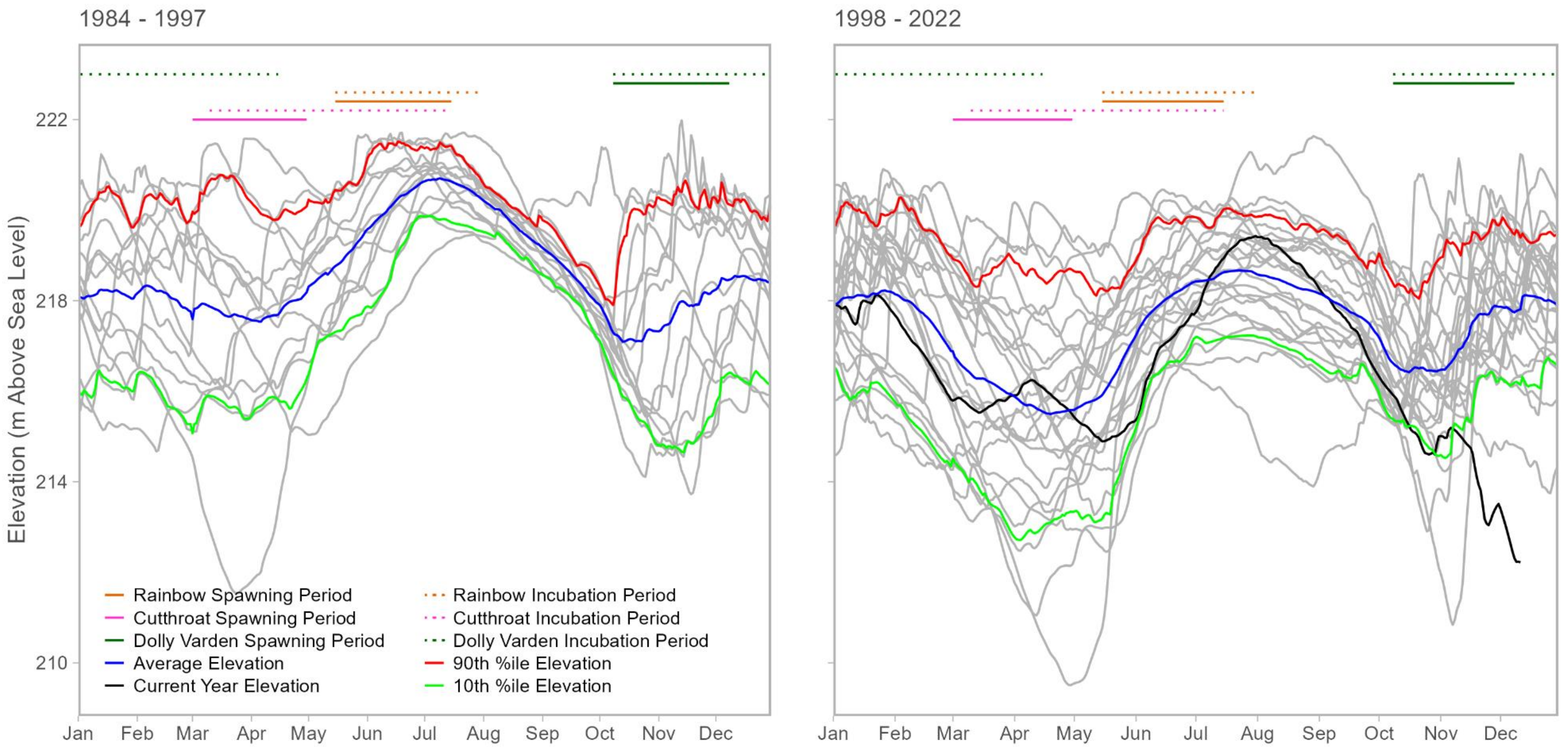
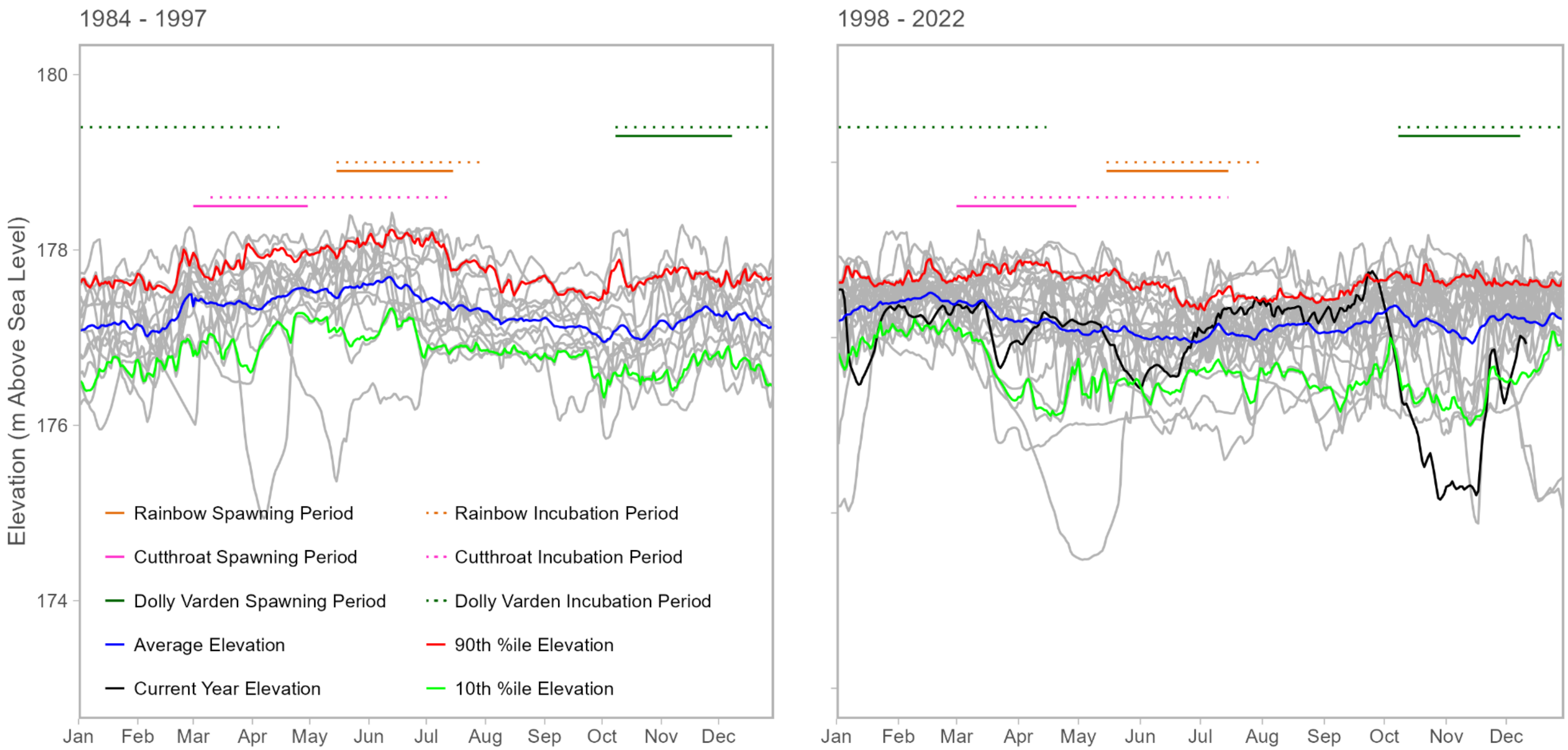


Figure 2. **Elevation of Lower Campbell Reservoir (recorded at Ladore Dam), pre- and post-implementation of the Interim Flow Management Strategy in October 1997. Grey lines represent elevations for individual years, blue lines represent mean elevations, red lines represent the 90th percentile elevations, green lines represent the 10th percentile elevations, and black line represent elevation in the current year. The 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 a 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; and
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).

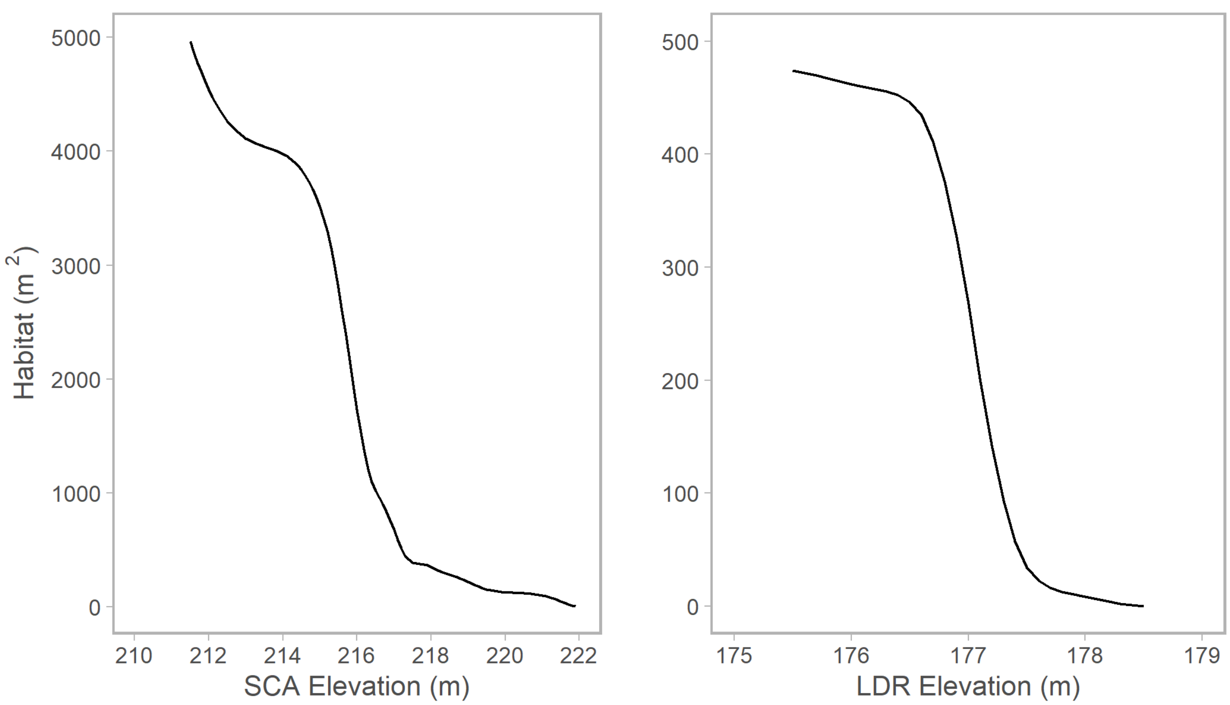


Figure 4. Water temperature trends used for effective spawning habitat model for Upper Campbell Reservoir at Strathcona Dam (SCA) and Lower Campbell Reservoir at Ladore Dam (LDR) (Leake, pers. comm. 2015).

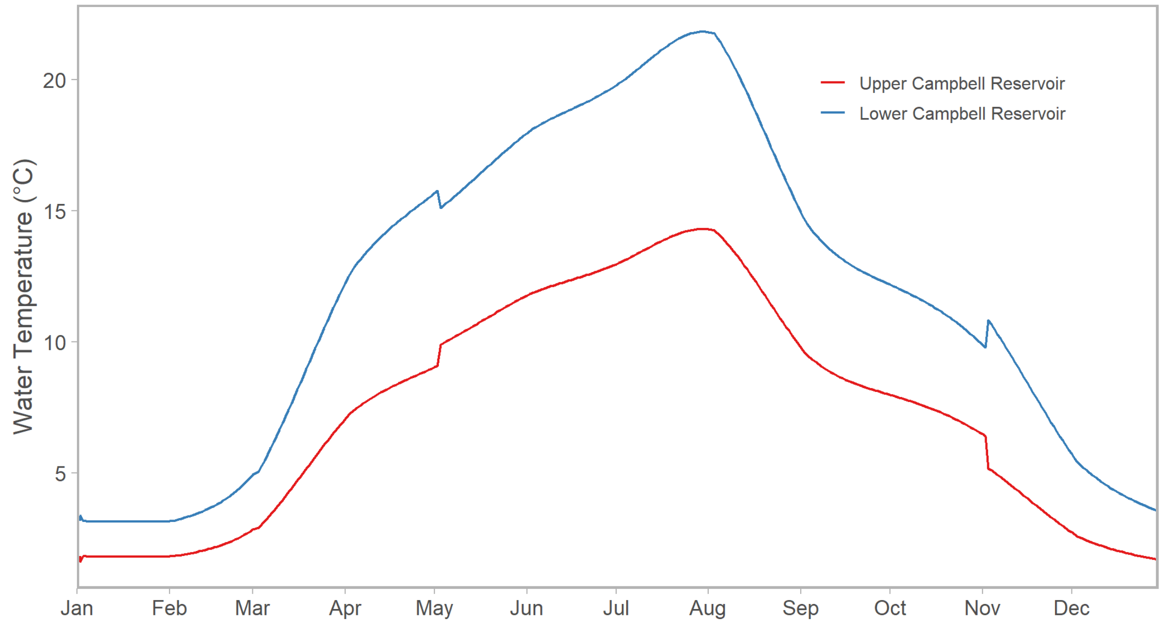
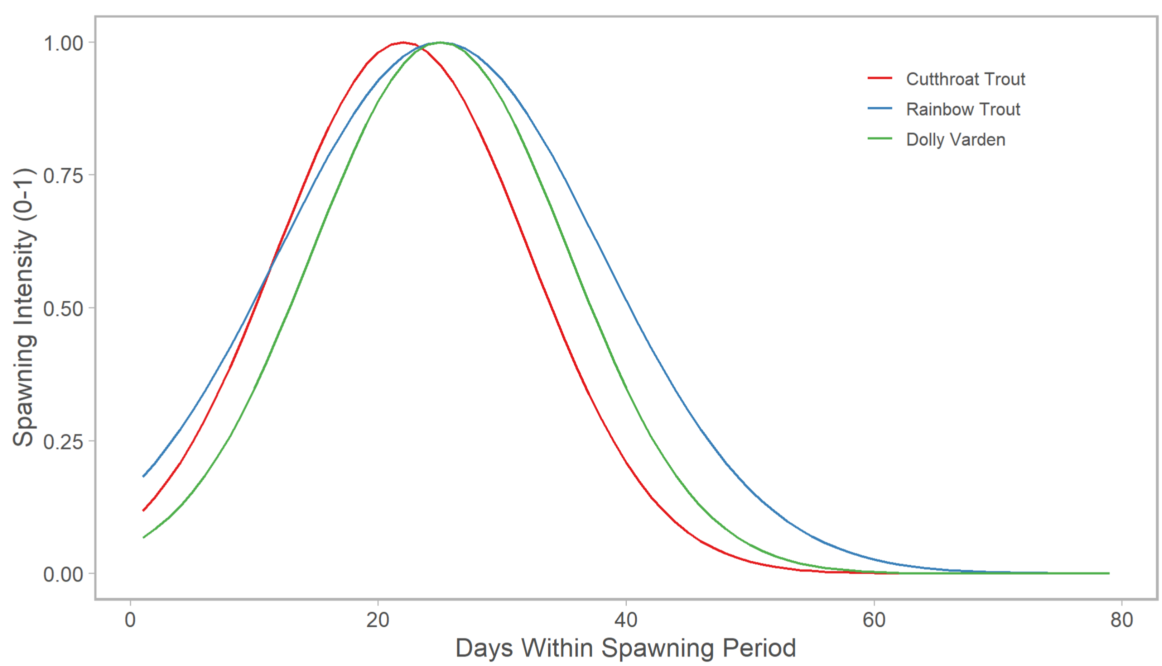


Figure 5. Timing of spawning intensity for Cutthroat Trout, Rainbow Trout, and Dolly Varden used in the effective spawning habitat model (Leake, pers. comm. 2015).



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 2022.

The Year 9 gill netting surveys of the Upper Campbell Reservoir were conducted using the same methods as Years 2 through 8 (2015-2021) studies. The 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 during similar dates in late summer (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 sets in the Upper Campbell Reservoir. However, sampling in 2022 was nearing the scientific collection permit the catch limit of 150 Rainbow Trout; therefore, no nets were deployed at sites UCR-LNKG07 or UCR-LNKG08, resulting in nine 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. The Nordic net at site UCR-LKGN07 was not deployed as catches were nearing the permit limit. 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 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 based on laboratory examination.

Table 2. Sampling dates, site locations, and site conditions for Year 9 gill netting surveys on Upper Campbell Reservoir, August 2022.

Site	Sampling Date	UTM			Set #	Net Type	Net Position[1]	Net Length (m)	Water Temp. (°C)	Turbidity[2]	Estimated Visibility (m)
		Zone	Easting	Northing							
UCR-LKGN01	15-Aug-22	10U	314096	5539930	1	RISC	SK	91.2	21.4	C	8
	15-Aug-22	10U	314096	5539930	2	RISC	FL	91.2	21.4	C	8
UCR-LKGN02	15-Aug-22	10U	314629	5537246	1	RISC	SK	91.2	21.5	C	8
	15-Aug-22	10U	314629	5537246	2	RISC	FL	91.2	21.5	C	8
UCR-LKGN04	16-Aug-22	10U	308638	5533904	1	RISC	SK	91.2	22.7	C	8
	16-Aug-22	10U	308638	5533904	2	RISC	FL	91.2	22.7	C	8
	16-Aug-22	10U	308638	5533904	3	Nordic	SK	30.0	22.7	C	8
UCR-LKGN06	16-Aug-22	10U	309419	5527967	1	RISC	SK	91.2	22.8	C	8
	16-Aug-22	10U	309419	5527967	2	RISC	FL	91.2	22.8	C	8

[1] SK - Sinking, FL - Floating

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

Gill nets were not deployed at two sites: UCR-LKGN07 and UCR-LKGN08 as catches were nearing the fish collection permit 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.

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 2022 surveys.

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 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 program (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 following Year 6 monitoring.

Stomach Content Analysis

Diets of Cutthroat Trout and Rainbow Trout were assessed in 2015, and 2017-2022, 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 nine 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.

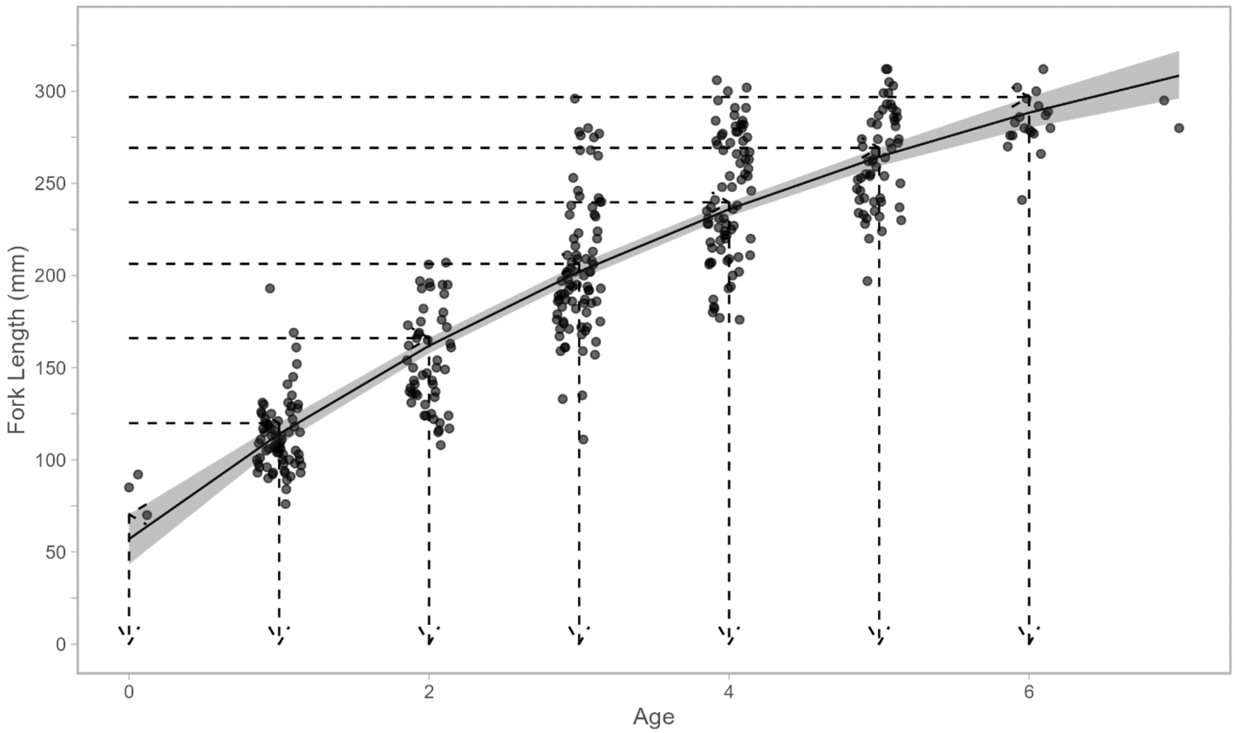
Rainbow Trout

A total of 342 scales, 37 fin rays, and 46 Rainbow Trout otoliths were read during Years 1 through 9 of the monitoring programs (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 9 of the monitoring program.

Species	Structure	Age	n
Rainbow Trout	Scales	0	5
		1	72
		2	52
		3	85
		4	77
		5	56
		6	19
		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

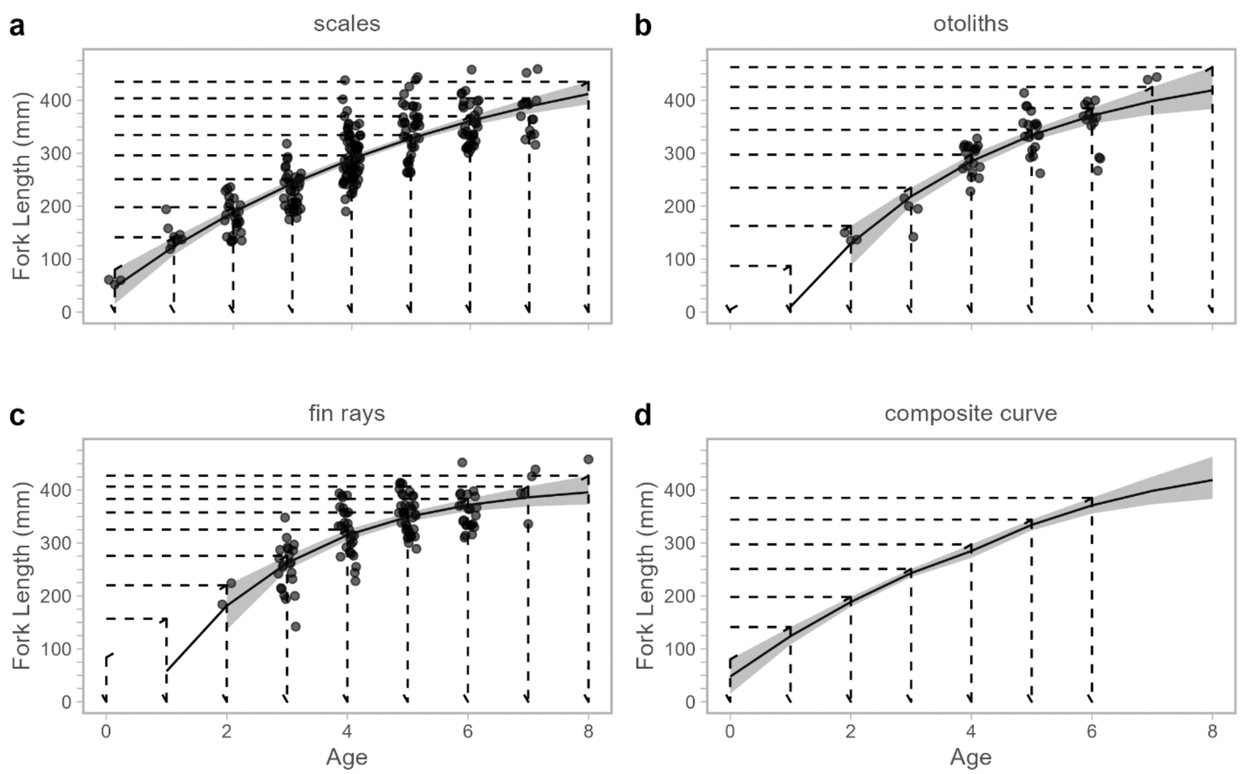
A total of 214 scales, 117 fin rays, and 45 Cutthroat Trout otoliths were read during Years 1 through 9 of the monitoring program (Table 4). This excludes fish that suffered total or partial damage due to e.g., being consumed by crayfish, and therefore an accurate fork length could not be measured. Most 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 9 of the monitoring program.

Species	Structure	Age	n
Cutthroat Trout	Scales	0	3
		1	9
		2	25
		3	36
		4	67
		5	38
		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	3
		3	4
		4	19
		5	18
		6	14
		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. Snorkel Surveys of Spawners in Reservoir Tributaries

Single snorkel survey of spawners and redds were undertaken in the lower reaches of select 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 March 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 2022 surveys followed standardized survey methods within each reach, as conducted during Years 1 to 8 (2014 to 2021) 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. Several 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 2022 surveys.

Surveys for the Cutthroat Trout spawning period were carried out in tributaries of the Lower Campbell Reservoir on March 7, 2022. Given the relatively cold conditions of Greenstone River compared to Miller and Fry Creeks, the survey of this river was delayed until April 19, 2022. 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 9, 2022 in the tributaries of Buttle Lake and Upper Campbell Reservoir. Data recorded from the 2022 Rainbow Trout spawning surveys were compared to the Years 1 to 8 (2014 to 2021) 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 9 surveys.

Watershed	Stream	Survey Date	Survey Distance (km)	Survey Start Location	Survey End Location
Upper Campbell	Upper Elk River	08-Jun-22	6.0	Drum Creek 200 m US confluence	HWY 28 take out/ put in
	Lower Elk River	08-Jun-22	5.4	HWY 28 take out/put in	Upper Campbell Lake
Buttle	Ralph River	01-Jun-22	0.9	50 m US Shepard Creek	Buttle Lake
	Thelwood Creek	09-Jun-22	2.5	Falls at powerhouse	Bridge at Buttle Lake
	Wolf River	07-Jun-22	0.3	Falls Pool	Buttle Lake
	Phillips Creek	07-Jun-22	0.3	300 m US lake	Buttle Lake
	Henshaw Creek	01-Jun-22	0.5	Cascades	Buttle Lake
Lower Campbell	Miller Creek	07-Mar-22	0.4	Cascades	Fry Lake
	Fry Creek	07-Mar-22	1.2	Barrier DS logging road	Lower Campbell Lake
	Greenstone River	19-Apr-22	2.4	~1.0 km US of Bridge	Lower Campbell Lake

Table 6. Variables measured during the Year 9 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 of estimated in meters
Fish size class	Fry/parr; 150-250 mm, 251-350 mm, 351-450 mm, and >450 mm
Fish species	Cutthroat Trout (CT), Rainbow Trout (RB), Dolly Varden (DV)
Fish condition	Bright, moderately coloured, mid-spawn, post-spawn, undetermined
Redd observation	Location/size/number/species

3. RESULTS

3.1. Effective Spawning Habitat (ESH)

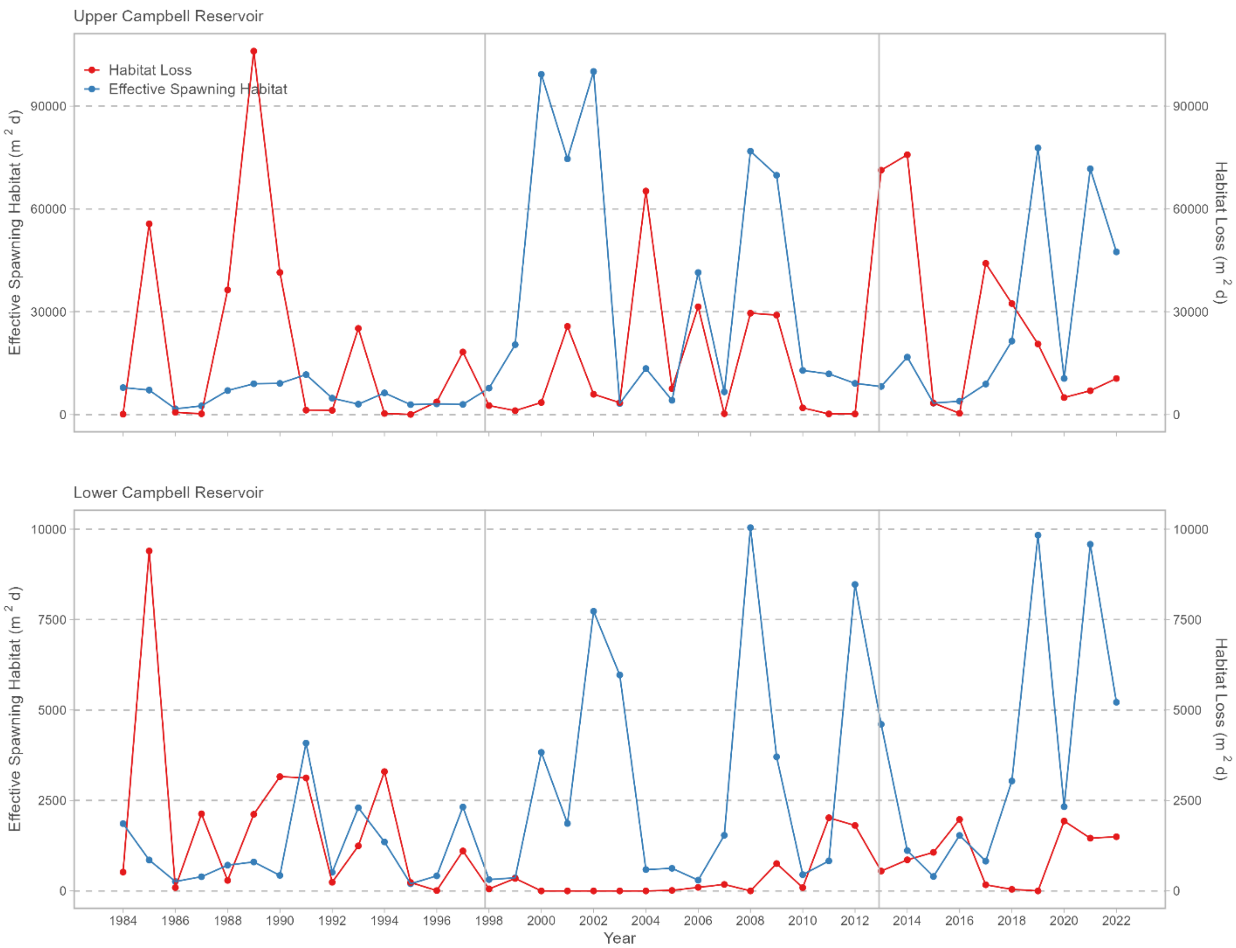
3.1.1. Cutthroat Trout

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 m²d; mean = 23,096 m²d) than the Lower Campbell Reservoir ESH (range of 198 to 10,043 m²d; mean = 2,605 m²d) (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 m²d). In 2022, the ESH for Cutthroat Trout in the Upper Campbell Reservoir was much higher than that recorded prior to the implementation of the Interim Flow Management Strategy (47,469 m²d). During this monitoring program (2014-2022), ESH in the Upper Campbell Reservoir was highest in 2019, followed by 2021 and 2022, 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 m²d (mean = 19,714 m²d). 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 m²d) and 2016 (363 m²d), and higher in 2014 (75,823 m²d), 2017 (44,131 m²d), 2018 (32,389 m²d), and 2019 (20,579 m²d). ESH loss was relatively low during 2022 (10,525 m²d).

Water levels in the Lower Campbell Reservoir are less variable, resulting in relatively minimal loss of ESH (range of 0 to 9,398 m²d; mean = 1,074 m²d; Figure 8).

Figure 8. Results of effective spawning habitat and loss of effective spawning habitat models for Cutthroat Trout from 1984 to 2022. 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.

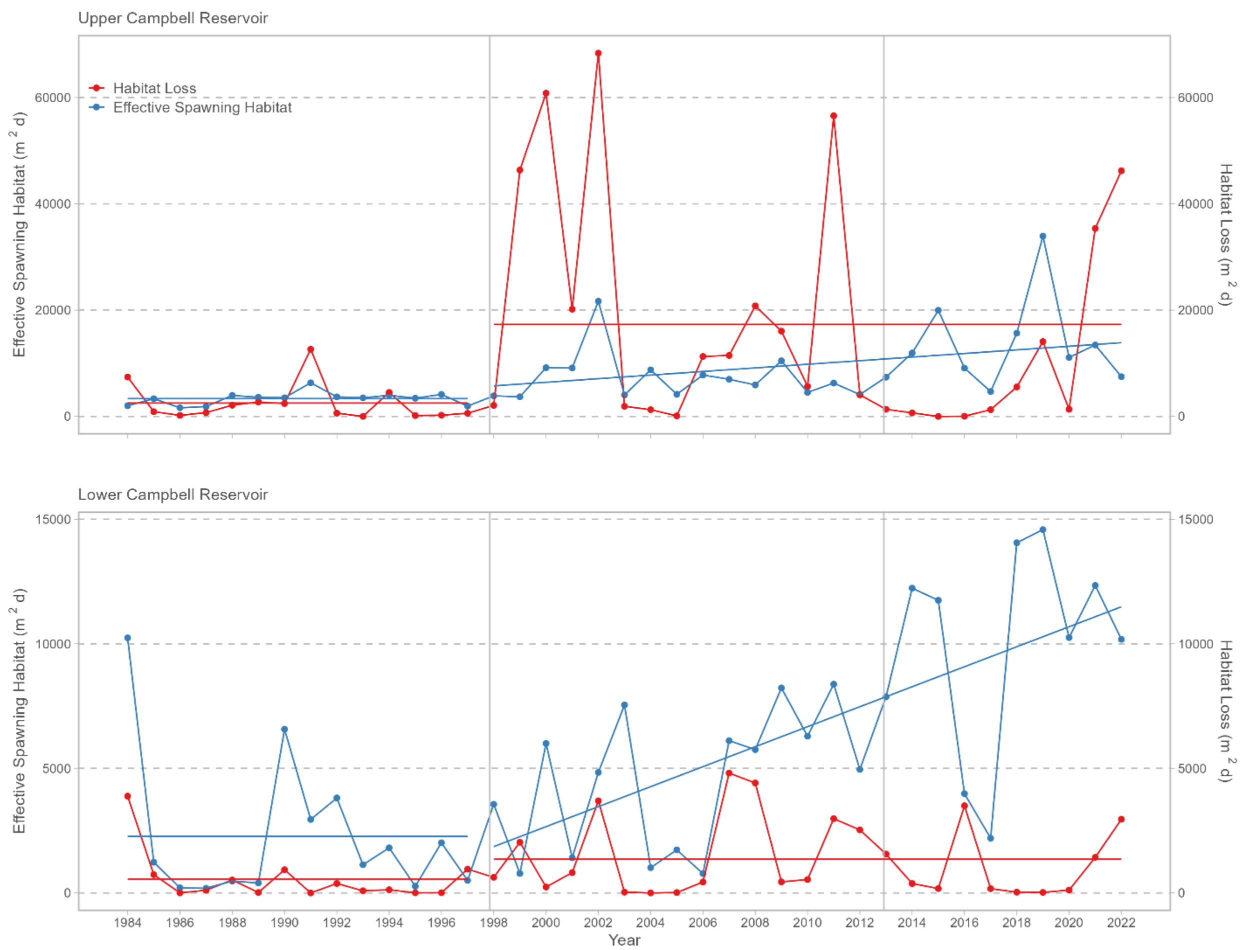


3.1.2. Rainbow Trout

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 = 7,490 m²d) than the Lower Campbell Reservoir ESH (range of 188 to 14,583 m²d; mean = 5,092 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, 2020, and 2022. 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 resulted in effective Rainbow Trout spawning habitat losses ranging from 0 to 68,352 m²d (mean = 12,000 m²d). Water levels in the Lower Campbell Reservoir are less variable, resulting in relatively minimal losses of ESH (range of 0 to 4,810 m²d; mean = 1,069 m²d) (Figure 9). It is noteworthy that ESH for Rainbow Trout in both reservoirs are completely in sync since at least 2007. ESH in the Lower Campbell Reservoir has increased substantially both in amplitude and slope since the IFMS (Figure 9).

Figure 9. Results of effective spawning habitat and loss of effective spawning habitat models for Rainbow Trout from 1984 to 2022. 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.

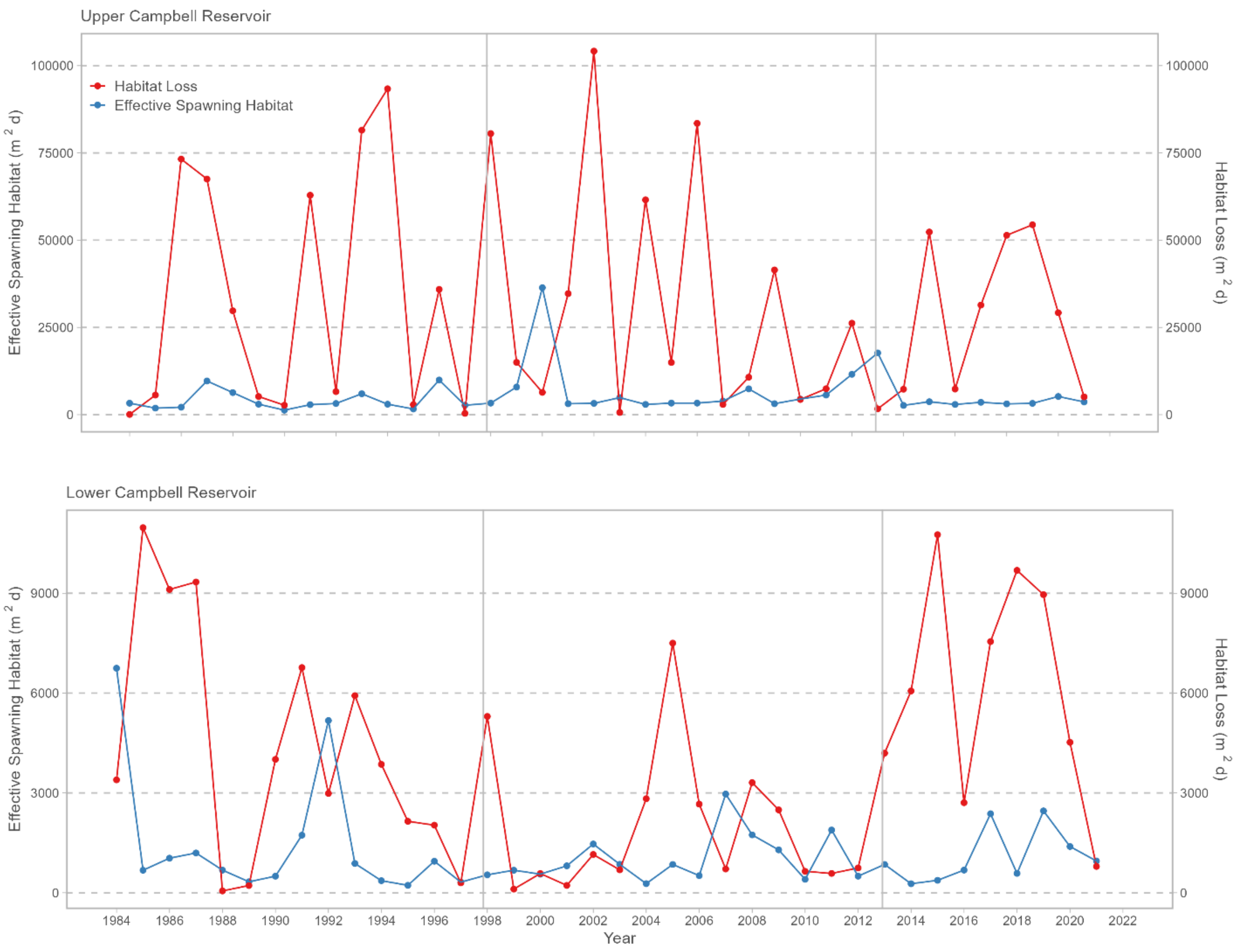


3.1.3. Dolly Varden

Given the timing of spawning and incubation of Dolly Varden (Figure 1) relative to reporting requirements, ESH metrics could only be calculated until 2021 (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 = 5,454 m^2d) than the Lower Campbell Reservoir ESH (range of 223 to 6,747 m^2d; mean = 1,212 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 (2014-2021) was consistently around 3,000 m^2d. The Lower Campbell Reservoir saw higher variability across years with low ESH observed from 2014-2016 and in 2018 (~400 m^2d), increased ESH in 2017 and 2019 (~2,400 m^2d), and decreased ESH in 2020 (~1,300 m^2d) and 2021 (~900 m^2d) compared to 2019 (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 = 31,639 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 = 3,839 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 790 m^2d in 2021 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 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.



3.2. 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 27 Cutthroat Trout, 144 Rainbow Trout, three Sculpin, four Cutthroat Trout/Rainbow Trout hybrids (Table 7). No Dolly Varden nor Threespine Stickleback were captured in 2022. Rainbow Trout had the greatest mean CPUE (0.986 fish/net hour), followed by Cutthroat Trout (0.171 fish/net hour). CPUE for Cutthroat Trout and Rainbow Trout varied among sites, with higher CPUE recorded at sites UCR-LKNG06 and UCR-LKNG02 (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 2022.

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	15-Aug-22	2	43.2	4	15	0	0	0	0.093	0.347	0.000	0.000	0.000
UCR-LKGN02	15-Aug-22	2	42.7	10	21	0	1	1	0.234	0.492	0.000	0.023	0.023
UCR-LKGN04	16-Aug-22	3	50.6	3	13	0	1	0	0.059	0.257	0.000	0.020	0.000
UCR-LKGN06	16-Aug-22	2	33.4	10	95	0	1	3	0.300	2.847	0.000	0.030	0.090
	Total	**9**	**170**	**27**	**144**	**0**	**3**	**4**	**-**	**-**	**-**	**-**	**-**
	Average		**42.5**	**6.8**	**36.0**	**0.0**	**0.8**	**1.0**	**0.171**	**0.986**	**0.000**	**0.018**	**0.028**
	SD		**7.1**	**3.8**	**39.5**	**0.0**	**0.5**	**1.4**	**0.114**	**1.245**	**0.000**	**0.013**	**0.043**

3.2.2. Cutthroat Trout

3.2.2.1. CPUE

Cutthroat Trout were caught at every gill net sampling site. The sampling site CPUE ranged from 0.059 to 0.330 fish/net hour at the gill netting sites, with an overall mean CPUE of 0.179 fish/net hour (Table 7). One Cutthroat Trout was captured at 2.5 m in floating nets (Table 8). Cutthroat Trout were captured at 7.5 m or 12.5 m in sinking nets (Table 8). These data suggest that Cutthroat Trout had a preference of habitats with a bottom depth less than 12.5 m. This preference may be related to water temperature in the water column.

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

a) All Cutthroat Trout

Net Type	**CPUE (no. fish / hour)**			
	Bottom Depth (m)			
	2.5	**7.5**	**12.5**	**17.5**
Floating	0.028	0	0	0
Sinking	0	0.021	0.026	0

Net depth for sinking nets is equal to bottom depth and 25 m for floating nets

b) Adult Cutthroat Trout

Net Type	**CPUE (no. fish / hour)**			
	Bottom Depth (m)			
	2.5	**7.5**	**12.5**	**17.5**
Floating	0	0	0	0
Sinking	0	0.021	0.026	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 27 Cutthroat Trout were captured during gill netting surveys in the Upper Campbell Reservoir and size of 15 captured fish (i.e., complete intact undamaged fish) ranged from 135 to 356 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, 2022. Grey bars represent data collected during the nine years of monitoring, and black bars represent data collected during 2022.

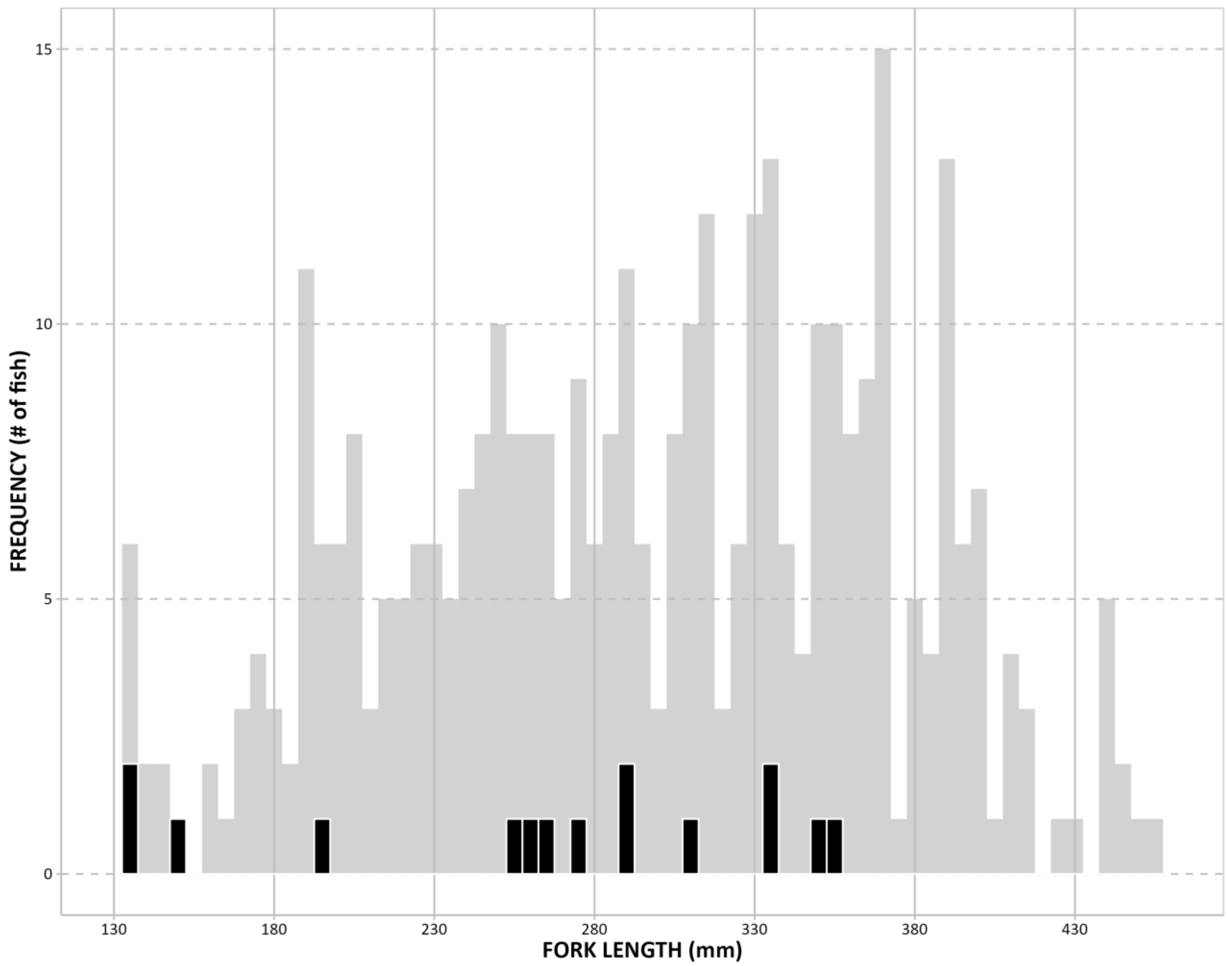
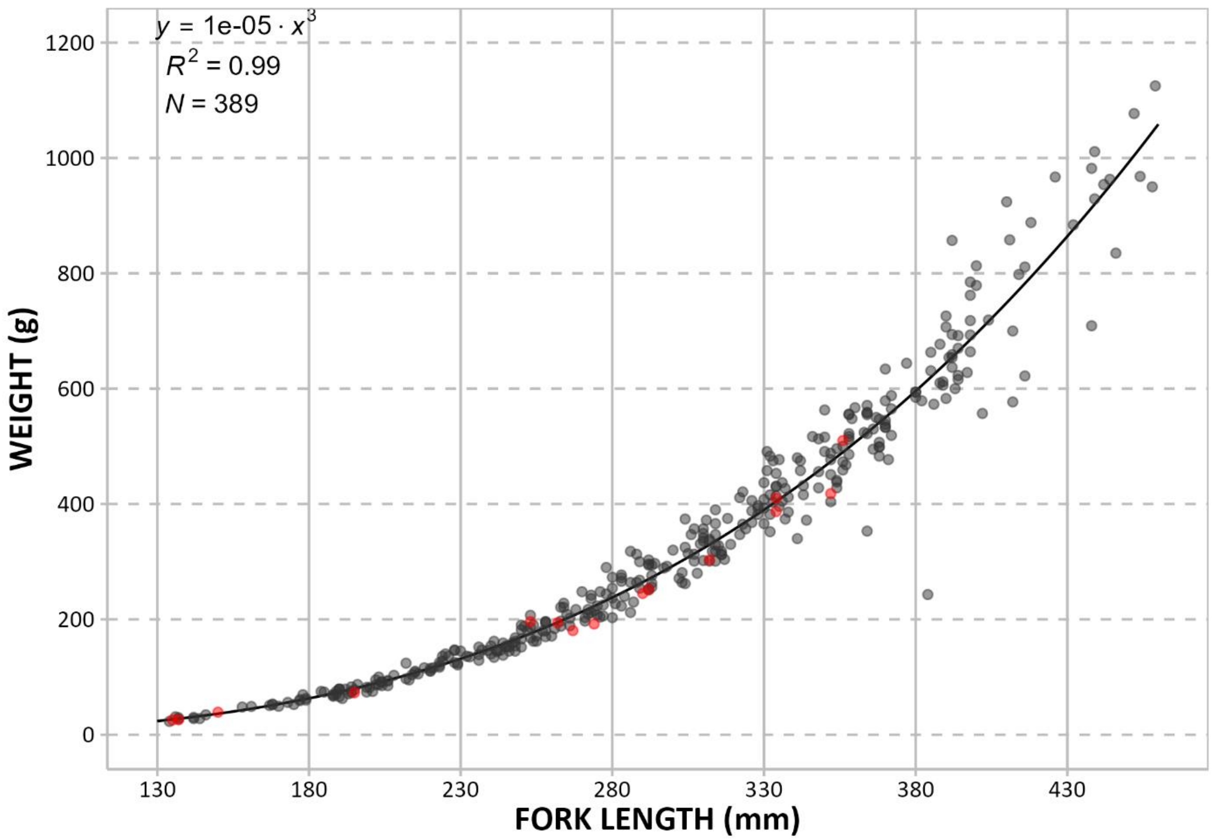


Figure 12. Length-weight relationship for Cutthroat Trout captured during gill net surveys in the Upper Campbell Reservoir, 2014-2022. Grey dots represent data collected during 2014-2021, and red dots represent data collected during 2022.



3.2.2.3. Stomach Content Analysis

A total of 164 Cutthroat Trout stomach contents have been analysed during the program (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 over the course of the monitoring program, to ~45% during 2018 and 2019, to ~25% in 2020, increased to ~61% in 2021, and decreased to ~44% in 2022. Consequently, the relative importance of benthic and terrestrial prey in the diet has increased from 2017 to 2020 and 2022 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 2017-2022. The data are presented as mean percent volume.

Year	Sample Size	Plankton	Fish	Benthic	Terrestrial	Other
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	-
2022	11	-	43.6	23.6	31.8	0.9

3.2.2.4. Age Cohort Analysis

Cutthroat Trout caught in gill nets in Year 9 ranged in age from 1+ to 2+ and 4+ to >6+ (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). A relative condition factor analysis comparing monitoring years was carried out separately from this report and is summarized in Kim *et al.* (2023b).

The CPUE of fish ages 4+ and >6+ were the highest recorded; 0.071 and 0.035 fish/net hour, respectively. CPUE for the other ages were 0.013 fish/net hour. Similar to previous years, no 0+ age fish were caught. No 3+ 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, 2022, excluding partially consumed fish (n = 12 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+	2	136.0	135.0	137.0	2	25.7	25.4	25.9	2	0.95	0.94	0.96
2+	2	172.5	150.0	195.0	2	55.9	39.0	72.8	2	0.99	0.91	1.08
3+	0	-	-	-	0	-	-	-	0	-	-	-
4+	6	273.0	253.0	292.0	6	209.9	180.5	252.0	6	0.96	0.87	1.13
5+	3	326.7	312.0	334.0	3	366.7	303.0	410.0	3	0.97	0.93	1.02
≥6+	2	354.0	352.0	356.0	2	464.0	418.0	510.0	2	0.97	0.89	1.05

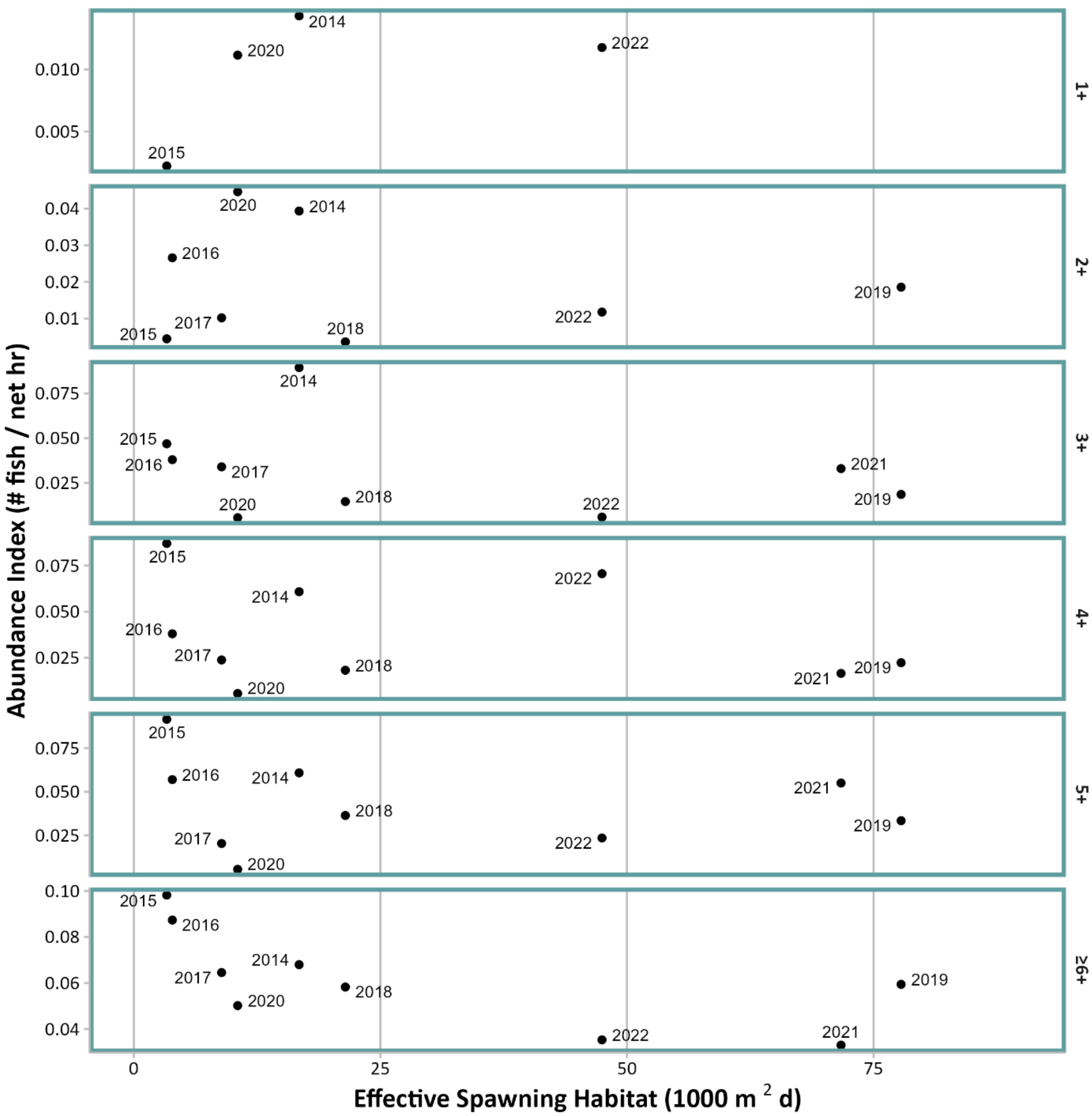
Table 11. CPUE of Cutthroat Trout age cohorts captured during gill netting surveys in Upper Campbell Reservoir, 2022.

Age	Number of Fish Caught	CPUE # of Fish/net hr)
0+	0	0.000
1+	2	0.012
2+	2	0.012
3+	1	0.006
4+	12	0.071
5+	4	0.024
≥6+	6	0.035

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 is substantial inter annual differences in CPUE; the largest values of CPUE were recorded for age >6+ fish in 2015 (0.098 fish/net hr), 5+ fish in 2015 and 3+ fish in 2014 (0.091, and 0.089 fish/net hr, respectively), with age-specific CPUE values in the last four years reduced substantially, particularly in 2022. 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, then further increased again to 71,706 m^2d in 2021, and then decreased again to 47,469 m^2d in 2022.

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 0.26 to 2.85 fish/net hour at the gill netting sites, with an overall mean CPUE of 0.99 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 7.5 and 12.5 m depth in floating nets whereas adult Rainbow Trout were captured at 2.5, 7.5, and 12.5 m in sinking nets. CPUE was generally higher for floating nets than for sinking nets (Table 12). CPUE for floating gill nets was higher when bottom depth increased, with the exception of a lack of captures at a bottom depth of 17.5 m (Table 12). CPUE for sinking nets varied by both depth and life stage. All Rainbow Trout CPUE was highest at a bottom depth of 2.5 m suggesting juveniles preferred shallower habitats. Conversely, adult Rainbow Trout CPUE was highest at depths of 7.5 and 12.5 m suggesting a preference of moderate depth habitats.

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	0.019	0.047	0.047	0
Sinking	0.046	0.025	0.021	0

Net depth for sinking nets is equal to bottom depth and 25 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	0.041	0.047	0
Sinking	0.005	0.021	0.021	0

Net depth for sinking nets is equal to bottom depth and 25 m for floating nets

3.2.3.2. Individual Fish Analysis

A total of 144 Rainbow Trout were captured during gill netting surveys and size of 132 captured fish (i.e., completely intact undamaged fish) ranged in fork length from 93 to 298 mm (Figure 14). The length frequency distribution of all Rainbow Trout caught in the Upper Campbell Reservoir had 4 modes at around 115 mm, 160 mm, 240 mm, and 265 mm (Figure 14). Length of fish caught during Year 9 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 (2014-2022) 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, 2022. Grey bars represent data collected during the nine years of monitoring, and black bars represent data collected during 2022.

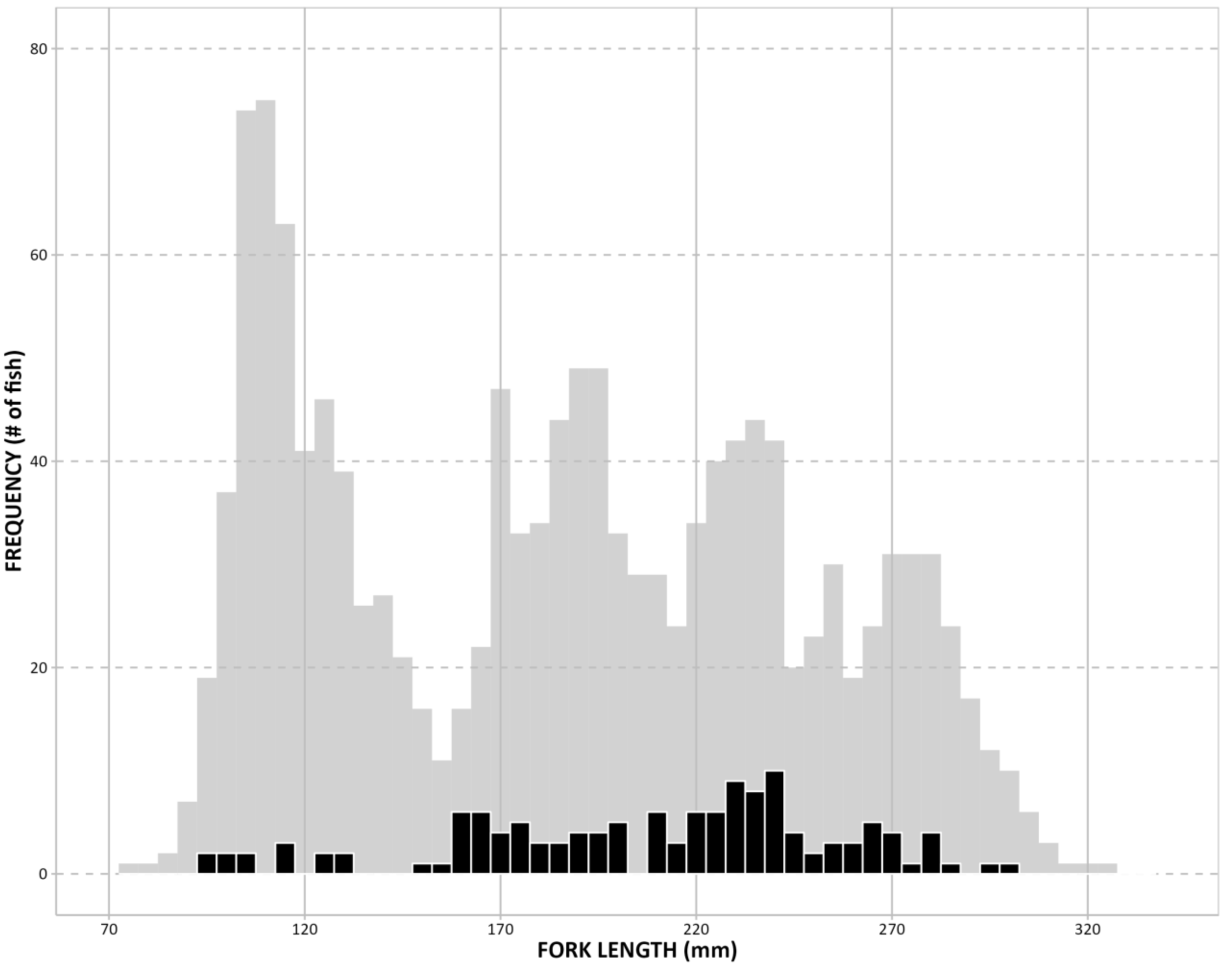
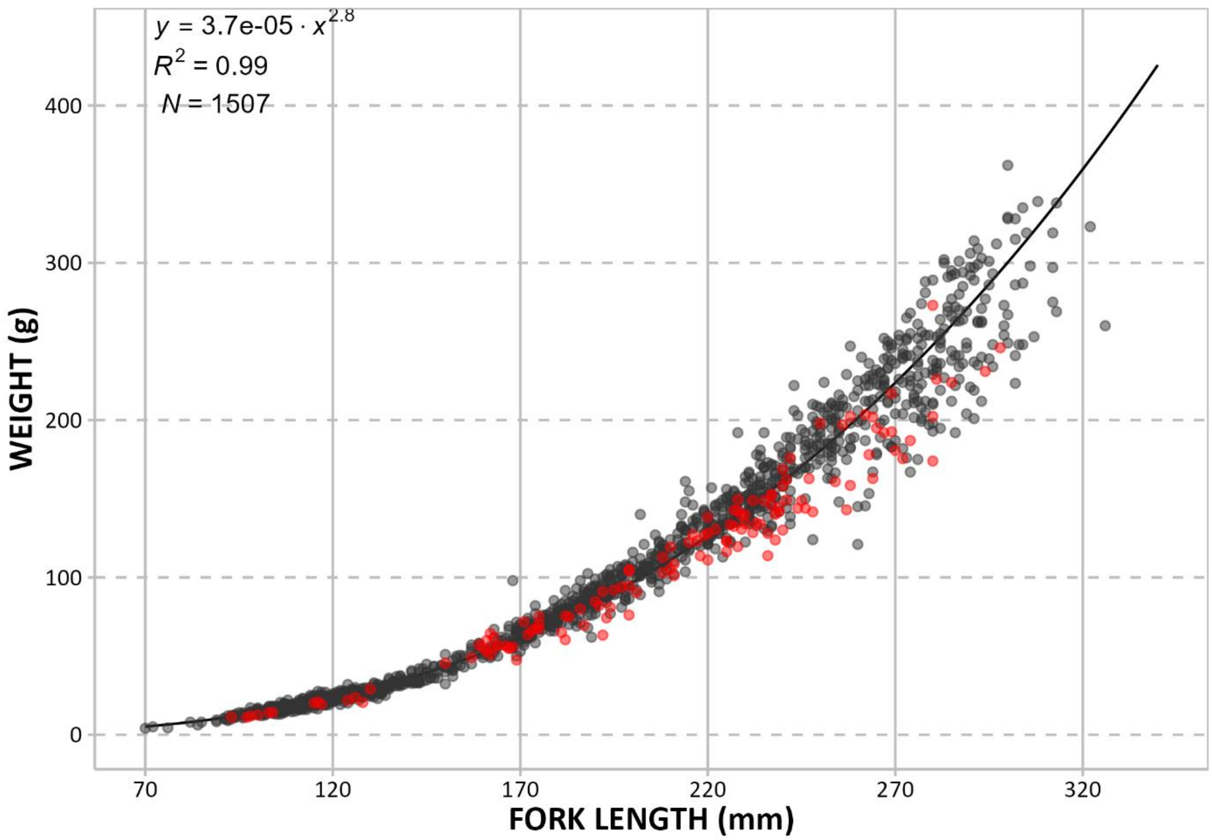


Figure 15. Length-weight relationship for Rainbow Trout captured during gill net surveys in the Upper Campbell Reservoir, 2014-2022. Grey dots represent data collected during 2014-2021, and red dots represent data collected during 2022.



3.2.3.3. Stomach Content Analysis

A total of 655 Rainbow Trout stomach contents have been analysed during the program; with a large proportion of the effort concentrated during 2018-2022 (Table 13). Stomach content has varied over time; in 2015 it was dominated by benthic prey, 2017-2019 was largely dominated by terrestrial prey, 2020 was dominated by plankton, in 2021 was evenly split between terrestrial prey and plankton, and in 2022, was largely dominated by plankton.

Table 13. Diet analysis of Rainbow Trout captured during gill net surveys in the Upper Campbell Reservoir, 2015, and 2017-2022. The data are presented as mean percent volume.

Year	Sample Size	Plankton	Fish	Benthic	Terrestrial	Other
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	-
2022	126	65.8	-	-	34.2	-

3.2.3.4. Age Cohort Analysis

The age of Rainbow Trout caught in gill nets in Year 9 ranged in age from 1+ to ≥6+ (Table 14). Most fish captured during Year 9 gill netting were between ages 2+ and 5+ (Table 14). Mean relative condition of Rainbow Trout was close to 1 for all ages (Table 14), except age ≥6+ and 5+ fish whose mean relative condition was low (0.84 and 0.92, respectively). The low condition of older fish is noticeable as lower than expected weights occur regularly in the length-weight relationship for fish larger than ~250 mm; however, this is also present in previous sampling years (Figure 15). A relative condition factor analysis comparing monitoring years was carried out separately from this report and is summarized in Kim *et al.* (2023b).

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). Similar to previous years, 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, 2022, excluding partially consumed fish (n = 11).

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+	9	104.8	93.0	117.0	9	15.0	11.0	20.7	9	0.92	0.86	0.98
2+	16	152.3	124.0	166.0	16	47.5	20.5	64.4	16	1.01	0.74	1.20
3+	31	184.4	167.0	201.0	31	75.3	47.5	105.0	31	0.97	0.73	1.15
4+	42	225.8	208.0	239.0	42	129.4	101.1	152.9	42	0.95	0.74	1.10
5+	25	253.2	240.0	269.0	25	171.5	130.1	217.0	25	0.92	0.73	1.10
≥6+	10	281.4	270.0	298.0	10	212.0	174.0	273.0	10	0.84	0.70	1.10

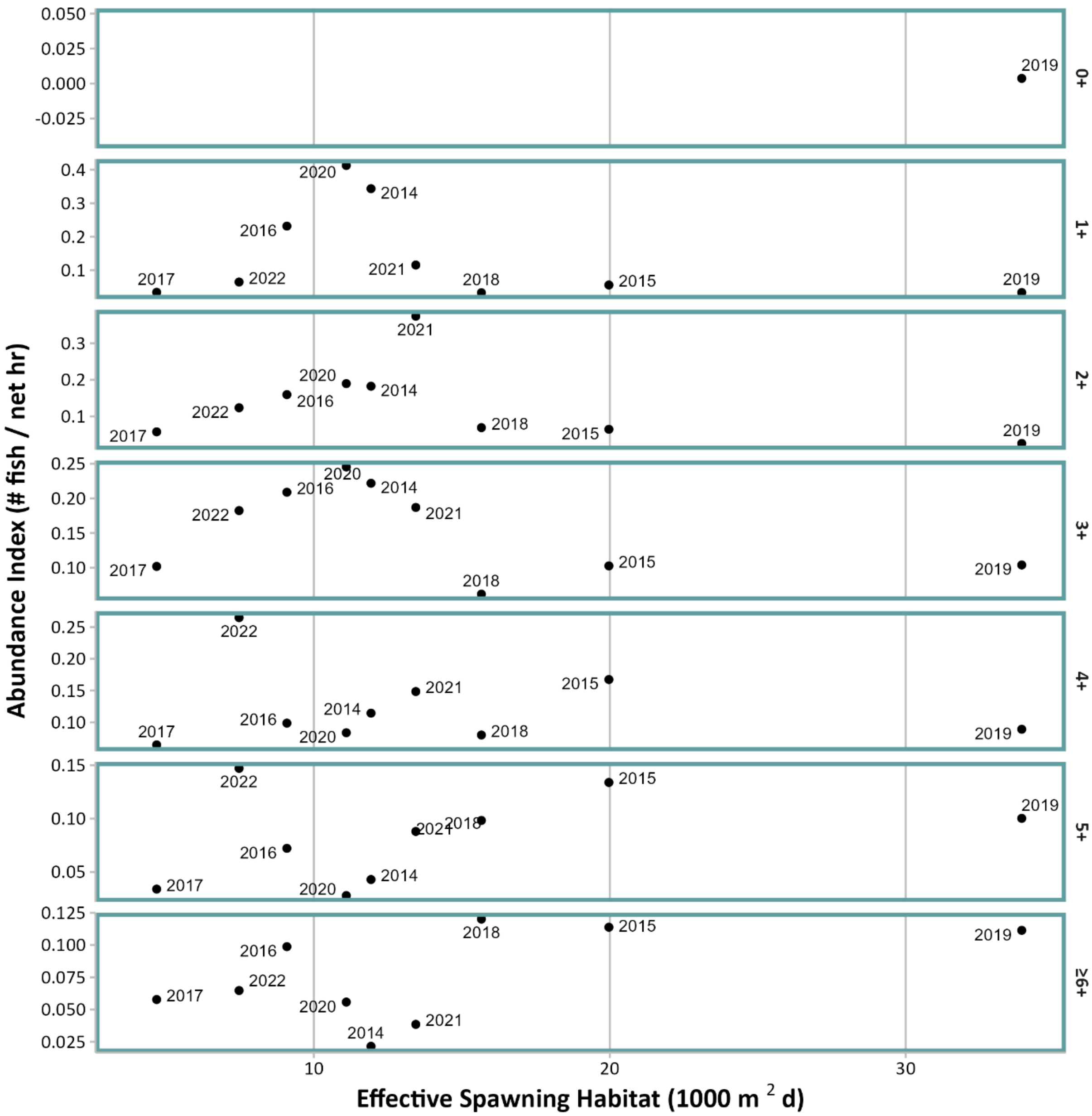
Table 15. CPUE (fish / net hour) of Rainbow Trout age cohorts captured during gill netting surveys in Upper Campbell Reservoir, 2022.

Age	Number of Fish Caught	CPUE (# of Fish/net hr)
0+	0	0.000
1+	11	0.065
2+	21	0.124
3+	31	0.182
4+	45	0.265
5+	25	0.147
≥6+	11	0.065

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+ (0.413 fish/net hr) in 2020 and age 2+ (0.374 fish/net hr) in 2021, and age 1+ (0.343 fish/net hr) in 2014. The values of ESH during this monitoring project (2014-2022) 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, increased in 2021 to ~13,000 m^2d, and then decreased in 2022 to ~7,400 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.



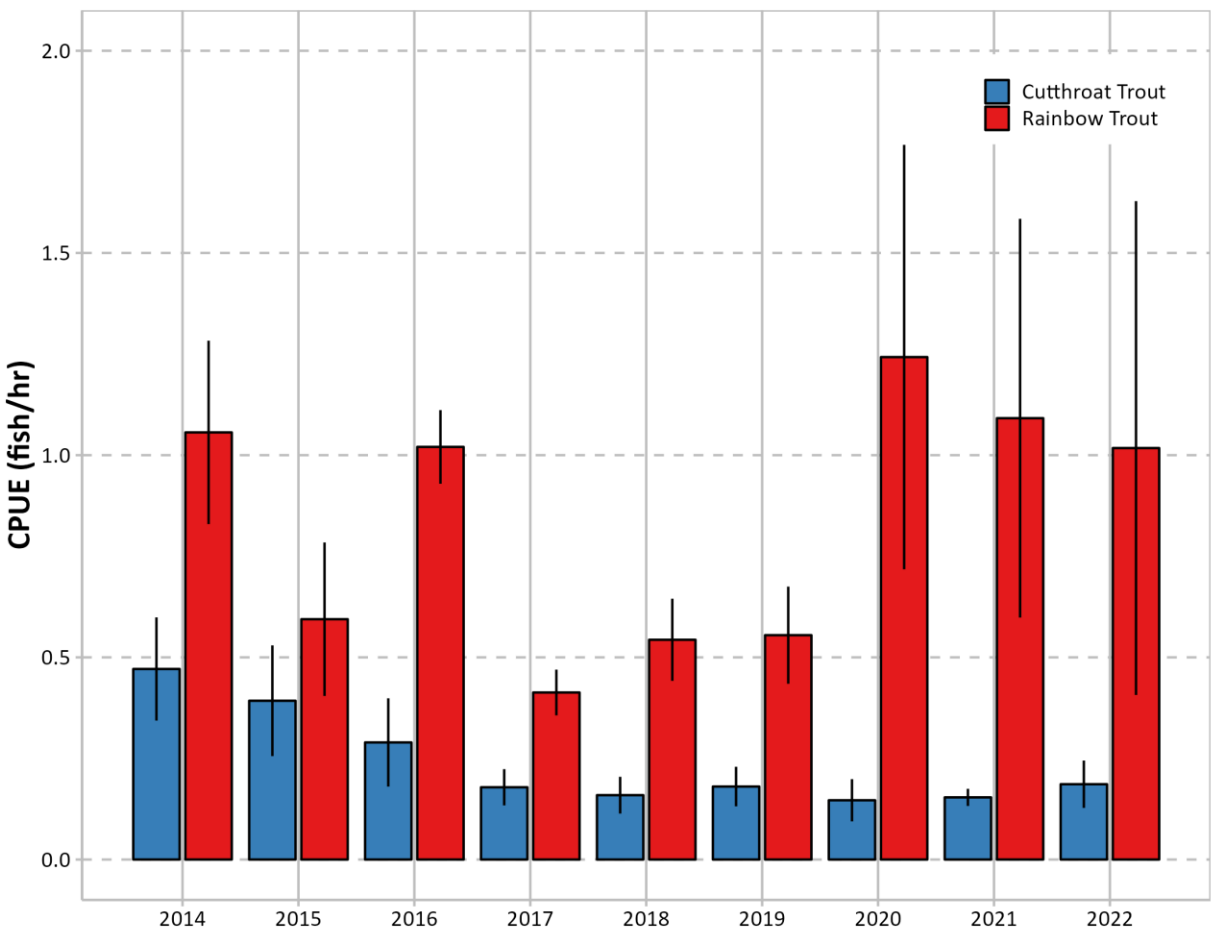
3.2.4. Historical Comparison

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 9 (2014 to 2022) suggests 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 and remaining low in Year 9 (0.18 fish/net hour). 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 and 9 (1.06 and 1.25 fish/net hour, respectively).

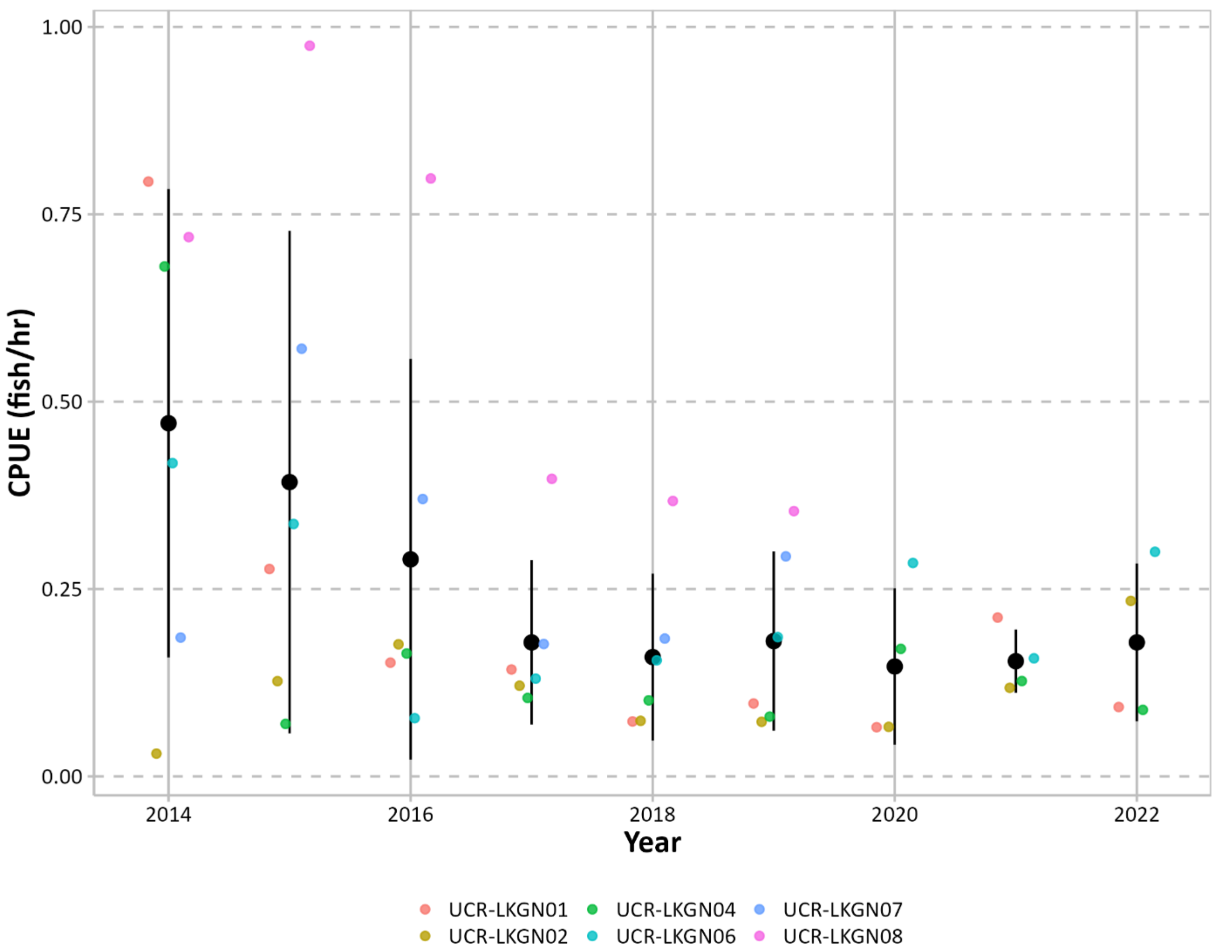
Figure 17. Comparison of Cutthroat and Rainbow Trout CPUE from littoral gill net surveys in the Upper Campbell Reservoir among the nine years of this program to date (2014-2022). The bars represent the annual mean CPUE, and the vertical error bars represent +/- SE.



Cutthroat Trout

Results from the Year 9 Population Index were comparable to past years (Figure 18), except that UCR-LKGN02 had higher Cutthroat Trout CPUE this year. Cutthroat Trout appeared to have a consistent preference for some sites over others, but trends for Cutthroat Trout CPUE are not apparent within sampling sites or across years.

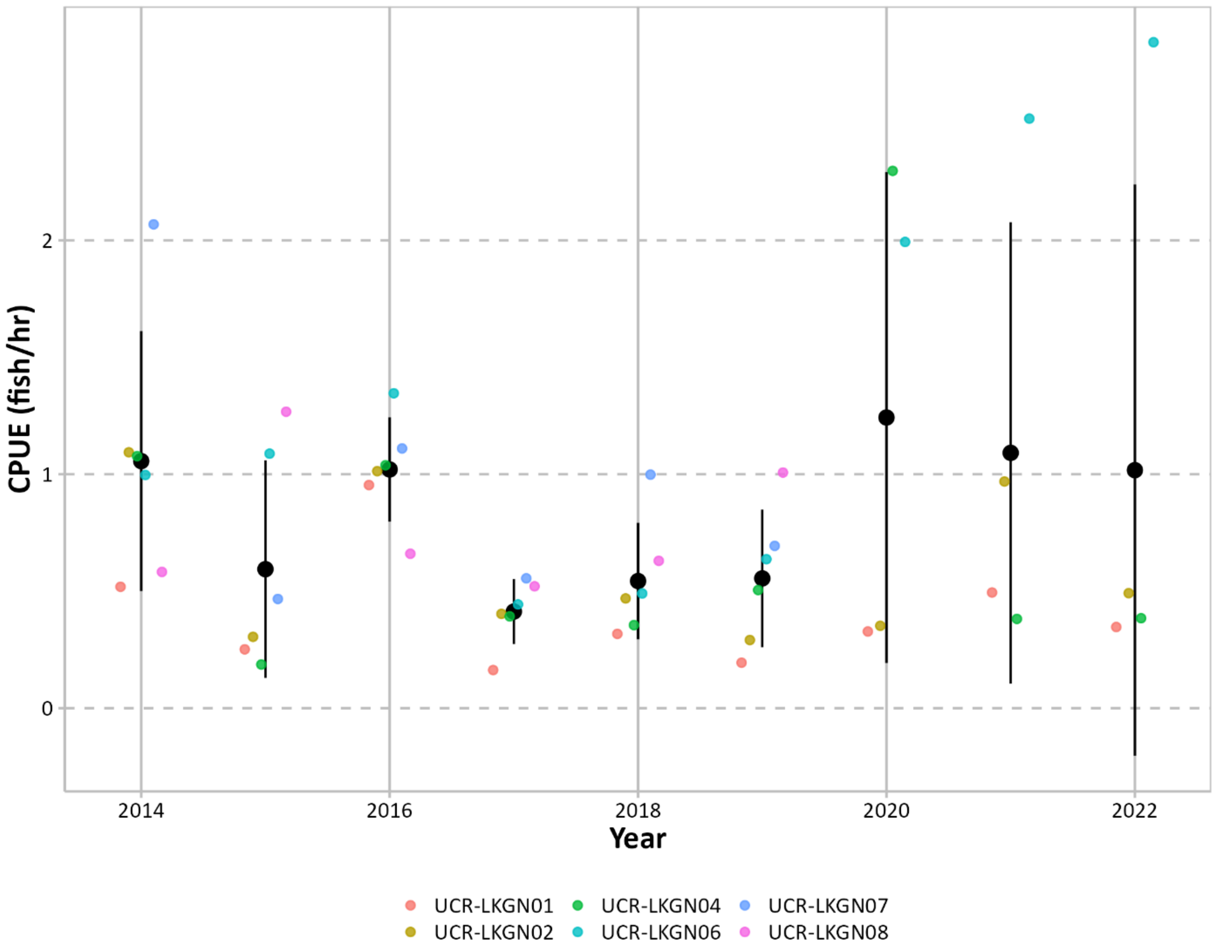
Figure 18. Comparison of Cutthroat Trout CPUE (mean ± SD) from littoral RISC gill net surveys by sample site among the nine years of this program to date (2014-2022).



Rainbow Trout

There was no consistent trend in CPUE results for Rainbow Trout among the sampling sites or across sampling years (Figure 19). In 2014 and 2016, CPUE was highest across most sites. 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 2022 reached the maximum level observed in site UCR-LKGN06 (2.85 fish/hr) (Figure 19).

Figure 19. Comparison of Rainbow Trout CPUE (mean ± SD) from littoral RISC gill net surveys by sample site among the nine years of this program to date (2014-2022).



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). Effective visibility during spring surveys ranged from 2 m in April to 6 m in March and with water temperatures ranging between 2.0°C and 4.0°C (Table 16). During summer surveys water temperatures ranged from 4.0 to 5.5 °C and visibility ranged from 5.5 to 6.0 m (Table 17). Representative photographs collected during snorkel surveys are presented in Appendix D.

Table 16. Sampling effort and conditions for Year 9 snorkel surveys in tributaries of the Lower Campbell Reservoir during spring surveys in 2022. 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	07-Mar-22	0.5	0.9	4.0	15.0	6.0	4.4	Partly Cloudy/Dry/None in 24 hours/Light Breeze
	Greenstone River	2.4	19-Apr-22	1.5	3.0	2.0	8.0	2.0	3.8	Partly Cloudy/Sunny
	Miller Creek	0.4	07-Mar-22	1.2	2.5	4.0	12.0	6.0	4.4	Partly Cloudy/Dry/None in 24 hours/Light Breeze

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

Table 17. Sampling effort and conditions for Year 9 snorkel surveys during summer 2022. 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
Buttle Lake	Henshaw Creek	0.5	01-Jun-22	0.5	0.9	4.0	11.0	6.0	17.7	Overcast
	Phillips Creek	0.3	07-Jun-22	0.4	0.8	4.0	10.0	6.0	18.2	Partly Cloudy
	Ralph River	0.9	01-Jun-22	0.5	1.0	n/a	n/a	6.0	17.7	Overcast
	Thelwood Creek	2.5	09-Jun-22	0.9	1.8	5.5	9.0	6.0	19.2	Rain
	Wolf River	0.3	07-Jun-22	0.4	0.9	5.5	12.0	5.5	18.2	Partly Cloudy
Upper Campbell	Lower Elk River	5.4	08-Jun-22	1.1	2.2	5.5	10.0	6.0	20.0	Partly Cloudy/Light Rain
	Upper Elk River	6.0	08-Jun-22	1.1	2.2	5.5	13.0	6.0	20.0	Partly Cloudy/Light Rain

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

3.3.2. Survey Results

3.3.2.1. Cutthroat Trout

Year 9 snorkel survey data for the Cutthroat Trout spring spawning period are summarized below (Table 18). Redds observed between March 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 Reservoir in March and April 2022. During these snorkel surveys all adult Cutthroat Trout observed were in post-spawn condition (*n* = 3) with two observed in Greenstone River, and one in Miller Creek; however, redds were observed in all three tributaries of the Lower Campbell Reservoir (Figure 21, Table 18).

Observed Cutthroat Trout numbers during summer surveys in 2022 were low in all tributaries (this reflects the low CPUE recorded in the gillnet sampling), reaching maximum of 5.2 fish/km in Thelwood Creek (Figure 20). Cutthroat Trout density in Wolf River has been variable throughout the monitoring program with >60 fish/km in 2019, compared to 5.2 fish/km in 2022. This variability is not unexpected as summer surveys are targeting Rainbow Trout spawn timing. Accordingly, all adult Cutthroat observed in 2022 were bright (*n* = 28) (Figure 21).

Table 18. Cutthroat Trout counts during 2022 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-22	1	0	0	1	0	0	0	n/a
		Phillips Creek	07-Jun-22	1	0	0	0	0	1	0	n/a
		Ralph River	01-Jun-22	2	0	0	1	1	0	0	n/a
		Thelwood Creek	09-Jun-22	13	0	0	2	7	4	0	n/a
		Wolf River	07-Jun-22	2	0	0	0	1	1	0	n/a
Lower Campbell	March	Fry Creek	07-Mar-22	0	0	0	0	0	0	0	107
		Miller Creek	07-Mar-22	1	0	0	0	1	0	0	233
	April	Greenstone River	19-Apr-22	2	0	0	0	0	2	0	43
Upper Campbell	June	Lower Elk River	08-Jun-22	8	0	0	1	5	2	0	n/a
		Upper Elk River	08-Jun-22	1	0	0	0	1	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 9 snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir.**

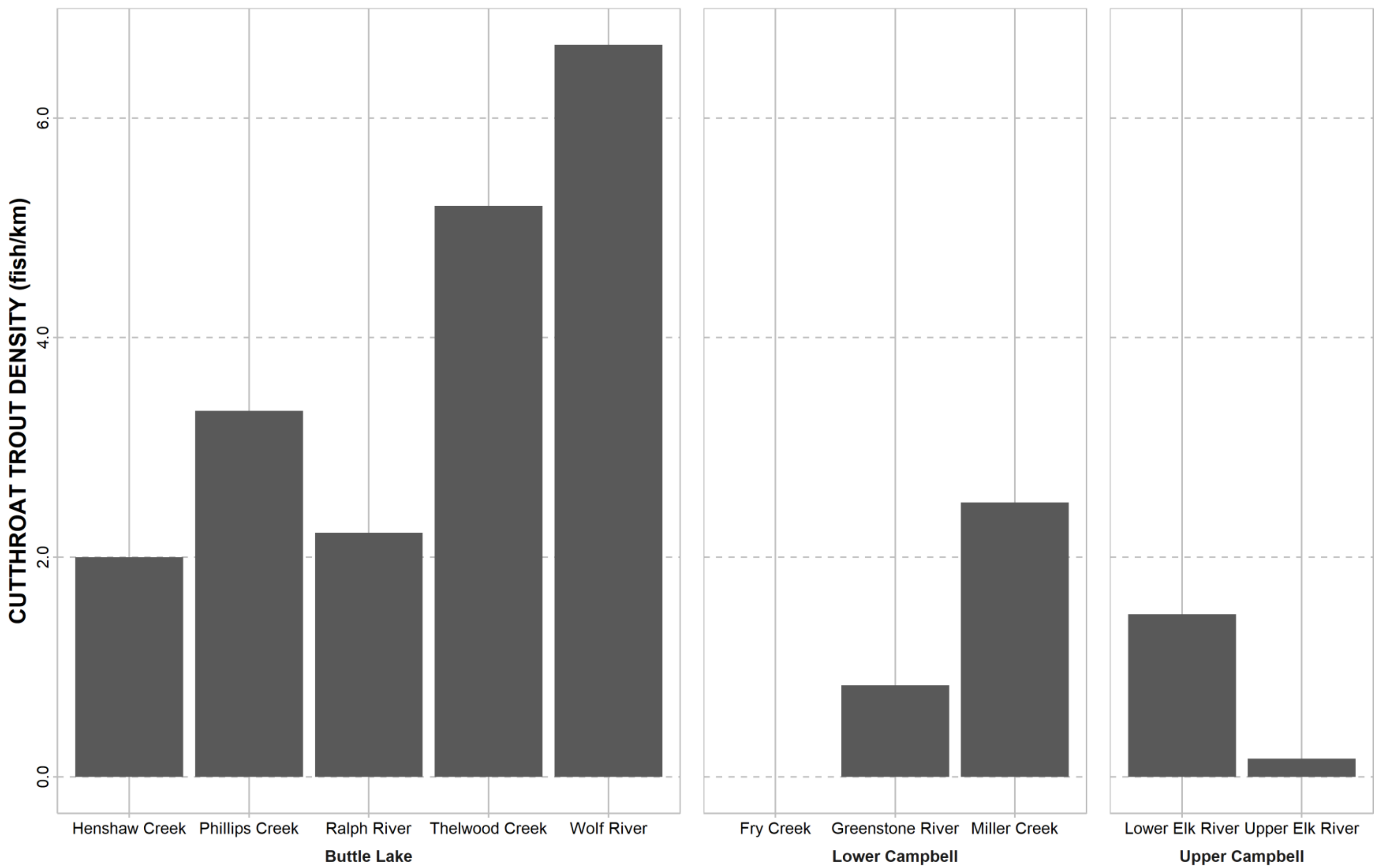
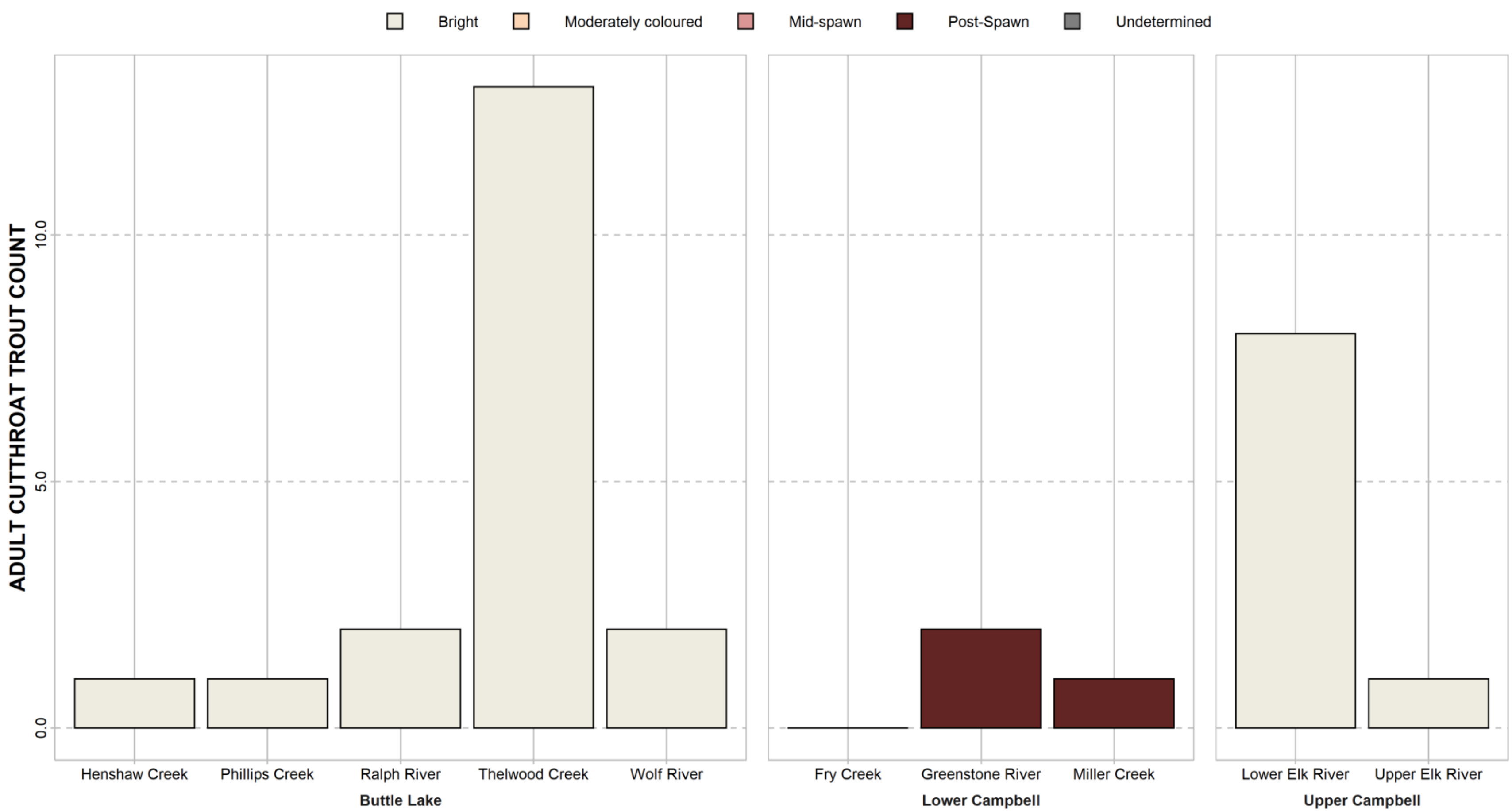


Figure 21. Counts of adult Cutthroat Trout observed during Year 9 snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir, by condition classes.



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 (518 redds), followed by Thelwood Creek (336 redds), and Upper Elk River (311 redds). The total number of Rainbow Trout redds recorded in the Elk River in Year 9 (1,429) was the lowest observed since Year 2 (1,846) with redd counts ranging from 1,087 in Year 4 to 2,079 in Year 8 over the course of the monitoring program (Kim *et al.* 2023a). The number of Rainbow Trout redds recorded in Thelwood Creek in Year 9 (336) was the lowest observed during the monitoring program to date with redd counts ranging from 576 in Year 4 to 1,782 in Year 6 Kim *et al.* 2023a)[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.

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 (1,657 fish/km), Thelwood Creek (643 fish/km), Lower Elk River (390 fish/km), and Ralph River (296 fish/km) (Figure 22, Figure 23). When interpreting these results, note that variability in channel width hinders direct comparison of this metric between tributaries.

Adult Rainbow Trout counts were consistently much higher than Cutthroat Trout throughout the monitoring program, which may have been a result of effective survey timing in relation to Rainbow Trout spawning. The highest count of adult Rainbow Trout were recorded in lower Elk River (2,107 fish); Thelwood Creek (1,607 fish); and upper Elk River (589 fish) (Figure 24). These watercourses also correspond to the highest counts from previous years.

Most of the observed Rainbow Trout were of moderately coloured (39.2%), or in mid-spawn (36.2%) condition, suggesting that these surveys may have occurred slightly early in the spawning period (Figure 24). Low numbers of fish in post-spawn condition were observed, representing only 6.1% (*n* = 313) across all waterbodies (Figure 24).

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

Table 19. Rainbow Trout counts during 2022 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-22	15	0	0	1	14	0	0	17
		Phillips Creek	07-Jun-22	77	0	0	24	50	3	0	8
		Ralph River	01-Jun-22	266	0	0	75	191	0	0	83
		Thelwood Creek	09-Jun-22	1607	0	0	389	1210	8	0	336
		Wolf River	07-Jun-22	497	0	0	145	349	3	0	156
Lower Campbell	March	Fry Creek	07-Mar-22	0	0	0	0	0	0	0	n/a
		Miller Creek	07-Mar-22	15	0	0	8	7	0	0	n/a
	April	Greenstone River	19-Apr-22	0	0	0	0	0	0	0	n/a
Upper Campbell	June	Lower Elk River	08-Jun-22	2107	0	3	467	1627	10	0	518
		Upper Elk River	08-Jun-22	589	0	8	65	514	2	0	311

[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 9 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.**

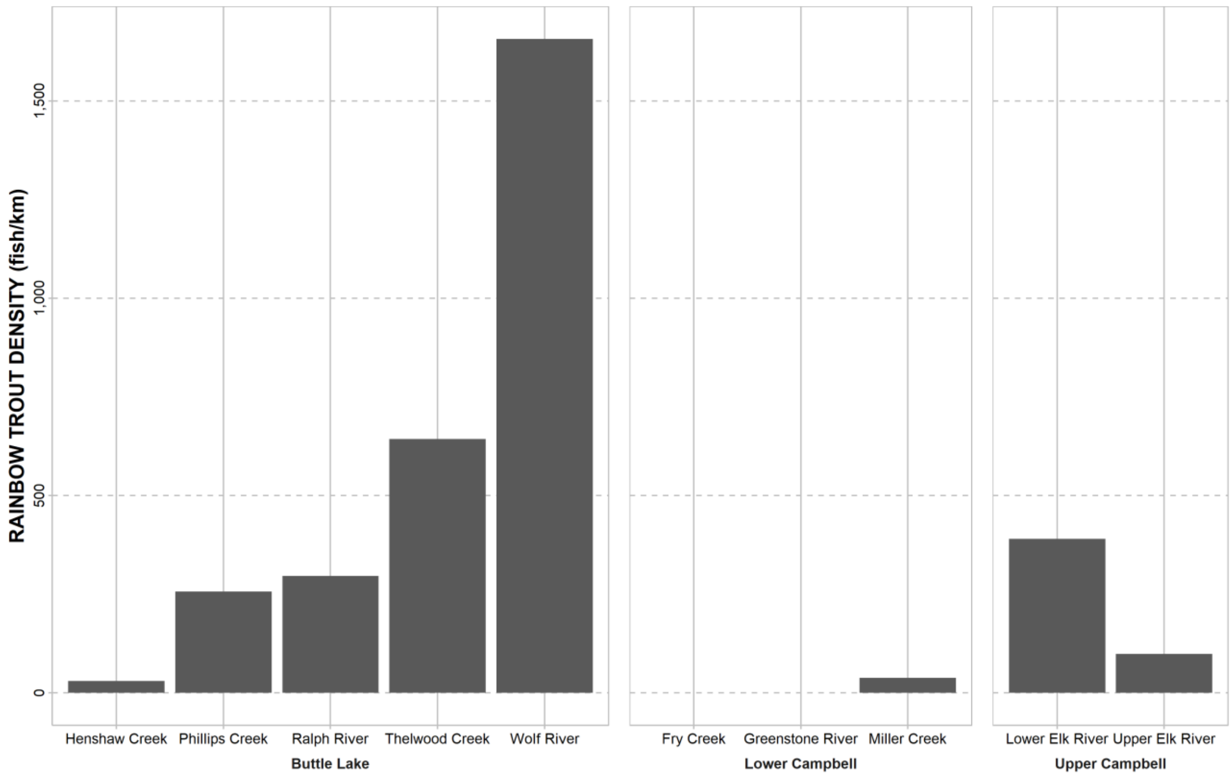


Figure 23. Rainbow Trout observed density (fish/km; all life stages) during Year 1-9 (2014-2022) snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir. Dotted horizontal lines represent 25th, 50th and 75th quantiles.

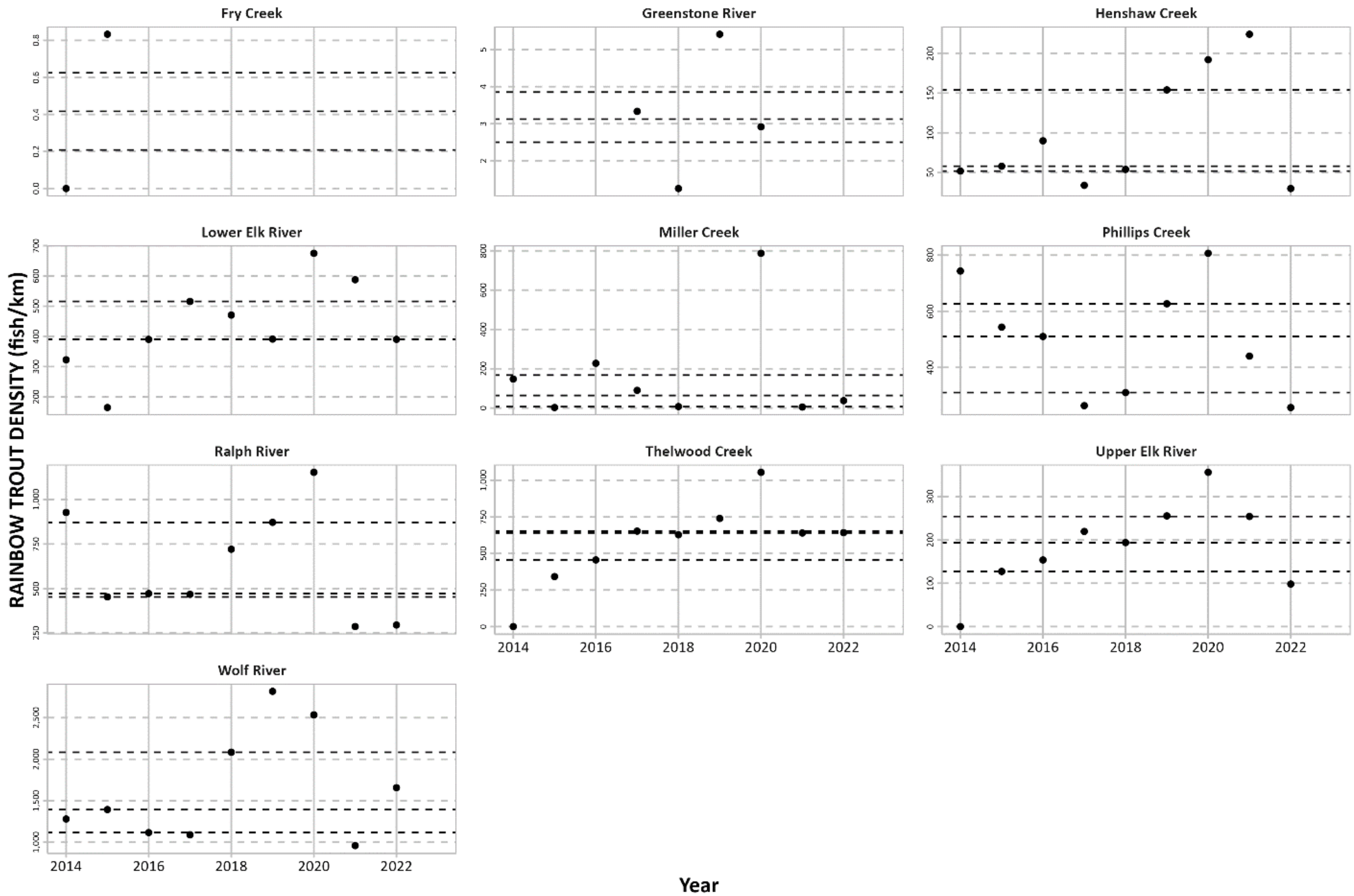
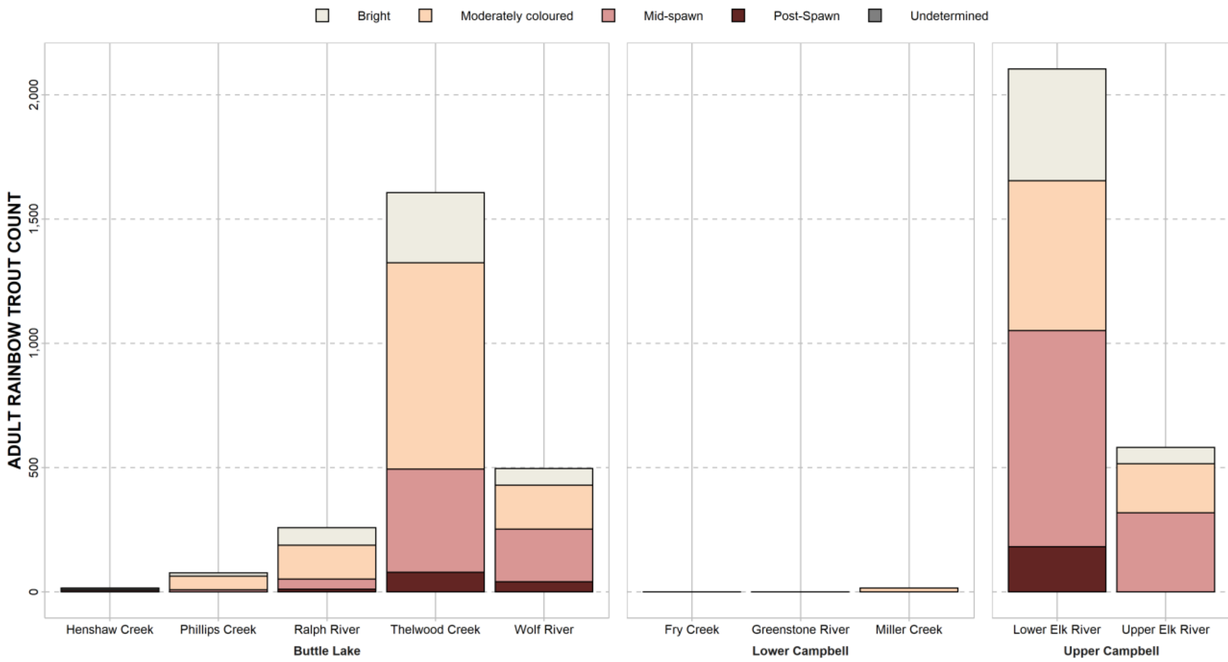


Figure 24. Counts of adult Rainbow Trout observed during Year 9 summer snorkel surveys in the tributaries of Upper Campbell Reservoir and Buttle Lake, by condition classes. Rainbow Trout observed incidentally during snorkel surveys for Cutthroat Trout in Lower Campbell Reservoir are not included.



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.

One Dolly Varden parr was observed in Greenstone River on April 19, 2022 (Table 20). The greatest number of adult Dolly Varden were observed in Thelwood Creek (1.6 fish/km) which was the third lowest number recorded through the 9 years of monitoring, with numbers ranging from zero in Year 1 to 8.8 fish/km in Year 2 (Figure 26; Kim *et al.* 2023a). The density of Dolly Varden in Wolf River and Ralph River (3.3 fish/km) were the highest densities observed, which is quite low through the 9 years of monitoring (Figure 25). Densities observed in other streams were 1.6 fish/km (Thelwood Creek) or below and were comparable to those recorded previously.

Figure 25. Dolly Varden observed density (fish/ km) from 2022 summer snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir.

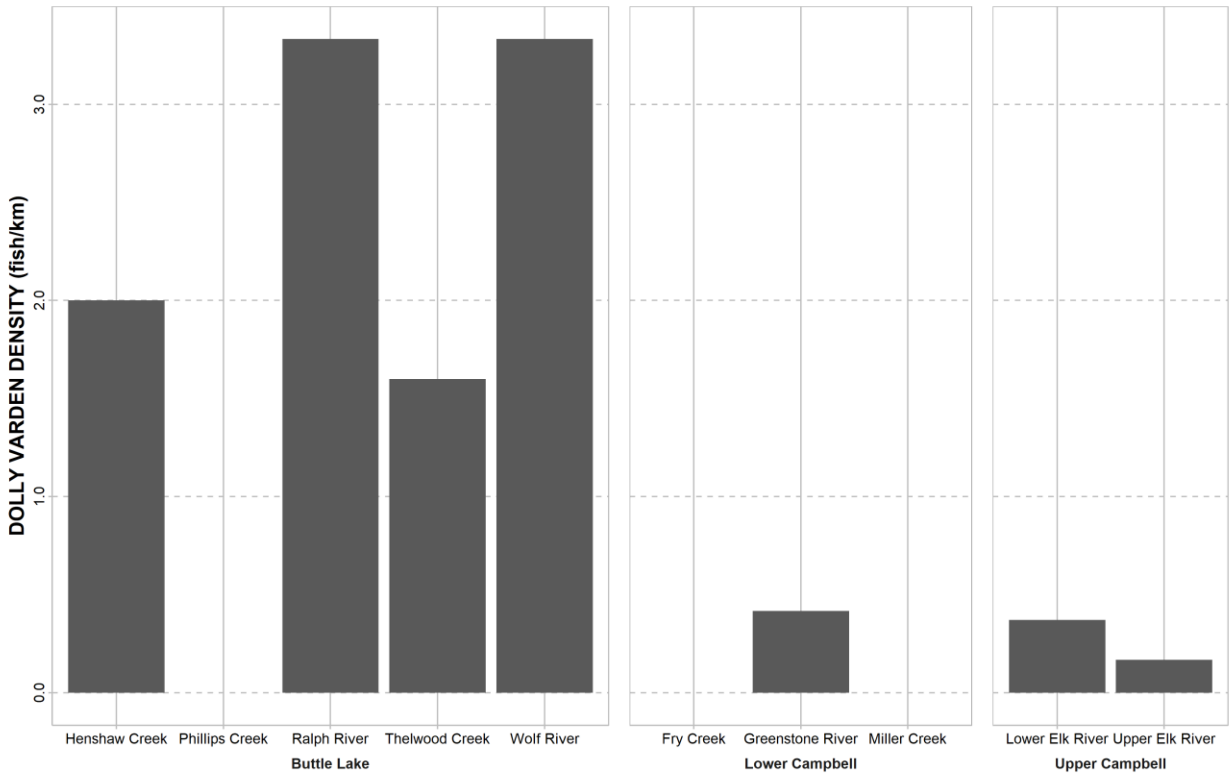


Figure 26. Dolly Varden observed density (fish/ km) from 2014 - 2022 snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir. Dotted horizontal lines represent 25th, 50th and 75th quantiles.

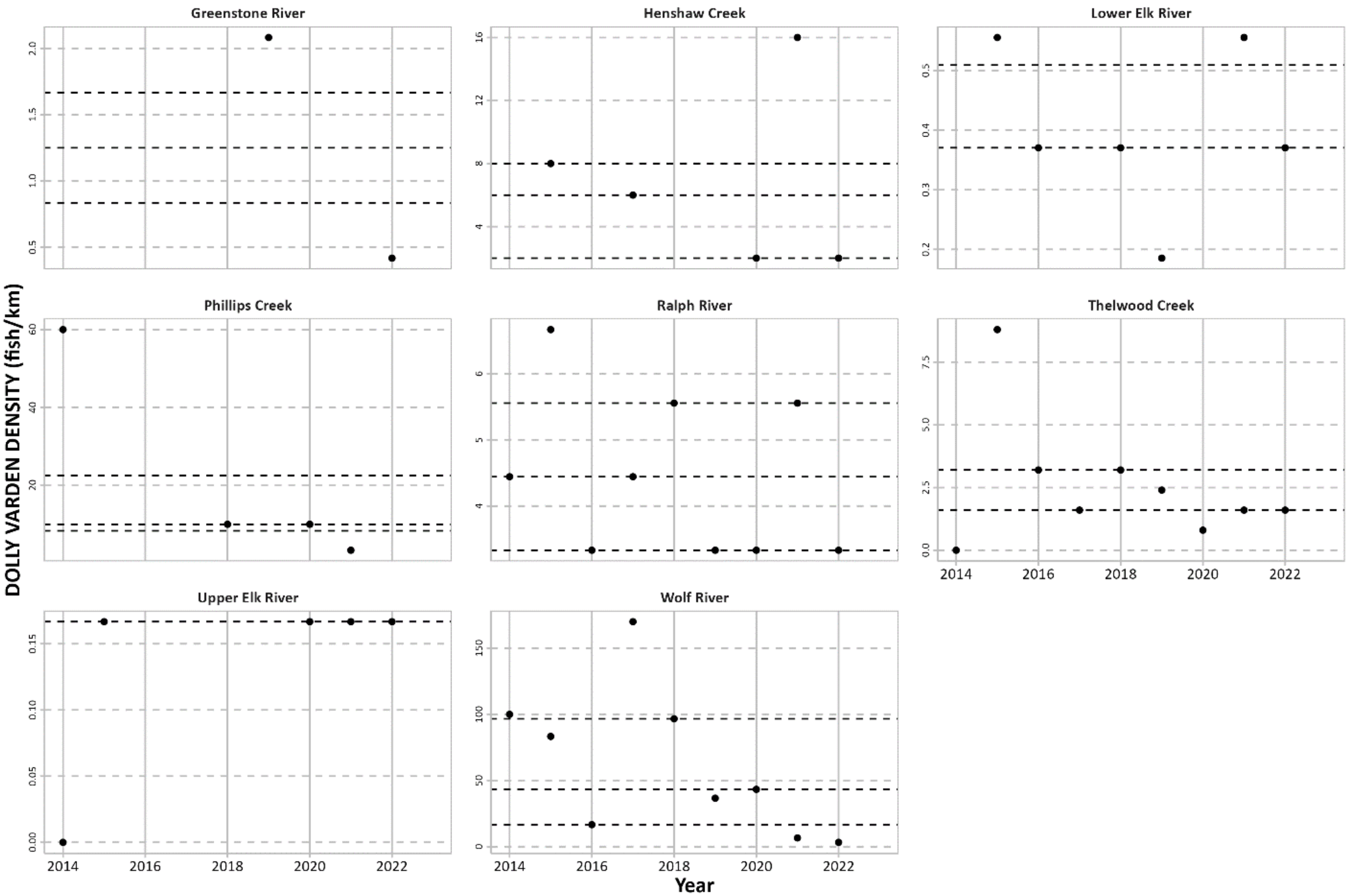


Table 20. Dolly Varden population counts (incidental) from 2022 snorkel surveys in the tributaries of Buttle Lake, Lower Campbell Reservoir, and Upper Campbell Reservoir.

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-22	1	0	0	1	0	0	0	n/a
		Ralph River	01-Jun-22	3	0	0	0	2	1	0	n/a
		Thelwood Creek	09-Jun-22	4	0	0	1	2	1	0	n/a
		Wolf River	07-Jun-22	1	0	0	0	0	1	0	n/a
		Greenstone River	19-Apr-22	1	0	1	0	0	0	0	n/a
Lower Campbell	March	Fry Creek	07-Mar-22	0	0	0	0	0	0	0	n/a
		Miller Creek	07-Mar-22	0	0	0	0	0	0	0	n/a
	April	Greenstone River	19-Apr-22	1	0	1	0	0	0	0	n/a
Upper Campbell	June	Lower Elk River	08-Jun-22	2	0	0	2	0	0	0	n/a
	June	Upper Elk River	08-Jun-22	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 (pre-2014) is not known, except for 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 2022 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 (1990–2022). Historical data (prior to 2014) were provided by BCCF (Pellett 2013).

Watershed[1]	Waterbody	Species[2]	Year															
			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

[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 21. Continued.

Watershed[1]	Waterbody	Species[2]	Year																	
			2006	2007	2008	2009	2010	2011	2012	2013		2014	2015	2016	2017	2018	2019	2020	2021	2022
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	581
		CT	4	0	2	5	10	n/a	11	10	8	2	3	2	21	13	4	14	3	1
		DV	6	1	1	1	2	n/a	1	0	1	1	1	0	0	0	0	1	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	2,104
		CT	3	3	11	4	20	n/a	5	5	7	2	4	6	11	19	23	10	25	8
		DV	9	2	0	2	1	n/a	0	1	0	0	1	2	0	2	1	0	3	2
Buttle	Ralph	RB	650	690	1,103	1,181	708	n/a	479	536		835	407	419	421	647	785	1,038	258	266
		CT	2	0	2	0	0	n/a	1	2		1	0	3	8	5	6	2	1	2
		DV	4	56	0	9	4	n/a	0	13		4	1	3	4	5	3	3	5	3
	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	1,607
		CT	25	10	12	4	17	32	26	15		0	11	11	14	28	19	22	11	13
		DV	24	6	4	9	5	2	0	0		0	7	8	3	8	6	2	4	4
	Wolf	RB	n/a	n/a	1,250	1,210	1,590	140	192	666		384	410	345	327	625	844	760	284	497
		CT	n/a	n/a	6	1	0	0	2	3		3	0	10	26	12	19	2	1	2
		DV	n/a	n/a	25	90	90	30	5	18		30	25	5	51	29	11	13	2	1
	Phillips	RB	n/a	n/a	162	624	540	106	145	191		223	157	153	79	93	188	236	125	77
		CT	n/a	n/a	1	0	0	0	2	0		2	0	0	1	2	3	2	2	1
		DV	n/a	n/a	3	4	40	21	3	8		18	0	0	0	3	0	3	1	0
	Henshaw	RB	5	42	24	93	27	n/a	8	37		26	29	44	17	26	77	96	111	15
		CT	0	0	1	0	0	n/a	0	0		0	0	0	3	1	3	1	2	1
		DV	0	0	0	0	0	n/a	0	0		0	0	0	0	0	0	0	8	1

[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, 2014-2022. 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
	2022	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

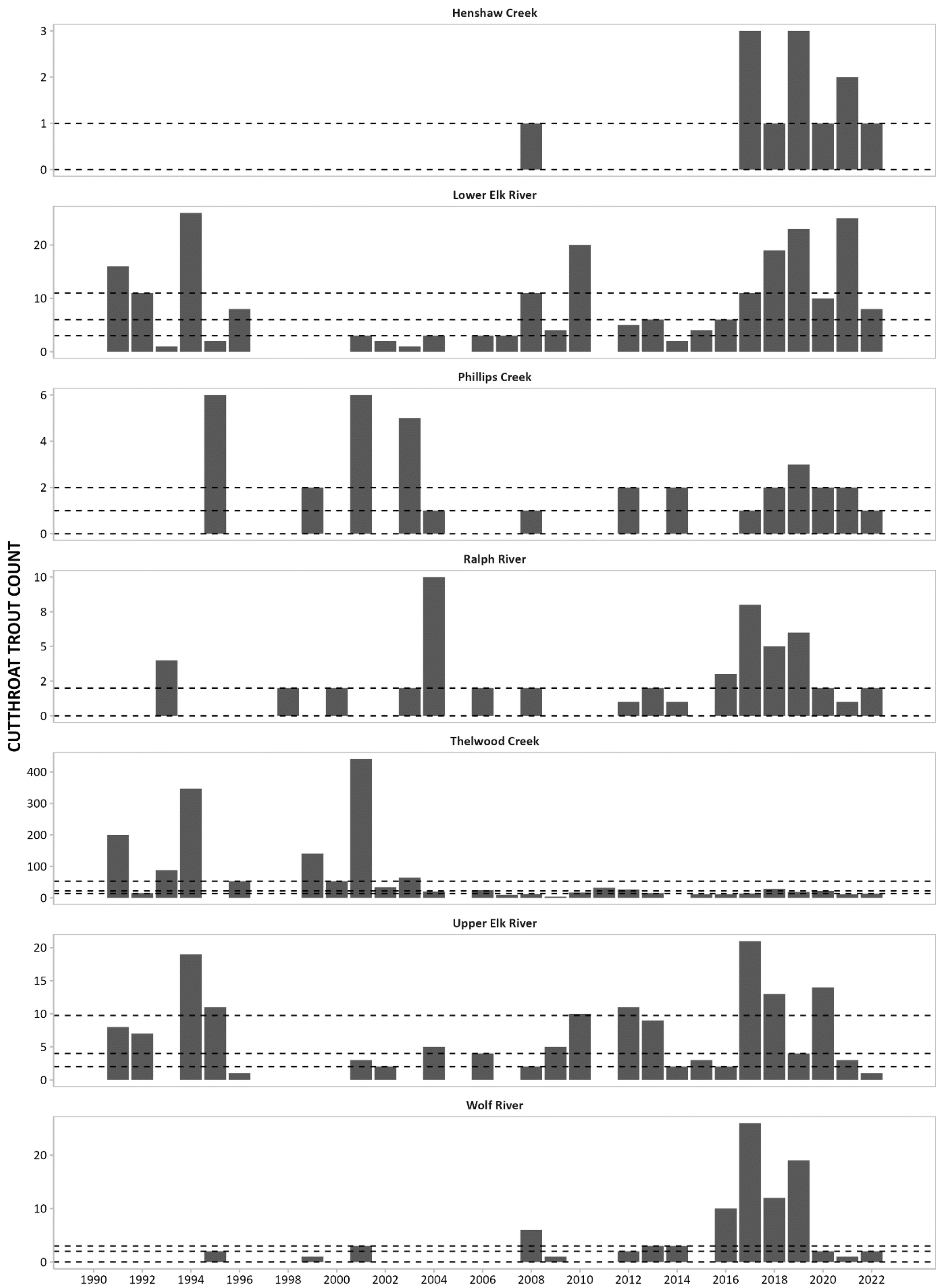
[2] RB - Rainbow Trout, CT - Cutthroat Trout, and DV - Dolly Varden

3.3.3.2. Cutthroat Trout

The data presented here for June 2022 are from Rainbow Trout spawning surveys, so any trends in Cutthroat Trout should be interpreted cautiously. Adult Cutthroat Trout counts in 2022 (ranging from 1 to 13 fish) are generally consistent with historical observations for the period 1990 to 2022 (Table 21, Figure 27). 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 2022 and 2020. In Wolf River we observed the largest decrease in number of fish, from 19 in 2019 to only 2 in 2022.

In Fry Creek, comparable survey data for March are only available in 2003 when 287 Cutthroat Trout were observed, and in the 2016-2022 period no fish were observed (Table 22). However, as mentioned in Section 3.3.2.1, surveys were likely conducted following 2022 Cutthroat Trout spawning which means that the 2022 counts are not an accurate measure of the spawner abundances in Fry Creek.

Figure 27. Adult Cutthroat Trout counts in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir (1990-2022). 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).



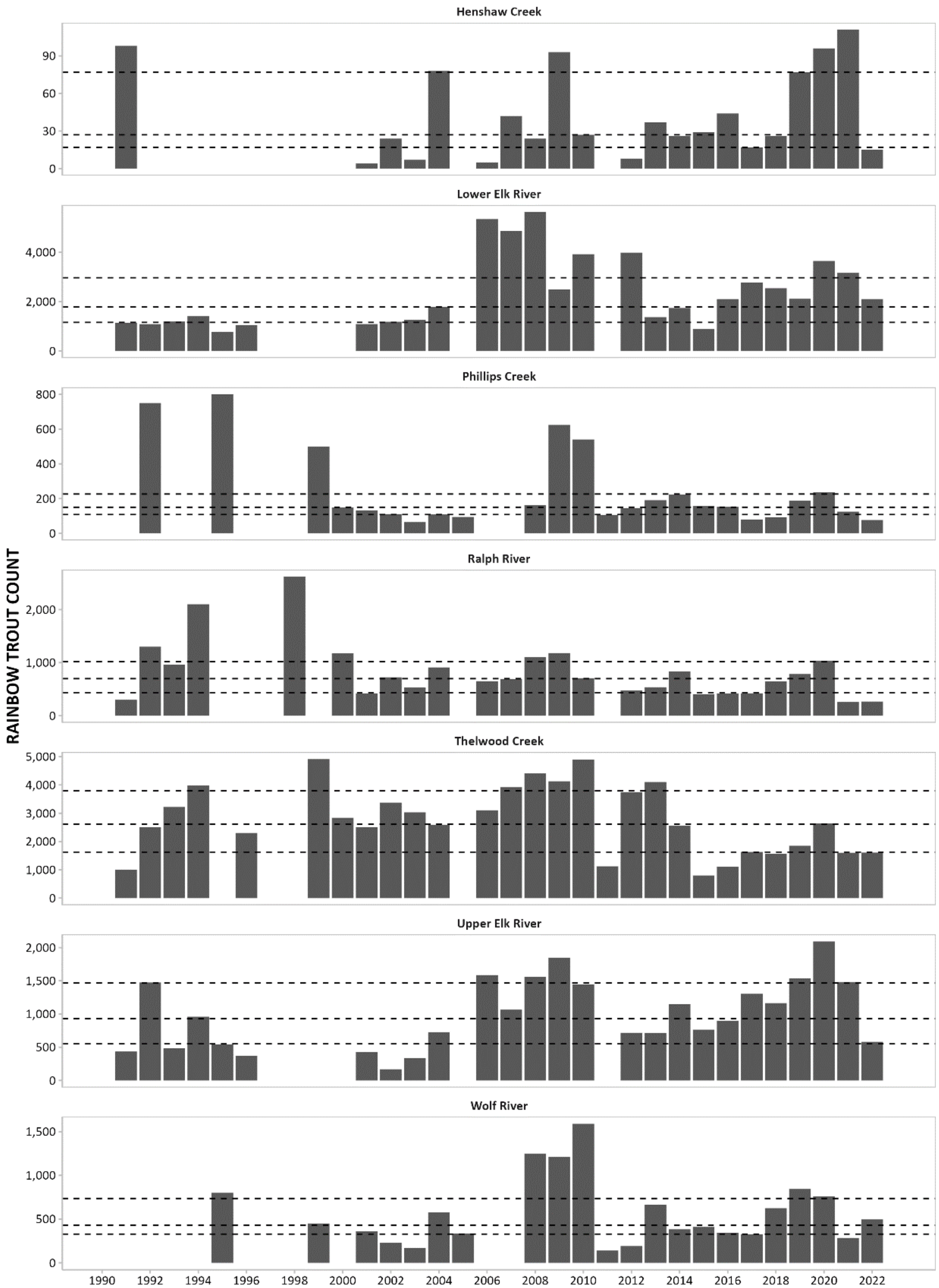
3.3.3.3. Rainbow Trout

There was high variability in adult Rainbow Trout counts among years for individual tributaries, and no clear trends across the entire time series (Table 21, Figure 28)[3]. There was an increasing trend during the last four years in Henshaw Creek (Figure 28) except for 2022. Although there was no clear temporal trend, the counts of adult Rainbow Trout were synchronous among streams, suggesting similar environmental conditions over broader geographic regions but different environmental conditions among streams.

No adult Rainbow Trout were recorded in Fry Creek in March 2022; however, this was comparable to sampling results from spring surveys in previous years (Table 22).

[3] Please note there was a mistake in this plot in the Year 8 report, which has been corrected here.

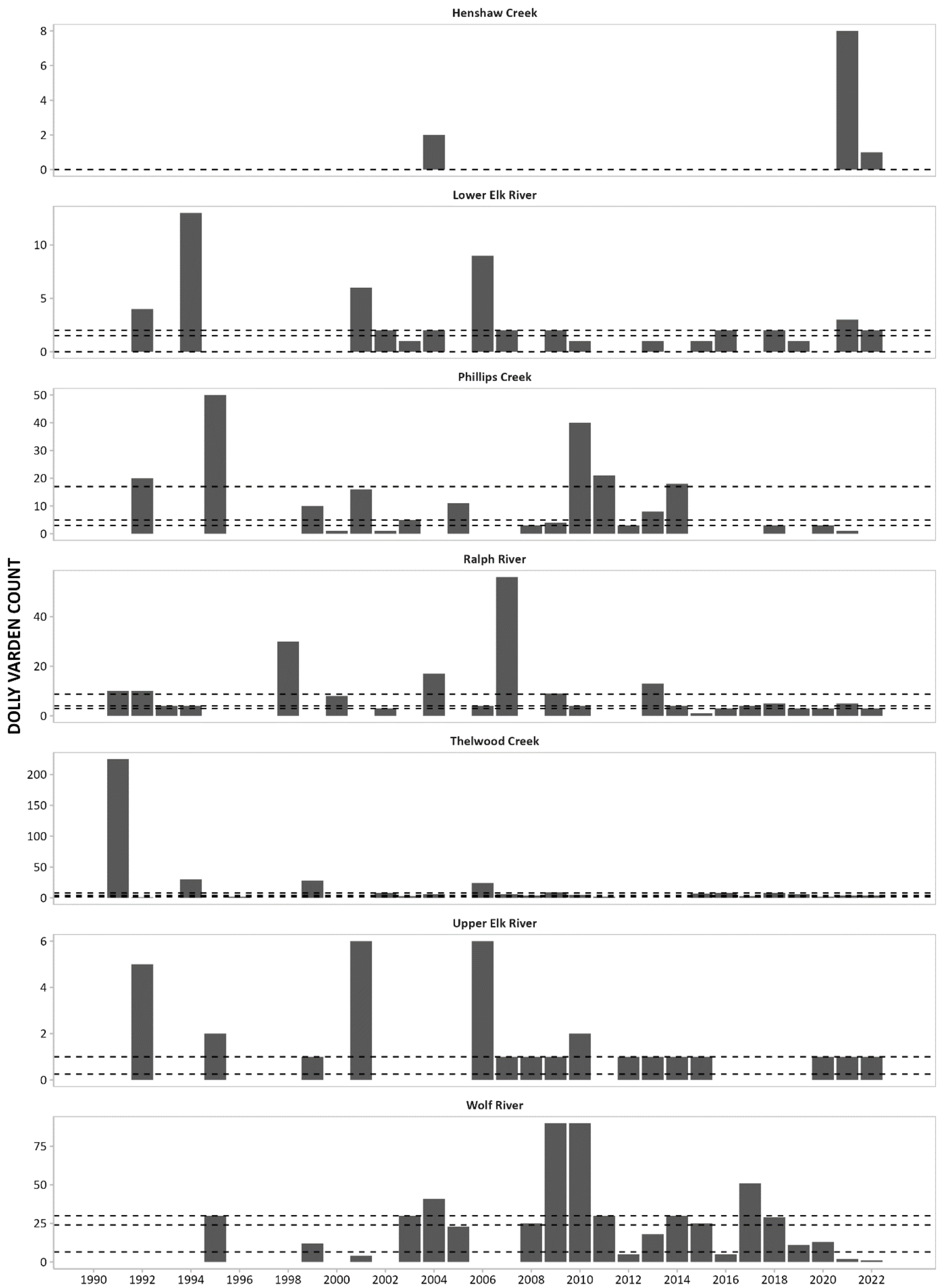
Figure 28. Adult Rainbow Trout counts in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir (1990-2022). Dotted horizontal lines represent 25th, 50th and 75th quantiles. Not all waterbodies were surveyed all years. Historical data (prior to 2014) were provided by BCCF (Pellett 2013).



3.3.3.4. Dolly Varden

The data presented here are from surveys completed outside the Dolly Varden spawning period, so any trends should be interpreted cautiously. The 2022 adult Dolly Varden counts were low (range = 0 to 4), 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, Figure 29). Of the seven survey reaches in Buttle Lake and Upper Campbell Reservoir, the 2022 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 (2022, *n* = 1; historical range = 0 to 90; median = 24).

Figure 29. Adult Dolly Varden counts in the tributaries of Buttle Lake, Lower Campbell Reservoir and Upper Campbell Reservoir (1990-2022). 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).



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 spawning habitat, as estimated by 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 likely not to the extent assumed during development of the Water Use Plan. The following sections highlight the main conclusions for each component of the study conducted in Year 9.

4.2. Effective Spawning Habitat (ESH)

The Year 9 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 2022, the ESH for Cutthroat Trout and Rainbow Trout in Upper Campbell Reservoir were lower than previous years 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). 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 the Cutthroat Trout population in the Upper Campbell Reservoir. The inundation of redds and related embryo mortality is expected to be independent of density. However, if spawning habitat is not limiting then population level effects may be absent or muted. Given the timing of spawning and incubation of Dolly Varden relative to reporting requirements, ESH metrics could only be calculated until 2021. ESH for Dolly Varden in 2021 was quite low for both reservoirs. Given the low reservoir elevations observed in the Upper Campbell Reservoir in the fall of 2022, ESH for Dolly Varden is predicted to be low compared to previous monitoring years.

4.3. Population Index for Upper and Lower Campbell Reservoirs

The Year 9 sampling results (2022) provide a ninth 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 year to develop abundance measures for individual ages and test the management hypotheses described in Section 1.4.

There were substantial inter-annual differences in age-specific CPUE of Cutthroat Trout and Rainbow Trout. CPUE of Cutthroat Trout aged ≥6+ in 2022 were among the lowest recorded during this monitoring program, whereas CPUE of Cutthroat Trout aged 4+ were above their age-specific average CPUEs.

CPUE of Rainbow Trout aged 4+ and 5+ were the largest recorded during this monitoring program. Relative condition of Rainbow Trout age ≥6+ and 5+ were lower than expected. Analysis of trends in relative condition of adult Cutthroat Trout and Rainbow Trout were carried out separately and are reported in Kim *et al.* (2023b).

4.4. Snorkel Survey of Spawners in Reservoir Tributaries

Linear densities (i.e., fish / m of stream length) of Rainbow Trout were higher in Year 9 than in most waterbodies in previous years. This is likely attributed to being earlier in the Rainbow Trout spawning period than in previous years due to the cold spring which resulted in a large portion of observed fish being in pre-spawn condition. Linear densities of Cutthroat Trout and Dolly Varden were also below average densities recorded during this monitoring program in most waterbodies. However, summer survey timing targets Rainbow Trout, and not Cutthroat Trout or Dolly Varden.

The numbers of Rainbow Trout redds recorded in 2022 in the Upper Campbell Reservoir and Buttle Lake were lower than the waterbody-specific averages recorded during this monitoring program. It is not clear whether ESH is affecting the number of Rainbow Trout redds. This decrease in redd observations in 2022 could be attributed to a delayed Rainbow Trout spawning period in the Upper Campbell Reservoir and Buttle Lake tributaries, which is supported by the relatively high proportion of bright fish in pre-spawn condition (18.6 % in 2022 compared to the all monitoring years average of 7.5%) and low proportion of fish in post spawn condition (6.1 % in 2022 compared to the all monitoring years average of 11.6%). Given these observations it can be assumed that surveys did not capture peak redd counts for 2022. The number of Cutthroat Trout redds recorded in 2022 in Miller Creek was the highest recorded during this monitoring program, and the number of Cutthroat Trout redds recorded in Greenstone River and Fry Creek were above the average in those waterbodies during this monitoring program.

The snorkel survey results for spawning Rainbow Trout in tributaries of Buttle Lake and Upper Campbell Reservoir yielded fish counts above historical median averages in two streams: Lower Elk River and Wolf River, while counts in the remaining streams except the Upper Elk River and Thelwood Creek were similar to historical median averages. No adult Rainbow Trout were recorded in Fry Creek (tributary to Lower Campbell Reservoir) during 2022, representing low count numbers that matched the previous reference number of zero Rainbow Trout observed in 2004, 2014, and 2016-2021. Fish counts above the historical median average are likely attributed to a delayed spawning period in 2022. Rainbow Trout typically return to the lake post spawn. As surveys were conducted early in the spawning period, we expect more fish to be present in each waterbody. This is also supported by lower than waterbody-specific averages redd observations as many fish in the system had not yet spawned.

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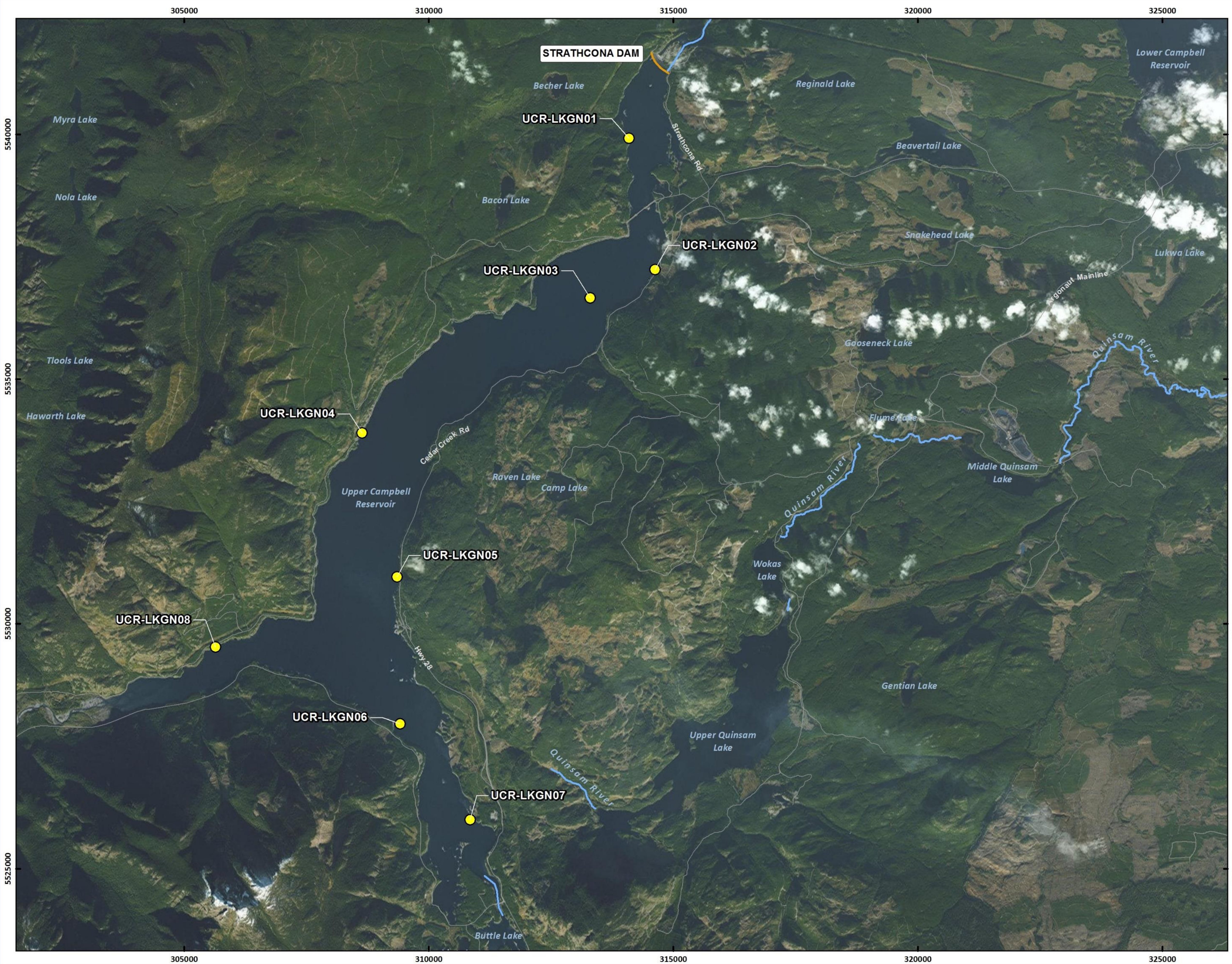
PROJECT MAPS

JHTMON Campbell River Water Use Plan

Upper Campbell Reservoir Gill Netting Locations



Legend

Sample Sites

- Gill Netting
- Dam

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 0.5 1 2 3 4 km

Scale: 1:75,000

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Date Saved: 16/11/2016
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 2

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APPENDICES

Appendix A. Aging Structure Collection and Reading Protocol - 2022

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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 Resources Inventory Committee Fish Collection Methods and Standards (RIC 1997) and Sjolund (1974).

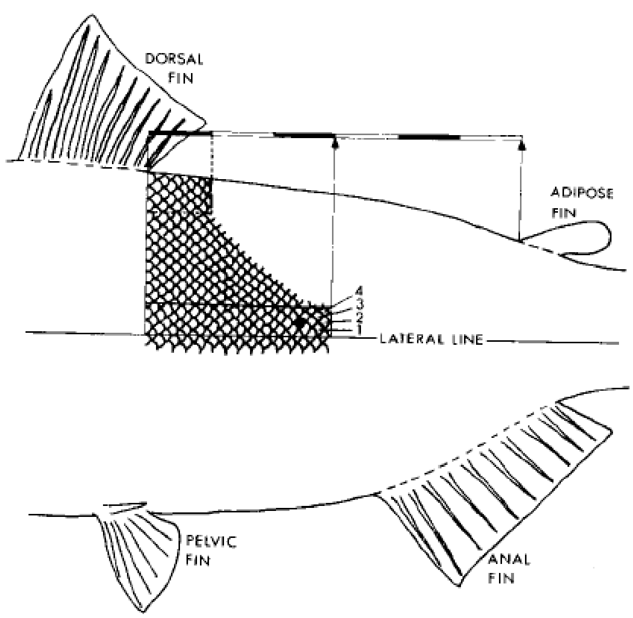
2. METHODS

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 Resources Inventory Committee Fish Collection Methods and Standards (RIC 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).

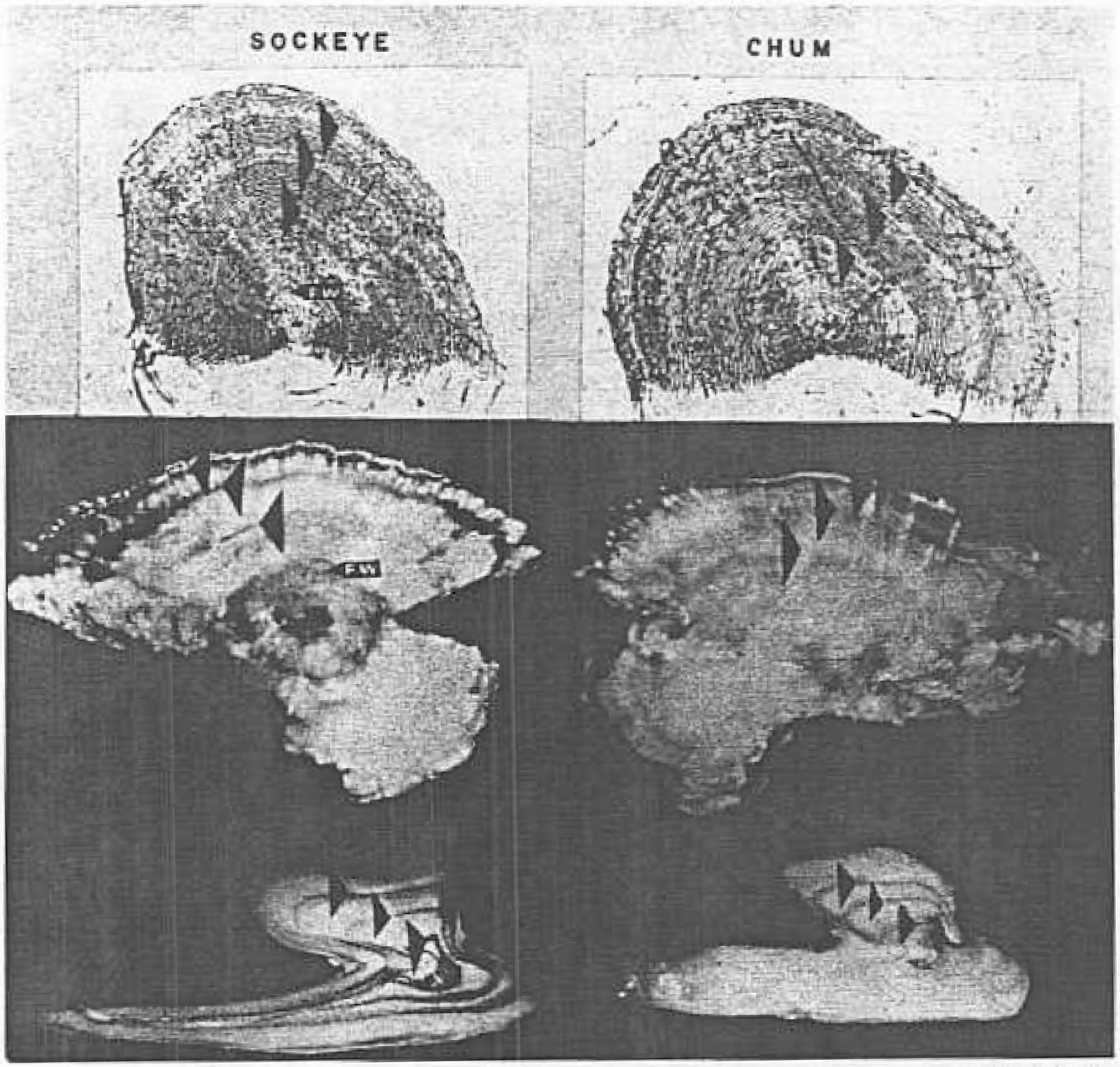


FIG. 4. Scale, otolith, and fin ray from a 1.3 sockeye and a 0.3 chum salmon: FW indicates freshwater annulus; arrows indicate ocean annuli.

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

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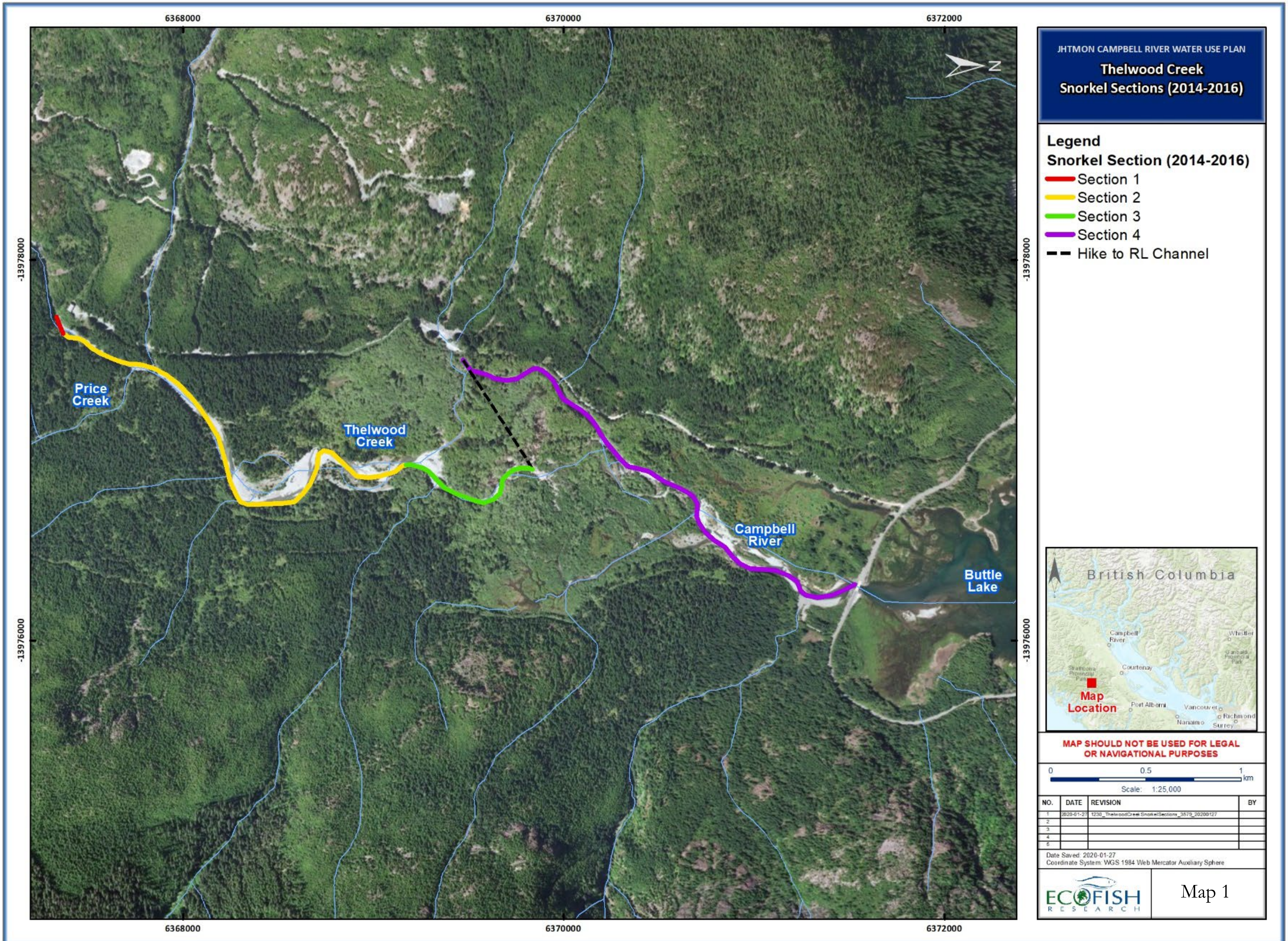
Appendix B. Thelwood Creek Geomorphological Changes (2014-2016, 2017-2018, 2019, and 2020-2022)

LIST OF MAPS



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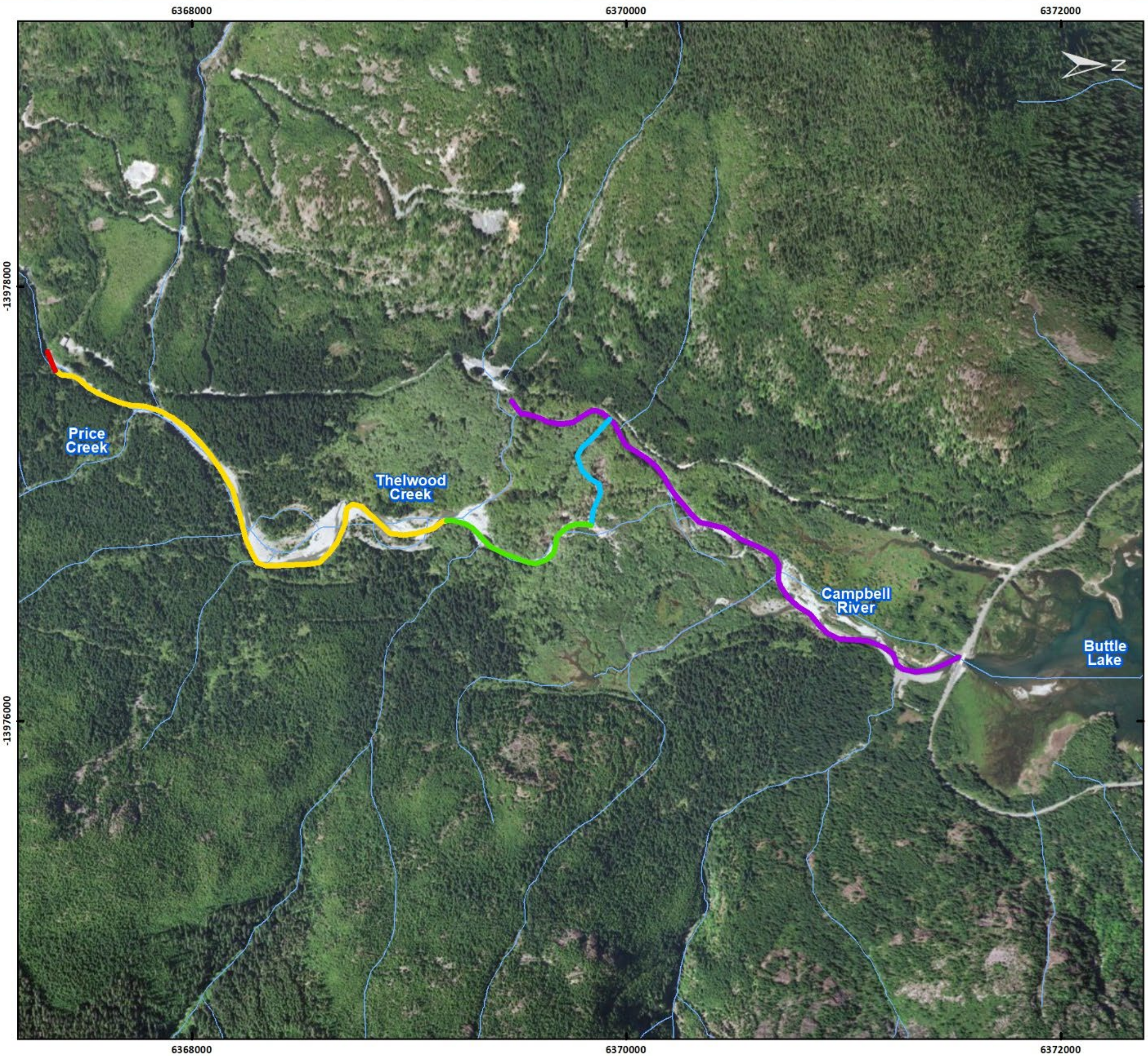
JHTMON CAMPBELL RIVER WATER USE PLAN

Thelwood Creek Snorkel Sections (2017-2018)



Legend

Snorkel Section (2017-2018)

- Section 1
- Section 2
- Section 3
- Section 4
- Newly Discovered Channel

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

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ECOFISH RESEARCH

Map 2

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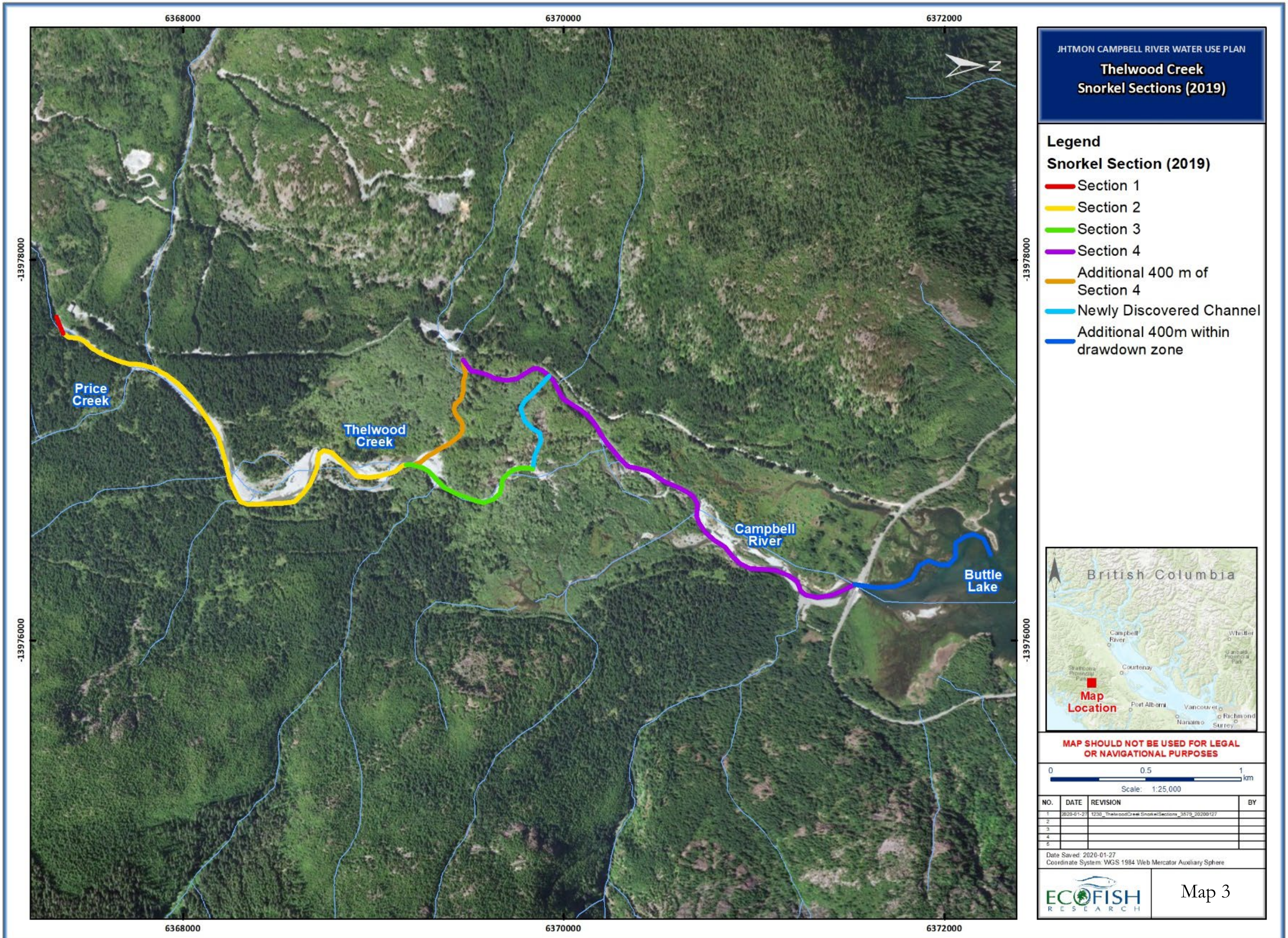

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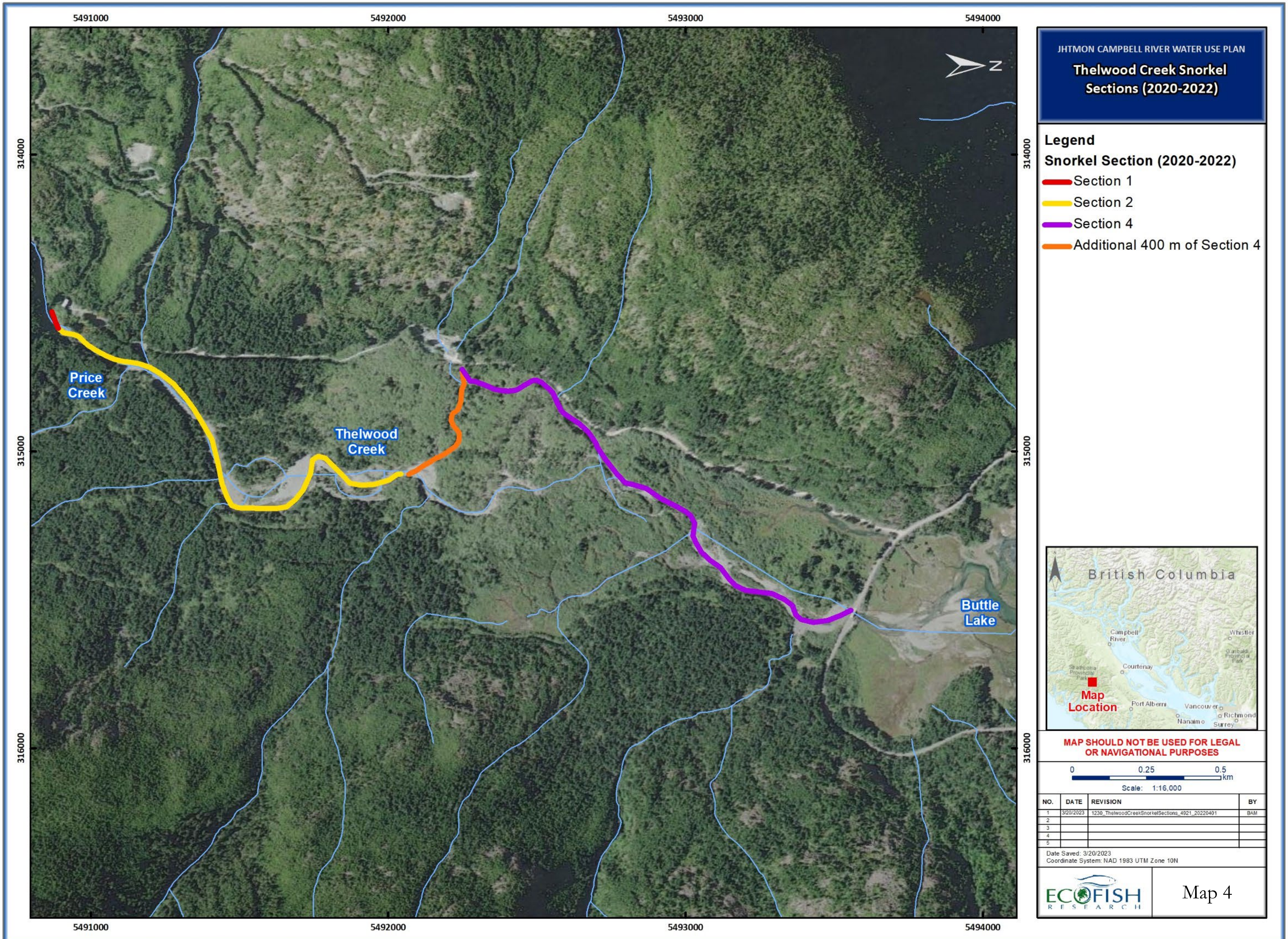

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Appendix C. Gill Net Capture Data and Representative Photographs - 2022

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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	2022-08-16	FL	2	2	RB	163	55.2	1.27								
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	1	RB	114	14.6	0.99		I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	1	RB	225	116.4	1.02		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	1	RB	150	45.5	1.35	M	I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	1	RB	241	149.3	1.07	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	4	RB	264	202.0	1.10	M	M	SC	6				
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	6	RB	274	187.0	0.91	M	M	SC	7				
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	172	63.6	1.25		I	SC	8				
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	195	92.0	1.24	M	I	SC	9				
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	208	103.0	1.14		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	160	55.2	1.35		I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	199	94.6	1.20		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	187	69.5	1.06		I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	201	90.4	1.11		I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	181	64.9	1.09	M	I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	161	52.8	1.27		I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	167	55.0	1.18		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	192	63.3	0.89	F	I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	167	54.9	1.18	F	I						
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Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	175	75.2	1.40		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	182	60.4	1.00		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	217	123.2	1.21	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	241	162.2	1.16	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	173	65.9	1.27		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	197	93.9	1.23		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	183	75.0	1.22		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	169	47.5	0.98		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	191	82.1	1.18		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	228	119.6	1.01		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	168	55.9	1.18		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	175	67.3	1.26	M	I						

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

Table 1. Continued (2 of 7).

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	2022-08-16	FL	2	5	RB	199	76.1	0.97	M	I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	190	84.7	1.23		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	210	105.4	1.14		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	171	71.8	1.44		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	232	128.5	1.03	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	186	79.9	1.24		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	233	134.6	1.06		UNK						
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Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	229	130.7	1.09	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	5	RB	227	142.8	1.22	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	238	140.1	1.04		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	216	127.1	1.26		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	226	133.5	1.16	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	236	113.8	0.87	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	225	123.2	1.08		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	240	158.1	1.14	F	M						
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Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	225	123.0	1.08		UNK						
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Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	239	144.8	1.06	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	232	148.9	1.19	F	M						
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Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	240	168.9	1.22	F	M						
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Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	272	175.5	0.87		UNK	SC	63				
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	258	158.5	0.92	F	M	SC	64				
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	270	180.7	0.92		UNK	SC	65				
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	FL	2	3	RB	239	141.7	1.04	M	I						

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

Table 1. Continued (3 of 7).

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	2022-08-16	FL	2	3	RB	280	202.4	0.92	F	M	SC	67				
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	1	NFC											
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	4	RB	187	82.7	1.26		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	162	64.4	1.51								
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	126	23.7	1.18		I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	140	0.0	0.00		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	182	75.5	1.25		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	227	132.5	1.13		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	194	81.0	1.11		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	164	56.7	1.29		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	228	149.6	1.26	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	192	91.0	1.29		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	218	113.7	1.10		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	211	101.1	1.08		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	228	142.3	1.20		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	5	RB	160	48.9	1.19	M	I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	230	140.0	1.15	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	199	104.1	1.32	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	224	121.3	1.08	F	I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	248	141.7	0.93	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	258	202.2	1.18	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	265	195.0	1.05	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	234	133.7	1.04	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	230	115.5	0.95	M	I						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	220	111.1	1.04	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	219	126.6	1.21	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	229	139.5	1.16	M	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB/CT	255	170.3	1.03	F	I					FC	26
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	215	122.3	1.23	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	262	203.5	1.13	F	M						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB	235	148.8	1.15		UNK						
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	CT	267	180.5	0.95	F	I	SC	30	OT	30		
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	CT	261							OT	31		

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

Table 1. Continued (4 of 7).

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	2022-08-16	SK	1	3	CT	280							OT	32		
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	CT	253	196.1	1.21	M	I	SC	33	OT	33		
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	RB/CT	287	258.0	1.09	F	I					FC	34
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	3	CT	312	303.0	1.00	F	M	SC	35	OT	35		
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	6	CT	193	110.5	1.54								
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	6	CT	292	252.0	1.01	F	M	SC	37	OT	37		
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	6	RB/CT	296	284.0	1.10	F	M					FC	38
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	6	CT	356	537.0	1.19	M	M	SC	39	OT	39		
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	2	CT	380			F	M	SC	40	OT	40		
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	2	CT	356	510.0	1.13	M	M	SC	41	OT	41		
Upper Campbell Reservoir	UCR-LKGN06	2022-08-16	SK	1	2	CT	426	818.0	1.06	M	M	SC	42	OT	42		
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	1	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	2	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	4	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	5	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	6	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	3	RB	294	231.0	0.91	M	M	SC	1				
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	3	RB	256	197.0	1.17	M	M	SC	2				
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	3	RB	263	178.0	0.98	F	M	SC	3				
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	3	RB	281	226.0	1.02	M	M	SC	4				
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	FL	2	3	RB	285	224.0	0.97		UNK	SC	5				
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	3	2	RB											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	3	1	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	3	3	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	3	4	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	2	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	4	NFC											
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	1	RB	116	20.7	1.33		I						
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	1	RB	127				I						
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	1	RB	129				I						
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	3	RB	257	143.0	0.84	F	M	SC	4				
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	3	RB	267	192.0	1.01	M	M	SC	5				
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	3	RB	236	128.0	0.97	F	M						

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

Table 1. Continued (5 of 7).

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	2022-08-16	SK	1	3	UNK	240										
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	6	CT	352	418.0	0.96			SC	8	OT	8		
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	6	CT	373	479.0	0.92	F	M	SC	9	OT	9		
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	5	CT	265				UNK			OT	10		
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	5	RB	242	176.0	1.24	F	M						
Upper Campbell Reservoir	UCR-LKGN04	2022-08-16	SK	1	5	CC	135										
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	2	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	4	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	6	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	1	CT	150	39.0	1.16		I	SC	1	OT	1		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	1	CT	135	25.4	1.03		I	SC	2	OT	2		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	1	CT	137	25.9	1.01		I	SC	3	OT	3		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	1	RB	124	21.9	1.15		I	SC	4				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	1	RB	117	19.4	1.21		I	SC	5				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	5	RB	237	152.9	1.15	M	M	SC	6				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	5	RB	175	70.3	1.31		I	SC	7				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	5	RB	174	67.5	1.28	M	I	SC	8				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	5	RB	157	49.0	1.27	M	I						
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	5	RB	159	57.1	1.42	M	I						
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	5	RB	193	74.3	1.03	M	I	SC	11				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	3	RB	211	108.3	1.15	M	M	SC	12				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	3	RB	220	138.4	1.30		UNK	SC	13				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	3	RB	269	192.6	0.99	F	M	SC	14				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	3	RB	246	144.0	0.97	F	M	SC	15				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	FL	2	3	RB	240	130.1	0.94	F	M	SC	16				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	2	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	4	NFC											
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	1	RB	130				I						

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

Table 1. Continued (6 of 7).

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	2022-08-15	SK	1	5	RB	275	215.0	1.03		UNK	SC	2				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	5	RB	163	61.8	1.43		I	SC	3				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	5	CT	195	72.8	0.98	M	I	SC	4	OT	4		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	5	RB/CT	249	162.4	1.05	F	I	SC	5	OT	5	FC	5
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	5	CT	274	192.0	0.93	F	I	SC	6	OT	6		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	5	CT	281	210.0	0.95	M	I	SC	7	OT	7		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	5	CT	218	96.4	0.93	M	I	SC	8	OT	8		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	5	UNK	245										
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	5	CC	120										
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	6	CT	334	387.0	1.04	F	M	SC	11	OT	11		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	6	RB	298	246.0	0.93	F	M	SC	12				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	6	RB	250	198.0	1.27	F	M	SC	13				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	3	CT	290	245.0	1.00	M	I	SC	14	OT	14		
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	3	RB	280	273.0	1.24	M	M	SC	15				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	3	RB	220	128.0	1.20	M	M						
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	3	RB	280	174.0	0.79	F	M	SC	17				
Upper Campbell Reservoir	UCR-LKGN02	2022-08-15	SK	1	3	CT	270										
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	2	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	3	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	5	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	128	20.5	0.98		I	SC	1				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	161	59.9	1.44	M	I	SC	2				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	130	29.1	1.32	M	I	SC	3				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	103	14.1	1.29		I	SC	4				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	104	14.1	1.25		I	SC	5				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	100	12.5	1.25		I	SC	6				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	115	20.1	1.32	M	I	SC	7				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	98	11.8	1.25		I	SC	8				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	1	RB	93	11.2	1.39		I	SC	9				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	4	RB	269	217.0	1.11		UNK	SC	10				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	6	CT	334	410.0	1.10	F	M	SC	11	OT	11		
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	6	CT	281	217.0	0.98	F	I	SC	12	OT	12		
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	6	CT	262	194.0	1.08	M	I	SC	13	OT	13		

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

Table 1. Continued (7 of 7).

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	2022-08-15	SK	1	6	CT	320							OT	14		
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	6	RB	244	144.0	0.99	M	I	SC	15				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	SK	1	6	RB	227	128.0	1.09	M	I	SC	16				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	FL	2	6	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	FL	2	4	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	FL	2	2	NFC											
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	FL	2	1	RB	97	11.0	1.21		I	SC	1				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	FL	2	5	RB	162	51.0	1.20		I	SC	2				
Upper Campbell Reservoir	UCR-LKGN01	2022-08-15	FL	2	3	RB	230	134.0	1.10	F	M	SC	3				

[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 2022 gill net surveys.

Figure 2. Example of typical gill net gear deployment location (UCR-LKGN04) during 2022 gill net surveys.

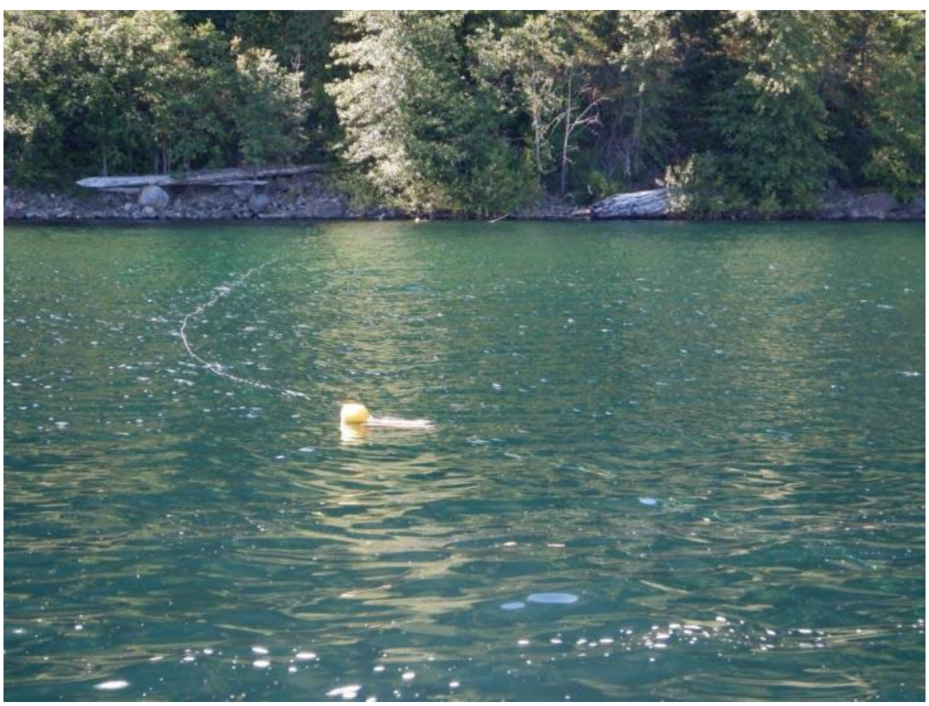

Figure 3. 334 mm Cutthroat Trout captured at UCR-LKGN01 on August 15, 2022.

Figure 4. 135 mm Cutthroat Trout captured at UCR-LKGN02 on August 15, 2022.

Figure 5. 334 mm Cutthroat Trout captured at UCR-LKGN02 on August 15, 2022.

Figure 6. 352 mm Cutthroat Trout captured at UCR-LKGN04 on August 16, 2022.

Figure 7. 426 mm Cutthroat Trout captured at UCR-LKGN06 on August 16, 2022.

Figure 8. 267 mm Cutthroat Trout captured at UCR-LKGN06 on August 16, 2022.

Figure 9. 100 mm Rainbow Trout captured at UCR-LKGN01 on August 15, 2022.

Figure 10. 269 mm Rainbow Trout captured at UCR-LKGN01 on August 15, 2022.

Figure 11. 280mm Rainbow Trout captured at UCR-LKGN02 on August 25, 2022.

Figure 12. 267 mm Rainbow Trout captured at UCR-LKGN04 on August 16, 2022.

Figure 13. 114 mm Rainbow Trout captured at UCR-LKGN06 on August 18 2022.

Figure 14. 175 mm Rainbow Trout captured at UCR-LKGN06 on August 18, 2022.

Appendix D. Snorkel Survey Observations and Representative Photographs - 2022

LIST OF FIGURES

Figure 1. Looking upstream at Greenstone River snorkel extreme windfall on April 19, 2022.

Figure 2. Looking at spawning habitat at Greenstone River snorkel on April 19, 2022.

Figure 3. Un-eyed eggs observed at Greenstone River on April 19, 2022.

Figure 4. Looking downstream at Miller Creek snorkel start on March 7, 2022.

Figure 5. Looking upstream at Miller Creek snorkel end on March 7, 2022.

Figure 6. Looking downstream at Fry Creek snorkel start on March 7, 2022.

Figure 7. Looking upstream at Fry Creek snorkel end on March 7, 2022.

Figure 8. Un-eyed egg observed at a redd at Fry Creek on March 7, 2022.

Figure 9. Redd observed at Fry Creek on March 7, 2022.

Figure 10. Looking downstream at Ralph River snorkel start on June 1, 2022.

Figure 11. Looking upstream at Ralph River snorkel end on June 1, 2022.

Figure 12. Redds observed at Ralph River on June 1, 2022.

Figure 13. Looking downstream at Henshaw Creek snorkel start on June 1, 2022.

Figure 14. Looking upstream at Henshaw Creek snorkel end on June 1, 2022.

Figure 15. Un-eyed egg observed at Henshaw Creek on June 1, 2022.

Figure 16. Rainbow Trout observed at Henshaw Creek on June 1, 2022.

Figure 17. Looking downstream at Wolf River snorkel start on June 7, 2022.

Figure 18. Looking upstream at Wolf River snorkel end on June 7, 2022.

Figure 19. Rainbow Trout observed at Wolf River snorkel on June 7, 2022.

Figure 20. Redds observed at Wolf River snorkel on June 7, 2022.

Figure 21. Un-eyed egg observed at Wolf River snorkel on June 7, 2022.

Figure 22. Looking downstream at Phillips Creek snorkel start on June 7, 2022.

Figure 23. Looking upstream at Phillips Creek snorkel end on June 7, 2022.

Figure 24. Rainbow Trout observed at Phillips Creek snorkel on June 7, 2022.

Figure 25. Un-eyed egg observed at Phillips Creek snorkel on June 7, 2022.

Figure 26. Looking downstream at Elk River upper section snorkel start on June 8, 2021.

Figure 27. Looking upstream at Elk River upper section snorkel end on June 8, 2021.

Figure 28. Un-eyed eggs observed at Elk River upper section snorkel on June 8, 2021.

Figure 29. Looking downstream at Elk River and Drum Creek confluence in the Elk River upper section snorkel on June 8, 2022.

Figure 30. Eyed eggs observed in Drum Creek in the Elk River upper section on June 8, 2022.

Figure 31. Rainbow Trout observed in Drum Creek in the Elk River upper section on June 8, 2022.

Figure 32. Looking downstream at Elk River lower section snorkel end on June 8, 2022.

Figure 33. Looking upstream at Elk River lower section snorkel end on June 8, 2022.

Figure 34. Un-eyed egg observed at Elk River lower section snorkel on June 8, 2022.

Figure 35. Redd observed at Elk River lower section snorkel on June 8, 2022.

Figure 36. Rainbow Trout observed at Elk River lower section snorkel on June 8, 2022.

Figure 37. Looking downstream at Thelwood Creek snorkel start on June 9, 2022.

Figure 38. Looking upstream at Thelwood Creek snorkel end on June 9, 2022.

Figure 39. Rainbow Trout observed at Thelwood Creek snorkel on June 9, 2022.

Figure 40. Un-eyed egg observed at Thelwood Creek snorkel on June 9, 2022.