# Campbell River Project Water Use Plan

## Upper and Lower Campbell Lake Fish Spawning Success Assessment

## Implementation Year 4

## Reference: JHTMON-3

***JHTMON-3: Upper and Lower Campbell Lake Fish Spawning Success Assessment Year 4 Annual Monitoring Report***

**Study Period: 2017**

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

**July 23, 2018**

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

## Year 4 Annual Monitoring Report

Prepared for:

**BC Hydro Water License Requirements**
**6911 Southpoint Drive, 11th Floor**
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July 23, 2018

Prepared by:

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**Ecofish Research Ltd.**

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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, 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. 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. 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 functional spawning habitat is sufficient to allow the salmonid populations to fully seed the reservoirs.

*Gill Netting Surveys*

Gill netting surveys between August 21 and August 23, 2017 in Upper Campbell Reservoir resulted in the capture of 45 Cutthroat Trout, 103 Rainbow Trout, one Dolly Varden, three sculpin, and five Cutthroat Trout/Rainbow Trout hybrids. Catch per unit effort (CPUE) ranged from 0.07 to 0.40 fish/net hour for Cutthroat Trout and 0.26 to 0.52 fish/net hour for Rainbow Trout.

A length-age relationship was developed for both Cutthroat Trout and Rainbow Trout captured during the Year 4 gill netting surveys. Age breaks were determined for 1+ and 2+ parr, with adult fish (3+) aged using scale and fin-ray analysis.

Cutthroat Trout were most abundant at bottom and gill nets depths of 7.5m. Rainbow Trout were most abundant in gill nets set in the offshore pelagic zone, particularly at depths less than 12.5m.

*Snorkel Surveys*

Snorkel surveys were undertaken in the Lower Campbell Reservoir during March and April 2017, to target the Cutthroat Trout spawning period, and in the Buttle Lake and Upper Campbell Reservoir in June 2017, to target the Rainbow Trout spawning period. The survey results for Rainbow Trout were incorporated into the existing enumeration of adult spawning fish in the six tributaries of Buttle Lake and Upper Campbell Reservoir since 1990.

Snorkel surveys were undertaken at three tributaries of Lower Campbell Reservoir for adult Cutthroat Trout spawners in 2017. Miller Creek and Fry Creek were sampled on March 23, 2017; Greenstone River was sampled on April 21, 2017 due to colder water conditions. Adult Cutthroat Trout were observed in Miller Creek (*n* = 163) and Greenstone River (*n* = 59), but not Fry Creek. However, Cutthroat Trout redds were observed in all three tributaries and were most abundant in Miller Creek (*n* = 249), followed by Fry Creek (*n* = 39) and Greenstone River (*n* = 17). Juvenile

Cutthroat Trout were not observed during Spring snorkel surveys. Cutthroat Trout densities were highest in Miller Creek (407.5 fish/km), followed by Greenstone River (24.9 fish/km). The condition and high number of adult Cutthroat Trout observed in Miller Creek suggest that spawning was ongoing on the survey date but that peak spawning occurred prior to March 23, 2017. The Green River snorkel survey was likely completed at the onset of peak spawning given that the number of adult Cutthroat Trout in moderately coloured condition (n = 40) and mid-spawn condition (n = 19) was greater than the number of observed redds (n = 17). In Fry Creek, the presence of redds and absence of adult Cutthroat suggests that peak spawning occurred prior to the snorkel survey. Snorkel surveys targeting adult Rainbow Trout spawners were undertaken in tributaries to Buttle Lake and Upper Campbell Reservoir during low flow conditions from June 5 to 8, 2017. Rainbow Trout redds were recorded in all sampled tributaries. The highest number of redds was observed in the Lower Elk River (568 redds), followed by Thelwood Creek (576 redds), upper Elk River (519 redds), Ralph River (196 redds), and Wolf River (117 redds). The majority of adult Rainbow Trout observed were in mid-spawning condition and highest numbers were recorded from the lower Elk River and Thelwood Creek. Low numbers of adult Rainbow Trout were recorded from Henshaw Creek. Observed densities of Rainbow Trout were greatest in Wolf River (1,090 fish/km), Thelwood Creek (653 fish/km) and Lower Elk River (516 fish/km). This order was similar to the Year 1, 2 and 3 surveys; except that Lower Elk River replaced Ralph River with the third highest density of adult fish.

*ESH Model Results*

The Effective Spawning Habitat (ESH) Performance Measure Model (described in section 1.2 and Smyth and Hatfield 2016) is a computer model that quantifies the amount of spawning habitat within the drawdown zone that is available to fish, and is not 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 in Upper Campbell Reservoir, and particularly for Cutthroat Trout. As there are only three years of ESH and CPUE data (2014-2017) for Cutthroat Trout and Rainbow Trout, and only two years of data (2014-2016) for Dolly Varden, we did not proceed with any analyses linking ESH values with age specific CPUE estimates, and recommend deferring this analysis to Year 5.

*Spawning Habitat Availability*

Spawning habitat availability was assessed across the entire length of accessible stream reaches entering the Lower Campbell Reservoir, Upper Campbell Reservoir (Elk River and associated tributaries) and Buttle Lake. A combination of UAV aerial surveys and ground-based field gravel surveys were used to generate a series of spawning habitat indicator metrics in GIS (geographic information system) maps. These metrics include linear and area-based summaries as well as a qualitative classification of reaches as low, medium or high quality spawning habitat. Summaries were generated across the drawdown zones and upstream sections of waterbodies.

Overall, approximately 80% of all accessible spawning habitat was located in upstream areas above the drawdown zones; however, results varied across individual waterbodies. The drawdown zones of the Elk River and all waterbodies within the Lower Campbell Reservoir were characterized as having a lower quality and quantity of spawning habitat relative to upstream areas. Waterbodies within Buttle Lake all had a larger portion of spawning habitat located within the drawdown zones relative to upstream areas. Spawning habitat within the upper limits of the drawdown zones of creeks entering Buttle Lake was characterized as being of high quality, although its overall extent was small. Despite the larger proportion of spawning habitat within the drawdown zones relative to upstream areas of Buttle Lake waterbodies, the upstream sections of the Elk River and Elk River tributaries accounted for over 70% of all accessible spawning habitat within the Upper Campbell/Buttle Lake Reservoir.

The methods used in this study to quantify spawning habitat within and above the drawdown zones were developed to integrate data sources from different field programs as well as quantify spawning habitat over a large area (over 31 km of streams covering 115 ha). Although the metrics used to quantify spawning habitat were relatively simple (e.g., linear distance, wetted area, channel width) the consistency of our results across linear and area-based metrics suggests that results would be relatively similar with the addition of other more customized spawning habitat indicator variables.

*Spawning Habitat Use*

Spawning habitat use was assessed across the entire length of accessible stream reaches throughout waterbodies entering the Lower Campbell Reservoir, Upper Campbell Reservoir (Elk River and associated tributaries) and Buttle Lake. Spawning habitat use was determined by the abundance and distribution of redds within the drawdown zones and upstream areas of each waterbody.

Overall, we identified a greater total number of redds ($n$ = 2,959) in upstream areas relative to redds located within the drawdown zones ($n$ = 632). The abundance and distribution of redds (habitat use) were largely consistent with habitat availability. Within drawdown zones of the Elk River and all waterbodies within the Lower Campbell Reservoir we found a much greater portion (97%) of redds in upstream areas relative to within the drawdown zones; however, for waterbodies within Buttle Lake approximately 90% of redds ($n$ =536) were located within the drawdown zones relative to upstream areas ($n$ = 55). Based on habitat availability alone, we expected that a large number of redds would be located within the drawdown zone of the Elk River; however, all redds within this waterbody were located further upstream in higher quality spawning habitat. Redds within the drawdown zones predominantly occupied the upstream most section of the drawdown zones along the thalweg mainstem in deeper fast moving water with abundant large gravel substrates. In upstream areas, redds were deposited in shallower water in side channels and along the margin of the mainstem. Across most waterbodies, redds occupied the full length of accessible spawning habitat prior to barriers and obstructions preventing fish passage, suggesting that spawning habitat use is not strongly limited by distance to lake.

In future phases we suggest that additional work be undertaken to quantify uncertainty and potential offset between the water surface elevation reported by WSC gauges and the water surface elevation recorded onsite relative to installed benchmarks.

**MON-3 Status of Objectives, Management Questions and Hypotheses after Year 4.**

| Study Objectives | Management Questions | Management Hypotheses | Year 4 (fiscal year 2017) 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 effective spawning habitat. 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 effective spawning habitat is sufficient to allow the salmonid populations to fully seed the reservoirs.<br><br>Implementation of the WUP in the Upper and Lower Campbell Reservoirs is predicted to increase the area of effective spawning habitat for both Cutthroat Trout and | 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. | The Year 4 results provide data that will contribute to testing this monitoring hypothesis. Trends in adult trout abundance require a longer period of monitoring before this management hypothesis can be tested.<br><br>Data were collected as planned, from standardized snorkel surveys of spawning fish in tributaries, and gill netting of multiple cohorts in reservoirs. The current study design is expected to answer the hypothesis. |
| | Are the trout populations in Upper and Lower Campbell reservoirs limited by the availability of effective spawning habitat? | $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. | Analysis of population abundance vs. ESH correlations will require data collection over a longer time frame. Testing of this hypothesis is expected to begin in Year 5.<br><br>The current study design is appropriate to address this hypothesis. |

| Study Objectives | Management Questions | Management Hypotheses | Year 4 (fiscal year 2017) Status |
|---|---|---|---|
| Rainbow Trout.<br><br>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 effective spawning habitat. | 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$3: The proportion of mature adults that spawn in the drawdown zones of Upper and Lower Campbell reservoirs is not biologically significant.<br><br>$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. | It is expected that these hypotheses will be tested using data collected in Years 5. |

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# 1. INTRODUCTION

The goal of water use planning is to provide a balance between competing uses of water such as 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 local stakeholders, government agencies, and First Nations. The framework for water use planning requires that a WUP be reviewed on a periodic basis and that monitoring addresses outstanding management questions in the years following the implementation of a WUP.

As the Campbell River Water Use Plan process reached completion, a number of uncertainties remained with respect to the effects of BC Hydro operations on aquatic resources. A key question throughout the WUP process was "what limits fish abundance?" For example, are fish abundance and biomass limited by available habitat, food, environmental perturbations or ecological interactions? Answering this question is an important step to better understanding how human activities in the watershed affect fisheries, and in effectively managing water uses to protect and enhance aquatic resources. To address uncertainty in our understanding of the factors that limit fish abundance and biomass, monitoring programs were designed to assess whether fish benefits are being realized under the WUP operating regime and to evaluate whether limits to fish production could be improved by modifying operations in the future. The *Upper and Lower Campbell Lake Fish Spawning Success Assessment* (JHTMON-3) is one of a number of effectiveness monitoring studies within the Campbell River WUP. The objective of JHTMON-3 is to test salmonid recruitment (trout and char) in the Upper Campbell Reservoir (Upper Campbell Reservoir and Buttle Lake) and Lower Campbell Reservoir to help resource managers better understand the potential biological effects of BC Hydro operations. JHTMON-3 assesses the relationship between salmonid recruitment in the reservoirs and drawdown, specifically assessing whether population abundance of salmonids is limited by spawning habitat within the drawdown zone. During the WUP, an "Effective Spawning Habitat" (ESH) performance measure was used to evaluate water management alternatives. The ESH performance measure tracks available habitat in tributaries within the drawdown zone and whether this habitat becomes inundated by rising reservoir levels during the spawning and incubation period; the ESH performance measure was calculated separately for Cutthroat Trout, Rainbow Trout and Dolly Varden Char.

## 1.1. BC Hydro Infrastructure, Operations, and Monitoring Context

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 the diversion infrastructure and operations are provided in BC Hydro (2013).

### 1.1.1. 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 historic operational water elevation has been between 221.0 m and 210.0 m. The storage licence for operations in Buttle Lake and Upper Campbell Lake Reservoir are between 212.00 m to 220.98 m and 192.00 to 220.98, respectively, providing a combined estimated active storage in the reservoirs of 880.18 $m^3$ (as measured at Strathcona Dam; BC Hydro 2012).

#### 1.1.2. 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 historic operational water elevation has been between 178.3 m and 174.0 m, while the current storage licence limits for operation are between 178.3 m and 163.65 m (BC Hydro 2012).

### 1.2. 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 availability of effective spawning habitat. 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.

Comparisons of measurements of fish abundance and spawning success before and after WUP implementation were conducted to test the assumption that salmonid recruitment is limited by availability of effective spawning habitat. Positive salmonid population responses are expected to occur if the area of functional spawning habitat is indeed a limiting factor, given that implementation of the WUP is predicted to increase the area of effective spawning habitat for both Cutthroat Trout and Rainbow Trout. To facilitate a quantitative comparison, an "Effective Spawning Habitat" (ESH) Performance Measure Model was developed for Upper and Lower Campbell reservoirs during the Campbell River WUP process. The Performance Measure Model quantifies the amount of spawning habitat within the reservoir drawdown zone that is available during the spawning period and is subsequently not inundated by rising water elevation during incubation. Thus, the Performance Measure is used to track the amount of available spawning habitat that remains effective throughout the incubation period and can be calculated separately for the three salmonid species of interest.

# Project Overview


**Legend**

Dam

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 2 4 6 8 10 12 km

Scale: 1:300,000

| NO. | DATE | REVISION | BY |
|---|---|---|---|
| 1 | | 10/02/2015 1230_JHT_ProjectOverview_2015Feb10_LB | CGA |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

Date Saved: 10/02/2015
Coordinate System: NAD 1983 UTM Zone 10N

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Map 1

Path: M:\Projects-Active\1230_JHTMON\MXD\Overview\1230_JHT_ProjectOverview_2015Feb10_LB.mxd

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

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

And, by corollary:

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

In addressing the questions, the Monitor 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. [Note that this will be tested by undertaking redd surveys.]

$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. [Note that this will be tested by undertaking incubation studies, which were not a component of the Year 4 studies.]

### 1.3. Scope of the JHTMON-3 Study

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

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

Methods for this multi-year study have changed in accordance with results from previous years. Results from the Year 1 studies (Hatfield *et al*. 2015) indicated weaknesses with the study design and its ability to address some of the management questions. Trap net sampling was tested in Year 2 and it was decided that this method would not be continued. Trap netting was found to be most effective at catching sculpin and stickleback, while 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 conducted.

The implemented Year 4 program followed the approach adopted for Year 3, with the addition of spawning distribution component. Methods related to $H_0$1 and $H_0$2 in Year 4 involved:

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

Methods related to $H_0$3 involved:

1. Estimating spawning habitat availability using habitat surveys and aerial imagery; and
2. Estimating spawning habitat availability using redd surveys.

This report describes the methods, results, and conclusions of the Year 4 study. Where possible, results are compared with those from Years 1 to 3 and comparisons are made to historic data to investigate trends over time. We have not attempted to relate trends to specific causes or to formally test the impact hypotheses; testing of hypotheses is expected to occur starting later in the monitoring program.

# 2. METHODS

## 2.1. Sample Sites

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 and Map 3. 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 2015, 2016, and 2017.

### 2.1.1. Drawdown Zone Delineations

Previous studies indicate that salmonids spawn in tributaries to the reservoirs, both within and above the drawdown zones. To evaluate spawning habitat use and availability within and upstream of the drawdown zones, endpoint boundaries were defined for the upper and lower extent of the drawdown zones. This involved comparing upper and lower operational water levels of each reservoir to LiDAR elevation data, which were available from LiDAR surveys completed by Terra

Remote at low water in 2017 with average point spacing in the drawdown zones of approximately 0.5 m. This dataset was compared qualitatively to bathymetry data collected in 2010 by CRA Canada Surveys Inc.

The upper extent of the drawdown zones was defined as the annual maximum operating levels for each reservoir as specified in the 2012 BC Hydro WUP (BC Hydro, 2012). This elevation was 220.5 m and 178.3 m for the Upper Campbell Reservoir (including Buttle Lake) and the Lower Campbell Reservoir, respectively (BC Hydro, 2012). LiDAR data were used to locate these elevation end points given that tributary channel banks at these locations were void of vegetation cover.

The lower endpoints of drawdown zones were more challenging to locate. Minimum annual operational levels were not captured by any available data sources. We therefore defined the lower extent of the drawdown zones at the locations where the main thalweg became unconfined within the alluvial fan at the lake confluence. These locations roughly corresponded with the elevation of the preferred minimum operational water level in summer months (June 21$^{st}$ – Sept 10$^{th}$) (Upper Campbell Reservoir: 217.0 m; Lower Campbell Reservoir: 176.5 m). The selection of these locations as drawdown zone endpoints was supported by an absence of redds or suitable spawning habitat near or beyond these endpoints.

## 2.2. Population Index for Upper Campbell Reservoir

### 2.2.1. Field and Laboratory Work

#### 2.2.1.1. Gill Netting

The Year 4 gill netting surveys of Upper Campbell Reservoir were conducted using the same methods as Year 2 (2015) and Year 3 (2016) studies. The gill netting sampling objective was to produce a fish abundance index by species and age. Gill netting targeted rearing areas for younger fish and sampled the same six sites from 2015 and 2016 (Table 1). Similar to Year 2 and 3, sampling was undertaken in late summer, between August 21 and August 23, 2017, to obtain representative fish samples from Upper Campbell Reservoir (Map 2). Both floating and sinking gill nets were used to target specific strata within the water column.

At each site, one surface and one bottom overnight gill net was set, for a total of 12 overnight RISC nets sets in Upper Campbell Reservoir. 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. Two Nordic nets were used in addition to the RISC nets at sites UCR-LKGN04 and UCR-LKGN07; these 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 19 to 25 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 fin rays were taken from Rainbow Trout and Cutthroat Trout to allow for age classes to be assigned to both species. The aim of field protocols associated with this sampling was to ensure that all live fish were returned to the reservoir in good condition. Captured live fish were anaesthetized as necessary to reduce handling stress.

**Table 1. Sampling dates, site locations, and site conditions for Year 4 gill netting surveys on Upper Campbell Reservoir, August 2017.**

| Waterbody | Site | Sampling Date | UTM | | | Set # | Net Type | Net Position[1] | Net Length | Water Temp. (°C) | Turbidity[2] | Estimated Visibility (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Zone | Easting | Northing | | | | | | | |
| Upper Campbell Reservoir | UCR-LKGN01 | 21-Aug-2017 | 10U | 314096 | 5539930 | 1 | RISC | FL | 91.2 | 19.7 | C | 8 |
| | | | | | | 2 | RISC | SK | 91.2 | 19.7 | C | 8 |
| | UCR-LKGN02 | 21-Aug-2017 | 10U | 314629 | 5537246 | 1 | RISC | SK | 91.2 | 19.8 | C | 8 |
| | | | | | | 2 | RISC | FL | 91.2 | 19.8 | C | 8 |
| | UCR-LKGN04 | 22-Aug-2017 | 10U | 308638 | 5533904 | 1 | RISC | SK | 91.2 | 21.7 | C | 8 |
| | | | | | | 2 | RISC | FL | 91.2 | 21.7 | C | 8 |
| | | | | | | 3 | Nordic | SK | 13 | 21.7 | C | 8 |
| | UCR-LKGN06 | 22-Aug-2017 | 10U | 309419 | 5527967 | 1 | RISC | SK | 91.2 | 21.4 | C | 8 |
| | | | | | | 2 | RISC | FL | 91.2 | 21.4 | C | 8 |
| | UCR-LKGN07 | 23-Aug-2017 | 10U | 310848 | 5526008 | 1 | RISC | SK | 91.2 | 21.1 | C | 8 |
| | | | | | | 2 | RISC | FL | 91.2 | 21.1 | C | 8 |
| | | | | | | 3 | Nordic | SK | 13 | 21.1 | C | 8 |
| | UCR-LKGN08 | 23-Aug-2017 | 10U | 305645 | 5529532 | 1 | RISC | SK | 91.2 | 20.7 | C | 8 |
| | | | | | | 2 | RISC | FL | 91.2 | 20.7 | C | 8 |

[1] SK - Sinking, FL - Floating

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

### 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 to describe spatial patterns of fish relative abundance in Upper Campbell Reservoir. CPUE was computed by individual net panel to estimate species relative abundance by 5 m depth intervals.

Beginning in Year 5, CPUE from nearshore gill net sampling will be used as a population index to analyze trends in abundance by species and age class over time, and to test the hypothesized relationship between recruitment and ESH.

*Individual Fish Analysis*

Biological statistics computed for individual species in the gill net catch include mean and standard deviation of length and weight, length-frequency and age distributions, weight-length regressions, and Fulton's condition factor (Ricker 1975). Age distributions were calculated for trout only. Individuals partially consumed by crayfish were excluded from analyses to ensure accuracy of fork length and/or weight measurements.

*Age Cohort Analysis*

Aging of fish by examination of the scales and fin rays collected in the field was undertaken by experienced Ecofish fisheries biologists, by examination of growth rings on scales and fin rays. A subset of the scale samples were measured while the remainder of samples were stored in case additional samples are required. In cases where fin ray and scale samples from a single fish were measured and found to differ, the scale ages were assumed to be more accurate. Aging protocols are provided in Appendix A.

The age estimates from the fin ray and scale samples, as well as the length-frequency histograms, were used to generate bin sizes to estimate fish age based on fork length. Due to limitations of using bin sizes to accurately age older fish, bin sizes were only generated for fry (0+) and parr (1+ and 2+) fish. All other fish that were not aged using fin ray or scale samples and were larger than the bin sizes for age 2+ were classified as age "unknown". As more age data are collected, the age bins can be more clearly defined and it is expected that it will be possible to estimate the age of these "unknown" fish with moderate certainty by Year 5.

### 2.3. Snorkel Surveys of Spawners in Reservoir Tributaries

Snorkel surveys of spawners and redds were undertaken in the lower reaches of the tributaries of Buttle Lake, Upper Campbell Reservoir, and Lower Campbell Reservoir during the Cutthroat Trout and Rainbow Trout spawning periods. 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 the Year 1 (2014), Year 2 (2016), and Year 3 (2016). 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 2). 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 2017 surveys followed standardized survey methods within each reach, as conducted during the Year 1 to Year 3 (2014 to 2016) surveys, and historically by MFLNRO and BCCF (Pellett 2013). A number of variables were measured (Table 3) and photographs were taken of each site. Rainbow Trout was the target species for these historic surveys in Upper Campbell Reservoir tributaries and this focus was maintained for JHTMON-3 snorkel surveys to maximize comparability with historic records.

Similar to previous years, a fork length of 150 mm was designated as the boundary between juvenile classifications 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 (with the exception of Miller Creek; 90 mm to 180 mm for parr), during the 2017 surveys.

Surveys for the Cutthroat Trout spawning period were carried out in tributaries of the Lower Campbell Reservoir on March 23. An additional survey of the Greenstone River was carried out on April 21 due to the relatively cold conditions of this river compared to Miller and Fry creeks. 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 utilized to provide a reference for adult spawning effort.

Surveys for the Rainbow Trout spawning period were undertaken from June 5 to 8 in the tributaries of Buttle Lake and Upper Campbell Reservoir. Data recorded from the 2017 Rainbow Trout spawning surveys were compared to the Year 1 to Year 3 (2014 to 2016) 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 sampled 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 good for conducting snorkelling surveys.

**Table 2. Snorkel survey reach details for Year 4 surveys.**

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

**Table 3. Variables measured during the Year 4 snorkel surveys in the selected tributaries of Upper Campbell Reservoir, Buttle Lake, and Lower Campbell Reservoir.**

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

### 2.4. Effective Spawning Habitat (ESH)

The effective spawning habitat (ESH) Performance Measure Model (described in section 1.2 and Smyth and Hatfield 2016) is a computer model that quantifies the amount of spawning habitat that is within the drawdown zone that is available to fish, and is not inundated by rising reservoir levels during the egg incubation period. The computer model uses a number of variables to quantify ESH, including time for incubation, and reservoir levels at the start of spawning and the end of incubation. To determine the time for incubation, fish species were considered individually because the time and temperature for spawning and incubation differs among species (Table 4, Figure 1).

The model was therefore run separately for Cutthroat Trout, Rainbow Trout, and Dolly Varden. Fish periodicity (Smyth and Hatfield 2016) was assumed to be fixed across years. The amount of spawning habitat present at the time of spawning was determined from reservoir water levels (Figure 2), and this spawning habitat area was tracked over the incubation period (estimated from temperature data in Figure 3) to determine if spawning habitat became inundated for long enough to cause egg mortality. Assumptions were made in the model to relate the length of inundation to egg mortality rate.

The ESH model completes the following steps for each species and each day within the spawning period:

1. The reservoir elevation was determined based on BC Hydro supplied reservoir elevation data for the entire calendar year (BC Hydro 2017);
2. The "effective spawning elevation" was based on its suitability for incubation, which was determined by temperature, specifically the total ATU (accumulated thermal unit) which were set to be the average water temperature for the spawning day based on a 24-hour average calculated from continuous temperature logger data (Figure 3);

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. This was repeated in increments as necessary as the reservoir rose;
    c. The ATU for the incubation day was added to the total ATU. At the end of incubation (when the total ATU meets the values in Table 4, or on the incubation end date in Table 4; whichever comes first) the effective spawning habitat area was determined from the effective spawning elevation (Figure 2);
4. Effective spawning habitat (area days, expressed as $m^2d$) was calculated by multiplying the effective spawning habitat area by the spawning intensity, which was provided as a function of calendar date (Figure 1);
5. The initial spawning habitat was calculated by determining the habitat area for the spawning elevation and multiplying by the spawning intensity; and
6. Loss of habitat was calculated by subtracting the effective spawning habitat from the initial spawning habitat.

Effective spawning habitat and loss of effective habitat were summed over each day of spawning to determine the total effective spawning habitat and total effective spawning habitat loss for the duration of the spawning period.

**Table 4. Spawning and incubation timing information used in the ESH model for Cutthroat Trout, Rainbow Trout, and Dolly Varden (Smyth and Hatfield 2016). μ is the days to peak spawning intensity, and σ is the total duration/6.**

| 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 | | | | | |

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

**Figure 1. Timing of spawning intensity for Cutthroat Trout, Rainbow Trout, and Dolly Varden used in the ESH model (Smyth and Hatfield 2016).**

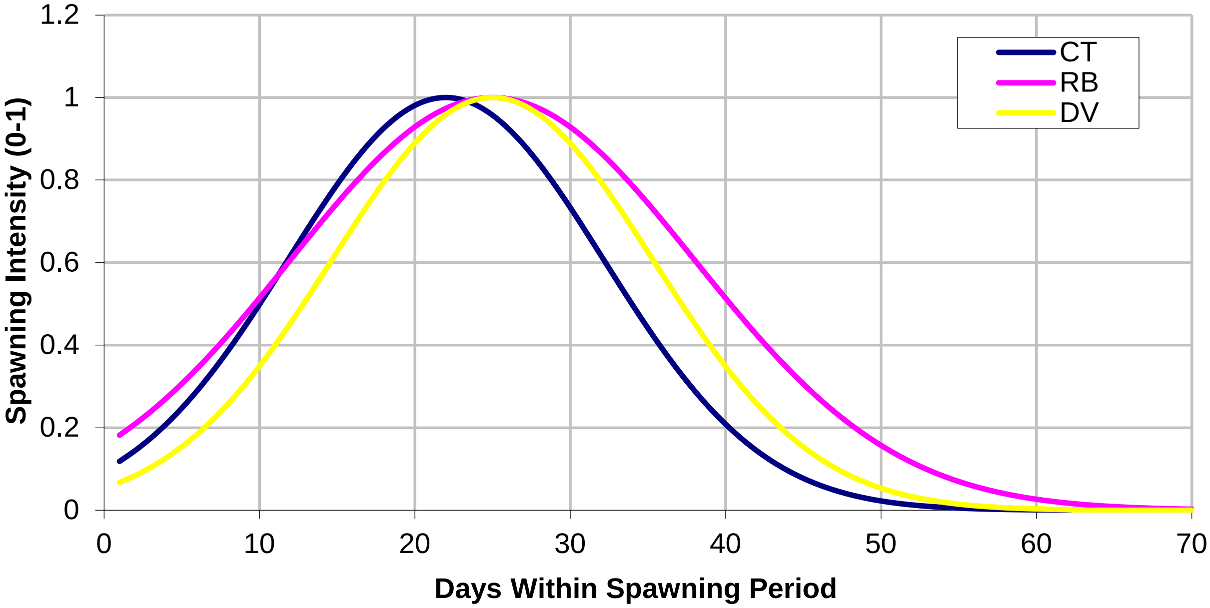



**Figure 2. Relationships between spawning habitat within the drawdown zone and reservoir elevation for Upper Campbell Reservoir at Strathcona Dam (SCA) and Lower Campbell Reservoir at Ladore Dam (LDR). Additional spawning habitat above the drawdown zone is not accounted for in the model.**

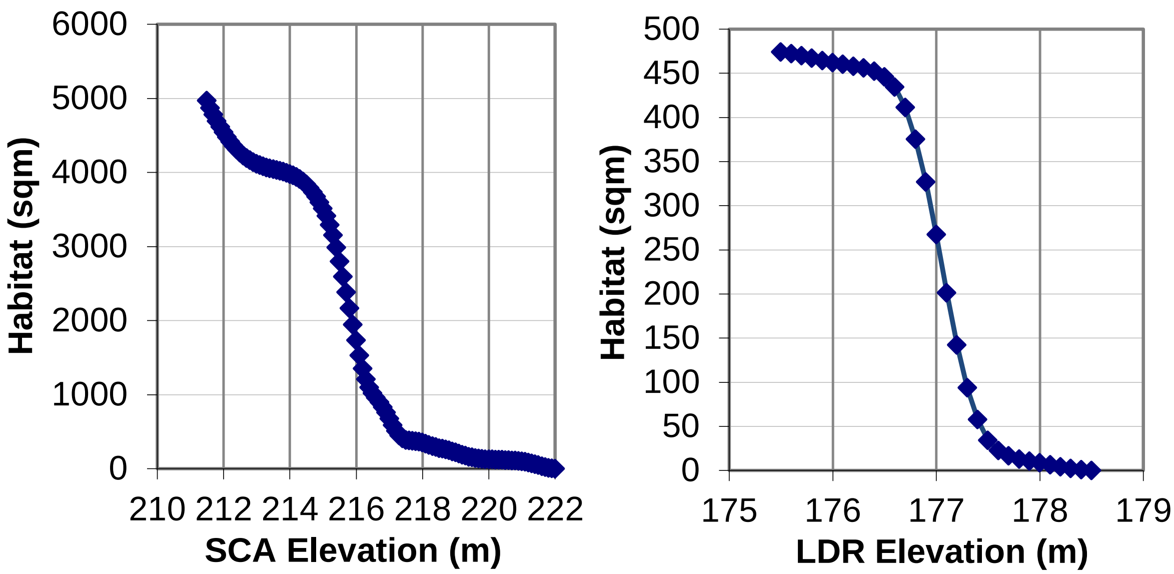
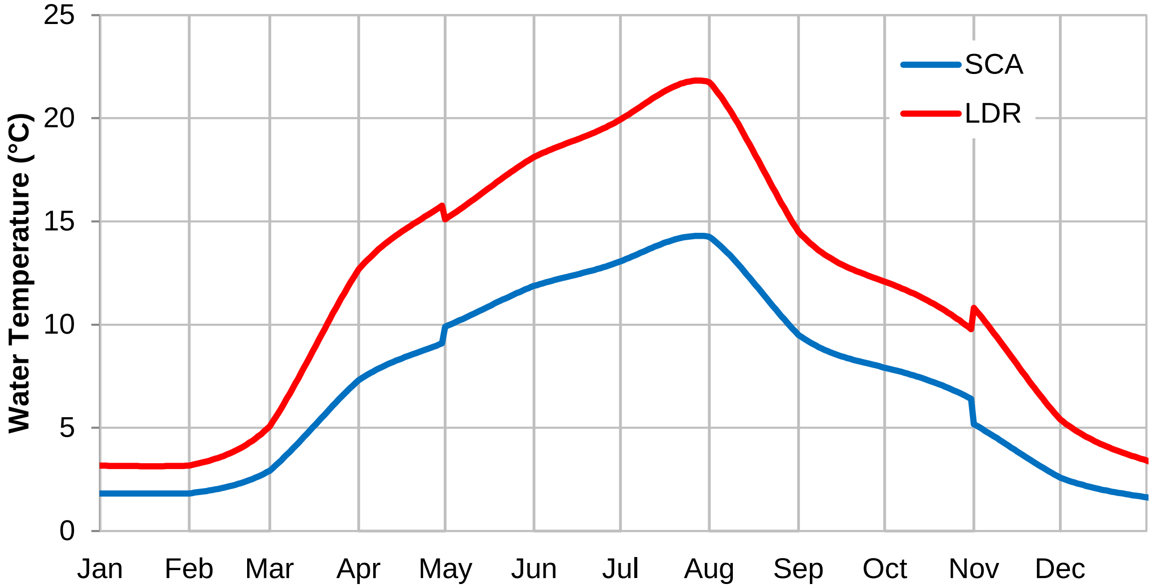


**Figure 3. Water temperature trends used for ESH model for Upper Campbell Reservoir at Strathcona Dam (SCA) and Lower Campbell Reservoir at Ladore Dam (LDR).**




## 2.5. Spawning Habitat Availability

Habitat surveys were conducted to assess quantity and quality of spawning habitat within and above the reservoir drawdown zones. Target waterbodies included:

1. Lower Campbell Reservoir: Fry Creek, Greenstone Creek and Miller Creek;
2. Upper Campbell Reservoir: Elk River mainstem (from Upper Campbell Reservoir to the Drum Creek confluence) and the following tributaries: Tlools Creek, Filberg Creek, Cervus Creek, Isardi Creek and Drum Creek, and
3. Buttle Lake: Ralph River, Phillips Creek and Wolf Creek.

Spawning habitat was summarized for each area using multiple metrics selected as indicators of spawning habitat availability. These metrics included linear stream distance, wetted area, bankfull channel width, bankfull channel area and an additional qualitative metric of spawning habitat potential. These metrics were summarized in GIS for each area.

A combination of Unmanned Aerial Vehicle (UAV) surveys and ground-based field inventory surveys were used to assess and quantify spawning habitat availability in the target waterbodies. UAV surveys were used to efficiently survey large areas, capture high resolution aerial imagery, and delineate habitat in GIS. Ground-based field surveys were undertaken to quantify spawning habitat in locations that were inaccessible to UAVs (e.g., overhanging vegetation obstructing view) and to survey redd distribution and abundance. Field surveys were also used to validate (ground truth) the

GIS analysis. Stream segments that were heavily obstructed from overhanging vegetation, and consequently could not be surveyed from UAVs, occurred in the furthest upstream sections of each tributary (usually in locations with steep banks and narrow channels; see Section 2.5.3.

The survey within each waterbody extended from the lower limit of the drawdown zone upstream to the first documented fish migration barrier. This allowed us to quantify the total spawning habitat available to adfluvial spawners. In cases where there were no clearly identifiable barriers, the upstream extent of spawning habitat was defined as the location prior to an extended length (>500m) of unsuitable spawning habitat (Table 5). An exception was made for the mainstem of Elk River, where the upstream survey extent was limited to the confluence of Drum Creek (12.2 km upstream from the Upper Campbell reservoir). This decision reflected the large size of the Elk River and its status as a major spawning tributary.

All UAV field surveys were completed in July and October 2017. These time periods were selected to maximize the area of exposed habitat in aerial imagery, which allowed better evaluation of depth profiles and substrates. Water levels at WSG Gauge 08HD031 ('Upper Campbell Reservoir') ranged from 219.41 m to 219.46 m across July survey dates and from 216.98 m to 216.82m across October survey dates (Table 6). Upstream sections above the drawdown zones were surveyed in July to correspond with a period of low stream flow. The drawdown zone sections were re-surveyed in October, when water levels within the reservoirs are low (Table 6).

**Table 5. Upstream survey endpoints for each waterbody**

| Waterbody | Creek Name | Date | UTM Zone | UTM Easting | UTM Northing |
|---|---|---|---|---|---|
| Lower Campbell | Fry Creek | 3/1/2017 | 10U | 314741 | 5550140 |
| | Greenstone Creek | 5/4/2017 | 10U | 313140 | 5543307 |
| | Miller Creek | 4/3/2017 | 10U | 324268 | 5538932 |
| Upper Campbell | Cervus Creek | 6/20/2017 | 10U | 299868 | 5526078 |
| | Drum Creek | 6/20/2017 | 10U | 293501 | 5524999 |
| | Elk River | 6/23/2017 | 10U | 294344 | 5524853 |
| | Filberg Creek | 6/21/2017 | 10U | 301902 | 5527471 |
| | Idsardi Creek | 6/22/2017 | 10U | 296506 | 5526537 |
| | Tlools Creek | 6/22/2017 | 10U | 301761 | 5529376 |
| Buttle Lake | Phillips Creek | 6/16/2017 | 10U | 315129 | 5505249 |
| | Ralph River | 6/19/2017 | 10U | 318228 | 5500339 |
| | Wolf Creek | 6/13/2017 | 10U | 310809 | 5516642 |

**Table 6. UAV field survey details for each waterbody.**

| Reservoir | Creek | Date | Start Time | End Time | Area (ha) | Altitude (m AGL) |
|---|---|---|---|---|---|---|
| Upper Campbell Reservoir | Cervus Creek | 7/10/2017 | 18:30 | 19:20 | 1.2 | 12 |
| | | 7/11/2017 | 12:03 | 12:20 | 0.2 | 6 |
| | | 7/14/2017 | 9:05 | 9:30 | 5.2 | 50 |
| | Drum Creek | 7/11/2017 | 13:20 | 14:46 | 2.2 | 14 |
| | | 7/17/2017 | 7:57 | 8:28 | 12.2 | 90 |
| | Elk Drawdown | 10/27/2017 | 9:50 | 14:29 | 29.2 | 25 |
| | | 10/27/2017 | 14:30 | 15:11 | 45.5 | 90 |
| | | 7/11/2017 | 8:00 | 10:38 | 12.6 | 25 |
| | | 7/13/2017 | 7:58 | 9:51 | 22 | 39 |
| | Elk River | 7/11/2017 | 10:39 | 10:44 | 5.1 | 50 |
| | | 7/13/2017 | 9:51 | 10:05 | 14.1 | 55 |
| | | 7/13/2017 | 10:56 | 13:34 | 46.2 | 55 |
| | | 7/13/2017 | 14:50 | 18:16 | 53.4 | 55 |
| | | 7/14/2017 | 9:48 | 13:19 | 50.3 | 55 |
| | | 7/14/2017 | 14:05 | 16:44 | 24.6 | 55 |
| | | 7/17/2017 | 8:30 | 13:22 | 48.7 | 53 |
| | | 7/17/2017 | 15:58 | 16:09 | 10.6 | 50 |
| | Idsardi Creek | 7/11/2017 | 15:55 | 17:09 | 1.9 | 18 |
| | Tlools Creek | 7/17/2017 | 14:33 | 15:20 | 2.3 | 18 |
| | | 7/17/2017 | 15:21 | 15:26 | 9.3 | 90 |
| Buttle Lake | Philips Creek | 7/12/2017 | 11:52 | 12:48 | 2.5 | 18 |
| | | 7/12/2017 | 12:22 | 12:58 | 14.2 | 90 |
| | | 10/28/2017 | 14:34 | 15:17 | 6.8 | 25 |
| | Ralph Creek | 10/27/2017 | 16:04 | 17:14 | 11.3 | 25 |
| | | 10/27/2017 | 16:39 | 17:13 | 21.7 | 90 |
| | | 7/12/2017 | 14:11 | 15:51 | 5.3 | 22 |
| | | 7/12/2017 | 14:23 | 15:02 | 17.6 | 90 |
| | Wolf Creek | 7/12/2017 | 9:24 | 10:34 | 5.1 | 19 |
| | | 7/12/2017 | 10:38 | 10:43 | 11 | 90 |
| | | 7/12/2017 | 16:57 | 17:03 | 11.3 | 90 |
| | | 10/28/2017 | 9:52 | 12:36 | 10.8 | 25 |
| | | 10/28/2017 | 10:50 | 11:18 | 42 | 90 |
| Lower Campbell Reservoir | Fry Creek | 7/8/2017 | 9:06 | 9:45 | 1.3 | 15 |
| | | 7/8/2017 | 9:54 | 12:31 | 44.6 | 90 |
| | | 7/8/2017 | 11:09 | 11:45 | 12.5 | 45 |
| | | 7/8/2017 | 13:10 | 13:19 | 13.8 | 90 |
| | | 7/8/2017 | 13:10 | 17:14 | 5.6 | 15 |
| | | 7/8/2017 | 13:43 | 14:16 | 1.2 | 15 |
| | | 7/8/2017 | 18:09 | 18:42 | 0.8 | 12 |
| | | 7/10/2017 | 12:14 | 12:46 | 1.1 | 15 |
| | | 7/10/2017 | 13:54 | 14:09 | 0.7 | 15 |
| | | 7/10/2017 | 14:44 | 15:17 | 0.5 | 15 |
| | | 7/10/2017 | 15:20 | 16:39 | 20.9 | 90 |
| | | 7/10/2017 | 15:49 | 16:03 | 1.3 | 20 |
| | Greenstone Creek | 7/9/2017 | 9:12 | 9:42 | 1.1 | 15 |
| | | 7/9/2017 | 9:42 | 9:54 | 8.5 | 90 |
| | | 7/9/2017 | 10:02 | 10:05 | 0.1 | 7 |
| | Miller Creek | 7/9/2017 | 12:48 | 14:21 | 2.5 | 15 |
| | | 7/9/2017 | 14:22 | 14:38 | 13.4 | 90 |

### 2.5.1. Spawning Habitat Delineation from UAV Imagery

High resolution aerial imagery was acquired with a DJI Phantom 3 Professional UAV. Overlapping images collected with the UAV were assembled into georeferenced orthomosaics using photogrammetric structure from motion techniques (Peterson *et al*. 2015). Resolution of the final orthomosaics depended on flight height and corresponding camera resolution. For this study, flight altitudes ranged from 12 m – 28 m above ground level (AGL) for flights in each of the smaller tributaries, and up to 50 m (AGL) for flights over the Elk River (Table 6). Pix4D Mapper Pro V3.3 (https://www.pix4d.com/product/pix4dmapper-pro) was used for all image processing and analysis. The final pixel resolution of the georeferenced orthomosaic layers ranged from 0.6 – 2.5 cm/pixel across the surveyed waterbodies.

Several unique spatial habitat metrics were calculated manually from the UAV orthomosaic. These metrics were used as indicators of spawning habitat availability (e.g., Figure 4). By evaluating multiple metrics, we were able to take advantage of the different strengths and limitations of each indicator and effectively reduce the overall subjectivity inherent in quantifying spawning habitat availability. Comparisons for each waterbody were made within the drawdown zone and upstream of the drawdown zone. All measurements and delineations were completed in QGIS (v. 2.18.14) (QGIS Development Team 2018) and ArcMap (v. 10.5) (ESRI 2016).

**Linear Distance**

Linear distance was calculated as the length of the surveyed mainstem of each stream. Drawdown zones and upstream areas were represented as lines extending the length of each area. Stream centrelines were initially extracted from the BC Freshwater Atlas. Streamlines were then evaluated and adjusted manually using underlying UAV imagery and tracing the thalweg centreline of each stream. Major side channels and secondary channels that were over 50 m wide were represented as separate lines. Streamlines were then clipped with drawdown zone boundaries for each tributary and summarized as the total length (m) within and above the drawdown zones.

**Wetted Area**

Wetted area was delineated manually from the UAV orthomosaics by drawing polygons over the water surface in GIS. The resolution of all imagery was sufficient to clearly identify the waterline along the lateral edge of each stream. All wetted area delineations were made using imagery collected at low water for each area (Table 6). UAV aerial surveys targeted time periods where the water levels were low (both upstream and within the drawdown zone). Consequently, these measurements do not reflect wetted area at spawning periods for each species, but instead represent wetted area at low water. Bankfull channel width measurements (described below) were included as an indicator of wetted area at high water.

Wetted area measurements in the drawdown zones were manually adjusted to follow the base of the thalweg sidewalls for each tributary, rather than covering the entire alluvial fan at the waterline. These wetted area adjustments in the drawdown zones were necessary in order to make wetted area summaries comparable across tributary surveyed on different dates at different water levels. These adjustments also excluded portions of the alluvial fan that were void of any suitable spawning habitat (substrate composition: fines and/or vegetation).

**Bankfull Channel Width**

Bankfull channel width measurements were taken along the length of each stream at fixed distance intervals. Initial attempts were made to delineate the bankfull channel width with polygons; however, dense vegetation along streambanks only allowed for accurate measurements of bankfull channel width intermittently from aerial imagery. Bankfull channel width measurements were summarized by calculating the median values for each waterbody within the drawdown zone and upstream of the drawdown zone separately. Distance intervals were set at 50 m, but adjusted to 200 m for the Elk River.

Bankfull channel width measurements in the drawdown zones were manually adjusted and set at the crest of the thalweg sidewalls for each tributary. These bankfull channel width adjustments in the drawdown zones were necessary due to the large unconfined extent of the alluvial fans at the tributary lake confluence zones, and they also made measurements comparable across tributaries and excluded portions of the alluvial fan that were void of any suitable spawning habitat (substrate composition: fines and/or vegetation).

**Bankfull Channel Area**

Bankfull channel area measurements were calculated as the median bankfull channel width (m) for each section multiplied by the linear distance (m). This metric was included to better represent the overall area at high water potentially available as spawning habitat. Bankfull channel area measurements were also useful for comparisons with wetted area measurements to evaluate potential discrepancies.

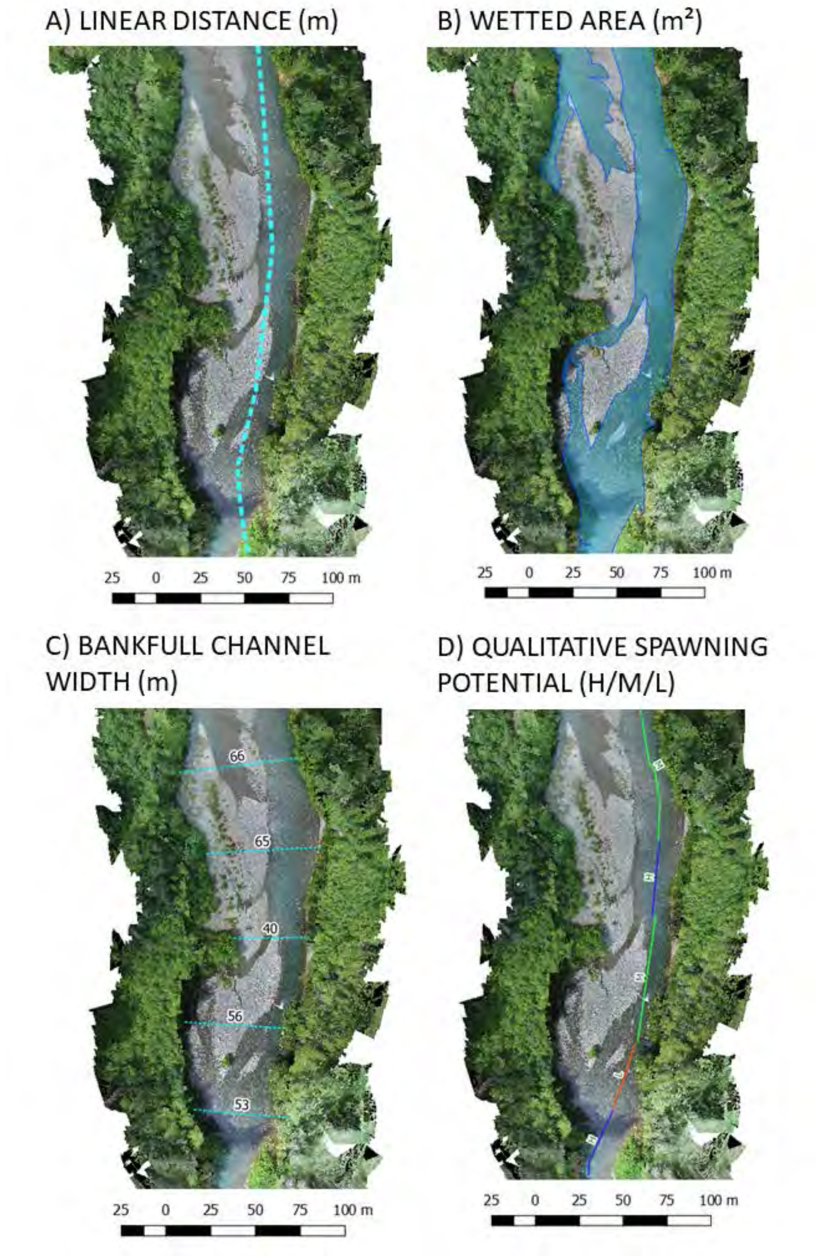
**Spawning Potential**

Spawning potential was evaluated qualitatively by identifying individual stream reach segments (based on meso-habitat characteristics) and then classifying each of these stream reach segments as having either 'Low', 'Medium', or 'High' potential as spawning habitat. Stream reaches dominated by fines, large boulders or bedrock substrates were classified as having 'Low' spawning potential. Stream reaches with a large portion of spawning gravel substrates ranging, in diameter from 10 mm to 75 mm, were classified as having 'High' spawning potential. Stream reaches were classified as 'Medium' if spawning gravel was limited.

Stream reach length was summarized for each potential classification for each tributary within and upstream of the drawdown zones. This metric was included to capture additional habitat attributes that are readily apparent in imagery but not easily quantifiable. Although useful, this metric is subjective because it is dependent on the opinion of the individual fisheries biologist completing the assessment. We therefore took precautions to limit the subjectivity and to assess repeatability. A single experienced fisheries biologist was assigned the task of delineating reaches and assessing spawning potential for all tributaries, so that relative comparisons would not be affected by observer bias.

To assess overall generalizability and repeatability, a second fisheries biologist repeated reach delineations and classifications (high, medium, or low) for an upper and lower sub-section of the Elk River, Fry Creek, and Ralph River. Repeatability was assessed by randomly sampling 38 100 m long sections of stream and comparing the relative percent differences of stream length classified as either high, medium, or low by each individual. Redd survey data (represented as points) were also overlayed onto the aerial imagery to help inform spawning habitat designations.

**Figure 4. Sample of spawning habitat availability indicator metrics calculated from UAV orthomosaic imagery.**




### 2.5.2. Ground-based Spawning Gravel Surveys

A spawning gravel inventory/assessment was conducted in areas where UAV access was restricted due to stream vegetation and other visual obstructions. Total spawning habitat was estimated and classified according to FHAP methods (Johnston and Slaney 1996) with minor modifications described below. Individual patches of gravel (10 mm to 75 mm diameter) were measured with a meter stick. Only spawning gravel patches suitable for resident trout were recorded, as all study streams have no access for anadromous fish. Only gravel patches greater than 1.0 $m^2$ were recorded. Patches were also classified as functional or non-functional based on location from wetted edge and extent of compaction and embeddedness.

For each spawning gravel patch, measurements included average length and width of the patch, average water depth, and depth range. Multiple small gravel patches located in close proximity, or those separated by only a few large cobbles or boulders, were recorded as a single composite patch. Johnston and Slaney (1996) describe functional spawning habitat as having water depths greater than 15 cm and water velocities between 0.3 m/s to 1.0 m/s during the spawning season. During time of assessment, flows were relatively low; therefore, to avoid underestimating functional spawning gravel area, only areas assumed to be dry during spawning and incubation periods were classified as non-functional.

Compaction was subjectively classified as low (L), moderate (M), or high (H) using a 'Boot Test', which is a relative measure of gravel compaction. The boot test involves kicking the substrate and evaluating the degree of penetration. Compaction was classified as "low" if the boot easily and deeply penetrates the gravel substrate (>4 cm), "moderate" if a portion of the boot penetrates the gravel (approximately 2 cm to 4 cm), and "high" if the boot only slightly enters or does not enter the substrate completely (<2 cm).

The embeddedness of the gravel was measured as the amount of fines (<2 mm) that were present in the substrate at each spawning gravel patch. Embeddedness was subjectively classified, based on visual inspection as: trace (T, <5%), low (L, 5% to 25%), medium (M, 25% to 50%), high (H, 50% to 75%), or very high (VH, >75%).

Photographs were taken of each spawning gravel patch to show relative location, approximate area, and substrate size of the gravel patch.

### 2.5.3. Quantifying Metrics Upstream of UAV Survey Extent

For some tributaries, it was not possible to collect UAV imagery in furthest upstream sections due to dense overhanging vegetation cover. This lack of complete coverage was problematic because it meant that the full upstream extent of available spawning habitat could not be quantified from the UAV imagery alone. To overcome this issue, we relied on information collected from the ground-based spawning gravel surveys to quantify spawning habitat availability in areas that could not be effectively surveyed by the UAV. The same five spawning habitat availability metrics (described above, Figure 4) were extended beyond the endpoint of the UAV survey extent using field survey data. These values were then combined with estimates of each spawning indicator from UAV imagery for a final comparison of available spawning habitat within and upstream of the drawdown zones.

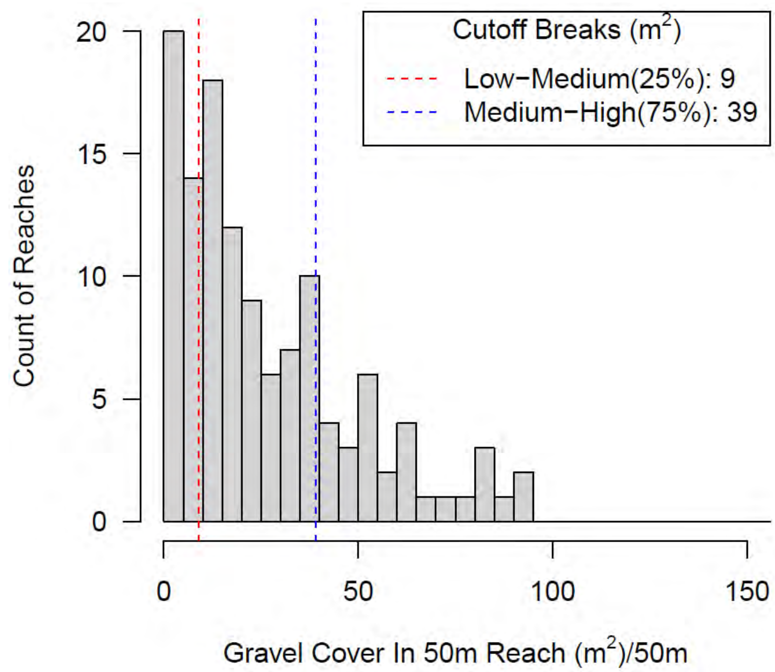
In areas upstream beyond the extent of UAV imagery coverage, linear stream distances were extracted from the BC Freshwater Atlas streamlines. Estimates of wetted area and bankfull channel width were made from representative location immediately downstream from the upper limit of

UAV imagery. To estimate the total wetted area we multiplied linear stream distances by the wetted width.

Spawning potential in sections upstream of the extent of UAV imagery was estimated by analyzing the field gravel survey data and making estimates of spawning potential based on the quantity of spawning gravel. To do this, we summed gravel patch areas to calculate the total spawning gravel area for every 50 m stream segment upstream of the boundary of the UAV imagery. We then evaluated the frequency distribution of these data across all waterbodies to identify thresholds for 'Low', 'Medium', and 'High' spawning potential. We chose the 25th and 75th percentiles from this distribution of gravel area as thresholds to define spawning potential breakpoints for each 50m stream segment. The 25th and 75th percentiles were chosen to approximately match the final distribution of 'High', 'Medium', and 'Low' classes in upstream areas with coverage from the UAV imagery (See Section 3.4, 24.5% 'Low', 43.3% 'Medium', and 31% 'High'). The resulting categories to define spawning potential from gravel coverage were: Low (0 – 9m²/50m); Medium (9 – 39m²/50m; and High (>39m²/50m) (Figure 5). Although these breakpoints may be an oversimplification, we expect this methodology to under estimate suitable spawning habitat in these upstream areas (further scrutinizing $H_0 3$).

Final analysis of spawning habitat metrics was then completed with data combined from areas with UAV aerial imagery and areas without UAV aerial imagery. Separating final summary statistics based on these two different methodologies allowed us to determine how sensitive our overall results were to including estimates from the upstream sections with no UAV coverage.

**Figure 5. Distribution of spawning habitat gravel (m²) for every 50m of stream identified from ground-based field surveys upstream of UAV survey extent. Vertical dashed lines correspond to the Low-Medium and Medium-High breakpoints chosen to classify these reaches as Low, Medium or High spawning potential.**




2.6. Spawning Habitat Use

2.6.1. Redd Surveys Within and Upstream of Drawdown Zones

Redd surveys were completed annually in each study stream to evaluate spawning habitat use within and upstream of the drawdown zones. The timing of these surveys targeted periods shortly after peak spawning for resident trout. Peak spawning periods were determined from snorkel surveys completed throughout March, April, and June (Table 2). In the Lower Campbell Reservoir, redd surveys targeted the post spawning period for Cutthroat Trout. In the Upper Campbell Reservoir and Buttle Lake, redd surveys targeted the post spawning period for Rainbow Trout.

Redds were enumerated visually and mapped for each tributary by a crew of two experienced field technicians. Field technicians walked and snorkeled the length of each tributary accessible to adfluvial spawners. The same field technicians were used for all within-stream comparisons to minimize observer error. A subset of redds in the drawdown zone (at least one redd in each target stream) was inspected to confirm that visually identified redds were active, and to determine the stage of egg development as un-eyed, eyed, or alevin. At each redd (or group of redds) the following attributes were recorded: number of redds per waypoint, location in stream channel, redd(s) depth or depth range, estimated velocity (L, M, H), habitat unit, dominant and sub-dominant substrate, cover, and whether the redd appeared to be new or old (i.e., created prior to the spawning period that was being assessed). Redd surveys within and above the drawdown zone were often conducted on different days. Effort depended on redd densities, stream accessibility, and total survey length.

Redd locations were mapped and the horizontal distribution of redds upstream of the drawdown zones were summarized based on distance intervals above the drawdown zones. Each redd (or group of redds) was georeferenced using either a Total Station Theodolite (TST) (in the drawdown zone) or a high accuracy GPS (above the drawdown zone). It was necessary to use a TST in the drawdown zones to achieve a high vertical accuracy and calculate inundation periods for redds from reservoirs levels (described below). However, for all other locations upstream from the drawdown zones, a Juniper Systems Geode high accuracy GPS receiver was used to map redd locations. Horizontal accuracies of this high accuracy GPS receiver are expected to be within 30 cm under ideal conditions, but these were rarely met due to overstory vegetation, canyon walls and other obstructions.

#### 2.6.2. Redd Elevations within the Drawdown Zones

Critical reservoir water levels at which redds become inundated or exposed were determined by surveying the elevation of redds in the drawdown zone and comparing these values to known reservoir levels. The vertical distribution of redds within the drawdown zones was summarized for each drawdown zone. Since a small change in reservoir levels can result in a large change in the inundated area, it was necessary to use survey methods with sub-centimeter accuracy and precision for this survey to be effective. Ecofish hired Chicalo-Burridge Land Surveying and Geomatics Ltd. to install benchmarks in the drawdown zone area of each tributary drawdown zone.

A Leica FlexLine TS06 plus model total station was used to collect a georeferenced waypoint at each redd(s) in the drawdown zone area. Vertical and horizontal accuracy using this equipment was +/- 1.5 mm.

Additional sources of error in redd elevation measurements likely originated from field error associated with difficulties in holding the survey rod steady in deep water (field technicians holding the survey rod often had to float/swim to hold the survey rod in place). Another potential source of error is a difference between reservoir elevation measured by BC Hydro at the dam reservoir levels and the water surface elevation at each stream mouth caused by spatial variations in reservoir elevation potentially due to internal waves and wind. These potential sources of error were not accounted for in our analysis.

## 3. RESULTS

### 3.1. Population Index for Upper and Lower Campbell Reservoirs

#### 3.1.1. Summary of Gillnet Sampling Results

Fish sampling from the six gill net monitoring sites recorded a total of 45 Cutthroat Trout, 103 Rainbow Trout, three Sculpin, five Cutthroat Trout/Rainbow Trout hybrids, and one Dolly Varden (Table 7). No Threespine Stickleback were captured in 2017. Rainbow Trout had the greatest mean

CPUE (0.35 fish/net hour), followed by Cutthroat Trout (0.15 fish/net hour). CPUE for Cutthroat Trout and Rainbow Trout varied among sites although site conditions were relatively similar (Table 7). At each site, CPUE for Rainbow Trout was greater than for Cutthroat Trout (Table 7).This difference was substantial given that CPUE for Cutthroat Trout was less than 0.15 at all but one site (UCR-LKGN08, CPUE = 0.40), whereas CPUE for Rainbow Trout was greater than 0.20 at all but one site (UCR-LKGN01, CPUE = 0.16).

**Table 7. Summary of gill net survey effort, catch statistics, and CPUE from the Upper Campbell Reservoir, August 2017.**

| Site | Sampling Date | # of Sets | Gill Netting Effort (hrs) | Gill Net Catch (# of Fish)[1] | | | | | Gill Net CPUE (# of Fish/net hr)[1] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CT | RB | DV | CC | CT/RB | CT | RB | DV | CC | CT/RB |
| UCR-LKGN01 | 21-Aug-17 | 2 | 24.7 | 7 | 8 | 0 | 0 | 1 | 0.28 | 0.32 | 0.00 | 0.00 | 0.04 |
| UCR-LKGN02 | 21-Aug-17 | 2 | 49.6 | 6 | 20 | 0 | 1 | 0 | 0.12 | 0.40 | 0.00 | 0.02 | 0.00 |
| UCR-LKGN04 | 22-Aug-17 | 3 | 57.5 | 4 | 15 | 0 | 2 | 2 | 0.07 | 0.26 | 0.00 | 0.03 | 0.03 |
| UCR-LKGN06 | 22-Aug-17 | 2 | 38.3 | 5 | 17 | 0 | 0 | 1 | 0.13 | 0.44 | 0.00 | 0.00 | 0.03 |
| UCR-LKGN07 | 23-Aug-17 | 3 | 59.6 | 7 | 22 | 1 | 0 | 0 | 0.12 | 0.37 | 0.02 | 0.00 | 0.00 |
| UCR-LKGN08 | 23-Aug-17 | 2 | 40.3 | 16 | 21 | 0 | 0 | 1 | 0.40 | 0.52 | 0.00 | 0.00 | 0.02 |
| | **Total** | **14** | **269.9** | **45** | **103** | **1** | **3** | **5** | **0.17** | **0.38** | **<0.01** | **0.01** | **0.02** |
| | **Average** | **2** | **45.0** | **8** | **17** | **0** | **1** | **1** | **0.19** | **0.39** | **0.00** | **0.01** | **0.02** |
| | **SD** | **0.5** | **13.2** | **4.3** | **5.2** | **0.4** | **0.8** | **0.8** | **0.13** | **0.09** | **0.01** | **0.01** | **0.02** |

### 3.1.2. Cutthroat Trout

#### 3.1.2.1. CPUE

Cutthroat Trout were caught at every gill net sampling site; however, CPUE was variable across gill netting sites as well as gill net depth. The sampling site CPUE ranged from 0.07 to 0.40 fish/net hour at the gill netting sites, with an overall mean CPUE of 0.19 fish/net hour (Table 7). Cutthroat trout were only captured when net depths were equivalent to bottom depths, and no Cutthroat Trout were captured in the upper 2.5 m of water when depths exceeded 2.5 m (Table 8). CPUE for all and adult Cutthroat Trout was greatest at a net and bottom depth of 7.5m (0.03 fish/hour), followed by a net and bottom depth of 12.5 m (0.0051 fish/hour). The data suggest that Cutthroat Trout do not inhabit the top of the water column in deep water and are most abundant near the bottom of moderately deep (7.5m and 12.5m) and shallow (2.5m) habitats.

**Table 8. CPUE (no. fish / net panel hour) of a) all Cutthroat Trout and b) adult Cutthroat Trout (>150 mm) based on gill net depth. Catches from Nordic gill nets were not included in this analysis.**

a) All Cutthroat Trout

| | | Bottom Depth (m) | | | |
|---|---|---|---|---|---|
| | | **2.5** | **7.5** | **12.5** | **17.5** |
| **Capture Depth (m)** | **2.5** | 0.0037 | 0.0000 | 0.0000 | 0.0000 |
| | **7.5** | - | 0.0300 | - | - |
| | **12.5** | - | - | 0.0051 | - |

"-" denotes no sampling occurred at this location

b) Adult Cutthroat Trout

| | | Bottom Depth (m) | | | |
|---|---|---|---|---|---|
| | | **2.5** | **7.5** | **12.5** | **17.5** |
| **Capture Depth (m)** | **2.5** | 0.0042 | 0.0000 | 0.0000 | 0.0000 |
| | **7.5** | - | 0.0300 | | - |
| | **12.5** | - | - | 0.0067 | - |

"-" denotes no sampling occurred at this location

3.1.2.2. Individual Fish Analysis

A total of 45 Cutthroat Trout were captured during gill netting surveys and size of captured fish ranged from 173 to 438 mm. Cutthroat Trout were distributed bimodally with clustering observed around 250 mm and 395 mm in length (Figure 6). A length-weight relationship was also generated and is best explained by a power function, where fork length accounted for 98.9% of the variability in Cutthroat Trout weight (Figure 7).

**Figure 6. Length-frequency histogram for Cutthroat Trout (CT) captured during the gill-netting surveys on Upper Campbell Reservoir, 2017.**

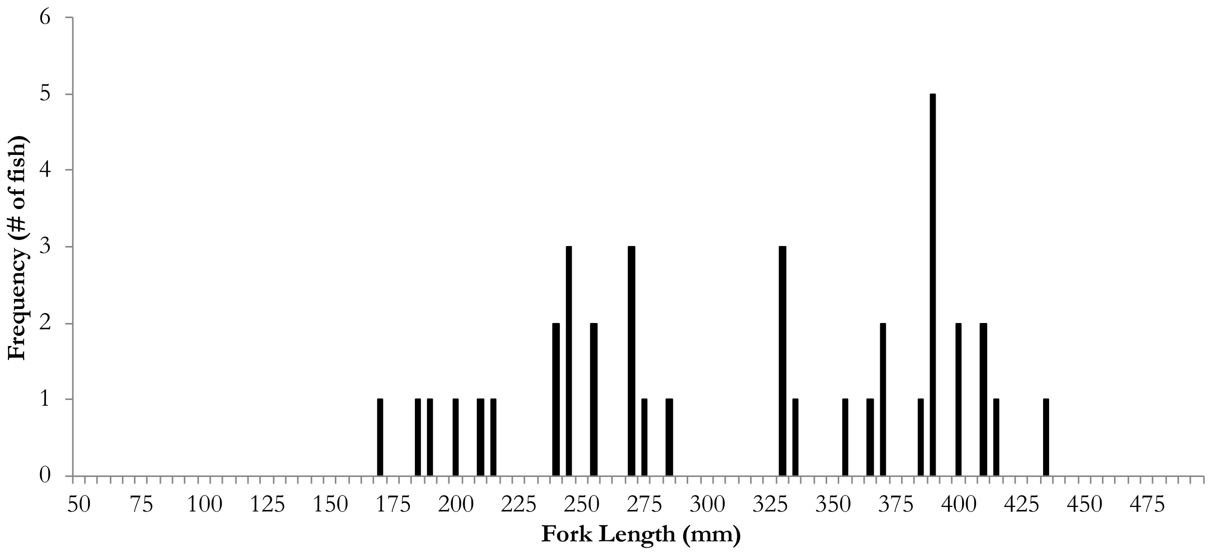
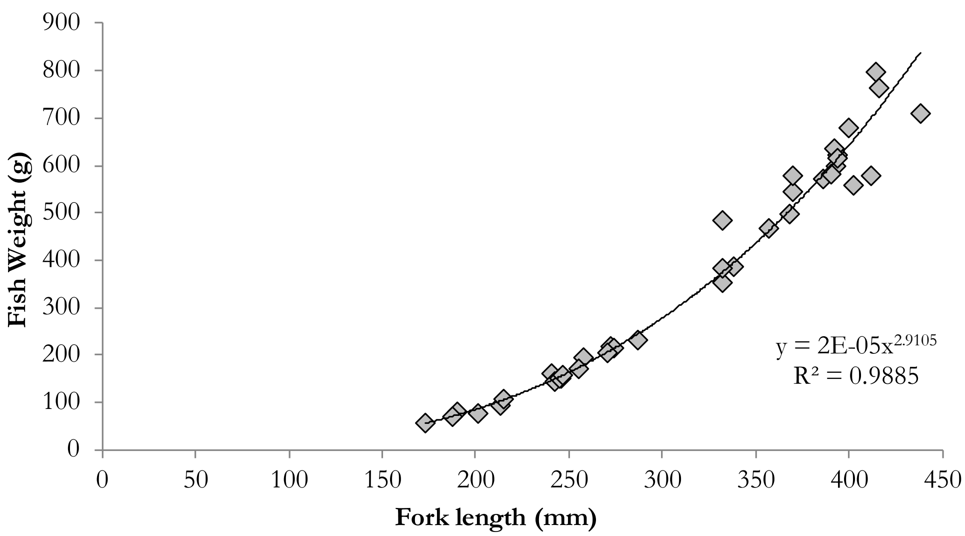



**Figure 7. Length-weight relationship for Cutthroat Trout captured during gill net surveys in the Upper Campbell Reservoir, 2017.**




3.1.2.3. Age Cohort Analysis

Cutthroat Trout caught in gill nets were estimated to range in age from 2+ to 7+ (Figure 8). Due to the complexity of aging older (3+) fish solely by frequency analysis, we focused our direct aging assessments on older fish. Age assessments indicated that no Age 1+, and only one age 2+

Cutthroat Trout (fork length = 173 mm, weight = 56 g) were captured during Year 4 gill netting. No Cutthroat Trout less than 173 mm were captured, thus size bins were not developed to estimate age of 1+ and 2+ fish and all unaged Cutthroat Trout were classified as having an "unknown" age. These fish of "unknown" age will be assigned ages in later years as more aging data become available, and fish can be assigned an age based on lengths. As more fin ray and scale data are collected, we can increase the precision of assigning ages to older fish and more accurately age older fish for which we have only length data.

The majority of captured fish (n =37, 88% of aged fish) were age 3+ to 5+, with age 4+ fish being most abundant (n = 16, 38%) (Table 9). CPUE for Age 3+ to 5+ fish ranged from 0.03 to 0.05 fish/net hour, and was highest for age 4+ fish (0.05 fish/net hour) (Table 10). CPUE of younger (age 1+ and 2+; n = 1, CPUE = 0 to < 0.00) and older fish (age 6+ and 7+; n = 4, CPUE = < 0.00 to 0.01) was significantly lower. The data support the conclusion made from the length frequency histogram that there is a sampling bias towards older juveniles and adult Cutthroat Trout. Five Cutthroat Trout were damaged by crayfish while in the gill net, of which three were aged (mean = 4+, range = 3+ to 7+).

**Figure 8. Length at age of Cutthroat Trout captured during gill netting surveys in Upper Campbell Reservoir, August 2017. Ages are based on scale and fin ray data from sampled fish and exclude Cutthroat Trout partially consumed by crayfish (n = 5).**

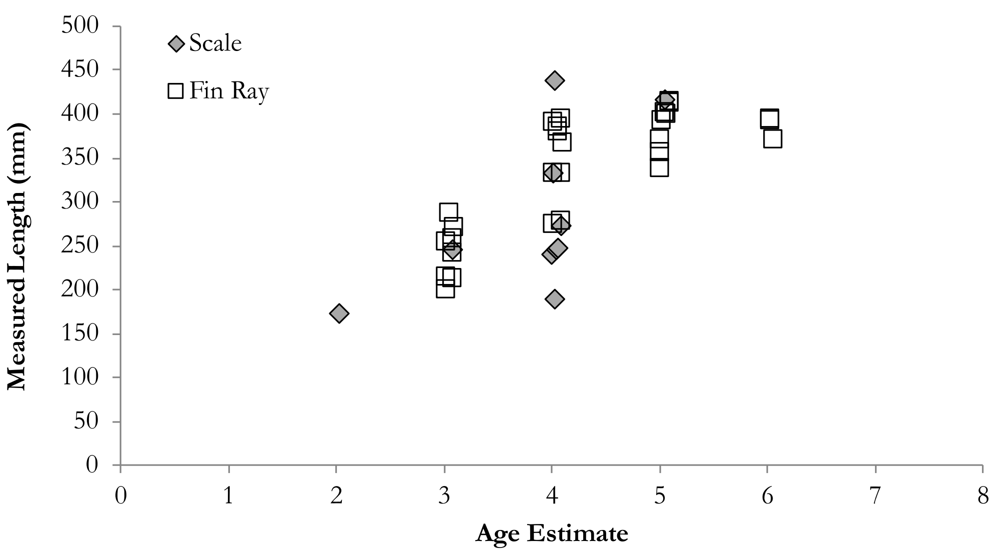


**Table 9. Summary of fork length, weight, and condition of Cutthroat Trout captured during gill netting surveys in Upper Campbell Reservoir, 2017, excluding fish partially consumed by crayfish (n = 5) and those that were not aged.**

| Age | Fork Length (mm) | | | | Weight (g) | | | | Condition (K) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Mean | Min | Max | n | Mean | Min | Max | n | Mean | Min | Max |
| 0+ | - | - | - | - | - | - | - | - | - | - | - | - |
| 1+ | - | - | - | - | - | - | - | - | - | - | - | - |
| 2+ | 1 | 173 | - | - | 1 | 56 | - | - | 1 | 1.1 | - | - |
| 3+ | 9 | 243 | 201 | 287 | 9 | 153 | 75 | 230 | 9 | 1.0 | 0.9 | 1.1 |
| 4+ | 15 | 321 | 190 | 438 | 15 | 381 | 79 | 709 | 15 | 1.0 | 0.8 | 1.3 |
| 5+ | 9 | 389 | 338 | 416 | 9 | 597 | 386 | 798 | 9 | 1.0 | 0.8 | 1.1 |
| 6+ | 3 | 385 | 370 | 394 | 3 | 613 | 579 | 637 | 3 | 1.1 | 1.0 | 1.1 |
| 7+ | - | - | - | - | - | - | - | - | - | - | - | - |
| 8+ | - | - | - | - | - | - | - | - | - | - | - | - |
| Unknown | 1 | 188 | - | - | 1 | 70 | - | - | 1 | 1.1 | - | - |

**Table 10. CPUE of Cutthroat Trout age cohorts captured during gill netting surveys in Upper Campbell Reservoir, 2017, including partially consumed fish that were aged, but excluding fish that were not aged.**

| Age | Number of Aged Fish | CPUE (# of Fish/net hr) |
|---|---|---|
| 0+ | - | - |
| 1+ | - | - |
| 2+ | 1 | 0.00 |
| 3+ | 12 | 0.04 |
| 4+ | 16 | 0.05 |
| 5+ | 9 | 0.03 |
| 6+ | 3 | 0.01 |
| 7+ | 1 | 0.00 |
| 8 + | - | - |
| Unknown | 3 | 0.01 |

### 3.1.3. Rainbow Trout

#### 3.1.3.1. 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 0.52 fish/net hour at the gill netting sites, with an overall mean CPUE of 0.38 fish/net hour (Table 7). CPUE was greatest in the upper 2.5 m of the water column at bottom depths of 17.5 m, when juvenile (<150 mm) and adult (> 150 mm) Rainbow Trout were included together, and when adults were assessed independently (Table 11). The data suggest that Rainbow Trout abundance is greatest in the top of the water column and that abundance in the upper water column may increase with increasing bottom depth.

**Table 11. CPUE (no. fish / net panel hour) of a) all Rainbow Trout and b) adult Rainbow Trout (>150 mm) based on gill net depth. Catches from Nordic gill nets were not included in this analysis.**

a) All Rainbow Trout

| | | Bottom Depth (m) | | | |
|---|---|---|---|---|---|
| | | **2.5** | **7.5** | **12.5** | **17.5** |
| **Capture Depth (m)** | **2.5** | 0.0118 | 0.0271 | 0.0448 | 0.1192 |
| | **7.5** | - | 0.0307 | - | - |
| | **12.5** | - | - | 0.0102 | - |

"-" denotes no sampling occurred at this location

b) Adult Rainbow Trout

| | | Bottom Depth (m) | | | |
|---|---|---|---|---|---|
| | | **2.5** | **7.5** | **12.5** | **17.5** |
| **Capture Depth (m)** | **2.5** | 0.0094 | 0.0271 | 0.0053 | 0.1015 |
| | **7.5** | - | 0.0307 | - | - |
| | **12.5** | - | - | 0.0000 | - |

"-" denotes no sampling occurred at this location

#### 3.1.3.2. Individual Fish Analysis

A total of 103 Rainbow Trout were captured during gill netting surveys ranging from sizes of 81 to 307 mm (Figure 9). This range of fish sizes suggests that older, mature fish (> 150 mm in length) were most frequently captured and that older, mature fish were distributed throughout Upper Campbell Reservoir. A length-weight relationship was also generated and is best explained by a power function, where fork length accounted for 96.9% of the variability in Rainbow Trout weight (Figure 10).

**Figure 9. Length-frequency histogram for Rainbow Trout captured during the gill-netting surveys on Upper Campbell Reservoir, 2017.**

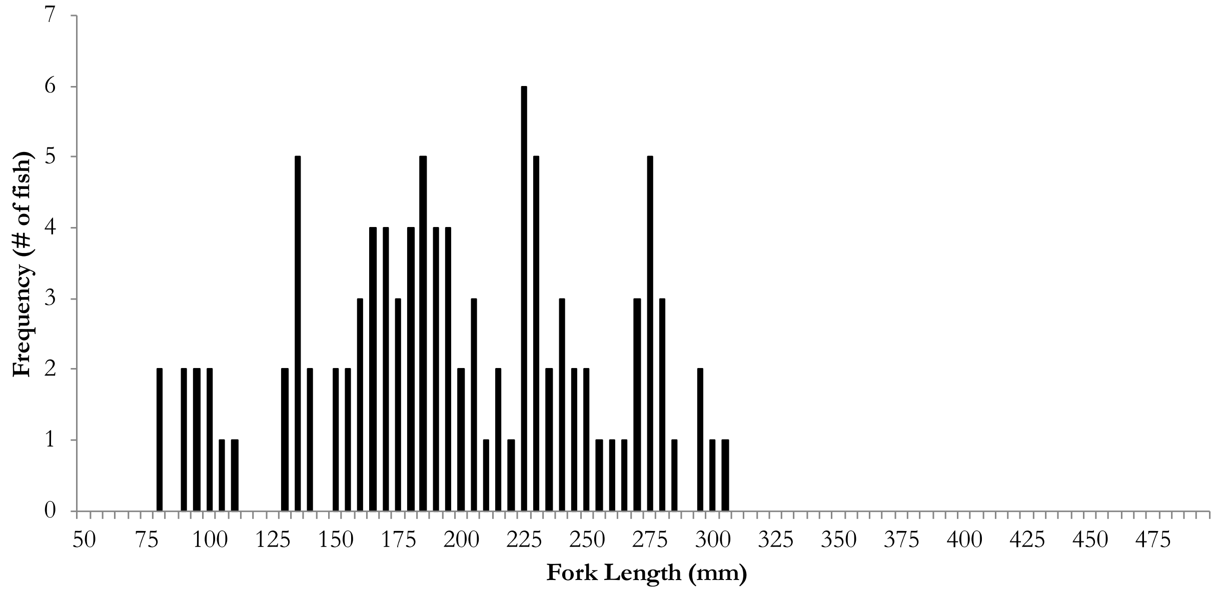
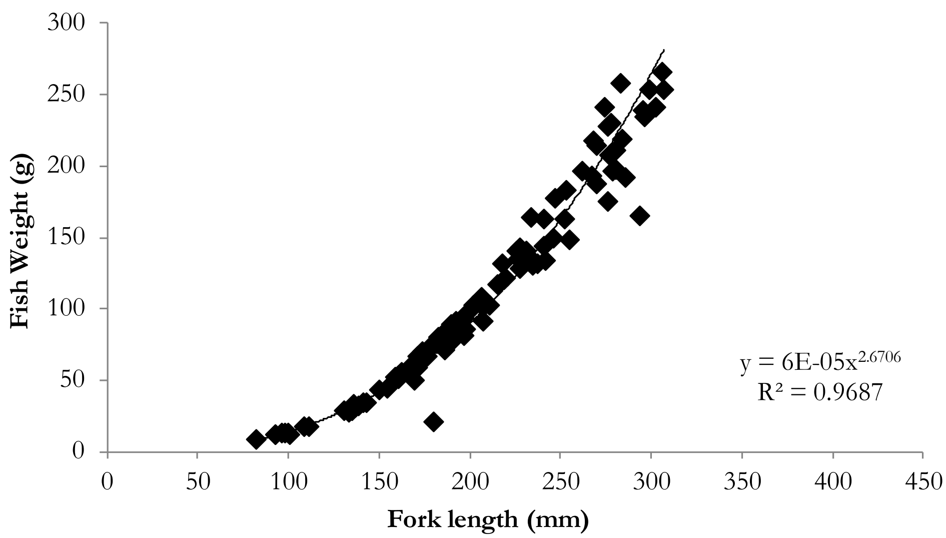



**Figure 10. Length-weight relationship for Rainbow Trout captured during gill net surveys in the Upper Campbell Reservoir, 2017.**



#### 3.1.3.3. Age Cohort Analysis

Rainbow Trout caught in gill nets were estimated to range in age from 0+ to 7+ fish based on both scale and fin ray aging methods (Figure 11). Due to the complexity of aging older (3+) fish solely by size, we focused our direct aging assessments on older fish. Clear overlaps in fork length between age groups are apparent in Figure 11, particularly between the larger age 3+ and 4+ fish, making aging estimates based on size alone difficult for these older fish. Rainbow Trout larger than 150 mm that were not aged were classified as having an "unknown" age. Age was assigned to two Rainbow Trout: one age 0+ fish (82 mm length, 8 g weight), and one age 1+ fish (93 mm length, 12 g weight). These fish of "unknown" age will be assigned ages in later years as more aging data become available, and fish can be assigned an age based on lengths. As more fin ray data are collected, we can increase the precision of assigning ages to older fish and more accurately age older fish for which we have only length data.

The majority of captured fish were age 3+ (28 Rainbow Trout) or age 5+ (17 Rainbow Trout) (Table 12). The age 3+ cohort had the greatest CPUE (0.10 fish/net hour), at least twice that of all other age cohorts (excluding age 5+ fish (CPUE = 0.06 fish/net hour)). (Table 13). It is important to note that this CPUE data does not include the nine fish of unknown age which, if included, would likely increase the CPUE of age 1+ to age 3+ Rainbow Trout.

**Figure 11. Length at age of Rainbow Trout captured during gill netting surveys in Upper Campbell Reservoir, August 2017. Ages based on scale and fin ray data from collected fish.**

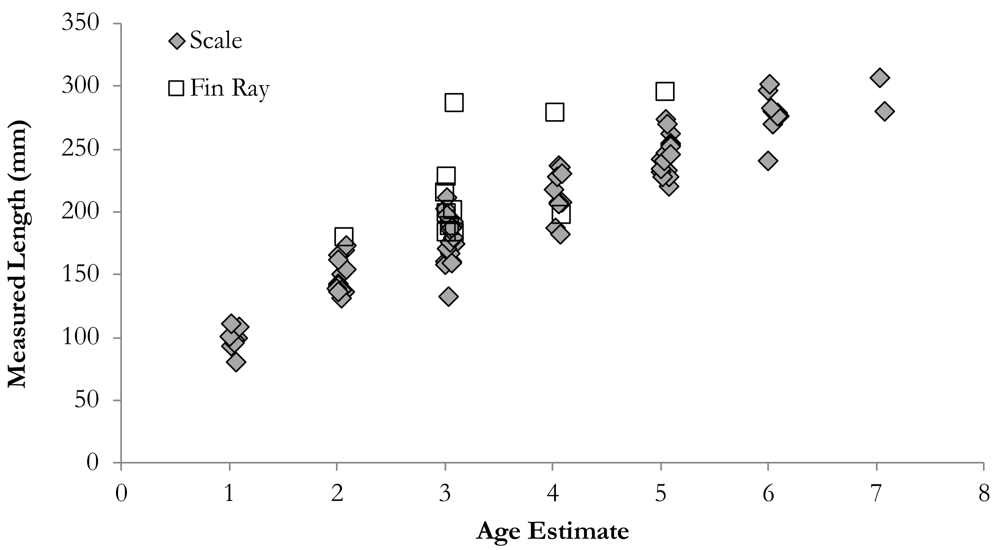


**Table 12. Summary of fork length, weight, and condition of Rainbow Trout captured during gill netting surveys in Upper Campbell Reservoir, 2017. "Unknown" age fish were fish that were not aged.**

| Age | Fork Length (mm) | | | | Weight (g) | | | | Condition (K) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Mean | Min | Max | n | Mean | Min | Max | n | Mean | Min | Max |
| 0+ | 1 | 82 | - | - | 1 | 8 | - | - | 1 | 1.4509 | - | - |
| 1+ | 8 | 100 | 93 | 111 | 8 | 14 | 12 | 17 | 8 | 1.4 | 1.2 | 1.5 |
| 2+ | 16 | 151 | 131 | 180 | 16 | 41 | 21 | 68 | 16 | 1.2 | 0.4 | 1.3 |
| 3+ | 28 | 188 | 133 | 286 | 28 | 83 | 27 | 192 | 28 | 1.2 | 0.8 | 1.3 |
| 4+ | 12 | 218 | 182 | 279 | 12 | 118 | 76 | 197 | 12 | 1.1 | 0.9 | 1.3 |
| 5+ | 17 | 248 | 220 | 295 | 17 | 165 | 121 | 241 | 17 | 1.1 | 0.9 | 1.3 |
| 6+ | 10 | 278 | 241 | 302 | 10 | 214 | 144 | 258 | 10 | 1.0 | 0.8 | 1.1 |
| 7+ | 2 | 294 | 280 | 307 | 2 | 226 | 198 | 253 | 2 | 0.9 | 0.9 | 0.9 |
| 8+ | 1 | 82 | 82 | 82 | 1 | 8 | 8 | 8 | 1 | 1.5 | 1.5 | 1.5 |
| Unknown | 7 | 230 | 190 | 270 | 6 | 134 | 78 | 218 | 6 | 1.2 | 1.1 | 1.2 |
| Predated | 2 | 120 | 81 | 158 | 2 | 28 | 7 | 48 | 2 | 1.3 | 1.2 | 1.3 |

**Table 13. CPUE (fish/net hour) of Rainbow Trout age cohorts captured during gill netting surveys in Upper Campbell Reservoir, 2017. "Unknown" age fish were fish that were not aged.**

| Age | Number of Measured | CPUE (# of Fish/net hr) |
|---|---|---|
| 0+ | 1 | 0.00 |
| 1+ | 9 | 0.03 |
| 2+ | 16 | 0.05 |
| 3+ | 29 | 0.10 |
| 4+ | 12 | 0.04 |
| 5+ | 17 | 0.06 |
| 6+ | 10 | 0.03 |
| 7+ | 2 | 0.01 |
| 8 + | 1 | 0.00 |
| Unknown | 7 | 0.02 |

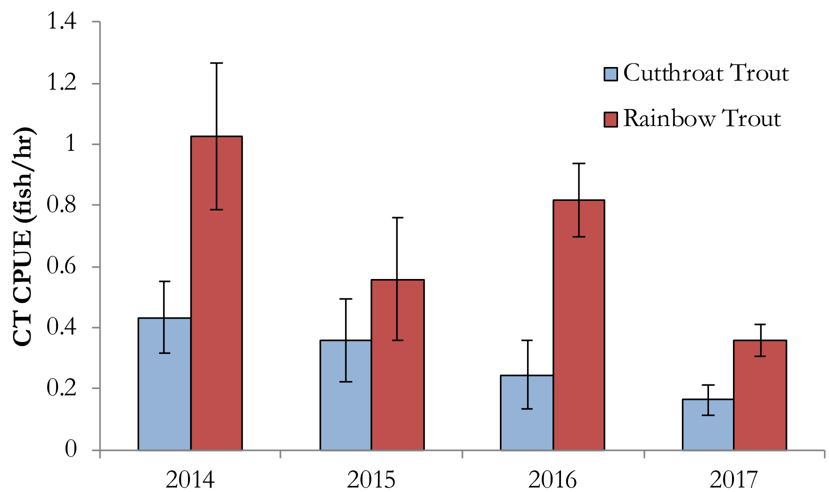
### 3.1.4. Historical Comparison

The historical comparison for the Year 4 report is limited by available data. A more comprehensive analysis will be completed for the Year 5 report. In the meantime, we provide brief summaries of historic 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.

#### 3.1.4.1. Upper Campbell Reservoir

Sampling results from Year 1 to Year 4 (2014 to 2017) suggests that mean Cutthroat Trout CPUE is in a declining trend, while average Rainbow Trout CPUE is highly variable (Figure 12) in the Upper Campbell Reservoir. Cutthroat Trout CPUE has declined since Year 1, but this trend has been most pronounced since Year 2 (2015). Rainbow Trout CPUE is variable among years with no discernible trend in CPUE. It is worth noting that Year 4 CPUE for Rainbow Trout and Cutthroat Trout CPUE was the lowest on record since 2014 and that mean Cutthroat Trout CPUE (0.16 fish/net hour) is now less than half of mean Cutthroat Trout CPUE reported in Year 1 (0.43 fish/net hour).

**Figure 12. Comparison of Cutthroat and Rainbow Trout CPUE from littoral gill net surveys in the Upper Campbell Reservoir among the four years of this program to date (2014, 2015, 2016, and 2017).**

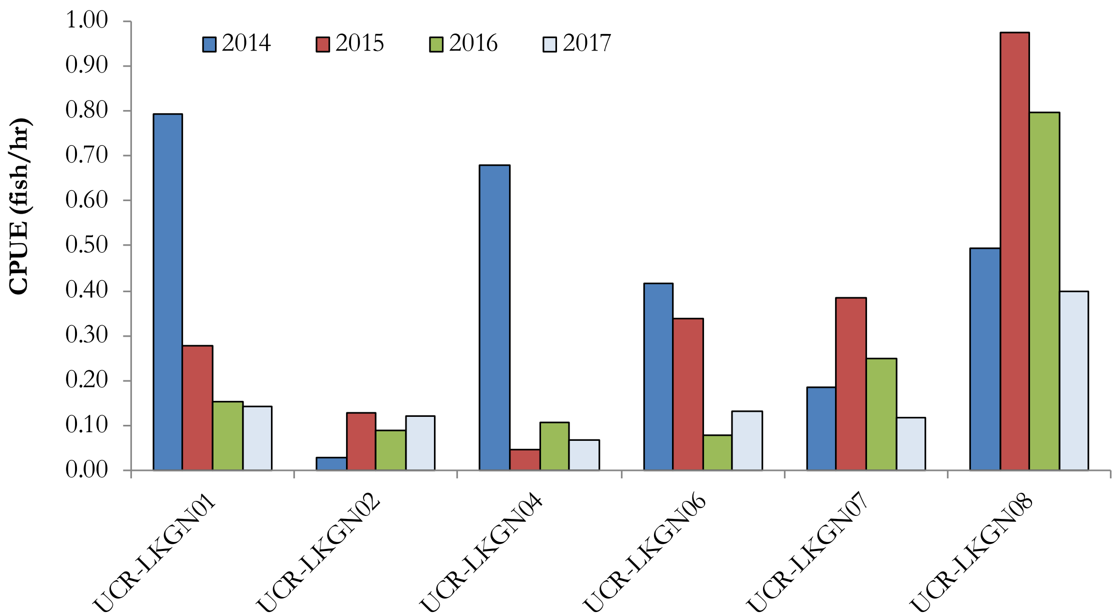



#### 3.1.4.2. Cutthroat Trout

Results from the Year 4 Population Index are comparable to past years. UCR-LKGN02 had consistently lower Cutthroat Trout CPUE compared to the other sites, whereas UCR-LKGN08 had relatively moderate to high Cutthroat Trout CPUE for all four years.

Cutthroat Trout appeared to have a consistent preference for some sites over others, but few trends for Cutthroat Trout CPUE are apparent within sampling sites or across years. In fact, the only site with a consistent trend across all sampling years is UCR-LKGN01, for which CPUE has decreased annually since 2014. Similar decreasing trends are also apparent across 2015 to 2017 sampling periods at UCR-LKGN07 and UCR-LKGN08. From 2016 to 2017, Cutthroat Trout CPUE increased at two sites (UCR-LKGN02 and UCR-LKGN06) and decreased at four sites (UCR-LKGN01, UCR-LKGN04, UCR-LKGN07 and UCR-LKGN08). CPUE for Cutthroat Trout at UCR-LKGN08 in 2017 was lower than all previous records for the site, but remained relatively higher than all other sites. In contrast, CPUE remained low at UCR-LKGN02 and UCR-LKGN04, as it has since 2014, and 2015, respectively. Assuming CPUE is an indication of habitat preference, it would appear that habitat at UCR-LKGN08 is preferred over that at the other sites, while UCR-LKGN02 and UCR-LKGN04 are less-preferred sites. The significance of trends in CPUE and potential causal factors will be evaluated later in the JHTMON-3 study.

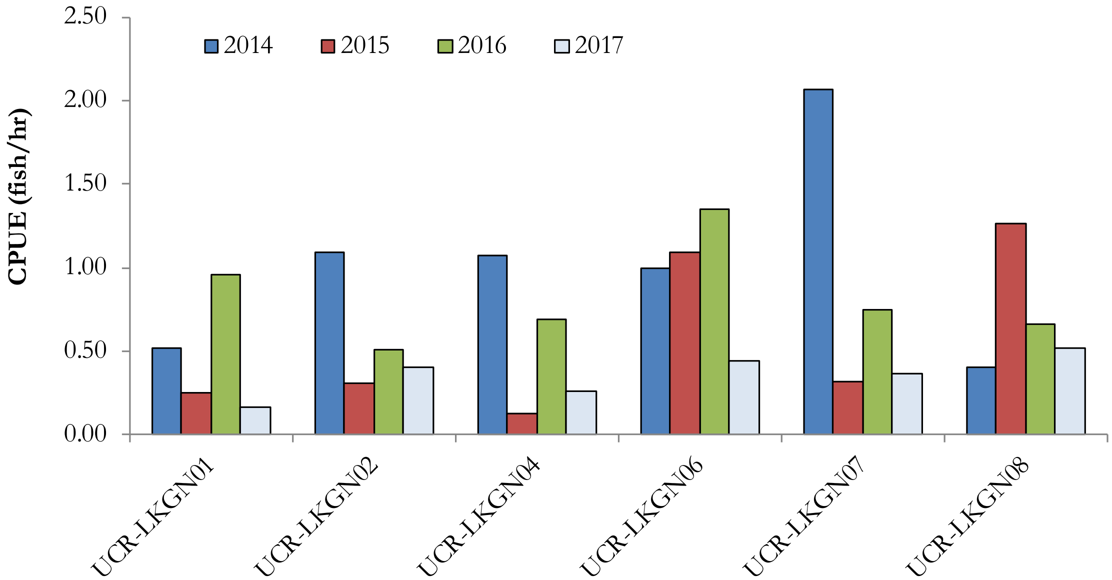
**Figure 13. Comparison of Cutthroat Trout CPUE from littoral RISC gill net surveys by sample site among the four years of this program to date (2014, 2015, and 2016).**




### 3.1.4.3. Rainbow Trout

There is no consistent trend in CPUE results for Rainbow Trout among the sampling sites or across sampling years. However, 2017 CPUE for Rainbow Trout was lower than 2016 CPUE at each sampling site. CPUE for Rainbow Trout in 2017 was less than half of previous year estimates at UCR-LKGN01, UCR-LKGN04, UCR-LKGN06, and UCR-LKGN07, and was lower than all previous recorded CPUE at UCR-LKGN01 and UCR-LKGN06. The trend of increasing CPUE observed at UCR-LKGN06 from 2014 to 2016 was not continued in 2017. The trend in CPUE at UCR-LKGN02 and UCR-LKGN06 was the reverse of that for Cutthroat Trout (Section 3.1.4.2), which may reflect competition between these two species. Since 2015, CPUE at UCR-LKGN08 has decreased consistently for both Rainbow Trout and Cutthroat Trout which may indicate a change in habitat quality or environmental conditions in 2015. As discussed for Cutthroat Trout, these comparisons are limited to four years of data; however, the results suggest that the density of Rainbow Trout at each site is independent of other sites. The significance of trends in CPUE and potential causal factors will be evaluated later in the JHTMON-3 study.

**Figure 14. Comparison of Rainbow Trout CPUE from littoral RISC gill net surveys by sample site among the four years of this program to date (2014, 2015, and 2016).**




### 3.1.5. Aging Comparisons

Both scale and fin ray samples were collected and aged from 26 Cutthroat Trout and from 12 Rainbow Trout in Year 4. An additional 33 fin ray samples collected from Cutthroat Trout (2015, n = 13; 2016, n = 17) and Rainbow Trout in 2015 (n = 2) and 2016 (n = 1) were aged in 2017 as a preliminary assessment of the accuracy and efficiency of each aging method prior to more detailed age analyses in Year 5. Ages derived from both methods have been used to compare and evaluate accuracy and efficiency of aging older fish (3+) using scales (as an easier and faster method) versus fin rays, where fin rays are recognized as being more accurate (Williamson and Macdonald 1997, Zymonas and McMahon 2009).

Scale and fin ray age estimates from the 2017 fish captures were the same in 19% and 33% of Cutthroat Trout and Rainbow Trout samples, respectively (Figure 15, Figure 16, and Table 14). The proportion of the Year 4 scales that resulted in older age estimates (Cutthroat Trout = 73%, Rainbow = 67%) or younger age estimates (Cutthroat Trout = 8%, Rainbow Trout = 0%), when compared to the Year 4 fin ray ages, show a bias of scale analysis in that it tends to overestimate the age of fish relative to fin ray analysis. Across samples from Year 2 to Year 4, scale and fin ray age estimates matched for 33% of Cutthroat Trout samples and 50% of Rainbow Trout samples. However, scale age was overestimated for 51% of Cutthroat trout samples and 42% of Rainbow Trout samples for this period. The fin ray age estimate was used as the reference for the current study, based on recommendations in the literature (Williamson and Macdonald 1997, Zymonas and McMahon 2009) and acknowledgement that scales can underestimate fish ages.

**Figure 15. Comparison between scale age and fin ray age estimates from Cutthroat Trout in 2015, 2016 and 2017. Scale and fin ray age estimates are provided in Appendix C. The dashed line provides a reference line of equivalent ages from each technique. Data points have been jittered to reduce overlap.**

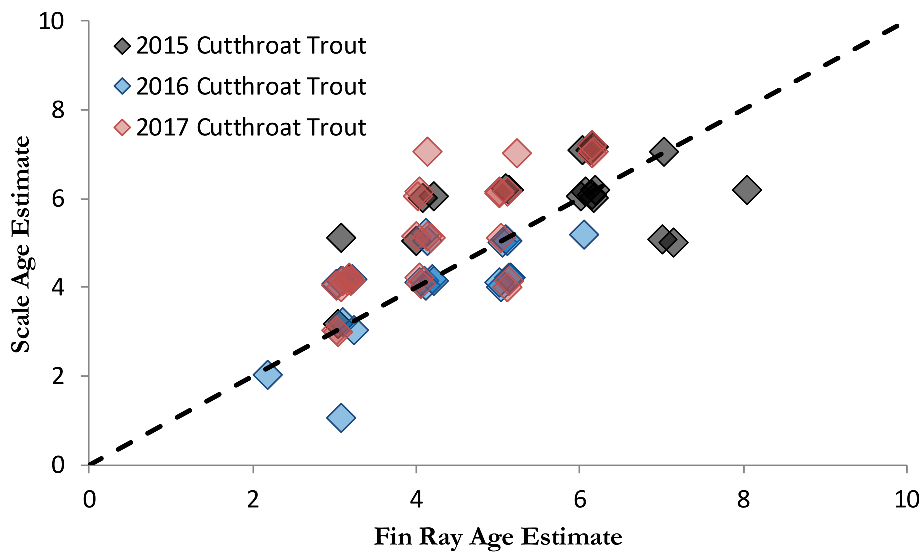


**Figure 16.** **Comparison between scale age and fin ray age estimates from Rainbow Trout in 2015, 2016, and 2017. Scale and fin ray age estimates are provided in Appendix C. The dashed line provides a reference line of equivalent ages from each technique. Data points have been jittered to reduce overlap.**

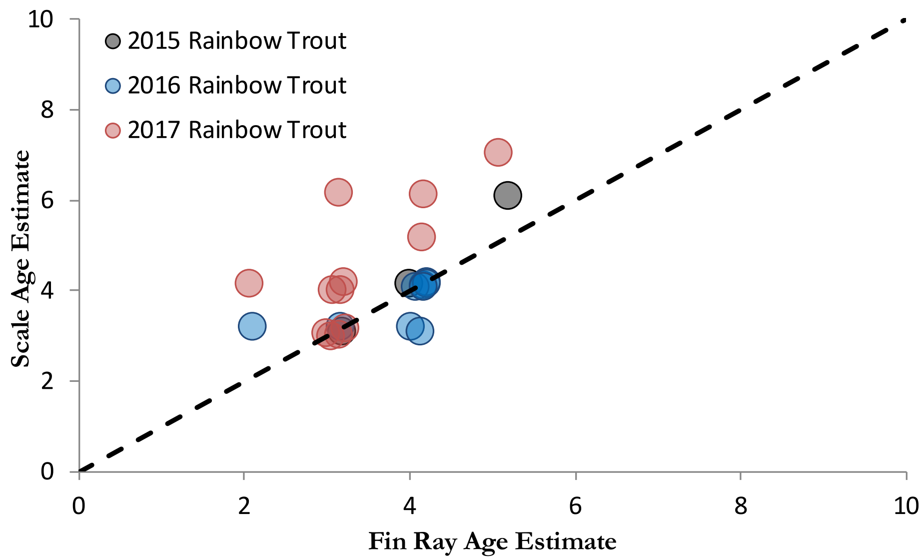



**Table 14.** **Summary of the number of Cutthroat Trout and Rainbow Trout scale age estimates that were greater than, equal to, and less than estimates of fin ray estimates in 2015, 2016 and 2017.**

| Species | Sample year | n | % Scale Age Underestimated[1] | % No Age Difference[1] | % Scale Age Overestimated[1] |
|---|---|---|---|---|---|
| Rainbow Trout | 2015 | 3 | 0% | 67% | 33% |
| | 2016 | 9 | 22% | 67% | 11% |
| | 2017 | 12 | 0% | 33% | 67% |
| **All Rainbow Trout** | | **24** | **8%** | **50%** | **42%** |
| Cutthroat Trout | 2015 | 21 | 14% | 33% | 52% |
| | 2016 | 22 | 27% | 50% | 23% |
| | 2017 | 26 | 8% | 19% | 73% |
| **All Cutthroat Trout** | | **69** | **16%** | **33%** | **51%** |

[1] Age difference calculated in fin ray age estimate minus scale age estimate.

## 3.2. Snorkel Survey of Spawners in Reservoir Tributaries

### 3.2.1. Survey Conditions

Survey conditions between the spring and summer surveys were relatively comparable. Details of survey locations, dates, effort, and conditions are presented for each separate survey during spring (Table 15) and summer (Table 16). All parameters (discharge, visibility, and temperature) during the spring surveys were influenced by seasonal freshet and precipitation with varying effective visibility from 3.5 m in March to 6.0 m in April and with temperatures ranging between 3.5°C and 4.0°C (Table 15). Relative to the spring, increased water temperature and visibility was experienced during summer surveys (Table 16). Representative photographs collected during surveys are presented in Appendix C.

**Table 15. Sampling effort and conditions for Year 4 snorkel surveys in tributaries of the Lower Campbell Reservoir during spring surveys in 2017. 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 | 23-Mar-17 | 0.7 | 1.4 | 4.0 | 5.5 | 3.5 | 7.6 | Overcast/Drizzle |
| | Miller Creek | 0.4 | 23-Mar-17 | 2.2 | 4.4 | 3.8 | 4.5 | 4.0 | 7.6 | Overcast/Drizzle |
| | Greenstone River | 2.4 | 21-Apr-17 | 2.7 | 8.0 | 3.5 | 7.0 | 6.0 | 9.7 | Dry/Partly Cloudy |

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

**Table 16. Sampling effort and conditions for Year 4 snorkel surveys during summer 2017. Survey distances are from LKT (2015).**

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Upper Campbell | Upper Elk River | 6.0 | 7-Jun-17 | 4.3 | 8.5 | 6.8 | 14.0 | 6.0 | 13.9 | Sunny/Dry |
| | Lower Elk River | 5.4 | 7-Jun-17 | 2.2 | 4.4 | 7.2 | 18.0 | 8.0 | 13.9 | Sunny/Dry |
| Buttle | Ralph River | 0.9 | 6-Jun-17 | 1.3 | 2.6 | 7.0 | 15.0 | 6.0 | 11.8 | Sunny/Dry |
| | Thelwood Creek | 2.5 | 8-Jun-17 | 2.5 | 5.0 | 7.8 | 13.0 | 5.0 | 17.3 | Sunny/Dry |
| | Wolf River | 0.3 | 5-Jun-17 | 0.8 | 1.5 | 6.5 | 14.0 | 6.0 | 10.8 | Sunny/Dry |
| | Phillips Creek | 0.3 | 5-Jun-17 | 0.7 | 1.3 | 5.0 | 12.0 | 6.0 | 10.8 | Partly Cloudy/Dry |
| | Henshaw Creek | 0.5 | 6-Jun-17 | 1.3 | 2.6 | 5.3 | 12.0 | 6.0 | 11.8 | Overcast/Light Rain |

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

### 3.2.2. Survey Results

#### 3.2.2.1. Cutthroat Trout Results

Year 4 snorkel survey data for the Cutthroat Trout spring spawning period are summarized below (Table 17); raw data are presented in Appendix C.

Snorkel surveys for spawning Cutthroat Trout were conducted in tributaries of the Lower Campbell River in March and April, 2017. During these Lower Campbell River snorkel surveys adult Cutthroat Trout were observed in Miller Creek and Greenstone River; however, redds were observed in all three tributaries of Lower Campbell Reservoir (Table 17). Miller Creek had the highest densities of Cutthroat trout with 407.5 fish/km and Greenstone River had the second highest density with 24.6 fish/km.

In Miller Creek, the majority of adult Cutthroat were in mid-spawn condition (70%, *n* = 114), or were moderately coloured (12%, n = 20), and only 18% (*n* = 29) were in post-spawn condition. A total of 249 putative Cutthroat trout redds were observed in Miller Creek. Thus, it is likely that peak spawning occurred prior to March 23, 2017, but was on-going on the survey date.

In Greenstone River, adult Cutthroat trout were moderately coloured (68%, *n* = 40), or in mid-spawn condition (32%, *n* = 19). No post-spawn adult Cutthroat trout were observed in the Greenstone River, though 17 Cutthroat redds were identified. Given the condition of Greenstone River cutthroat and presence of redds it is likely that the survey was completed at the onset of peak spawning.

No Cutthroat trout were observed during the 2017 snorkel survey of Fry Creek, however 39 putative Cutthroat redds were identified. It is noted that Year 4 Fry Creek redd count values are significantly lower than values recorded in Year 2 and Year 3 (Hatfield *et al.* 2015 and 2016). Given the presence of redds but lack of adult Cutthroat in Fry Creek it is likely that spawning occurred prior to surveying.

**Table 17. Cutthroat Trout counts during 2017 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+ | |
| Lower Campbell | March | Fry Creek | 23-Mar-17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 39 |
| | | Miller Creek | 23-Mar-17 | 163 | 0 | 0 | 51 | 103 | 9 | 0 | 249 |
| | April | Greenstone River | 21-Apr-17 | 59 | 0 | 0 | 2 | 11 | 28 | 18 | 17 |
| Upper Campbell | June | Lower Elk River | 07-Jun-17 | 11 | 0 | 0 | 0 | 11 | 0 | 0 | n/a |
| | | Upper Elk River | 07-Jun-17 | 58 | 0 | 37 | 7 | 2 | 11 | 1 | n/a |
| Buttle | | Phillips Creek | 05-Jun-17 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | n/a |
| | | Wolf River | 05-Jun-17 | 26 | 0 | 0 | 2 | 6 | 18 | 0 | n/a |
| | | Henshaw Creek | 06-Jun-17 | 3 | 0 | 0 | 0 | 1 | 2 | 0 | n/a |
| | | Ralph River | 06-Jun-17 | 8 | 0 | 0 | 0 | 7 | 1 | 0 | n/a |
| | | Thelwood Creek | 08-Jun-17 | 14 | 0 | 0 | 0 | 1 | 11 | 2 | 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.

#### 3.2.2.2. Rainbow Trout Results

Year 4 snorkel survey data for the summer Rainbow Trout spawning period are summarized below; raw data are presented in tabular form in Appendix C.

Rainbow Trout redds were recorded in all surveyed tributaries of Upper Campbell and Buttle Lake (Table 18). The highest number of redds was observed in Thelwood Creek (576 redds), followed by lower Elk River (568 redds). Redd counts in Year 4 were lower than counts in Year 2 and Year 3 (Hatfield *et al.* 2016 and 2017) when 1,441 and 1,217 redds were recorded in Thelwood Creek, respectively[1]. Similarly, the total number of Rainbow Trout redds recorded in the Elk River in Year 4 (1,087) was lower than in Year 2 (1,846) and Year 3 (1,833) (Hatfield *et al.* 2016 and 2017). Redds were observed during snorkel surveys in tributaries of the Lower Campbell Reservoir in March and April; however, they are assumed to have been excavated by Cutthroat Trout.

Total Rainbow Trout density per km of stream (juvenile and adult fish combined) varied considerably between the ten stream reaches, with observed densities greatest in Wolf River (1,090 fish/km), Thelwood Creek (653 fish/km), and Lower Elk River (516 fish/km) (Figure 17). When interpreting these results, note that variability in channel width hinders direct comparison of this metric between tributaries.

Adult Rainbow Trout counts were much higher than Cutthroat Trout, which may have been a result of effective survey timing in relation to Rainbow Trout spawning, or due to differences in effective population size between the species. Highest count numbers of adult Rainbow Trout observations were recorded from lower Elk River (2,784 fish); Thelwood Creek (1,633 fish); and upper Elk River (1,318 fish) (Figure 18). These watercourses also correspond to the highest counts from the Year 1 (Hatfield *et al.* 2015), Year 2 (Hatfield *et al.* 2016), and Year 3 (Smythe and Hatfield, 2017) surveys. The majority of the observed Rainbow Trout were in mid-spawn (67%) or of moderately coloured (23%) condition, suggesting that these surveys occurred during spawning (Figure 18). The exception to this; however, was in Henshaw Creek where the majority of fish were of bright (53%), or moderately coloured (35%) condition, and only 12% of fish were in mid-spawn condition. All Rainbow Trout observed in Miller Creek during March snorkel surveys were moderately coloured, suggesting that they were in a pre-spawn condition.

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

**Table 18. Rainbow Trout counts during 2017 snorkel surveys in the tributaries of Upper and Lower Campbell Reservoirs and Buttle Lake.**

| Month | Waterbody | Date | Rainbow Trout Observations (# of fish)[1] | | | | | | | Redds[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Fry | Parr | 151-250 | 251-350 | 351-450 | 450+ | |
| March | Fry Creek | 23-Mar-17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | n/a |
| | Miller Creek | 23-Mar-17 | 36 | 0 | 0 | 12 | 23 | 1 | 0 | n/a |
| April | Greenstone River | 21-Apr-17 | 0 | 1 | 3 | 0 | 4 | 0 | 0 | n/a |
| June | Phillips Creek | 05-Jun-17 | 79 | 0 | 0 | 1 | 54 | 24 | 0 | 7 |
| | Wolf River | 05-Jun-17 | 327 | 0 | 0 | 25 | 250 | 52 | 0 | 117 |
| | Henshaw Creek | 06-Jun-17 | 17 | 0 | 0 | 1 | 14 | 2 | 0 | 5 |
| | Ralph River | 06-Jun-17 | 421 | 0 | 0 | 32 | 350 | 39 | 0 | 196 |
| | Lower Elk River | 07-Jun-17 | 2,784 | 0 | 10 | 772 | 1,745 | 257 | 0 | 568 |
| | Upper Elk River | 07-Jun-17 | 1,318 | 0 | 14 | 162 | 899 | 243 | 0 | 519 |
| | Thelwood Creek | 08-Jun-17 | 1,633 | 0 | 0 | 241 | 1,292 | 100 | 0 | 576 |

[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 17.** **Rainbow Trout observed density (fish/km; all life stages) during Year 4 summer snorkel surveys in the tributaries of Upper Campbell Reservoir and Buttle Lake. Rainbow Trout observed incidentally during snorkel surveys for Cutthroat Trout in the Lower Campbell Reservoir are not included.**

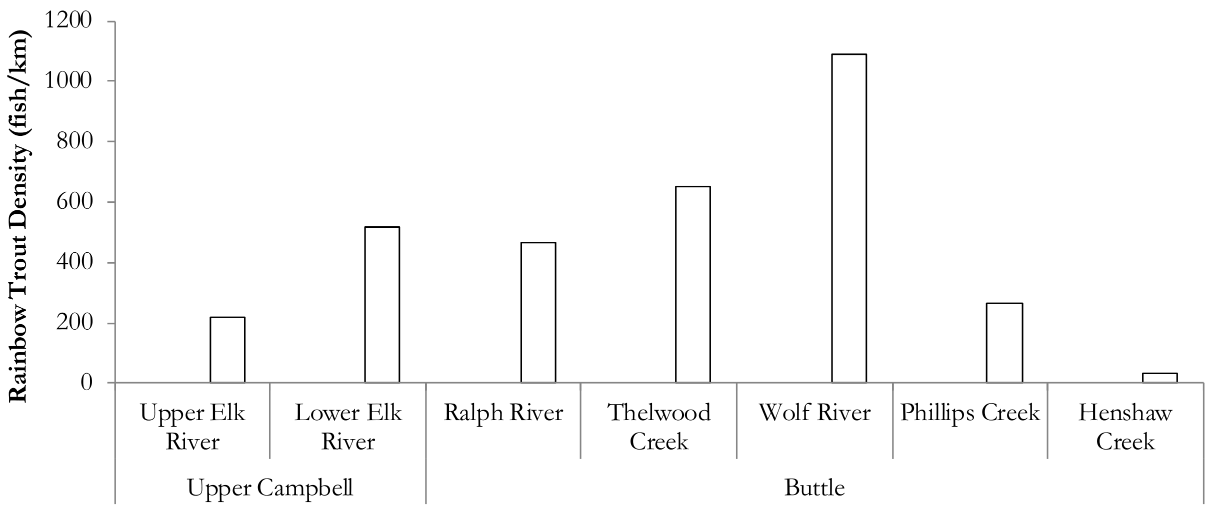
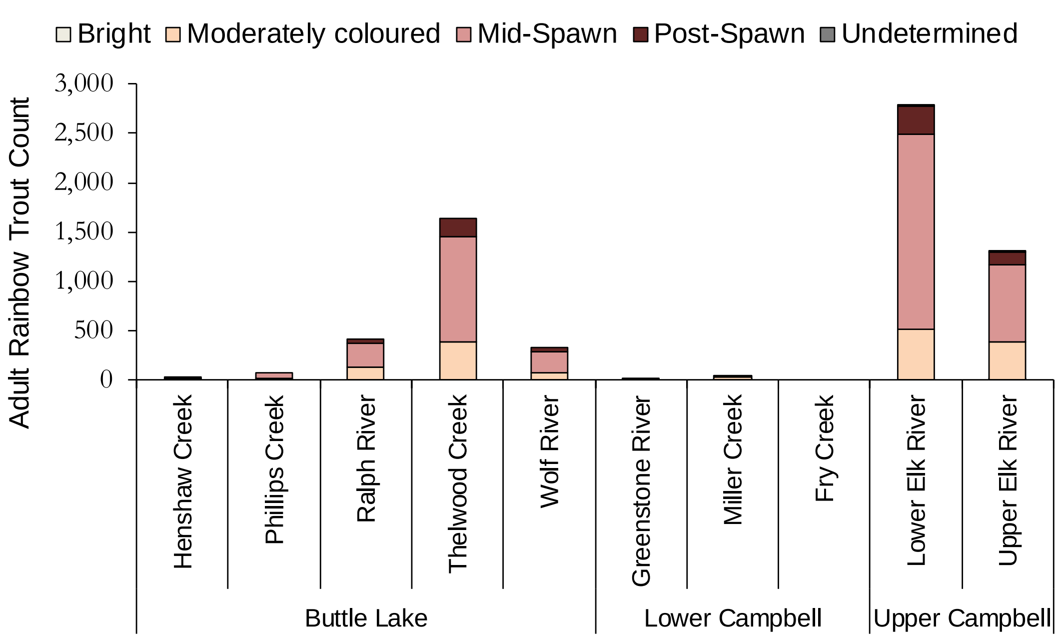



**Figure 18.** **Counts of adult Rainbow Trout observed during Year 4 summer snorkel surveys in the tributaries of Upper Campbell Reservoir and Buttle Lake, by condition classes. Rainbow trout observed incidentally during snorkel surveys for Cutthroat Trout in Lower Campbell Reservoir are not included.**



#### 3.2.2.3. Dolly Varden and Unidentified Salmonids

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

Dolly Varden were not recorded during the spring surveys and limited observations occurred during the summer surveys (Table 19). The greatest number of adult Dolly Varden were observed in Wolf River (51 fish) which held the highest number of incidental Dolly Varden observations in the Year 1 (Hatfield *et al.* 2015) and Year 2 (Hatfield *et al.* 2016) and the second highest number in Year 3 (Hatfield *et al.* 2017). In Year 4, the density of Wolf River Dolly Varden (170 fish/km) surpassed all previous density records and was an order of magnitude greater than densities reported in Year 3 (Hatfield *et al.* 2015, 2016 and 2017). Densities observed in Ralph River and Henshaw and Thelwood creeks were comparable to densities observed in previous years.

**Figure 19. Dolly Varden observed density (fish/ km) from 2017 summer snorkel surveys in the tributaries of Upper Campbell Reservoir and Buttle Lake. No Dolly Varden were observed in Lower Campbell Reservoir tributaries.**

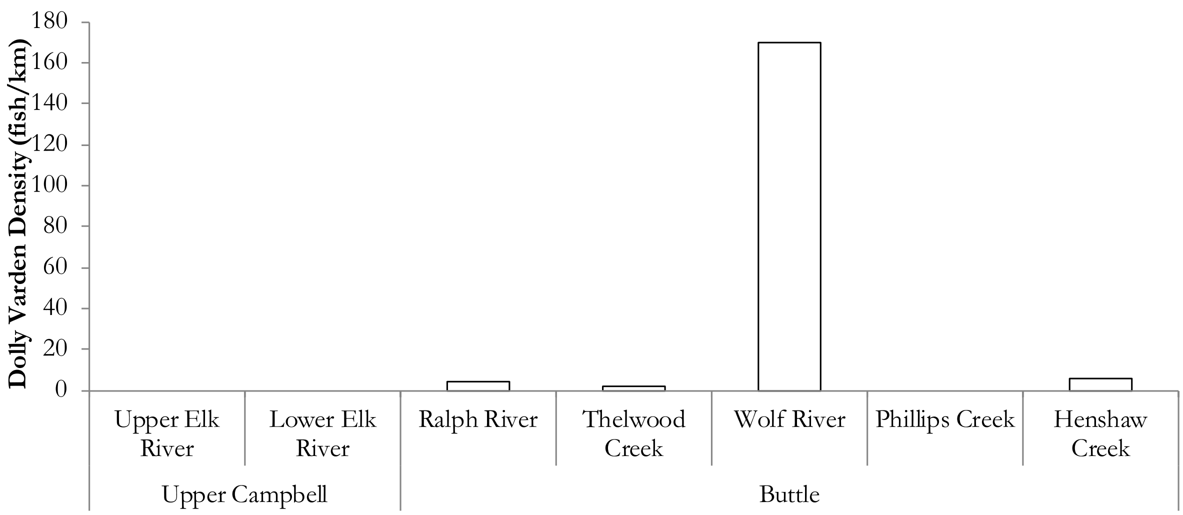


**Table 19. Dolly Varden population counts (incidental) from 2017 snorkel surveys in the tributaries of Upper and Lower Campbell Reservoirs and Buttle Lake.**

| Month | Waterbody | Date | Dolly Varden Observations (# of fish) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Fry | Parr | 151-250 | 251-350 | 351-450 | 450+ |
| March | Fry Creek | 23-Mar-17 | 0 | 0 | 0 | 0 | 0 | 0 | n/a |
| | Miller Creek | 23-Mar-17 | 0 | 0 | 0 | 0 | 0 | 0 | n/a |
| April | Greenstone River | 21-Apr-17 | 0 | 0 | 0 | 0 | 0 | 0 | n/a |
| June | Phillips Creek | 05-Jun-17 | 0 | 0 | 0 | 0 | 0 | 0 | n/a |
| | Wolf River | 05-Jun-17 | 51 | 0 | 0 | 10 | 25 | 16 | n/a |
| | Henshaw Creek | 06-Jun-17 | 3 | 3 | 0 | 0 | 0 | 0 | n/a |
| | Ralph River | 06-Jun-17 | 4 | 0 | 0 | 1 | 3 | 0 | n/a |
| | Lower Elk River | 07-Jun-17 | 0 | 0 | 0 | 0 | 0 | 0 | n/a |
| | Upper Elk River | 07-Jun-17 | 0 | 0 | 0 | 0 | 0 | 0 | n/a |
| | Thelwood Creek | 08-Jun-17 | 4 | 1 | 0 | 2 | 0 | 1 | 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.

### 3.2.3. Comparison with historic data

#### 3.2.3.1. 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 has not been consistent from year to year for several of the tributaries. The size limit used to define "adult" fish during historic surveys is not known, with the exception of Fry Creek (fork length > 100 mm). Fish count data for the six tributaries that are part of this monitoring program (data for the survey reaches in the upper and lower Elk River are presented separately) are presented in Table 20; of the three species enumerated, counts have historically been highest for Rainbow Trout, which was also true for the June 2017 surveys.

Regular annual snorkel surveys have not been 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 historic data are derived from surveys undertaken across a range of months and are thus presented separately in Table 21; note that no fish were recorded during the 2014 survey of Fry Creek.

**Table 20. Summary of adult fish count data in six tributaries of Upper Campbell Reservoir and Buttle Lake that were surveyed (1990–2017). Historic 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 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | | 2014 | 2015 | 2016 | 2017 |
| 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 | 1,586 | 1,066 | 1,562 | 1,847 | 1,445 | n/a | 716 | 551 | 877 | 1,147 | 764 | 900 | 1304 |
| | | CT | n/a | 8 | 7 | 0 | 19 | 11 | 1 | n/a | n/a | n/a | n/a | 3 | 2 | 0 | 5 | n/a | 4 | 0 | 2 | 5 | 10 | n/a | 11 | 10 | 8 | 2 | 3 | 2 | 21 |
| | | DV | n/a | 0 | 5 | 0 | 0 | 2 | n/a | n/a | n/a | 1 | n/a | 6 | 0 | 0 | 0 | n/a | 6 | 1 | 1 | 1 | 2 | n/a | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| | 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 | 5,340 | 4,862 | 5,630 | 2,501 | 3,919 | n/a | 3,980 | 1,537 | 1,204 | 1,742 | 886 | 2104 | 2774 |
| | | CT | 7 | 16 | 11 | 1 | 26 | 2 | 8 | n/a | n/a | n/a | n/a | 3 | 2 | 1 | 3 | n/a | 3 | 3 | 11 | 4 | 20 | n/a | 5 | 5 | 7 | 2 | 4 | 6 | 11 |
| | | DV | 0 | 0 | 4 | 0 | 13 | 0 | n/a | n/a | n/a | 0 | n/a | 6 | 2 | 1 | 2 | n/a | 9 | 2 | 0 | 2 | 1 | n/a | 0 | 1 | 0 | 0 | 1 | 2 | 0 |
| 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 | 650 | 690 | 1,103 | 1,181 | 708 | n/a | 479 | 536 | | 835 | 407 | 419 | 421 |
| | | CT | n/a | 0 | 0 | 4 | 0 | n/a | n/a | n/a | 2 | n/a | 2 | 0 | 0 | 2 | 10 | n/a | 2 | 0 | 2 | 0 | 0 | n/a | 1 | 2 | | 1 | 0 | 3 | 8 |
| | | DV | n/a | 10 | 10 | 4 | 4 | n/a | n/a | n/a | 30 | n/a | 8 | 0 | 3 | 0 | 17 | n/a | 4 | 56 | 0 | 9 | 4 | n/a | 0 | 13 | | 4 | 1 | 3 | 4 |
| | 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 | 3,105 | 3,921 | 4,408 | 4,128 | 4,892 | 1,123 | 3,748 | 4,104 | | 2,567 | 800 | 1110 | 1633 |
| | | CT | n/a | 200 | 15 | 88 | 347 | n/a | 53 | n/a | n/a | 141 | 53 | 441 | 34 | 64 | 20 | n/a | 25 | 10 | 12 | 4 | 17 | 32 | 26 | 15 | | 0 | 11 | 11 | 14 |
| | | DV | n/a | 225 | 1 | 0 | 30 | n/a | 2 | n/a | n/a | 28 | 0 | 0 | 8 | 3 | 6 | n/a | 24 | 6 | 4 | 9 | 5 | 2 | 0 | 0 | | 0 | 7 | 8 | 3 |
| | 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 | n/a | n/a | 1,250 | 1,210 | 1,590 | 140 | 192 | 666 | | 384 | 410 | 345 | 327 |
| | | 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 | n/a | n/a | 6 | 1 | 0 | 0 | 2 | 3 | | 3 | 0 | 10 | 26 |
| | | 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 | n/a | n/a | 25 | 90 | 90 | 30 | 5 | 18 | | 30 | 25 | 5 | 51 |
| | 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 | n/a | n/a | 162 | 624 | 540 | 106 | 145 | 191 | | 223 | 157 | 153 | 79 |
| | | CT | n/a | n/a | 0 | n/a | n/a | 6 | n/a | n/a | n/a | 2 | 0 | 6 | 0 | 5 | 1 | 0 | n/a | n/a | 1 | 0 | 0 | 0 | 2 | 0 | | 2 | 0 | 0 | 1 |
| | | DV | n/a | n/a | 20 | n/a | n/a | 50 | n/a | n/a | n/a | 10 | 1 | 16 | 1 | 5 | 0 | 11 | n/a | n/a | 3 | 4 | 40 | 21 | 3 | 8 | | 18 | 0 | 0 | 0 |
| | 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 | 5 | 42 | 24 | 93 | 27 | n/a | 8 | 37 | | 26 | 29 | 44 | 17 |
| | | 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 | 0 | 0 | 1 | 0 | 0 | n/a | 0 | 0 | | 0 | 0 | 0 | 3 |
| | | 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 | 0 | 0 | 0 | 0 | 0 | n/a | 0 | 0 | | 0 | 0 | 0 | 0 |

[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. Historic adult fish count data for Fry Creek, from survey dates 2003, 2004, 2014, 2015, 2016, and 2017. 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 |

[1] Fish counts for 2003 and 2004 include fish $\geq$ 100 mm and fish counts from 2014 onwards include fish $\geq$ 150 mm
[2] RB - Rainbow Trout, CT - Cutthroat Trout, and DV - Dolly Varden

3.2.3.1. Cutthroat Trout

The data presented here for June, 2017 are from Rainbow Trout spawning surveys, so any trends in Cutthroat Trout should be interpreted cautiously. Adult Cutthroat Trout counts in 2017 (ranging from 1 to 26 fish) are generally consistent with historic observations for the period 1990 to 2016 (Table 20), but greater than median historic values (Table 19). Exceptions include Thelwood Creek, which had lower counts than those observed in historical data (2017, $n$ = 14; historical range = 0 to 441, median = 25.5, $n$ = 22) and Upper Elk River (2017, $n$ = 21; historical range = 0 to 19, median =4, $n$ = 21), Wolf River (2017, $n$ = 26; historical range = 0 to 10, median = 1, $n$ = 16), and Henshaw Creek (2017, $n$ = 3; historical range = 0 to 1, median = 0, $n$ = 16), which had 2017 counts exceeding those in historical records. In Fry Creek, comparable survey data for March is only available in 2003 and 2016 where 287 and 0 Cutthroat Trout were observed, respectively (Table 21). Abundance of Fry Creek Cutthroat Trout in 2017 ($n$ = 0) was comparable to abundance in 2016 ($n$ = 0), but substantially lower than in 2003 ($n$ = 287). However, as mentioned in Section 3.2.2.1, surveys were likely conducted following 2017 Cutthroat Trout spawning which means that the 2017 counts are not an accurate measure of the spawner abundances in Fry Creek.

#### 3.2.3.2. Rainbow Trout

There is high variability in adult Rainbow Trout counts among years for individual tributaries (Table 20, Figure 20 to Figure 24). Most tributaries were substantially below the median historical values, including for Ralph River (Figure 22), Thelwood Creek (Figure 23), Wolf River (Figure 24), and Phillips Creek (Figure 25). It is worth noting that Year 4 counts were significantly reduced in Philips and Henshaw Creek relative to Year 3 observations (Figure 25 and Figure 26, respectively). No adult Rainbow Trout were recorded in Fry Creek in March 2017; however, this was comparable to sampling results from March 2003 and 2016 (Table 21). There is no definite trend over time in any of the tributaries, but a rising trend is apparent in the Upper and Lower Elk Rivers (Figure 20 and Figure 21, respectively) and Thelwood Creek (Figure 23); however, additional data are needed to determine if these observations are indicative of an increase in population or due to interannual variability.

**Figure 20. Adult Rainbow Trout counts on Upper Elk River (1990-2017). No surveys were completed in 1990, 1997, 1998, 1999, 2000, 2005, and 2011. Historic data (prior to 2014) were provided by BCCF (Pellett 2013).**

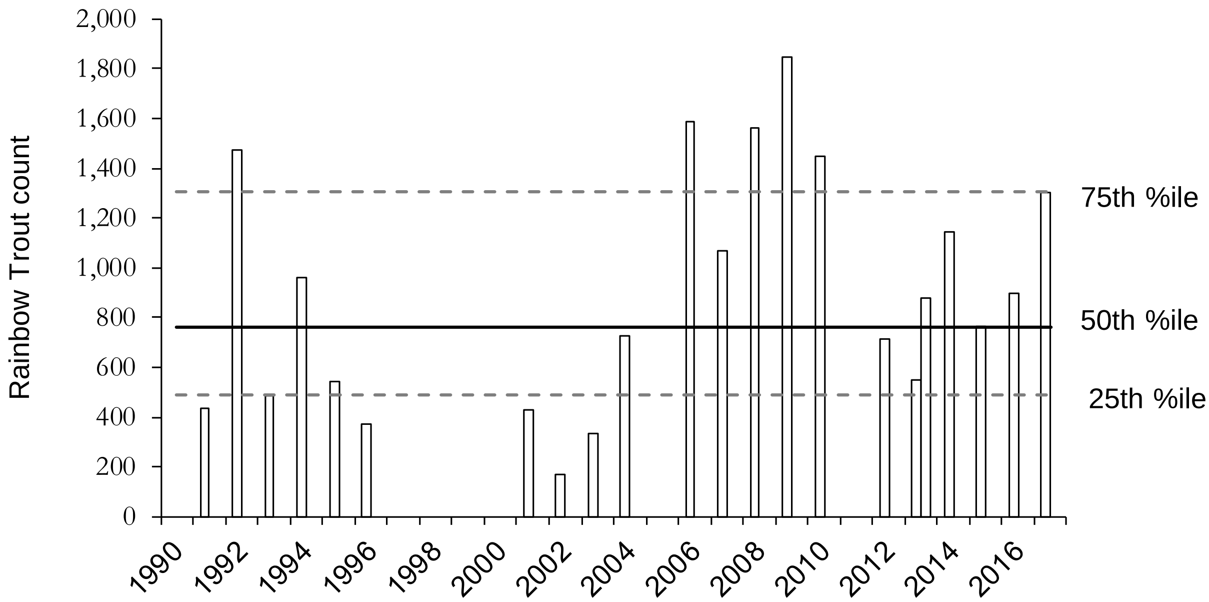


**Figure 21. Adult Rainbow Trout counts on Lower Elk River (1990-2017). No surveys were completed in 1997, 1998, 1999, 2000, 2005, and 2011. Historic data (prior to 2014) were provided by BCCF (Pellett 2013).**

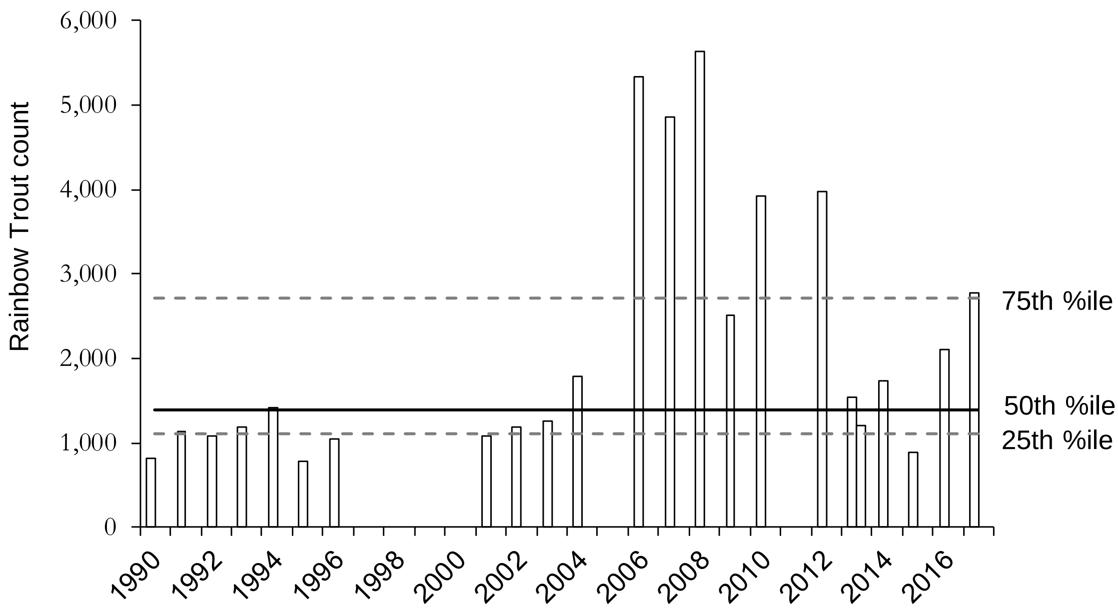



**Figure 22. Adult Rainbow Trout counts in Ralph River (1990-2017). No surveys were completed in 1990, 1995-1997, 1999, 2005, and 2011. Historic data (prior to 2014) were provided by BCCF (Pellett 2013).**

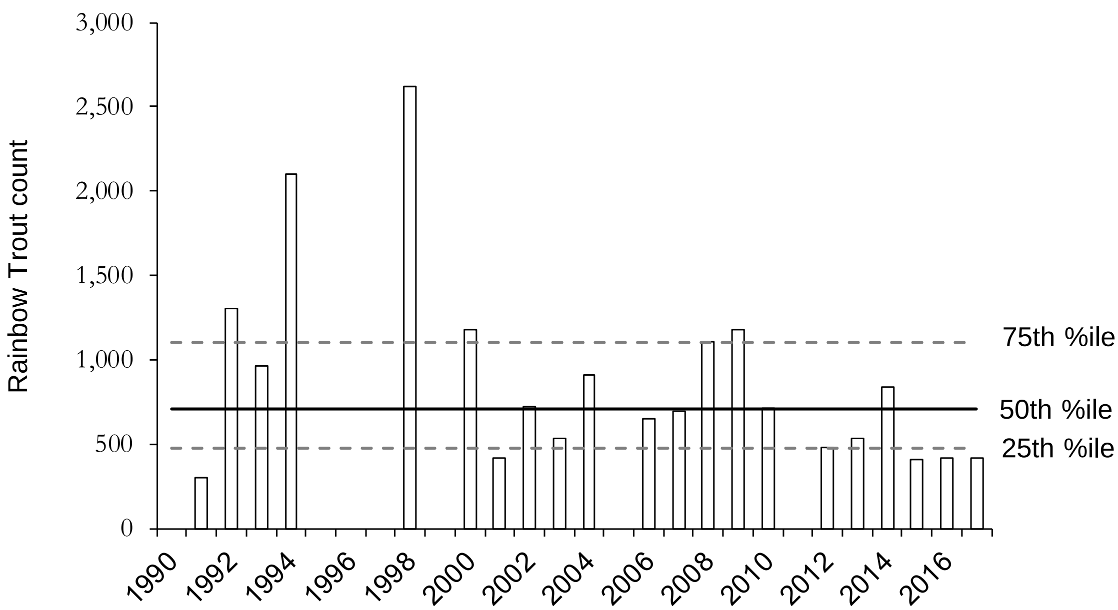


**Figure 23. Adult Rainbow Trout counts in Thelwood Creek (1990-2017). No surveys were completed in 1990, 1995, 1997, 1998, and 2005. Historic data (prior to 2014) were provided by BCCF (Pellett 2013).**

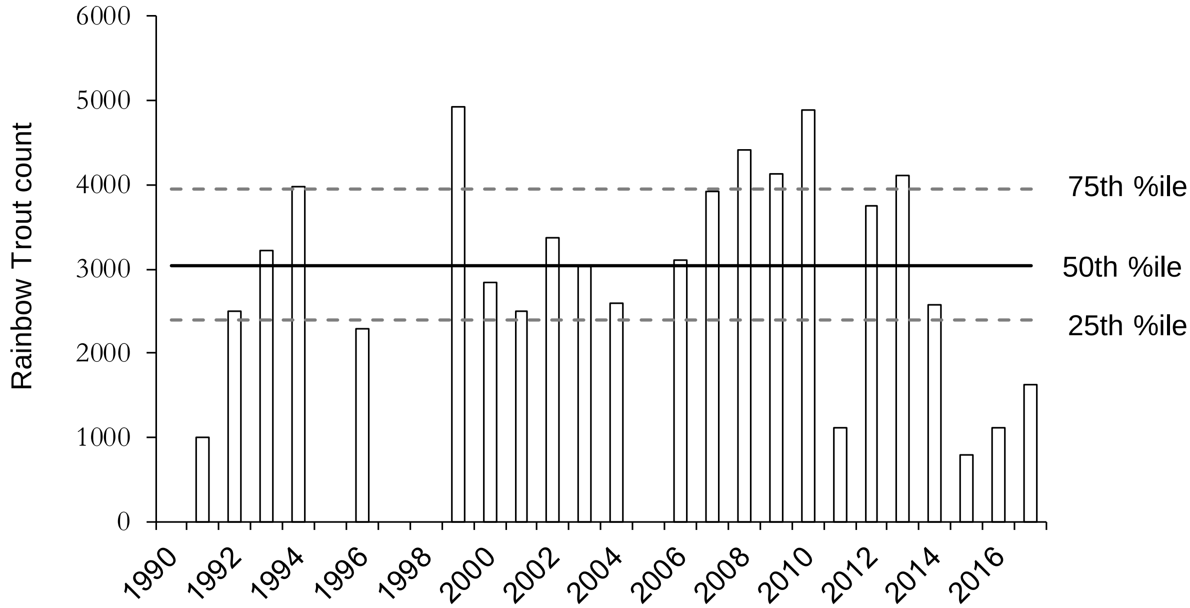



**Figure 24. Adult Rainbow Trout counts in Wolf River (1990-2017). No surveys were completed in 1990-1994, 1996-1998, 2000, and 2006-2007. Historic data (prior to 2014) were provided by BCCF (Pellett 2013).**

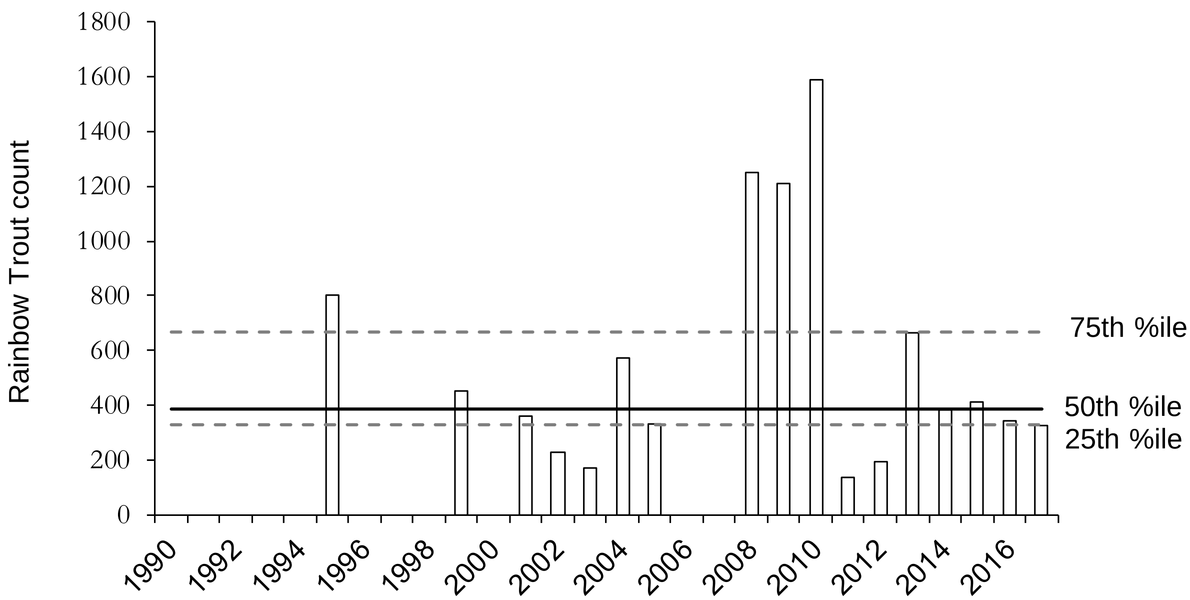


**Figure 25. Adult Rainbow Trout counts in Phillips Creek (1990-2017). No surveys were completed in 1990-1991, 1993-1994, 1996-1998, and 2006-2007. Historic data (prior to 2014) were provided by BCCF (Pellett 2013).**

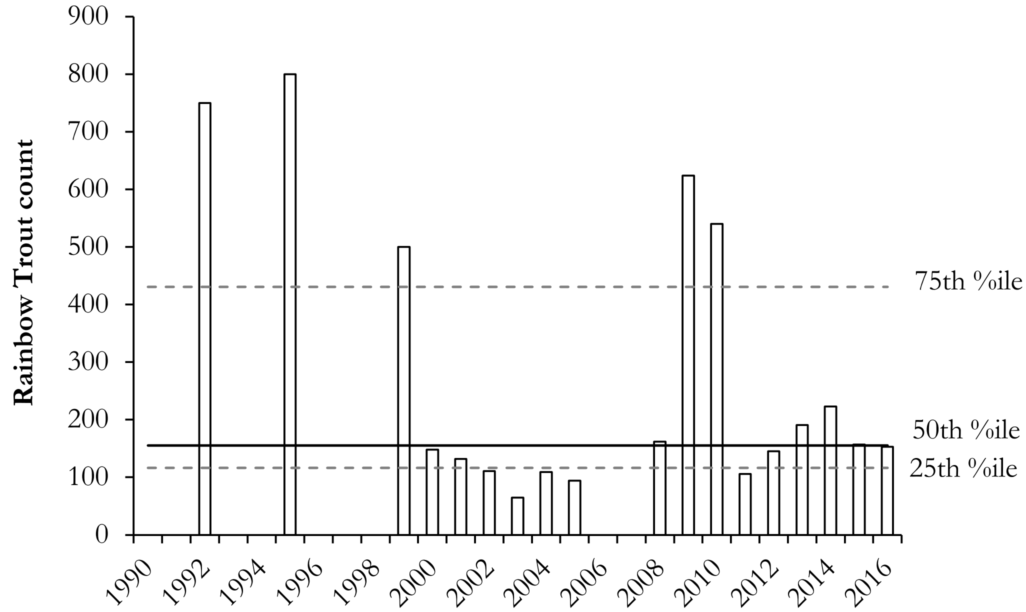
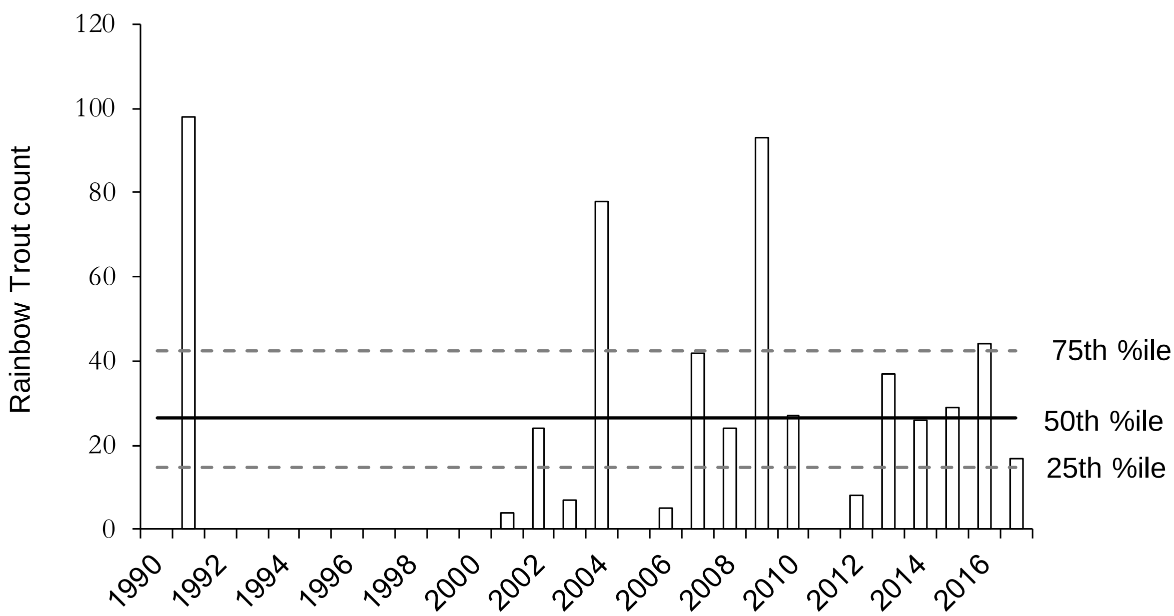



**Figure 26. Adult Rainbow Trout counts in Henshaw Creek (1990-2017). No surveys were completed in 1990, 1992-2000, 2005, and 2011. Historic data (prior to 2014) were provided by BCCF (Pellett 2013).**



#### 3.2.3.3. Dolly Varden

The data presented here are from surveys completed during the month of June which targeted Rainbow Trout spawning, so any trends in Dolly Varden should be interpreted cautiously. The 2017 adult Dolly Varden counts were generally low (range = 0 to 51) and are comparable to the results of the 2015 and 2016 surveys and furthermore, are broadly comparable with historic surveys (Table 20). Of the seven survey reaches in Buttle Lake and Upper Campbell Reservoir, the 2017 adult Dolly Varden counts were in line with the median values for the majority of tributaries (Table 20), but was substantially below the historical median value for Phillips Creek (2017, $n$ = 0; historical range = 0 to 50; median = 7; $n$ = 18) and significantly greater than the historical median value for Wolf Creek (2017, $n$ = 51; historical range = 0 to 90, median = 25, $n$ = 16). No adult Dolly Varden were counted in Fry Creek in 2017, consistent with the previous surveys conducted in the month of March in 2003 and 2016 (Table 21).

## 3.3. Effective Spawning Habitat (ESH)

The ESH will vary among years depending on the reservoir elevation during spawning, and the magnitude of reservoir level increase during the egg incubation period. We therefore carefully consider the variation in reservoir elevations during the period of the TOR (Section 3.3.1), which will assist in the Year 5 assessment of WUP success for the ESH Performance Measure (Section 1.2). The ESH for Cutthroat Trout, Rainbow Trout and Dolly Varden were modelled separately as described in Section 2.4, because of their different life histories.

### 3.3.1. Lake elevation for Upper and Lower Campbell Reservoirs

The Upper Campbell Reservoir elevations showed a cyclical pattern of changes in elevation throughout the year where elevation is usually low in spring (January to mid-April) and fall (mid-September through mid-November). This pattern was apparent in both the extended data set (1984 – 2017; Figure 27) and following the interim flow management strategy (IFMS) period (1998 onwards) that was ordered in October 1997 (Figure 28) (BC Hydro 2014). The post-IFMS data set differs from the extended data set in that there are decreases in the 10$^{th}$ percentile, average, and 90$^{th}$ percentile values. The elevations observed in 2017 were notably different from the average elevations but did not exceed the 90$^{th}$ percentile for the extended data. Exceedances of the 90$^{th}$ percentile were observed at the end of May and end of November for the post-IFMS period. Average elevations were generally above the 10$^{th}$ percentile for both the extended data set and the post-IFMS period with exceptions occurring in both datasets in January and October where values dipped slightly below the 10$^{th}$ percentile.

The Lower Campbell Reservoir elevations showed relatively stable elevations throughout the year, in both the extended data set (Figure 29) and the post-IFMS period (Figure 30). Similar to the Upper Campbell Reservoir, the post-IFMS data set differs from the extended data set in that there are decreases in the 10$^{th}$ percentile in elevation; however, this difference is relatively small. Similar to the Upper Campbell Reservoir, elevations observed in the Lower Campbell Reservoir during 2017 were beyond the 10$^{th}$ and 90$^{th}$ percentile at certain times of the year. The most notable differences occurred when values dropped below the 10th percentile in July, October, and November. Elevations exceeded the 90th percentile only once in the post-IFMS occurring for a short duration in late May. No exceedances were observed relative to the extended data set.

**Figure 27. Upper Campbell Reservoir elevations (masl) during the extended data period (1984 to 2017).**

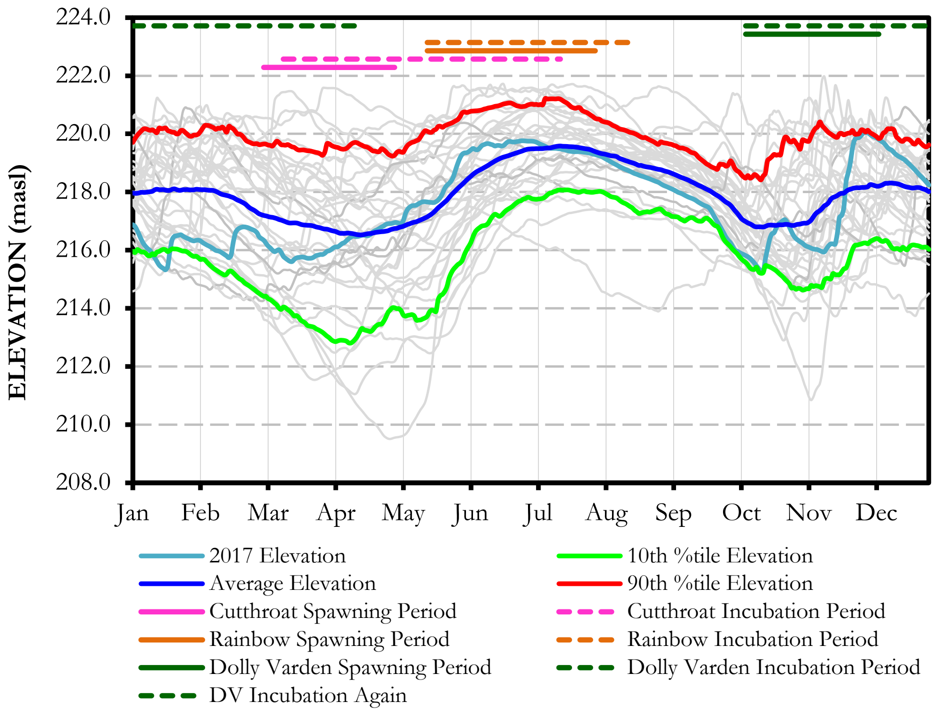


Figure 28. Upper Campbell Reservoir elevations (masl) during the post-IFMS period (1998 to 2017).

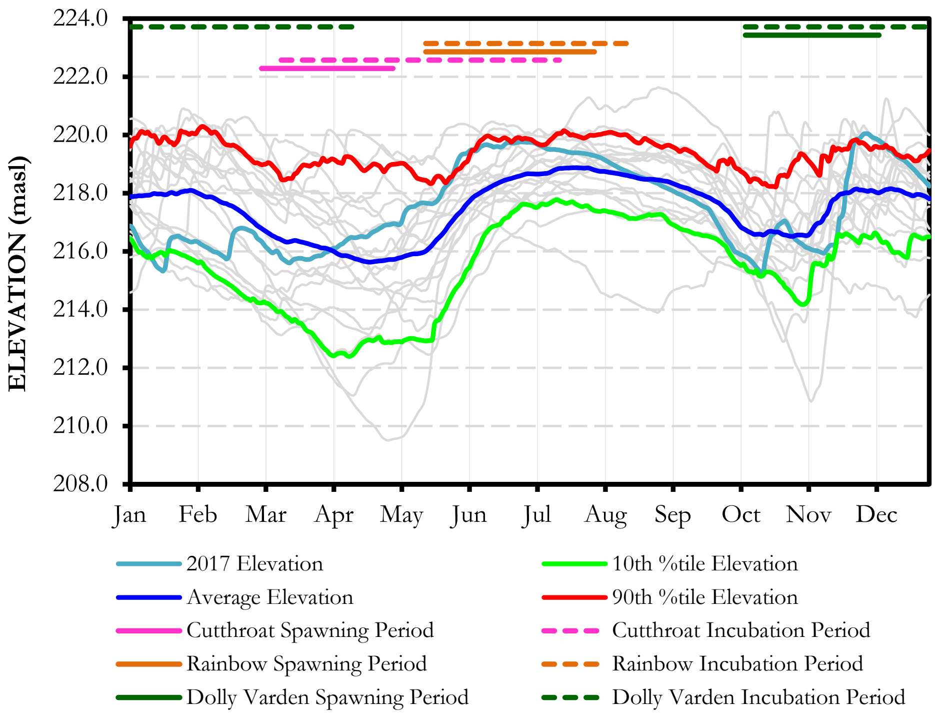



Figure 29. Lower Campbell Reservoir elevations (masl) during the extended data period (1984 to 2017).

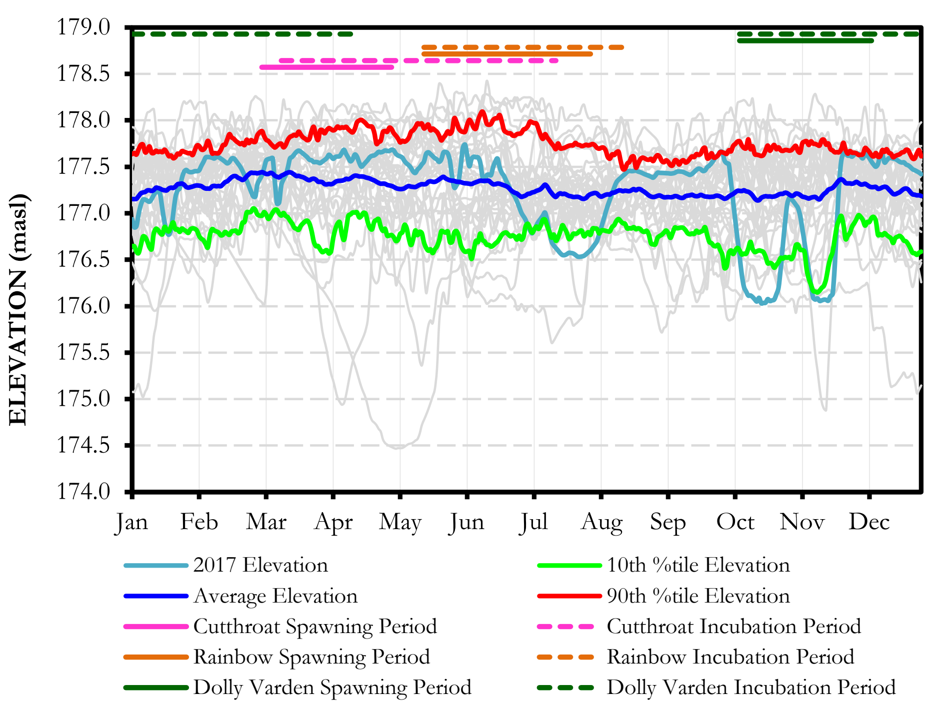
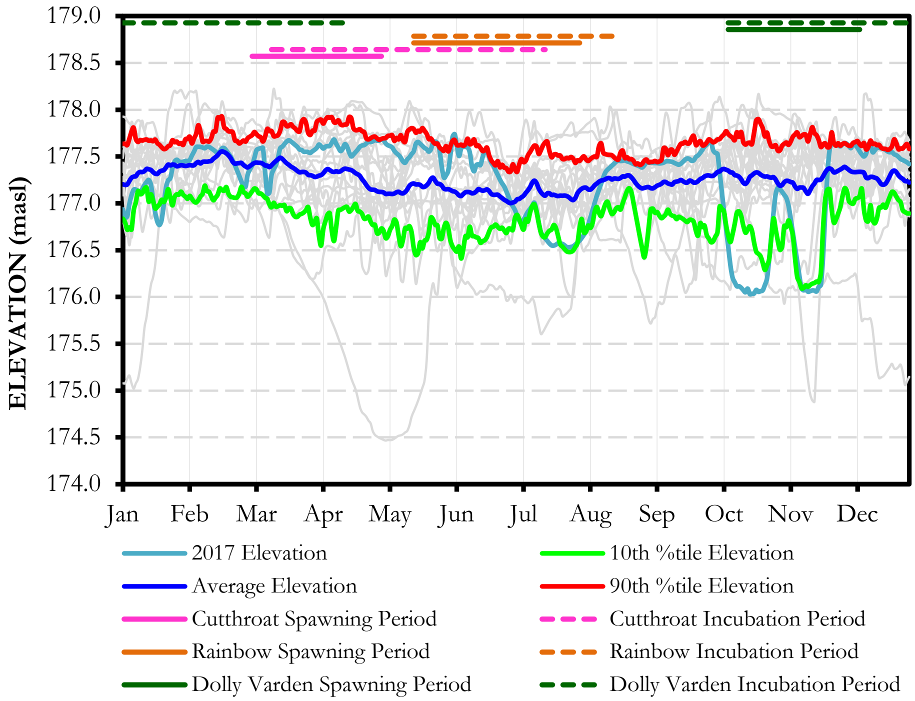


**Figure 30. Lower Campbell Reservoir elevations (masl) during the post-IFMS period (1998 to 2017).**



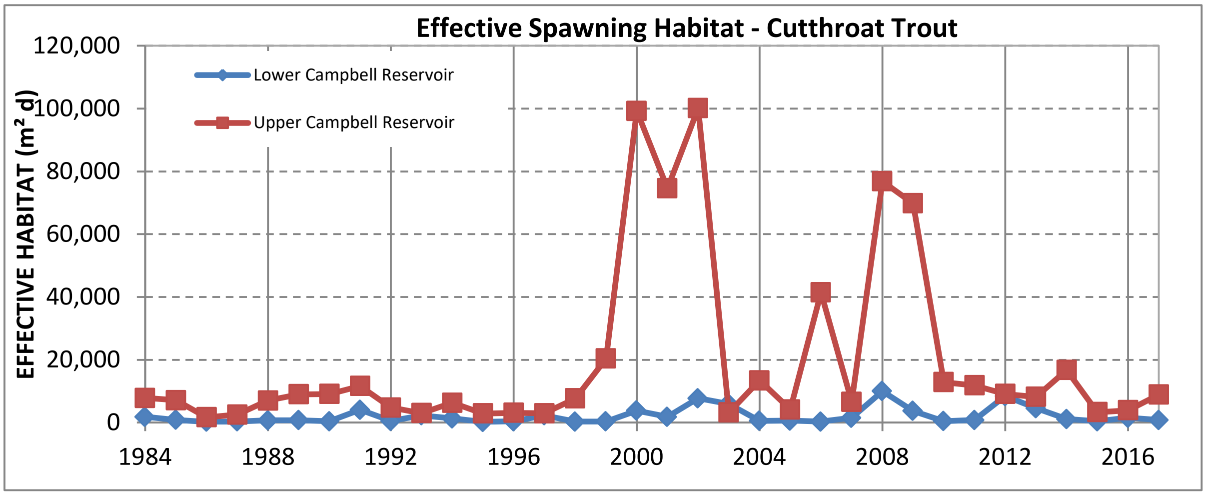

### 3.3.2. Cutthroat Trout

Effective spawning habitat values for both Lower and Upper Campbell reservoirs were variable among years, with much greater variability in the Upper Campbell Reservoir effective spawning habitat (range of 1,676 to 100,111 m²d; mean = 19,759 m²d) than the Lower Campbell Reservoir effective spawning habitat (range of 198 to 10,043 m²d; mean = 2,106 m²d) (Figure 31). Effective spawning habitat loss was calculated as the difference between effective spawning habitat and initial spawning habitat during the spawning and incubation period. Oscillations in the water level of the Upper Campbell Reservoir are associated with effective spawning habitat losses ranging from 44 to 106,046 $m^2$d (mean = 20,394 $m^2$d). Water levels in the Lower Campbell Reservoir are less variable, resulting in relatively minimal loss of effective spawning habitat (range of 0 to 9,398 m²d; mean = 1,086 m²d; Figure 31).

#### 3.3.2.1. Comparison to Abundance Index

Currently, there are density estimates for Cutthroat Trout age cohorts from 2013 through to 2017 for cohorts aged from 0+ to 2+ (Figure 32). These CPUE estimates are preliminary and do not include fish that are currently listed as age 3+ as the CPUE for these cohorts do not include fish of unknown age (could not accurately be aged) and therefore are likely to change substantially once these fish are aged. As more data are collected and these fish of unknown age can be aged accurately, these CPUE estimates will be updated and additional years of sampling will extend the time series. As these CPUE estimates are updated, alternative units (i.e., # of fish/100 net hours) will also be used to increase the resolution of the results. Since there are only four years of data, we have not completed analysis linking the ESH values with the CPUE estimates. More detailed analyses will begin as part of the Year 5 report.

**Figure 31. Results of effective spawning habitat and loss of effective spawning habitat models for Cutthroat Trout from 1984 to 2017.**



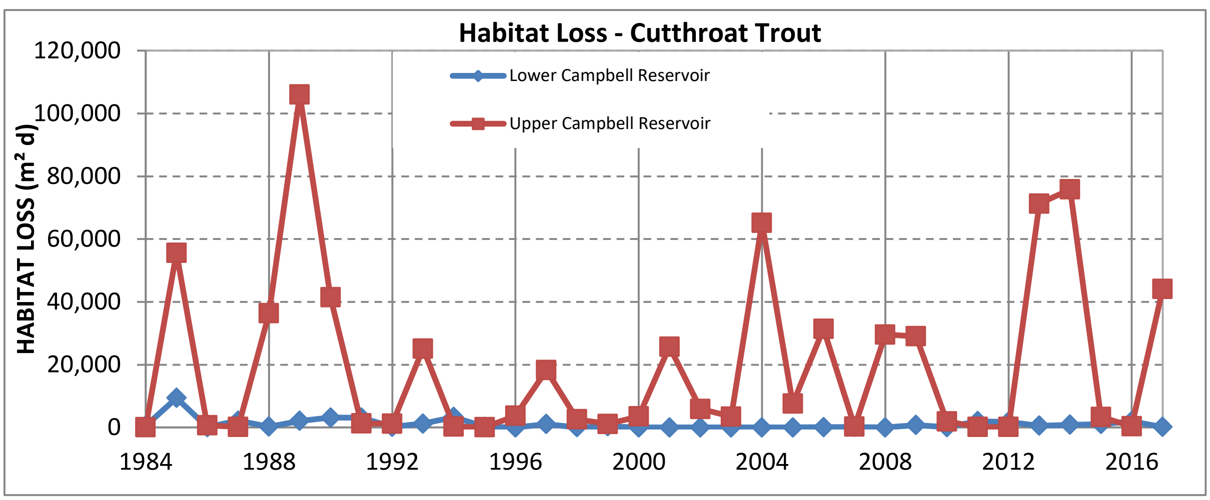



**Figure 32. ESH values in relation to Cutthroat Trout abundance index for each age cohort. Abundance index values for age cohorts 3+ and older are not provided, as age "unknown" fish have yet to be aged leading to underestimates for abundance index values for the older age cohorts.**

| Spawning Year | | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ESH ($m^2d$) | | 6,633 | 76,846 | 69,836 | 12,880 | 11,874 | 9,103 | 8,191 | 16,760 | 3,338 | 3,904 | 8,900 |
| Fish Abundance Index (# of Fish/net hr) | 0+ | | | | | | | | | 0.00 | 0.00 | 0.00 |
| | 1+ | | | | | | | | 0.00 | 0.01 | 0.01 | |
| | 2+ | | | | | | | 0.01 | 0.05 | 0.05 | | |
| | 3+ | | | | | | | | | | | |
| | 4+ | | | | | | | | | | | |
| | 5+ | | | | | | | | | | | |
| | 6+ | | | | | | | | | | | |
| | 7+ | | | | | | | | | | | |
| | 8+ | | | | | | | | | | | |

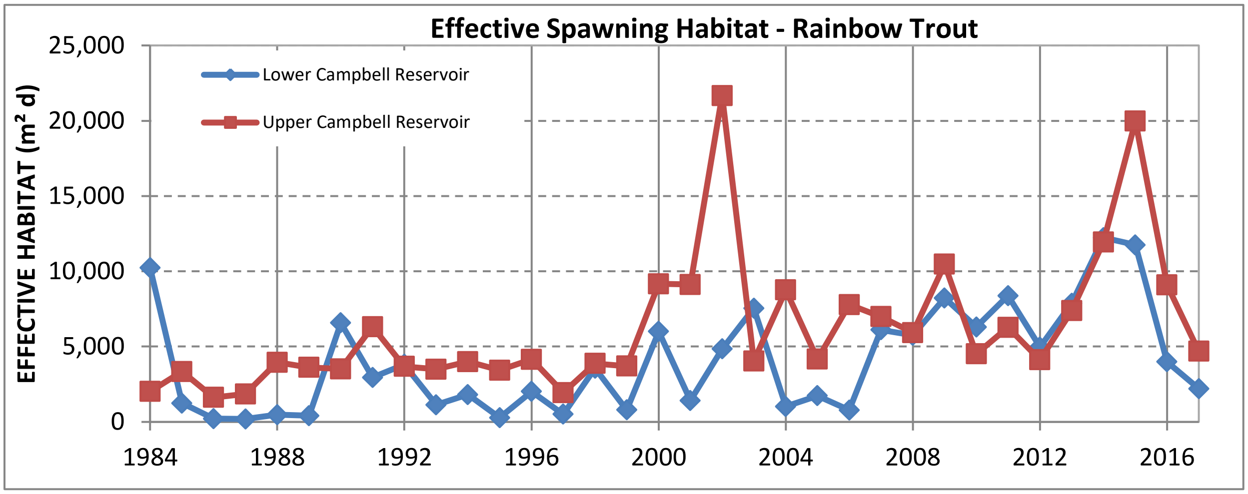
### 3.3.3. Rainbow Trout

Effective spawning habitat values for both Lower and Upper Campbell reservoirs were variable among years, with greater variability in the Upper Campbell Reservoir effective spawning habitat (range of 1,619 to 21,674 m²d; mean = 6,192 m²d) than the Lower Campbell Reservoir effective spawning habitat (range of 188 to 12,233 m²d; mean = 4,035 m²d). Effective spawning habitat loss was calculated as the difference between effective spawning habitat and initial spawning habitat during the spawning and incubation period. Oscillations in the water level of the Upper Campbell Reservoir are associated with effective Rainbow Trout spawning habitat losses ranging from 0 to 68,352 m²d (mean = 10,749 m²d). Water levels in the Lower Campbell Reservoir are less variable, resulting in relatively minimal loss of effective spawning habitat (range of 0 to 4,810 m²d; mean = 1,092 m²d) (Figure 33).

#### 3.3.3.1. Comparison to Abundance Index

Currently, there are density estimates for Rainbow Trout age cohorts from 2013 through to 2017 for cohorts aged from 0+ to 2+ (Figure 34). As with those for Cutthroat Trout, these CPUE estimates are preliminary and do not include fish that are currently listed as age 3+ as the CPUE for these cohorts do not include fish of unknown age and therefore are likely to change substantially once these fish are aged. As more data are collected and these fish can be aged accurately, these CPUE estimates will be updated and additional years of sampling will extend the time series. As these CPUE estimates are updated, alternative units (i.e., # of fish/100 net hours) will also be used to increase the resolution of the results. Since there are only four years of data, we have not completed any preliminary analysis linking the ESH values with the CPUE estimates. More detailed analyses will begin as part of the Year 5 report.

**Figure 33. Results of effective spawning habitat and loss of effective spawning habitat models for Rainbow Trout from 1984 to 2017.**



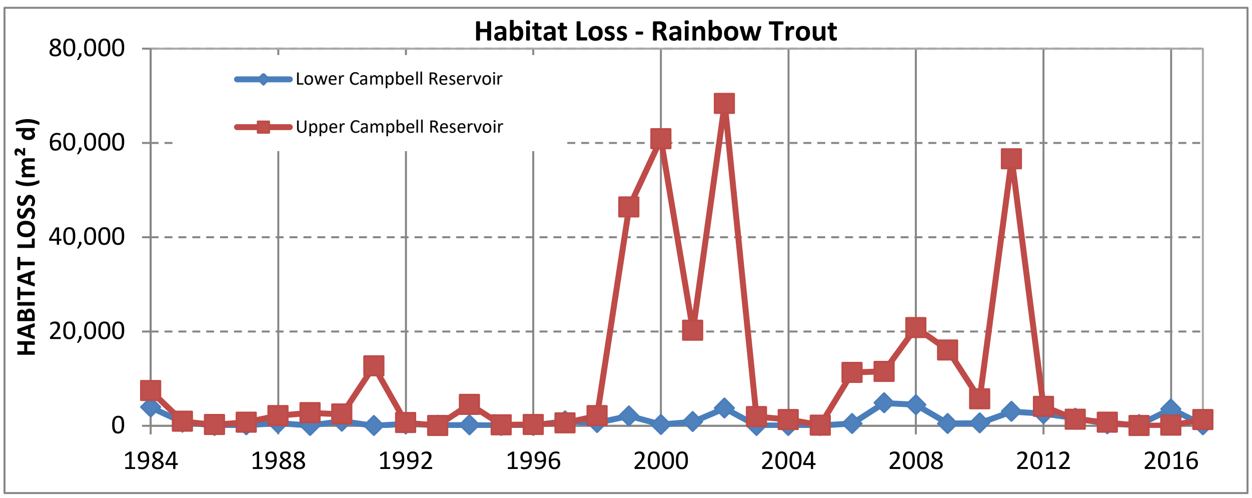



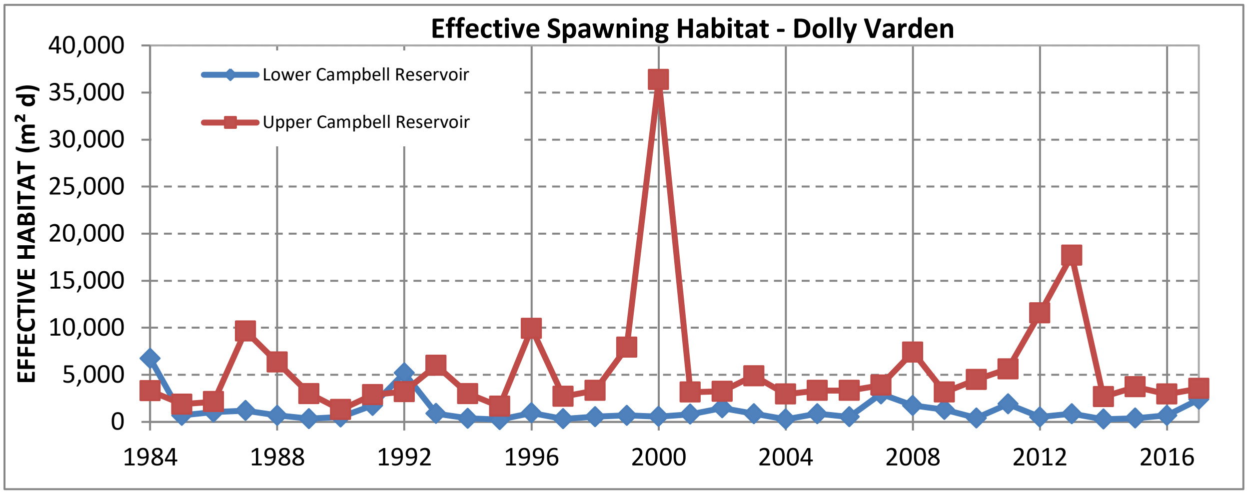
**Figure 34. ESH values in relation to Rainbow Trout abundance index for each age cohort. Abundance index values for age cohorts 3+ and older are not provided, as age "unknown" fish have yet to be aged leading to underestimates in abundance index values for the older age cohorts.**

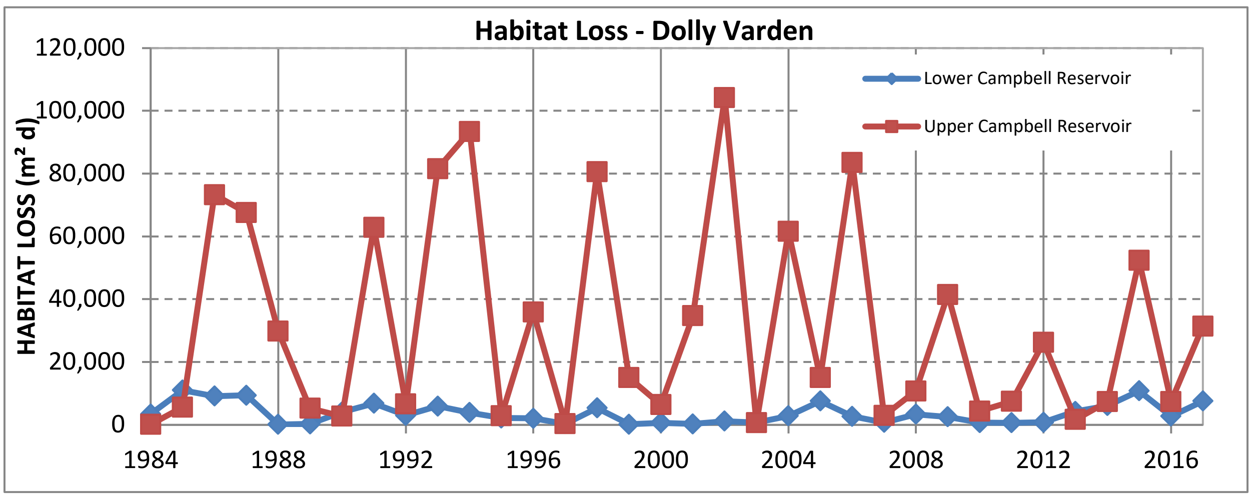
| **Spawning Year** | | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** |
|---|---|---|---|---|---|---|---|---|---|---|
| ESH ($m^2d$) | | 10,466 | 4,512 | 6,275 | 4,112 | 7,383 | 11,932 | 19,970 | 9,090 | 4,690 |
| Fish Abundance Index (# of Fish/net hr) | 0+ | | | | | | | 0.00 | 0.01 | 0.00 |
| | 1+ | | | | | | 0.09 | 0.09 | 0.28 | |
| | 2+ | | | | | 0.05 | 0.08 | 0.05 | | |
| | 3+ | | | | | | | | | |
| | 4+ | | | | | | | | | |
| | 5+ | | | | | | | | | |
| | 6+ | | | | | | | | | |

### 3.3.4. Dolly Varden

Effective habitat values for both Lower and Upper Campbell reservoirs were variable among years with much greater variability for the Upper Campbell Reservoir effective spawning habitat (range of 1,295 to 36,389 $m^2d$; mean = 5,648 $m^2d$) than the Lower Campbell Reservoir effective spawning habitat (range of 223 to 6,747 $m^2d$; mean = 1,196 $m^2d$) (Figure 35). Effective spawning habitat loss was calculated as the difference between effective spawning habitat and initial spawning habitat during the spawning and incubation period. Oscillations 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 = 31,240 $m^2d$). 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 = 3,586 $m^2d$) (Figure 35).

**Figure 35. Results of effective spawning habitat and loss of effective spawning habitat models for Dolly Varden from 1984 to 2017.**




## 3.4. Spawning Habitat Availability

### 3.4.1. Habitat Surveys

Spawning habitat availability was summarized for tributary areas within the drawdown zone and upstream of the drawdown zone for each major waterbody (Lower Campbell, Upper Campbell, and Buttle Lake). Spawning habitat availability summaries were also generated individually for each tributary. Although Buttle Lake and the Upper Campbell Reservoir are effectively one reservoir, habitat availability summaries are separated for each of these waterbodies for ease of interpretation. Redd counts within each area were provided as an additional spawning habitat metric, but their results are described in further detail in section 3.5. Overall, we identified a larger portion (approximately 77% across metrics) of available spawning habitat upstream of the drawdown zones relative to areas within the drawdown zones (Table 22). However, for all three tributaries within Buttle Lake, a larger portion of available spawning habitat was located within the drawdown zones. Overall differences between spawning habitat availability in the drawdown zones and upstream areas were generally consistent across each of the different spawning habitat availability indicators (Table 22). The largest quantity of 'High' and 'Medium' quality spawning habitat was located within the mainstem of the Elk River. The drawdown zones of tributaries located within Buttle Lake also had a large quantity of potentially suitable spawning habitat.

**Table 22. Spawning habitat availability summaries for all tributaries within the Upper and Lower Campbell Reservoirs and Buttle Lake.**

| Reservoir | Zone | Linear Distance (m) | Wetted Area ($m^2$) | Channel Width (m) | Channel Area ($m^2$) | Spawning Potential (m) | | | Redd Count (n)[3] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | Medium | High | |
| Upper Campbell | Upstream | 18,404 | 378,282 | 16.8 | 813,244 | 3,592 | 7,141 | 5,568 | 2,603 |
| Upper Campbell | Drawdown | 3,798 | 85,018 | 40.1 | 152,300 | 958 | 2,710 | 0 | 0 |
| Buttle Lake | Upstream | 1,226 | 16,084 | 20.9 | 22,297 | 264 | 505 | 415 | 55 |
| Buttle Lake | Drawdown | 2,134 | 59,074 | 49.3 | 106,831 | 118 | 845 | 1,171 | 536 |
| Lower Campbell | Upstream | 5,008 | 31,891 | 9.3 | 46,601 | 1,845 | 2,042 | 997 | 301 |
| Lower Campbell | Drawdown | 1,042 | 11,583 | 14.1 | 13,172 | 674 | 343 | 0 | 96 |
| Total | Upstream | 24,638 | 426,257 | 15.7 | 882,142 | 5,701 | 9,688 | 6,980 | 2,959 |
| | Drawdown | 6,974 | 155,675 | 34.5 | 272,303 | 1,750 | 3,898 | 1,171 | 632 |

[1] Direct measurements from UAV aerial imagery.
[2] Estimated channel widths, wetted area and spawning potential based on field surveys.
[3] Redd counts consider total redds upstream across all tributaries

### 3.4.2. Lower Campbell Reservoir

Linear distance, channel area and redd counts were greatest above the drawdown zone for the three tributaries surveyed on the Lower Campbell Reservoir, Miller Creek, Greenstone Creek, and Fry Creek (Table 23). Fry Creek was the only tributary within the Lower Campbell Reservoir that could be surveyed entirely with the UAV. Spawning habitat upstream of the drawdown zones for Greenstone Creek and Miller Creek consisted of narrower streams; however, the extended length of these streams provided a large area of spawning habitat. Upstream sections of Greenstone Creek had the largest absolute quantity of spawning habitat followed by Fry Creek and then Miller Creek (Table 23).

Qualitative spawning habitat delineations did not identify any 'high' quality spawning habitat in the drawdown zones of Lower Campbell Reservoir tributaries (Figure 36). Fry Creek had the largest portion of 'low' quality spawning habitat in both the drawdown zone and upstream areas, whereas upstream sections of Miller Creek and Greenstone Creek consisted mostly of 'medium' or 'high' quality spawning habitat.

#### 3.4.2.1. Tributaries of the Lower Campbell Reservoir

Surveys of Fry Creek were completed up to the south end of Gray Lake prior to reaching any impassible or obstructions barriers. This potentially underestimated the full extent of upstream spawning habitat in Fry Creek. The drawdown zone of Fry Creek was characterized by a poorly defined shallow channel and large quantity of fines covering the substrate. There was only a small section of the drawdown zone characterized as having moderately suitable spawning habitat (Figure 36), whereas all other sections would likely have insufficient flow and heavy deposition of fines. Suitable spawning habitat in upstream sections of Fry Creek was limited to locations immediately downstream of lake outflows. Some of these areas have been modified by habitat enhancement projects (e.g., spawning habitat enhancement near the outlet of Brewster Lake; Pellet 2012).

Upstream sections of Greenstone Creek had the largest quantity of high quality spawning habitat, but proportional to its length most sections of Greenstone Creek consisted of low or medium quality habitat. Field surveys of Greenstone Creek were also completed prior to reaching impassible or obstructions barriers, suggesting that additional spawning habitat may be present upstream beyond the field survey endpoint. The drawdown section of Greenstone Creek was small and truncated by a poorly defined channel and large alluvial fan. Although there were some small sections of the drawdown zones classified as having moderate spawning habitat (Figure 36), substrate in these sections were covered by a layer of fines at the time of field surveys.

Miller Creek had the most clearly defined channel when entering the drawdown zone. This defined channel was expected to contribute to higher quality spawning habitat. Although some areas of the drawdown zone for Miller Creek were classified as having medium spawning potential (Figure 36), lower sections of the drawdown zone had considerably more fines covering the substrate.

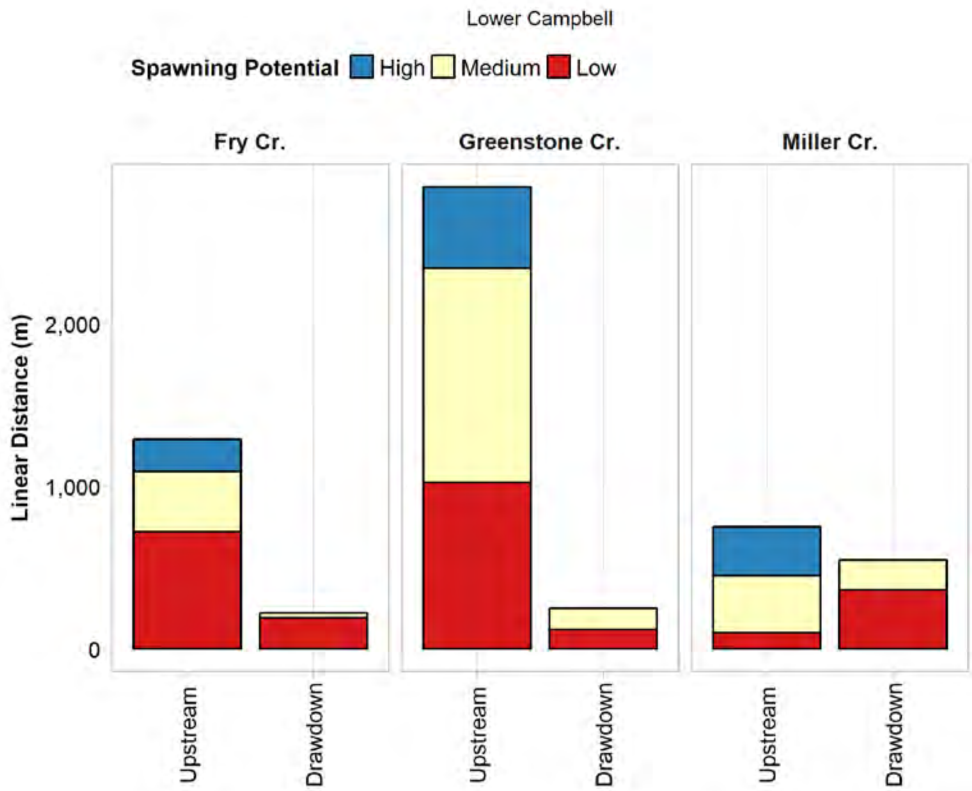
**Table 23. Spawning habitat availability summaries for tributaries of the Lower Campbell Reservoir**

| Tributary | Zone | Linear Distance (m) | Wetted Area ($m^2$) | Channel Width (m) | Channel Area ($m^2$) | Spawning Potential (m) | | | Redd Count (n) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | Medium | High | |
| Fry Creek | Upstream[1] | 1,307 | 13,286 | 12.8 | 16,730 | 721 | 372 | 197 | 150 |
| Fry Creek | Drawdown | 218 | 4,017 | 18.7 | 4,077 | 192 | 29 | 0 | 5 |
| Greenstone Creek | Upstream[1] | 17 | 242 | 7.6 | 129 | 0 | 20 | 0 | 2 |
| Greenstone Creek | Upstream[2] | 2,886 | 15,242 | 7.9 | 22,799 | 1,024 | 1,300 | 500 | 29 |
| Greenstone Creek | Drawdown | 269 | 2,639 | 13.8 | 3,712 | 118 | 131 | 0 | 2 |
| Miller Creek | Upstream[2] | 798 | 3,121 | 8.7 | 6,943 | 100 | 350 | 300 | 120 |
| Miller Creek | Drawdown | 555 | 4,927 | 9.7 | 5,384 | 364 | 183 | 0 | 89 |

[1] Direct measurements from UAV aerial imagery.

[2] Estimated channel widths, wetted area and spawning potential based on field surveys.

**Figure 36. Qualitative spawning potential summaries for drawdown zones and upstream sections of the Lower Campbell Reservoir**




### 3.4.3. Upper Campbell Reservoir

The mainstem of the Elk River contained the largest overall quantity of spawning habitat across all waterbodies and all spawning habitat indicators evaluated. The drawdown zone of the Elk River also contained a large portion of potentially suitable spawning habitat, roughly equivalent to combined tributaries of the Elk River (Table 24, Figure 37). Although qualitative spawning habitat delineations did not identify any 'high' quality spawning habitat in the drawdown zone of the Elk River (Figure 37), this area still contained a large quantity of potentially suitable spawning habitat. Upstream sections of the Elk River and Elk River tributaries also had a proportionately large quantity of 'high' and 'medium' quality spawning habitat (Figure 37).

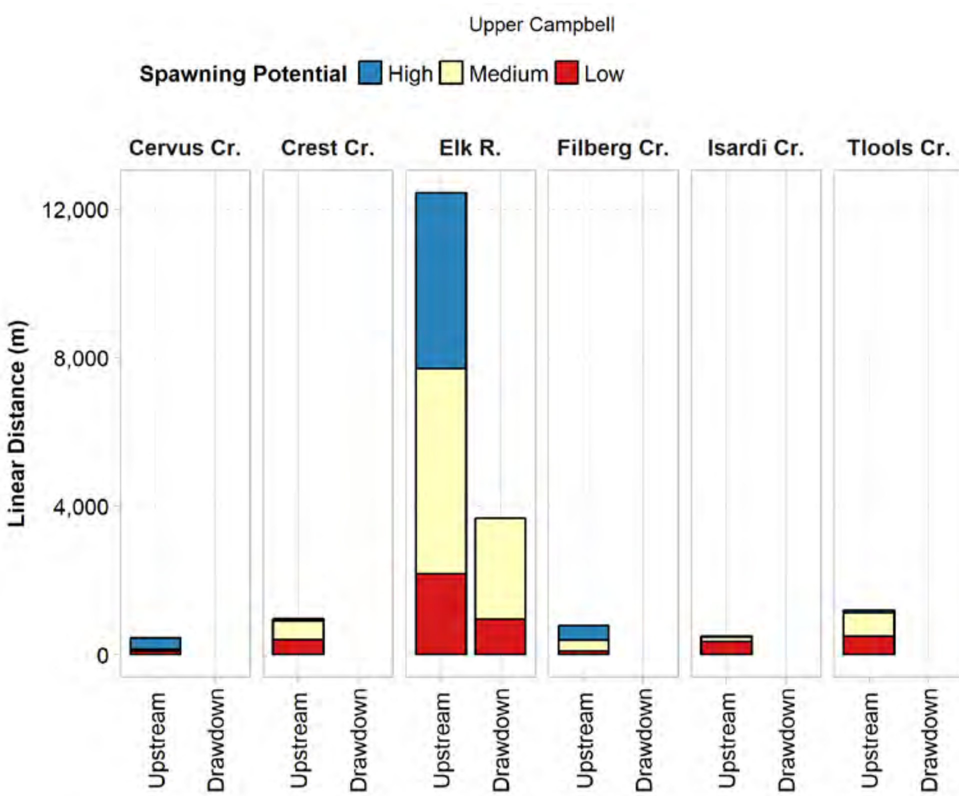
Of all five tributaries of the Elk River, Cervus Creek and Filberg Creek were characterized as having the largest quantity of 'high' quality habitat (Table 24; Figure 37). Drum Creek, Tlools Creek, and Isardi Creek all had relatively similar quantities of accessible spawning habitat (Table 24), but these areas were characterized as being of poorer quality based on gravel availability and other habitat attributes (Figure 37).

**Table 24. Spawning habitat availability summaries for Elk River tributaries of the Upper Campbell Reservoir**

| Tributary | Zone | Linear Distance (m) | Wetted Area ($m^2$) | Channel Width (m) | Channel Area ($m^2$) | Spawning Potential (m) | | | Redd Count (n) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | Medium | High | |
| Drum Creek | Upstream[1] | 649 | 6,147 | 14.1 | 9,151 | 290 | 277 | 45 | 55 |
| Drum Creek | Upstream[2] | 382 | 2,461 | 15.0 | 5,730 | 112 | 236 | 0 | 6 |
| Isardi Creek | Upstream[1] | 432 | 3,194 | 11.9 | 5,141 | 328 | 130 | 10 | 0 |
| Isardi Creek | Upstream[2] | 34 | 95 | 15.0 | 510 | 17 | 8 | 0 | 0 |
| Cervus Creek | Upstream[1] | 615 | 6,955 | 13.7 | 8,426 | 85 | 64 | 301 | 253 |
| Filberg Creek | Upstream[2] | 844 | 5,064 | 8.0 | 6,752 | 85 | 300 | 400 | 2 |
| Tlools Creek | Upstream[1] | 446 | 3,883 | 11.5 | 5,129 | 288 | 147 | 19 | 7 |
| Tlools Creek | Upstream[2] | 761 | 3,793 | 8.2 | 6,240 | 209 | 478 | 50 | 13 |
| Elk River Mainstem | Upstream[1] | 14,241 | 346,690 | 53.8 | 766,166 | 2,178 | 5,501 | 4,743 | 2,267 |
| Elk River | Drawdown | 3,798 | 85,018 | 40.1 | 152,300 | 958 | 2,710 | 0 | 0 |

[1] Direct measurements from UAV aerial imagery.
[2] Estimated channel widths, wetted area and spawning potential based on field surveys.

**Figure 37. Qualitative spawning potential summaries for drawdown zones and upstream sections of the Upper Campbell Reservoir**



### 3.4.4. Buttle Lake Tributaries (Upper Campbell Reservoir)

In contrast to the Elk River and tributaries within the Lower Campbell Reservoir, Wolf Creek and Phillips Creek (and in some aspects Ralph River) had a larger portion of spawning habitat available in the drawdown zones relative to upstream areas (Table 25). This trend was consistent across all spawning habitat metrics evaluated (linear and area-based summaries). The relative quantity of spawning habitat availability in the drawdown zone of Ralph River was variable depending on which spawning habitat indicator was considered (Table 25). The Ralph River had a larger portion of spawning habitat located in the drawdown zones relative to upstream area, according to spawning channel area and median channel width, but not linear distance or spawning habitat potential (Figure 37, Table 25).

The larger portions of spawning habitat located in the drawdown zones relative to upstream areas in Buttle Lake tributaries were partially the result of barriers and obstructions to fish base passage located only a short distance upstream from the lake. Drawdown zones of Buttle Lake tributaries also had deep clearly defined channel, with large quantities of spawning gravel/cobble, free of fine sediments.

#### 3.4.4.1. Tributaries of Buttle Lake

Wolf Creek had no upstream area and was characterized as being entirely within the drawdown zone of Buttle Lake. The upstream extent of spawning habitat is limited by falls/cascades immediately upstream from the drawdown zone. The entire drawdown reach of Wolf Creek was characterized as having high quality spawning habitat.

Phillips Creek was characterized by 'High' to 'Medium' quality spawning habitat throughout, especially near the upstream section of the drawdown zones. A steep gradient barrier (15% - 20%) prevented access to additional spawning beyond the drawdown zone.

Similar to Wolf Creek and Phillips Creek, Ralph River also had an extended drawdown and barrier located only a short distance upstream from the drawdown zone. The mainstem of Ralph River forks into Sheppard Creek upstream from the drawdown zone. Accessible spawning habitat in Sheppard Creek is limited by a bedrock canyon and the mainstem of the Ralph River was limited by a boulder cascade gradient barrier (~ 20%).

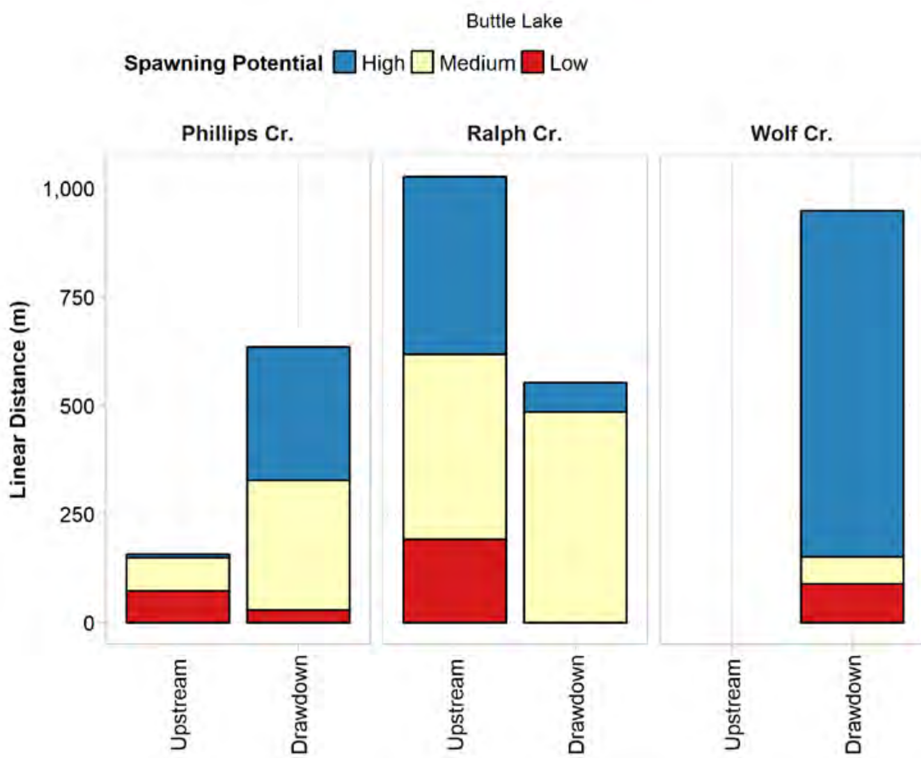
**Table 25. Spawning habitat availability summaries for Buttle Lake tributaries (Upper Campbell Reservoir)**

| Tributary | Zone | Linear Distance (m) | Wetted Area ($m^2$) | Channel Width (m) | Channel Area ($m^2$) | Spawning Potential (m) | | | Redd Count (n) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | Medium | High | |
| Wolf Creek | Drawdown | 950 | 31,221 | 56.6 | 53,770 | 89 | 62 | 797 | 439 |
| Phillips Creek | Upstream[1] | 157 | 2,640 | 21.4 | 3,360 | 73 | 77 | 7 | 5 |
| Phillips Creek | Drawdown | 638 | 12,628 | 34.9 | 22,266 | 29 | 298 | 308 | 43 |
| Ralph Creek | Upstream[1] | 295 | 7,380 | 27.2 | 8,024 | 127 | 94 | 75 | 11 |
| Ralph Creek | Upstream[2] | 774 | 6,064 | 14.1 | 10,913 | 64 | 334 | 333 | 39 |
| Ralph Creek | Drawdown | 546 | 15,225 | 56.4 | 30,794 | 0 | 485 | 66 | 54 |

[1] Direct measurements from UAV aerial imagery.

[2] Estimated channel widths, wetted area and spawning potential based on field surveys.

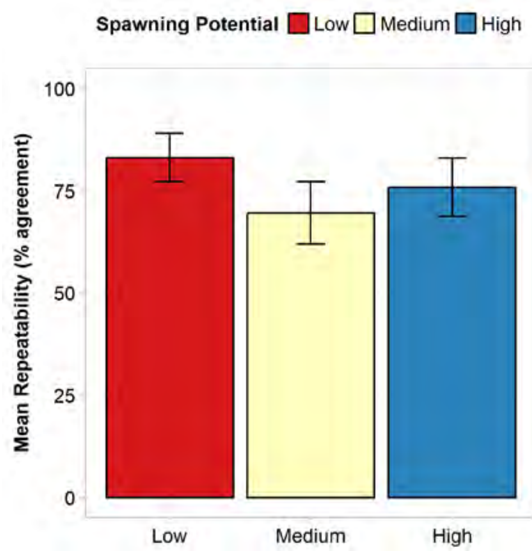
**Figure 38. Qualitative spawning potential summaries for drawdown zones and upstream sections of the Buttle Lake Tributaries (Upper Campbell Reservoir)**



#### 3.4.5. Repeatability of Spawning Potential Classifications

Repeatability of qualitative spawning potential delineations (Section 2.5.1) ranged from 69% to 83% across stream reaches (*n* = 38, Figure 39) as measured by comparing results between fisheries biologists (Section 2.5). Differences in spawning habitat classification between assessors were mainly due to uncertainties in classifying reaches as either 'Medium' or 'High' spawning potential. However, even if reaches classified as 'Medium' or 'High' are reclassified into a single group, our overall results and conclusions of spawning habitat potential in the drawdown zones vs upstream areas remain unchanged.

**Figure 39. Repeatability of qualitative spawning habitat delineations between two fisheries bioloigists. Error bars show 95% confidence intervals for percent similarity within each habitat rating class across 100 m long stream reach segments (*n* = 38).**




### 3.5. Spawning Habitat Use

#### 3.5.1. Redd Surveys Summaries

Spawning habitat use was summarized with counts of redds for areas within the drawdown zones and upstream of the drawdown zone for each major waterbody (Lower Campbell, Upper Campbell, and Buttle Lake). The distribution (within and upstream of the drawdown zones) were also summarized for each tributary. Although Buttle Lake and the Upper Campbell Reservoir are effectively one reservoir, habitat use summaries are separated for each of these waterbodies for ease of interpretation.

Results of spawning habitat use were largely consistent with spawning habitat availability (Section 3.4). We identified a higher prevalence of redds in upstream areas relative to areas within the drawdown zones for the Elk River (Upper Campbell Reservoir) and all waterbodies within the

Lower Campbell Reservoir (Table 26). Waterbodies within Buttle Lake had a higher abundance of redds in the drawdown zones relative to upstream areas (Table 26). Maps showing the distribution and abundance of redds throughout each waterbody are provided in Appendix D.

Physical habitat attributes of redds within the drawdown were distinct from redds located in upstream areas. Over 90% of redds within the drawdown zone were located along the mainstem of the thalweg in deep (1 - 3 m), slow moving water (Table 26). Conversely, in areas upstream of the drawdown zone, redds were distributed throughout the available spawning habitat in shallow (0.5 – 0.8 m), medium to high velocity runs, glides, and riffles. Redds upstream of the drawdown zones were also located at the margins of the main channel rather than within the main thalweg (Table 26).

**Table 26. Redd survey attribute summary table for Buttle Lakd and the Upper and Lower Campbell reservoirs.**

| Reservoir | | Buttle Lake | | Lower Campbell | | Upper Campbell | | All Reservoirs | |
|---|---|---|---|---|---|---|---|---|---|
| Zone | | Drawdown | Upstream | Drawdown | Upstream | Drawdown | Upstream | Drawdown | Upstream |
| Redd Count | (n) | 536 | 55 | 96 | 301 | - | 2,603 | 632 | 2,959 |
| Median Depth | (m) | 2.9 | 0.77 | 1.16 | 0.7 | - | 0.5 | 2 | 0.66 |
| Location | Margin | 4% | 61% | 9% | 59% | - | 68% | 7% | 63% |
| | Thalweg | 96% | 33% | 91% | 41% | - | 32% | 94% | 35% |
| Velocity | Low | 88% | 22% | 81% | 2% | - | 53% | 85% | 26% |
| | Medium | 12% | 61% | 19% | 66% | - | 44% | 16% | 57% |
| | High | - | 11% | - | 31% | - | 3% | - | 15% |
| Habitat[1] | PO | - | 33% | - | 1% | - | 2% | - | 12% |
| | RF | - | 44% | 3% | 23% | - | 10% | 3% | 26% |
| | RN | 30% | 17% | 11% | 34% | - | 87% | 21% | 46% |
| | GL | 70% | - | 86% | 41% | - | - | 78% | 41% |
| | OTHER | - | 6% | - | - | - | 1% | - | 4% |
| Substrate[2] (Dominant) | BO | - | - | - | - | - | - | - | - |
| | LGCO | - | - | - | - | - | 1% | - | 1% |
| | LGGR | 100% | 83% | 79% | 66% | - | 56% | 90% | 68% |
| | SMCO | - | 11% | 1% | - | - | 43% | 1% | 27% |
| | SMGR | - | - | 20% | 33% | - | - | 20% | 33% |
| Substrate[2] (Subdominant) | BO | - | - | - | - | - | - | - | - |
| | LGCO | - | - | - | - | - | - | - | - |
| | LGGR | - | 11% | 20% | 33% | - | 42% | 20% | 29% |
| | SMCO | - | - | 2% | 8% | - | 3% | 2% | 6% |
| | SMGR | 100% | 83% | 78% | 58% | - | 55% | 89% | 65% |
| Portion New[3] | | 99% | 94% | 100% | 100% | - | 97% | 100% | 97% |

[1] Habitat (PO = pool, RF = riffle, RN = run, GL = glide).

[2] Substrate (BO = boulders LGCO = large cobble, LGGR = large gravel, SMCO = small cobble, SMGR = small gravel)

[3] Portion of observed redds classified as 'new' out of all new and old redds.

### 3.5.2. Lower Campbell Reservoir

In all three tributaries of the Lower Campbell Reservoir, redd counts were higher in upstream areas relative to areas within the drawdown zone (Table 23). Most redds upstream of the drawdown zones were located at least 200 m upstream from the high water line of the WUP annual maximum operating level (178.3 m; Figure 40; Figure 42; Figure 44). All redds in Fry Creek and Greenstone Creek, surveyed with the Total Station Theodolite, were vertically distributed above the preferred summer minimum (176.5 m, Figure 41, Figure 43). Forty-nine redds surveyed with the TST in Miller Creek were below the WUP preferred summer minimum water level (Figure 45). All redds were above the minimum annual operating level of 174.0 m.

### 3.5.3. Upper Campbell Reservoir

The upstream mainstem of the Elk River contained more redds that all other waterbodies combined (*n* = 2,267 Table 24). No redds were identified in the drawdown zone section of the Elk River. Most redds within upstream sections of the Elk River were found between 4 km and 12 km upstream from the drawdown zone (Figure 46).

### 3.5.4. Buttle Lake Tributaries (Upper Campbell Reservoir)

In contrast to the Elk River and tributaries within the Lower Campbell Reservoir, Wolf Creek, Phillips Creek and Ralph River all had a higher portion of redds located within the drawdown zone relative to areas above the drawdown zones (Table 25; Table 26). Redds upstream of the drawdown zone were located less than 200 m (Phillips Creek, Figure 48) to 600 m (Ralph Creek, Figure 50) away from the the high water line of the WUP annual maximum operating level (220.5 m). Redds within Phillips Creek and Ralph Creek, surveyed with the TST, were all vertically distributed above the WUP preferred summer minimum operating level (217 m, Figure 49; Figure 51). Most redds surveyed in Wolf Creek were below the preferred summer minimum operating level (Figure 47).

**Figure 40. Redd distribution upstream of the drawdown zone upstream limit, by distance category, for Fry Creek.**

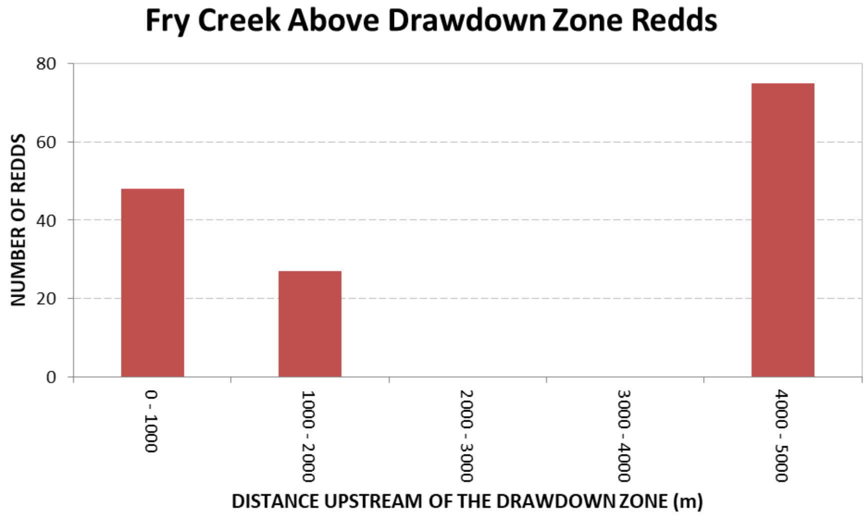



**Figure 41. Vertical distribution of redds within the drawdown zone for Fry Creek from TST surveys (reservoir annual operating levels: 174 - 178.3 m).**

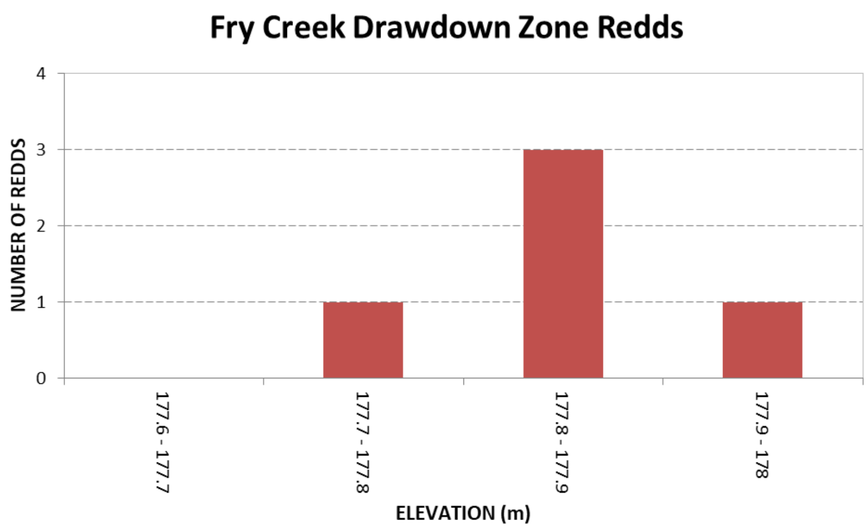


**Figure 42.** **Redd distribution upstream of the drawdown zone upstream limit, by distance category, for Greenstone Creek.**

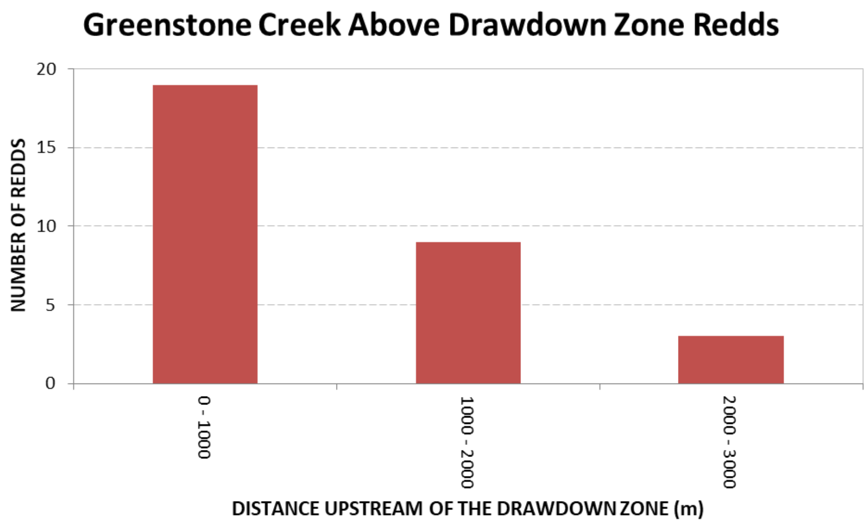



**Figure 43.** **Vertical distribution of redds within the drawdown zone for Greenstone Creek from TST surveys (reservoir annual operating levels: 174 - 178.3 m).**

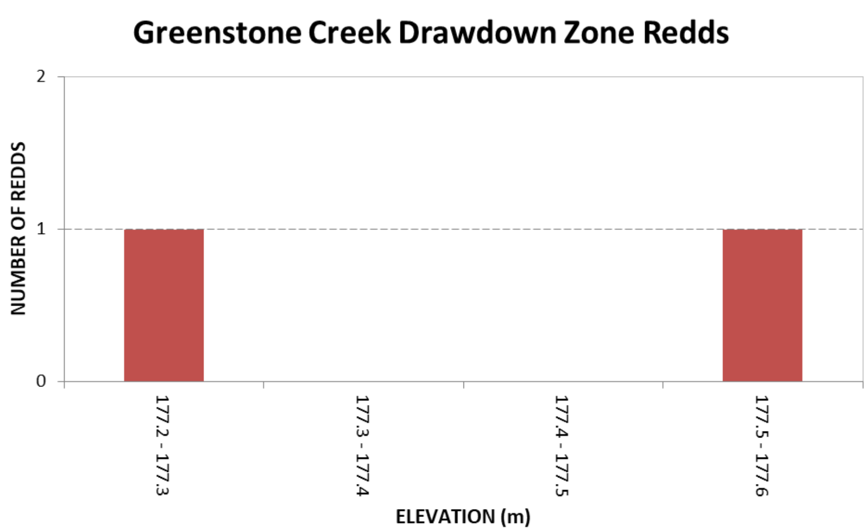


**Figure 44.** Redd distribution upstream of the drawdown zone upstream limit, by distance category, for Miller Creek.

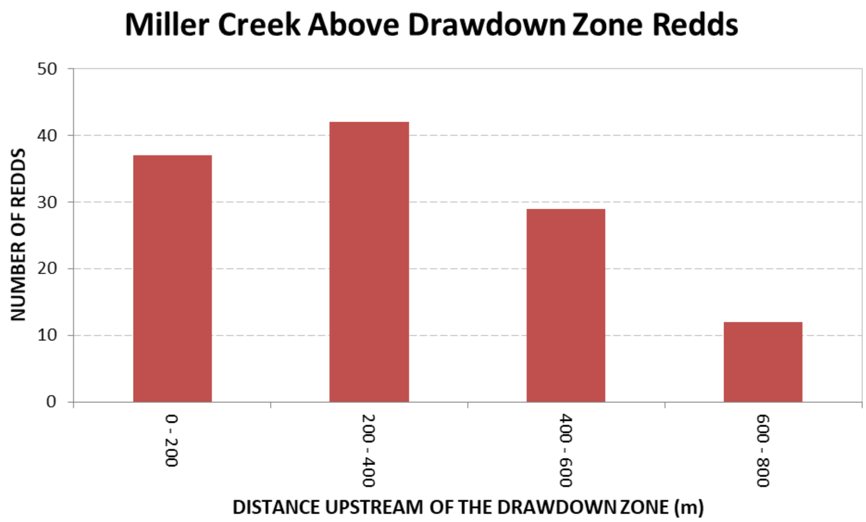



**Figure 45.** Vertical distribution of redds within the drawdown zone for Miller Creek from TST surveys (reservoir annual operating levels: 174 - 178.3 m).

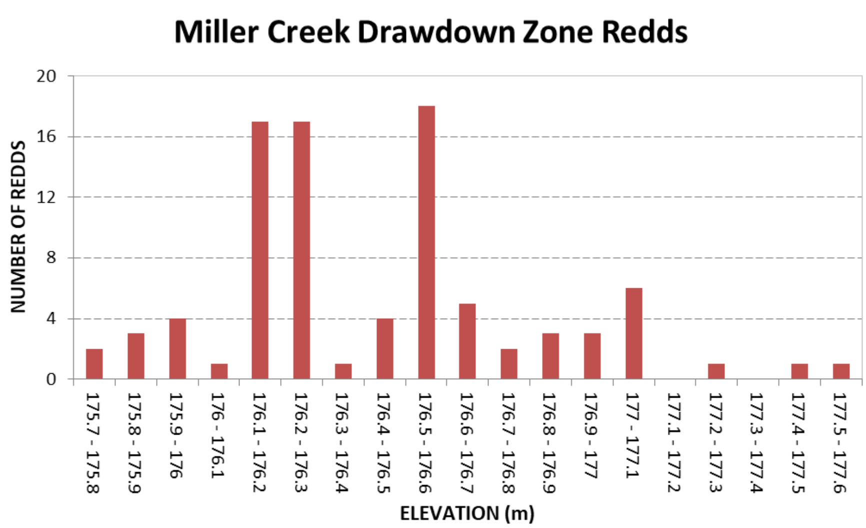


Figure 46. Redd distribution upstream of the drawdown zone upstream limit, by distance category, for the mainstem of the Elk River.

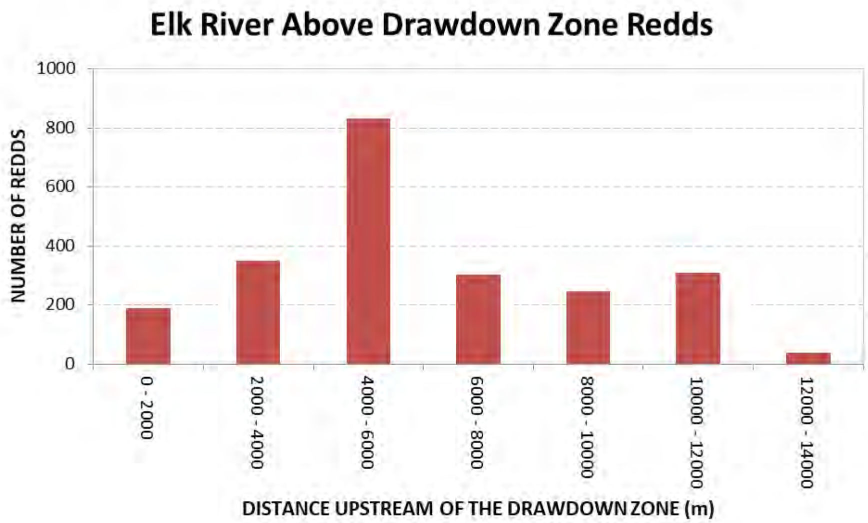



Figure 47. Vertical distribution of redds within the drawdown zone for Wolf Creek from TST surveys (reservoir annual operating levels: 212 – 220.5 m).

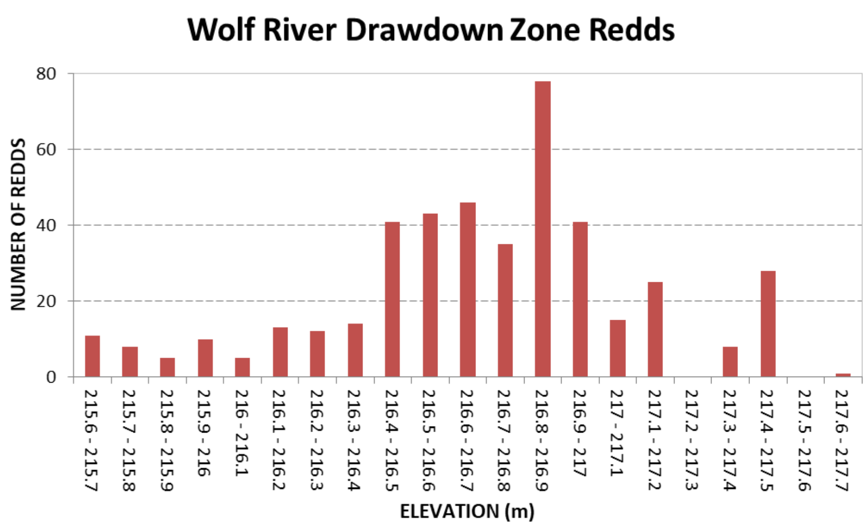


**Figure 48. Redd distribution upstream of the drawdown zone upstream limit, by distance category, for Phillips Creek.**

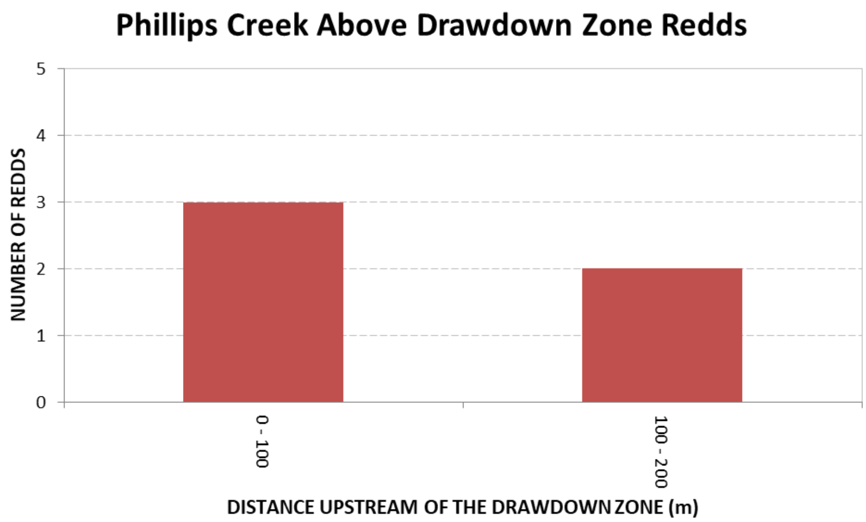



**Figure 49. Vertical distribution of redds within the drawdown zone for Phillips Creek from TST surveys [*additional redds surveyed in drawdown zone with high accuracy GPS not included in this figure*](reservoir annual operating levels: 212 – 220.5 m).**

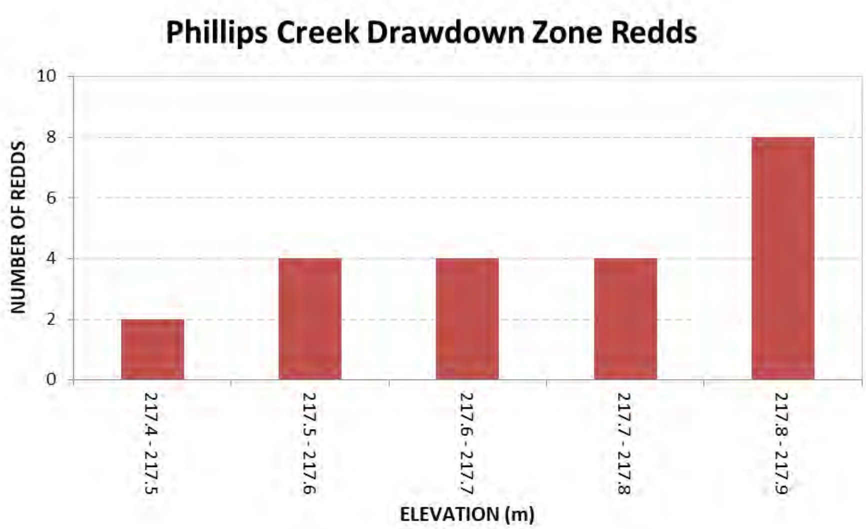


**Figure 50.** **Redd distribution upstream of the drawdown zone upstream limit, by distance category, for Ralph River**

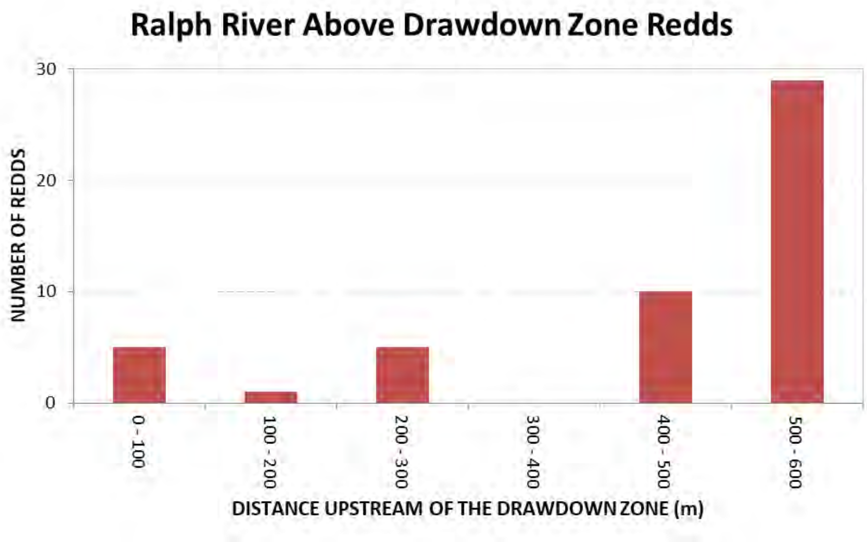
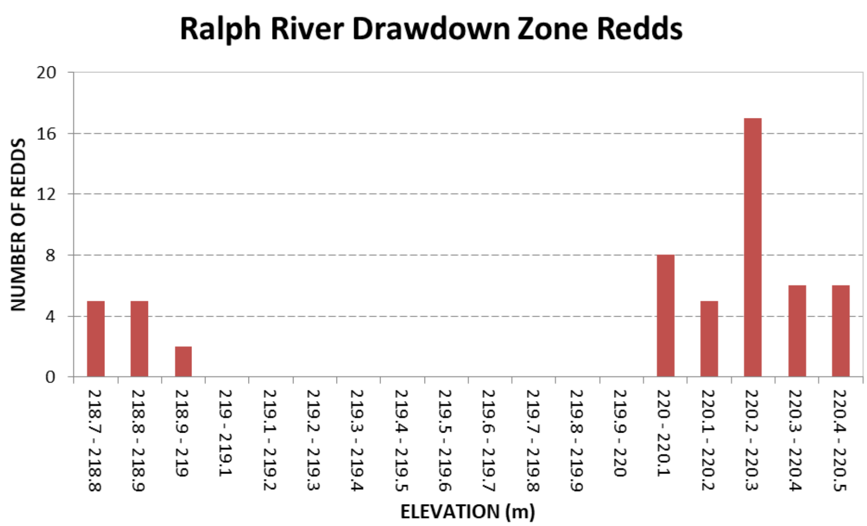



**Figure 51.** **Vertical distribution of redds within the drawdown zone for Ralph River from TST surveys (reservoir annual operating levels: 212 – 220.5 m).**



# 4. SUMMARY AND RECOMMENDATIONS FOR 2018

Comparisons of measurements of fish abundance and spawning success before and after the WUP implementation were conducted are meant to test the assumption that salmonid recruitment is limited by availability of effective spawning habitat. In 2017 (year 4) we successfully collected the planned datasets such that one additional year of data collection planned for 2018 will be sufficient to test the hypotheses described in Section 1.2.

## 4.1. Population Index for Upper and Lower Campbell Reservoirs

The Year 4 sampling results (2017) provide a fourth 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. These data have then been attributed to ESH values for each age class for the 2017 sampling year. This approach will be built upon in future years to develop abundance measures for individual ages and test the management hypotheses noted in Section 1.2.

The population index requires detailed aging information for the fish captures. In 2017, there were 6 Cutthroat Trout and 9 Rainbow Trout that were not attributed an age class and designated as "unknown", due to the lack of defined age bins for older fish. The study allows for the age of these "unknown" fish to be estimated as more aging data are collected in later monitoring years and resolution for age bins of older fish become refined. The additional 2015 and 2016 samples aged in 2017 will assist in defining these age bins; however, we will defer estimating the age of any "unknown" fish until Year 5 of the monitoring program, at which point sufficient aging information is expected to have been collected. To aid with refining the age analyses for older fish we suggest that fin ray, otolith and scale sampling continue in 2018. A preliminary assessment of fin rays collected in Years 2 to 4 revealed considerable variability in age assignment, indicating they may be of low utility for accurate determination of age in older fish. In light of this variability, we suggest that otoliths be collected from a subset of fish captured from gill netting to confirm age estimates from scales and fin rays. These comparisons can be used to determine the accuracy of fin ray age estimates for older fish.

## 4.2. Snorkel Survey of Spawners in Reservoir Tributaries

Snorkel surveys were completed in five tributaries to Buttle Lake, one tributary to Upper Campbell Reservoir, and three tributaries to Lower Campbell Reservoir during the Year 4 surveys in 2017. Spring snorkel surveys carried out in March and April targeted the Cutthroat Trout spawning period in the tributaries of Lower Campbell Reservoir. Few Cutthroat Trout were recorded during the spring snorkel surveys; however, high numbers of redds were identified, attributed to early Cutthroat Trout spawning.

The summer snorkel survey results for spawning Rainbow Trout in tributaries of Buttle Lake and Upper Campbell Reservoir identified counts below historical median averages in Ralph River. Thelwood Creek, Henshaw Creek, and Phillips River counts were above historical median averages in the Upper and Lower Elk River. In Wolf Creek, counts were similar to median historical values. No adult Rainbow Trout were recorded in Fry Creek (tributary to Lower Campbell Reservoir) during 2017, representing low count numbers that matched the previous reference number of zero Rainbow Trout observed in 2003 and 2016.

Overall, the 2017 snorkel results were successful and we suggest that the snorkel surveys continue in 2018 to satisfy the expectations of the program.

### 4.3. Effective Spawning Habitat (ESH)

The Year 4 ESH study builds on results from the previous year and was successful in providing an improved understanding of trends in habitat loss and ESH for the two target species, Cutthroat Trout and Rainbow Trout, as well as for Dolly Varden. We suggest that this component be continued in future years, given that any ESH trends across fish age and abundance are anticipated to become increasingly more informative.

The work plan focusses 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 the general trend of rising water levels during the Cutthroat Trout incubation period. Any effect observed in Upper Campbell Reservoir is assumed to apply to Lower Campbell and John Hart reservoirs; however, the response is expected to be less due to the more stable water levels in these two reservoirs. 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 recommend that analysis of the potential relationship between ESH and fish population index for either Rainbow or Cutthroat trout be deferred until Year 5 or later in the monitoring program, due to the large number of fish of unknown age and the need for multiple years of data to conduct a trend analysis. With data from additional years, retrospective analysis can be performed and ages can be assigned to fish of unknown age caught during early years of the program. This assignment of age classes is planned for Year 5, along with a preliminary statistical analysis of the relationship between ESH of fish species and WUP operations, and the possible biological responses to this relationship.

### 4.4. Spawning Habitat Availability

The quantity of available habitat was assessed within the Lower and Upper Campbell reservoirs (including Buttle Lake) and within each sub-tributary within these systems. Overall our summary analysis demonstrates that the total amount of available spawning habitat is greater in upstream areas relative to areas within the drawdown zones; however, tributaries in Buttle Lake had a greater portion of spawning habitat within the drawdown zone relative to upstream areas. Across all habitat metrics evaluated, areas within the drawdown zone accounted for approximately 16% - 19% of total available spawning habitat for tributaries in the Upper and Lower Campbell reservoirs and up to 63% – 82% for tributaries within Buttle Lake.

The mainstem of the Elk River had an overwhelming effect on our summaries of habitat availability due it its size. Buttle Lake tributaries were the only locations where we identified a higher quantity of spawning habitat within drawdown zones relative to areas upstream of the drawdown zones. This was a result of high quality spawning habitat within the drawdown zones and impassible barriers located only a short distance upstream of the lake limiting the extent of upstream habitat. Although a majority of available spawning habitat identified in this study was located in upstream areas above the drawdown zones, additional spawning habitat within the drawdown zones accounted for 22% - 27% of the total available spawning habitat. In summary, the majority of spawning habitat occurs above the drawdown zone; however, a substantial portion (approximately 1/5$^{th}$) of spawning habitat occurs within the drawdown zone.

It is likely that the methods used in this study underestimated spawning habitat availability in areas above drawdown zones. In several instances the upstream survey end points were chosen in the field based on the absence of any redds or high quality spawning habitat for an extended distance. In the absence of any barrier to fish passage, areas further upstream and beyond these endpoints are likely to contain additional spawning habitat, further increasing the ratio of spawning habitat availability above vs within the drawdown zones.

Results showed some variability depending on which spawning habitat indicator metric was considered, but overall differences between drawdown zones and upstream areas were generally consistent across each variable. This general consistency across metrics and positive correlation with counts of redd surveyed across each area suggests that habitat metrics developed in this study accurately reflected spawning habitat availability. Inconsistent trends across metrics were largely the result of differences between linear and area-based summaries (e.g., channel area and linear distance between the drawdown zones and upstream areas of Ralph River (Table 25)). We expect area-based metrics to be more reliable indicators of spawning habitat. For example, the length of spawning habitat in Greenstone Creek extended for 2.8 km upstream of the drawdown zone; however, the creek is narrow with limited total spawning area (Table 23).

Quantifying available spawning habitat in the drawdown zones was challenging due to the large size of alluvial fans extending into lakes. We believe that the methods developed to quantify spawning habitat in these areas were adequate and accurately reflected spawning habitat availability for two reasons. First, by focusing on the defined channels within the drawdown zone we excluded areas with fines and vegetated substrates that were void of spawning habitat. This also made results more comparable to upstream areas. These conclusions were also supported by a higher count of redd observations upstream of the drawdown zones relative to areas within the drawdown zones for the Elk River and Lower Campbell reservoir and a higher count of redd observations in the drawdown zones of Buttle Lake tributaries.

Our conclusions of habitat availability were based on habitat indicator metrics developed primarily in a GIS environment with aerial imagery (linear distance, wetted area, bankfull channel width/area and qualitative spawning potential). The advantage of these habitat indicator metrics is the ability to rapidly obtain complete survey coverage of each waterbody; however, these metrics are only proxies for total available habitat. By conducting UAV aerial surveys (in combination with field surveys in areas with dense riparian cover) we were able to fully survey the entire length of all spawning habitat across all tributaries regardless of accessibility. High resolution UAV aerial imagery is also invaluable for numerous ongoing and future studies such as change detection and/or developing and evaluating alternative habitat metrics. An additional approach for continued studies could involve developing a modified FHAP procedure customized for the scale and resolution of our aerial imagery. This may help to further delineate and classify reaches based on mesohabitat characteristics. However, an FHAP procedure was not included in the original TOR budget, and due to the consistent differences between the drawdown zones and upstream areas across almost all tributaries, we do not expect these additional metrics to change general conclusions from this study. Therefore, we do not recommend an FHAP procedure at this time.

4.5. Spawning Habitat Use

Results of spawning habitat use, based on the abundance and distribution of redds, were consistent with results of habitat availability, suggesting that spawning intensity is roughly correlated with habitat availability. Overall, only 17% of all redds were located within drawdown zones; however for each major waterbody this portion ranged from 90% (Buttle Lake) to 0% (Upper Campbell Reservoir). Based on the relative density of redds across waterbodies and available spawning habitat, the use of available spawning habitat in the drawdown zones is low (especially for the Upper Campbell Reservoir).

The Elk River and Elk River tributaries accounted for a majority of all redds observed in Upper Campbell Reservoir, reinforcing its significance as a dominant source of spawning habitat. Despite the limited quantity of spawning habitat within drawdown zones of Buttle Lake, these areas still had over 500 redds. (For context, this is more than the sum of all redds within Lower Campbell Reservoir).

The abundance of redds in the drawdown zones of Buttle Lake and absence of redds in the drawdown zone of the Elk River is likely jointly the result higher quality spawning habitat immediately upstream from the Elk River drawdown zone and higher quality of spawning habitat within the Buttle Lake drawdown zones. For example, Wolf Creek had a wide, well-defined channel with low to moderate compaction throughout and a substrate composition of cobble and gravel. Most redds within Wolf Creek were located below the falls near the most upstream point of drawdown zone rather than further downstream in the drawdown zone towards the opening to the lake and alluvial fan (Appendix D). Similarly, for Phillips Creek and Ralph Creek, redds within the drawdown zone were primarily found in the furthest upstream sections. For tributaries of the Lower Campbell Reservoir (Fry, Greenstone and Miller Creek), the drawdown zone was characterized by a moderately to poorly defined channel (although less so for Miller Creek), decreased water velocities and heavy deposition of fines.

Future analyses could consider the development of quantitative occupancy models and related analytical methods to better integrate habitat availability with habitat use. These analyses are not included in the TOR budget, but BC Hydro may wish to consider them at a future date. Advantages of this approach would include the ability to rank different areas according to their relative use, given available habitat. Areas within and above the drawdown zones would be analyzed as residuals in the fit of a model between habitat availability and habitat use. Additional metrics such as adult presence and abundance could be included as covariates to better understand habitat use in a demographic context.

Redd elevations, drawdown zone boundaries and reference water surface elevations were obtained from three different sources for this study (TST surveys with installed benchmarks; LiDAR sourced externally; water surface elevation from Water Survey Canada Gauging Stations). Although QA/QC procedures were undertaken for each of these sources there was no formal uncertainty analysis completed to better understand the relative error and offset between each of these sources. For example, the water elevation from the WSC gauging station is unlikely to exactly match the water surface elevation of the entire reservoir perimeter due to waves, wind, narrows and other inputs. Without quantifying this potential elevation offset we may under or overestimate individual redd elevations.

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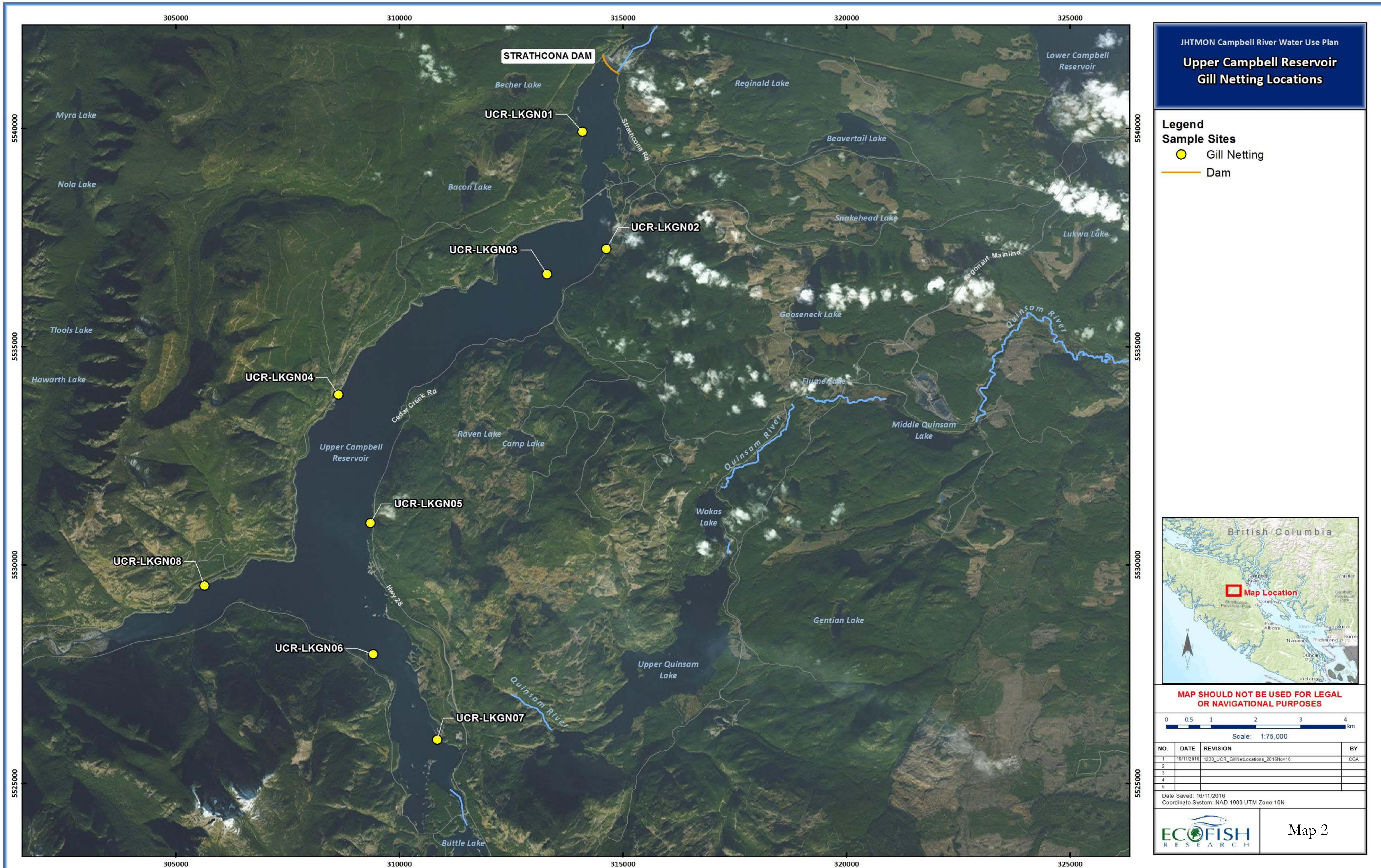
## PROJECT MAPS

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JHTMON Campbell River Water Use Plan

# JHTMON-3
# Snorkel Survey Reaches

**Legend**

- Snorkel Survey Reach
- Campsites
- Boat Launch
- Strathcona Lodge
- Diversion Dam Intake
- Quinsam River Fish Hatchery
- Quinsam Coal Mine
- First Nation Reserve
- Recreational Sites
- Parks and Protected Areas


MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 1 2 4 6 8 10 km

Scale: 1:250,000

| NO. | DATE | REVISION | BY |
|---|---|---|---|
| 1 | 16/11/2016 | 1230_JHT_SnorkelSurveyReaches_2014Dec01 | CGA |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

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

ECOFISH RESEARCH

Map 3

Path: M:\Projects-Active\1230_JHTMON\MXD\Fisheries\1230_JHT_SnorkelSurveyReaches_2014Dec01.mxd

# APPENDICES

# Appendix A. Ecofish Aging Structure Collection and Analysis Protocol

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# 1. BACKGROUND

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

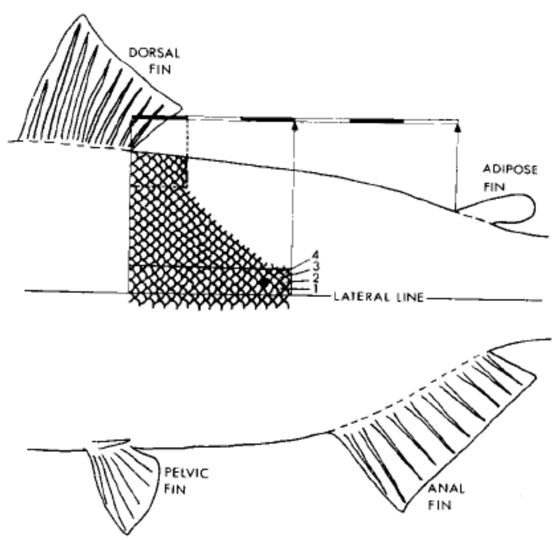
# 2. METHODS

## 2.1. Sample Collection and Preparation

### 2.1.1. Scales

The method for collecting scales depends on fish size. 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 same area. The scales are smeared or placed onto a microscope slide, taking care to separate overlapping scales. A second slide is placed over the scales to sandwich them between the two slides. The slides are then taped together with scotch tape. Each sample placed within a labelled scale envelope. Scale samples are stored in a plastic container (specific to the Project file) inside a locked metal filing cabinet.

**Figure 1. The preferred area for removing scales from a fish (crosshatched area posterior to dorsal fin) (Sjolund 1974).**



#### 2.1.2. Fin Ray

Fin ray samples can be taken from either the pectoral or pelvic fins. Two or three of the longest rays are removed from the fin by clipping them near the base of the fin and peeling the fin ray back. Fin rays are placed in a labelled scale envelope.

Fin ray samples are dried in the laboratory and cut into 0.5 – 1.0 mm sections using a fine cut-off blade. If the fin rays are small and brittle, they are be covered in epoxy so that they stay together when cut. Electricians tape is wrapped around the fin ray to prevent the cuttings from flying away. Sections are cut from the base of the fin ray. Eye protection is worn when sectioning fin rays. The cut cross-sections are polished and mounted on microscope slides with Krazy Glue. A drop of thin oil or water can be applied to the fin ray to enhance the appearance of winter annuli when viewing through the microscope.

#### 2.1.3. Otoliths and Other Bony Structures

Fish must be dead to collect otoliths and other bony structures. Fish are typically euthanized by overdosing in anaesthetic. Once euthanized, the structures are removed by dissecting the fish as per the methods outlined in Section 6 of the BC Resource Inventory Standards Committee Fish Collection Methods and Standards (RISC 1997). Bony structures are stored dry in labelled scale envelopes, or in labelled vials filled with a solution of glycerine and water.

Otoliths and other bony structure samples are dried in the lab and are processed in a similar fashion to fin rays.

#### 2.1.4. Sample Archiving

For each sample, a minimum of two scales or fin ray sections, or one otolith section, are photographed from each individual fish using a digital camera and a compound microscope. The two photographed scales or fin rays 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. Each technician ages the samples independently without any other aging information or biological data (length or weight) for the fish. The independent ages provided by each technician are compared to identify any discrepancies. Where ages for a single sample are different between technicians, 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).**

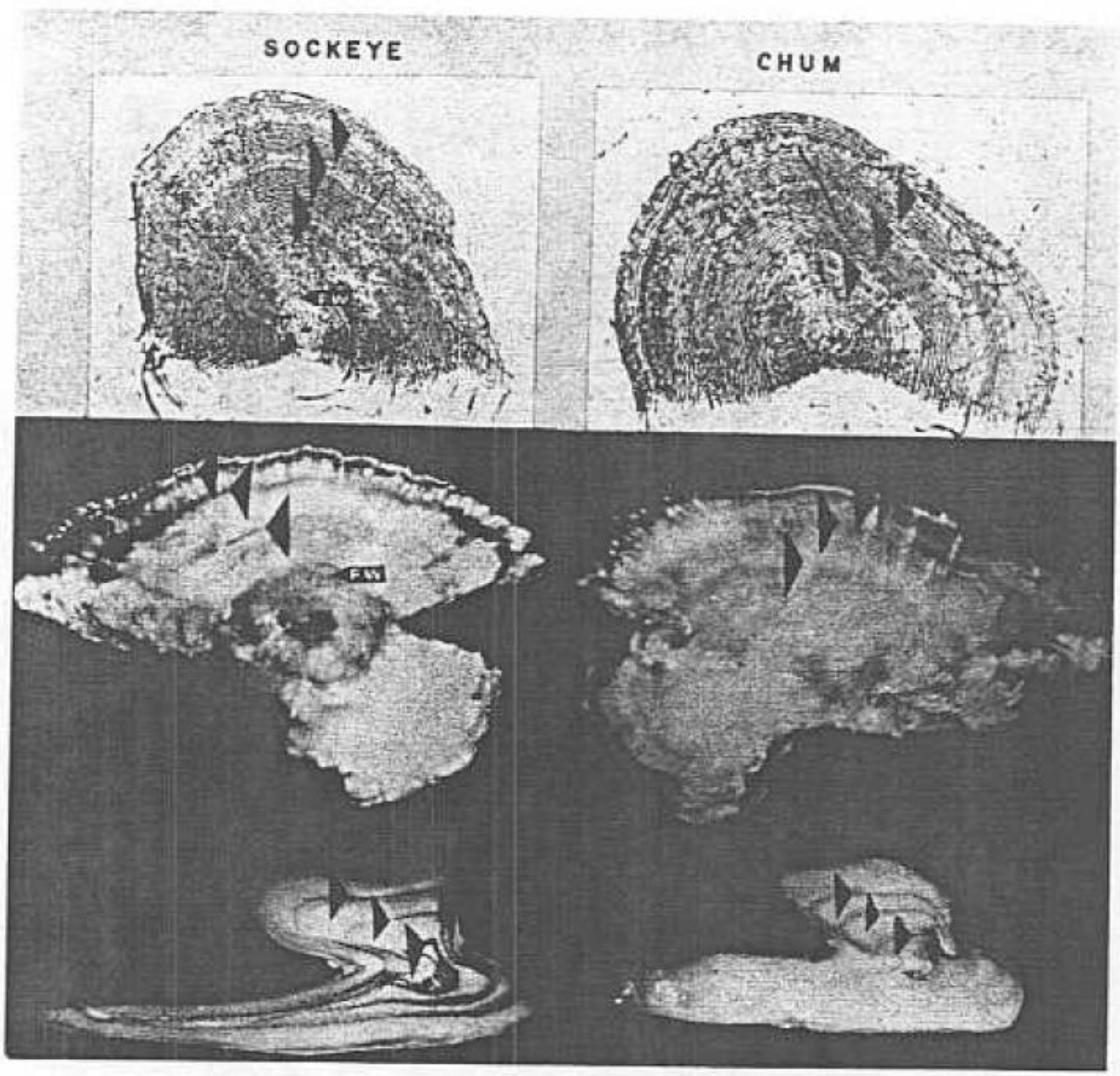



FIG. 4. Scale, otolith, and fin ray from a 1.3 sockeye and a 0.3 chum salmon: FW indicates freshwater annulus; arrows indicate ocean annuli.

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

### 2.1.6. Data

Ages are recorded in a MS Excel file (copy of the raw fish file) that is stored within the scale images folder. Once all structures have been aged, the file will be saved as a PDF within the network data sheet archive drive. A RNQA number is created and a copy of the age data is printed and filed in the appropriate Project folder and binder. If access to a computer is limited, the data is recorded onto a datasheet (e.g., Figure 3). The sheet contains information on the technician aging samples, date of aging, location, site, date collected, species, length, weight, and sample number. Once complete the datasheet is RNQAed, scanned, and filed in the appropriate Project folder and binder.

**Figure 3. Example datasheet for age entry.**

Technician: Date:

| Location | Site | Date | Species | Length | Weight | Sample # | Age |
|---|---|---|---|---|---|---|---|
| North Creek | NTH-DVEF02 | 04-Oct-10 | BT | 169 | 53.1 | FR-1 | X |
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Sjolund, W.R. 1974. Collection and preparation of scales, otoliths and fin rays for fish age determination. Fisheries Technical Circular No. 12. British Columbia Fish and Wildlife Branch. 22pp. (Available at: http://wlapwww.gov.bc.ca/wld/documents/fisheriesrpts/FTC12.pdf)

# Appendix B. Gill Net Capture Data and Representative Photographs

## LIST OF TABLES



## LIST OF FIGURES

**Table 1. Individual net set and capture data for Upper Campbell Lake gill netting.**

| Waterbody | Site | Set # | Net Type | Net Position[1] | Net Length (m) | Water Temp (°C) | Turbidity[2] | Estimated Visibility (m) | Time In | Time Out | Catch[3] | | | | | | Soak Time (hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | CT | RB | DV | CC | TSB | CT/RB | |
| Upper Campbell Reservoir | UCR-LKGN01 | 1 | RISC | FL | 91.2 | 19.7 | C | 8 | 10:25:00 | 10:50:00 | 0 | 2 | 0 | 0 | 0 | 0 | 24.4 |
| | | 2 | RISC | SK | 91.2 | 19.7 | C | 8 | 10:38:00 | 11:18:00 | 7 | 6 | 0 | 0 | 0 | 1 | 24.7 |
| | UCR-LKGN02 | 1 | RISC | SK | 91.2 | 19.8 | C | 8 | 11:00:00 | 11:59:00 | 6 | 8 | 0 | 1 | 0 | 1 | 25.0 |
| | | 2 | RISC | FL | 91.2 | 19.8 | C | 8 | 11:11:00 | 11:48:00 | 0 | 12 | 0 | 0 | 0 | 0 | 24.6 |
| | UCR-LKGN04 | 1 | RISC | SK | 91.2 | 21.7 | C | 8 | 14:42:00 | 10:16:00 | 4 | 4 | 0 | 2 | 0 | 1 | 19.6 |
| | | 2 | RISC | FL | 91.2 | 21.7 | C | 8 | 15:12:00 | 09:53:00 | 0 | 10 | 0 | 0 | 0 | 1 | 18.7 |
| | | 3 | Nordic | SK | 13 | 21.7 | C | 8 | 15:21:00 | 10:34:00 | 0 | 1 | 0 | 0 | 0 | 0 | 19.2 |
| | UCR-LKGN06 | 1 | RISC | SK | 91.2 | 21.4 | C | 8 | 15:33:00 | 10:53:00 | 5 | 9 | 0 | 0 | 0 | 0 | 19.3 |
| | | 2 | RISC | FL | 91.2 | 21.4 | C | 8 | 16:06:00 | 11:06:00 | 0 | 8 | 0 | 0 | 0 | 1 | 19.0 |
| | UCR-LKGN07 | 1 | RISC | SK | 91.2 | 21.1 | C | 8 | 14:33:00 | 10:23:00 | 7 | 6 | 1 | 0 | 0 | 0 | 19.8 |
| | | 2 | RISC | FL | 91.2 | 21.1 | C | 8 | 14:19:00 | 10:05:00 | 0 | 12 | 0 | 0 | 0 | 0 | 19.8 |
| | | 3 | Nordic | SK | 13 | 21.1 | C | 8 | 14:02:00 | 10:00:00 | 0 | 4 | 0 | 0 | 0 | 0 | 20.0 |
| | UCR-LKGN08 | 1 | RISC | SK | 91.2 | 20.7 | C | 8 | 15:05:00 | 11:14:00 | 16 | 10 | 0 | 0 | 0 | 0 | 20.2 |
| | | 2 | RISC | FL | 91.2 | 20.7 | C | 8 | 15:21:00 | 11:30:00 | 0 | 11 | 0 | 0 | 0 | 1 | 20.2 |

[1] SK - Sinking, FL - Floating.

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

[3] CT - Cutthroat Trout, RB - Rainbow Trout, DV - Dolly Varden, CC - Sculpin Species, TSB - Three-Spine Stickleback, CT/RB - Cutthroat Trout/Rainbow Trout.

**Table 2. Raw fish data from gill net sampling.**

| Water Body | Year | Site Name | Date | Capture Method | Set # | Panel # | Species[1] | Measured Length (mm) | Weight (g) | K | Sex | Sexual Maturity (I, M, UNK) | Age Sample Type 1 | Age Sample Number | Age Sample Type 2 | Age Sample Number 2 | DNA Sample Type | DNA Sample Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | FL | 1 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | FL | 1 | 2 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | FL | 1 | 3 | RB | 227 | 135 | 1.15 | F | I | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | FL | 1 | 4 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | FL | 1 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | FL | 1 | 6 | RB | 278 | 230 | 1.07 | F | I | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 2 | CT | 386 | 573 | 1 | F | M | SC | 14 | FR | 14 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 3 | CT | 241 | 162 | 1.16 | M | I | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 3 | CT | 258 | 196 | 1.14 | F | I | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 3 | CT | 272 | 217 | 1.08 | F | I | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 3 | CT | 279 | 193 | 0.89 | F | I | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 3 | CT/RB | 299 | 254 | 0.95 | F | M | SC | 05 | FR | 05 | FC | 05 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 3 | RB | 220 | 121 | 1.14 | M | I | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 3 | RB | 277 | 208 | 0.98 | F | M | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 4 | CT | 201 | 75 | 0.92 | M | I | SC | 11 | FR | 11 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 4 | CT | 205 | 89 | 1.03 | F | I | SC | 13 | FR | 13 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 4 | RB | 171 | 59 | 1.18 | | I | SC | 12 | FR | 12 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 4 | RB | 182 | 76 | 1.26 | F | I | SC | 10 | FR | 10 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 4 | RB | 183 | 78 | 1.27 | F | I | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 4 | RB | 187 | 85 | 1.3 | F | I | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN01 | 2017-08-21 | SK | 2 | 6 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 2 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 3 | RB | 226 | 140 | 1.21 | M | M | SC | 05 | FR | 05 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 3 | RB | 279 | 197 | 0.91 | M | M | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 3 | RB | 280 | 198 | 0.9 | F | M | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 3 | RB | 296 | 234 | 0.9 | M | M | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 3 | RB | 307 | 253 | 0.87 | F | M | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 4 | RB | 161 | 51 | 1.22 | | I | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 4 | RB | 161 | 53 | 1.27 | | I | SC | 10 | FR | 10 | | |

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

**Table 2. Raw fish data from gill net sampling *continued*.**

| Water Body | Year | Site Name | Date | Capture Method | Set # | Panel # | Species[1] | Measured Length (mm) | Weight (g) | K | Sex | Sexual Maturity (I, M, UNK) | Age Sample Type 1 | Age Sample Number | Age Sample Type 2 | Age Sample Number 2 | DNA Sample Type | DNA Sample Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 4 | RB | 168 | 60 | 1.27 | M | I | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 4 | RB | 169 | 50 | 1.04 | | I | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 4 | RB | 187 | 84 | 1.28 | M | I | SC | 11 | FR | 11 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 4 | RB | 190 | 77 | 1.12 | | I | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 4 | RB | 268 | 218 | 1.13 | M | M | SC | 12 | FR | 12 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | FL | 2 | 6 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 2 | CT | 390 | 583 | 0.98 | M | M | SC | 16 | FR | 16 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 2 | CT | 393 | 600 | 0.99 | F | M | SC | 14 | FR | 14 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 2 | CT | 394 | 623 | 1.02 | M | M | SC | 15 | FR | 15 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 3 | CT | 246 | 152 | 1.02 | | I | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 3 | RB | 201 | 100 | 1.23 | M | I | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 3 | RB | 202 | 103 | 1.25 | M | I | SC | 05 | FR | 05 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 4 | CC | 137 | 39 | 1.52 | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 4 | CT | 332 | 352 | 0.96 | M | M | SC | 12 | FR | 12 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 4 | RB | 180 | 21 | 0.36 | F | I | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 4 | RB | 192 | 91 | 1.29 | M | I | SC | 10 | FR | 10 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 4 | RB | 197 | 81 | 1.06 | M | I | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 4 | RB | 198 | 86 | 1.11 | | I | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 4 | RB | 211 | 102 | 1.09 | M | I | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 4 | RB | 262 | 197 | 1.1 | F | M | SC | 11 | FR | 11 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 6 | CT | 338 | 386 | 1 | M | M | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN02 | 2017-08-21 | SK | 1 | 6 | CT/RB | 295 | 284 | 1.11 | F | M | SC | 02 | FR | 02 | FC | 02 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 1 | RB | 133 | 27 | 1.15 | | I | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 1 | RB | 135 | 29 | 1.18 | | I | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 2 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 3 | CT/RB | 284 | 219 | 0.96 | M | M | SC | 11 | FR | 11 | FC | 11 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 3 | RB | 215 | 117 | 1.18 | M | M | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 3 | RB | 231 | 137 | 1.11 | M | M | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 3 | RB | 231 | 138 | 1.12 | M | M | SC | 08 | FR | 08 | | |

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

**Table 2. Raw fish data from gill net sampling *continued*.**

| Water Body | Year | Site Name | Date | Capture Method | Set # | Panel # | Species[1] | Measured Length (mm) | Weight (g) | K | Sex | Sexual Maturity (I, M, UNK) | Age Sample Type 1 | Age Sample Number | Age Sample Type 2 | Age Sample Number 2 | DNA Sample Type | DNA Sample Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 3 | RB | 241 | 144 | 1.03 | F | M | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 3 | RB | 255 | 148 | 0.89 | F | M | SC | 05 | FR | 05 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 3 | RB | 280 | 211 | 0.96 | M | M | SC | 10 | FR | 10 | FC | 10 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 4 | RB | 174 | 70 | 1.33 | F | I | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 4 | RB | 175 | 65 | 1.21 | | I | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | FL | 2 | 6 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 2 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 3 | CC | 174 | 69 | 1.31 | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 3 | CT | 255 | 171 | 1.03 | F | I | SC | 10 | FR | 10 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 3 | RB | 228 | 141 | 1.19 | M | I | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 4 | CT | 190 | 79 | 1.15 | M | I | SC | 05 | FR | 05 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 4 | CT | 274 | 215 | 1.05 | F | M | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 4 | CT/RB | 306 | 266 | 0.93 | M | I | SC | 03 | FR | 03 | OT | 03 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 4 | RB | 207 | 91 | 1.03 | F | I | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 4 | RB | 233 | 133 | 1.05 | F | M | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 4 | RB | 242 | 134 | 0.95 | F | M | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 6 | CC | 148 | 47 | 1.45 | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 1 | 6 | CT | 360 | | | F | M | | | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 3 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 3 | 2 | RB | 93 | 12 | 1.49 | | I | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 3 | 3 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN04 | 2017-08-22 | SK | 3 | 4 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 2017-08-22 | FL | 2 | 1 | RB | 143 | 34 | 1.16 | M | I | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 2017-08-22 | FL | 2 | 1 | RB | 150 | 43 | 1.27 | M | I | SC | 05 | FR | 05 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 2017-08-22 | FL | 2 | 1 | RB | 183 | 80 | 1.31 | F | I | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 2017-08-22 | FL | 2 | 1 | RB | 197 | 93 | 1.22 | M | I | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 2017-08-22 | FL | 2 | 1 | RB | 207 | 101 | 1.14 | M | M | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 2017-08-22 | FL | 2 | 1 | RB | 302 | 241 | 0.87 | F | M | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 2017-08-22 | FL | 2 | 2 | NFC | | | | | | | | | | | |

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

## Table 2. Raw fish data from gill net sampling *continued*.

| Water Body | Year | Site Name | Date | Capture Method | Set # | Panel # | Species[1] | Measured Length (mm) | Weight (g) | K | Sex | Sexual Maturity (I, M, UNK) | Age Sample Type 1 | Age Sample Number | Age Sample Type 2 | Age Sample Number 2 | DNA Sample Type | DNA Sample Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | FL | 2 | 3 | CT/RB | 294 | 165 | 0.65 | M | I | SC | 09 | FR | 09 | FC | 09 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | FL | 2 | 3 | RB | 274 | 241 | 1.17 | M | M | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | FL | 2 | 4 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | FL | 2 | 5 | RB | 190 | 89 | 1.3 | | UNK | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | FL | 2 | 6 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 1 | RB | 136 | 33 | 1.31 | | I | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 1 | RB | 141 | 34 | 1.21 | M | I | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 2 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 3 | RB | 218 | 132 | 1.27 | F | I | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 3 | RB | 237 | 132 | 0.99 | M | M | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 3 | RB | 270 | 187 | 0.95 | M | M | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 3 | RB | 286 | 192 | 0.82 | M | M | SC | 05 | FR | 05 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 4 | CT | 188 | 70 | 1.05 | F | I | SC | 11 | FR | 11 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 4 | CT | 213 | 95 | 0.98 | M | I | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 4 | CT | 232 | | | | I | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 4 | RB | 158 | 48 | 1.22 | M | I | SC | 13 | FR | 13 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 4 | RB | 166 | 57 | 1.25 | M | I | SC | 10 | FR | 10 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 4 | RB | 190 | 78 | 1.14 | | I | SC | 12 | FR | 12 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 5 | CT | 400 | 680 | 1.06 | M | M | SC | 14 | FR | 14 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN06 | 42969 | SK | 1 | 6 | CT | 392 | 637 | 1.06 | F | M | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 93 | 12 | 1.49 | | I | SC | 05 | FR | 05 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 96 | 13 | 1.47 | | I | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 98 | 13 | 1.38 | | I | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 100 | 13 | 1.3 | | I | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 101 | 12 | 1.16 | | I | SC | 10 | FR | 10 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 109 | 17 | 1.31 | | I | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 131 | 29 | 1.29 | F | I | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 136 | 31 | 1.23 | | I | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 137 | 31 | 1.21 | | I | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 1 | RB | 139 | 32 | 1.19 | | I | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 2 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 3 | RB | 206 | 108 | 1.24 | F | I | SC | 12 | FR | 12 | | |

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

## Table 2. Raw fish data from gill net sampling *continued*.

| Water Body | Year | Site Name | Date | Capture Method | Set # | Panel # | Species[1] | Measured Length (mm) | Weight (g) | K | Sex | Sexual Maturity (I, M, UNK) | Age Sample Type 1 | Age Sample Number | Age Sample Type 2 | Age Sample Number 2 | DNA Sample Type | DNA Sample Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 3 | RB | 228 | 143 | 1.21 | M | I | SC | 11 | FR | 11 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 4 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | FL | 2 | 6 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 2 | CT | 370 | 545 | 1.08 | F | M | SC | 01 | FR | 01 | OT | 01 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 3 | CT | 287 | 230 | 0.97 | F | M | SC | 05 | FR | 05 | OT | 05 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 3 | CT | 310 | 305 | 1.02 | F | M | SC | 04 | FR | 04 | OT | 04 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 3 | RB | 228 | 128 | 1.08 | F | I | SC | 03 | FR | 03 | OT | 03 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 3 | RB | 253 | 183 | 1.13 | F | M | SC | 02 | FR | 02 | OT | 02 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 4 | CT | 215 | 108 | 1.09 | | I | SC | 12 | FR | 12 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 4 | DV | 189 | 74 | 1.1 | F | I | SC | 13 | FR | 13 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 4 | RB | 159 | 52 | 1.29 | M | I | SC | 10 | FR | 10 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 4 | RB | 167 | 57 | 1.22 | M | I | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 4 | RB | 171 | 67 | 1.34 | M | I | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 4 | RB | 196 | 94 | 1.25 | M | M | SC | 11 | FR | 11 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 5 | CT | 416 | 762 | 1.06 | F | M | SC | 07 | FR | 07 | OT | 07 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 5 | CT | 438 | 709 | 0.84 | M | M | SC | 06 | FR | 06 | OT | 06 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 1 | 6 | CT | 368 | 499 | 1 | F | M | SC | 14 | FR | 14 | OT | 14 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 3 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 3 | 2 | RB | 81 | 7 | 1.32 | | I | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 3 | 2 | RB | 82 | 8 | 1.45 | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 3 | 3 | RB | 270 | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN07 | 42970 | SK | 3 | 4 | RB | 111 | 17 | 1.24 | | I | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 1 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 2 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 3 | RB | 176 | 67 | 1.23 | F | I | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 3 | RB | 247 | 177 | 1.17 | M | M | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 3 | RB | 270 | 214 | 1.09 | M | M | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 3 | RB | 295 | 239 | 0.93 | F | M | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 4 | CT/RB | 267 | 193 | 1.01 | M | I | SC | 12 | FR | 12 | FC | 12 |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 4 | RB | 154 | 44 | 1.2 | | I | SC | 05 | FR | 05 | | |

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

**Table 2. Raw fish data from gill net sampling *continued*.**

| Water Body | Year | Site Name | Date | Capture Method | Set # | Panel # | Species[1] | Measured Length (mm) | Weight (g) | K | Sex | Sexual Maturity (I, M, UNK) | Age Sample Type 1 | Age Sample Number | Age Sample Type 2 | Age Sample Number 2 | DNA Sample Type | DNA Sample Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 4 | RB | 173 | 68 | 1.31 | F | I | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 4 | RB | 179 | 75 | 1.31 | M | I | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 4 | RB | 186 | 71 | 1.1 | M | I | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 4 | RB | 189 | 83 | 1.23 | M | I | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 4 | RB | 228 | 136 | 1.15 | M | I | SC | 11 | FR | 11 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 4 | RB | 235 | 131 | 1.01 | F | I | SC | 10 | FR | 10 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | FL | 2 | 6 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 1 | CT | 173 | 56 | 1.08 | | I | SC | 01 | FR | 01 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 2 | CT | 357 | 468 | 1.03 | M | M | SC | 03 | FR | 03 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 2 | CT | 370 | 579 | 1.14 | F | M | SC | 04 | FR | 04 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 2 | CT | 380 | 540 | 0.98 | F | M | SC | 05 | FR | 05 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 2 | CT | 402 | 557 | 0.86 | F | M | SC | 06 | FR | 06 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 2 | CT | 412 | 577 | 0.83 | F | M | SC | 07 | FR | 07 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 2 | CT | 414 | 798 | 1.12 | F | M | SC | 08 | FR | 08 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 2 | RB | 252 | 163 | 1.02 | F | M | SC | 02 | FR | 02 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 3 | CT | 242 | 144 | 1.02 | M | I | SC | 13 | FR | 13 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 3 | CT | 271 | 203 | 1.02 | M | I | SC | 14 | FR | 14 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 3 | RB | 231 | 141 | 1.14 | F | M | SC | 09 | FR | 09 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 3 | RB | 234 | 164 | 1.28 | F | M | SC | 10 | FR | 10 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 3 | RB | 276 | 175 | 0.83 | F | M | SC | 11 | FR | 11 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 3 | RB | 276 | 228 | 1.08 | M | I | SC | 12 | FR | 12 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 4 | CT | 245 | 152 | 1.03 | M | I | SC | 15 | FR | 15 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 4 | CT | 247 | 159 | 1.06 | F | M | SC | 16 | FR | 16 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 4 | RB | 162 | 55 | 1.29 | | I | SC | 17 | FR | 17 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 4 | RB | 187 | 85 | 1.3 | | I | SC | 18 | FR | 18 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 4 | RB | 241 | 163 | 1.16 | M | I | SC | 19 | FR | 19 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 4 | RB | 246 | 150 | 1.01 | M | I | SC | 20 | FR | 20 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 4 | RB | 283 | 258 | 1.14 | F | M | SC | 21 | FR | 21 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 5 | NFC | | | | | | | | | | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 6 | CT | 332 | 382 | 1.04 | F | M | SC | 24 | FR | 24 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 6 | CT | 332 | 483 | 1.32 | F | M | SC | 23 | FR | 23 | | |

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

## Table 2. Raw fish data from gill net sampling *continued*.

| Water Body | Year | Site Name | Date | Capture Method | Set # | Panel # | Species[1] | Measured Length (mm) | Weight (g) | K | Sex | Sexual Maturity (I, M, UNK) | Age Sample Type 1 | Age Sample Number | Age Sample Type 2 | Age Sample Number 2 | DNA Sample Type | DNA Sample Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 6 | CT | 340 | 413 | 1.05 | F | M | SC | 22 | FR | 22 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 6 | CT | 384 | 598 | 1.06 | M | M | SC | 25 | FR | 25 | | |
| Upper Campbell Reservoir | 2017 | UCR-LKGN08 | 42970 | SK | 1 | 6 | CT | 394 | 616 | 1.01 | M | M | SC | 26 | FR | 26 | | |

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

**Figure 1. Example of gill net gear deployed at each site during 2017 gill net surveys.**

**Figure 2. Example of typical gill net gear deployment location (UCR-LKGN02) during 2017 gill net surveys.**

**Figure 3. 278 mm Rainvow Trout captured at UCR-LKGN01 on August 21, 2017.**


**Figure 4. 272 mm Cutthroat Trout captured at UCR-LKGN01 on August 21, 2017.**

Figure 5. 187 mm Rainbow Trout captured at UCR-LKGN01 on August 21, 2017.

Figure 6. 201 mm Cutthroat Trout captured at UCR-LKGN01 on August 21, 2017.

**Figure 7.** **Stomach content assessment of a 332 mm Cutthroat Trout captured at UCR-LKGN02 on August 21, 2017.**


**Figure 8.** **148 mm sculpin captured at UCR-LKGN04 on August 22, 2017.**

**Figure 9. 174 mm sculpin captured at UCR-LKGN04 on August 22, 2017.**

**Figure 10. 392 mm Cutthroat Trout captured at UCR-LKGN06 on August 22, 2017.**

**Figure 11. 141 mm Rainbow Trout captured at UCR-LKGN06 on August 22, 2017.**

**Figure 12. 98 mm Rainbow Trout captured at UCR-LKGN07 on August 23, 2017.**

Figure 13. 438 mm Cutthroat Trout captured at UCR-LKGN07 on August 23, 2017.

# Appendix C. Snorkel Survey Representative Photographs

## LIST OF FIGURES

**Figure 1. Looking upstream at Miller Creek snorkel section start on March 23, 2017.**

**Figure 2. Looking downstream at Fry Creek snorkel section start on March 23, 2017.**

**Figure 3. Looking from river right to river left at Fry Creek snorkel section start on March 23, 2017.**

**Figure 4. Looking upstream at Thelwood Creek snorkel section start on June 8, 2017.**

**Figure 5. Looking downstream at Thelwood Creek snorkel section start on June 8, 2017.**

**Figure 6. Looking downstream at Thelwood Creek snorkel section end on June 8, 2017.**

**Figure 7. Looking upstream at Thelwood Creek snorkel section end on June 8, 2017.**

**Figure 8. Looking upstream at Upper Elk snorkel section start at Drum Creek start in on June 7, 2017.**

**Figure 9. Looking downstream at Upper Elk snorkel section start in Drum Creek at on June 7, 2017.**

**Figure 10. Looking downstream at Upper Elk snorkel section end on June 7, 2017.**

**Figure 11. Looking upstream at Upper Elk snorkel section end on June 7, 2017.**

**Figure 12. Looking upstream at Lower Elk snorkel section end on June 7, 2017.**

**Figure 13. Looking upstream at Shepard Creek in Ralph River snorkel section start on June 6, 2017.**

**Figure 14. Looking downstream at Shepard Creek in Ralph River snorkel section start on June 6, 2017.**

**Figure 15. Looking downstream at Ralph River snorkel section end on June 6, 2017.**

**Figure 16. Looking upstream at Ralph River snorkel section end on June 6, 2017.**

**Figure 17. Looking upstream at Henshaw Creek snorkel section start on June 6, 2017.**

**Figure 18. Looking downstream at Henshaw Creek snorkel section start on June 6, 2017.**

**Figure 19. Looking downstream at Henshaw Creek snorkel section end on June 6, 2017.**

**Figure 20. Looking upstream Henshaw Creek snorkel section end on June 6, 2017.**

**Figure 21. Looking upstream at Wolf River snorkel section start on June 5, 2017.**

**Figure 22. Looking downstream at Wolf River snorkel section start on June 5, 2017.**

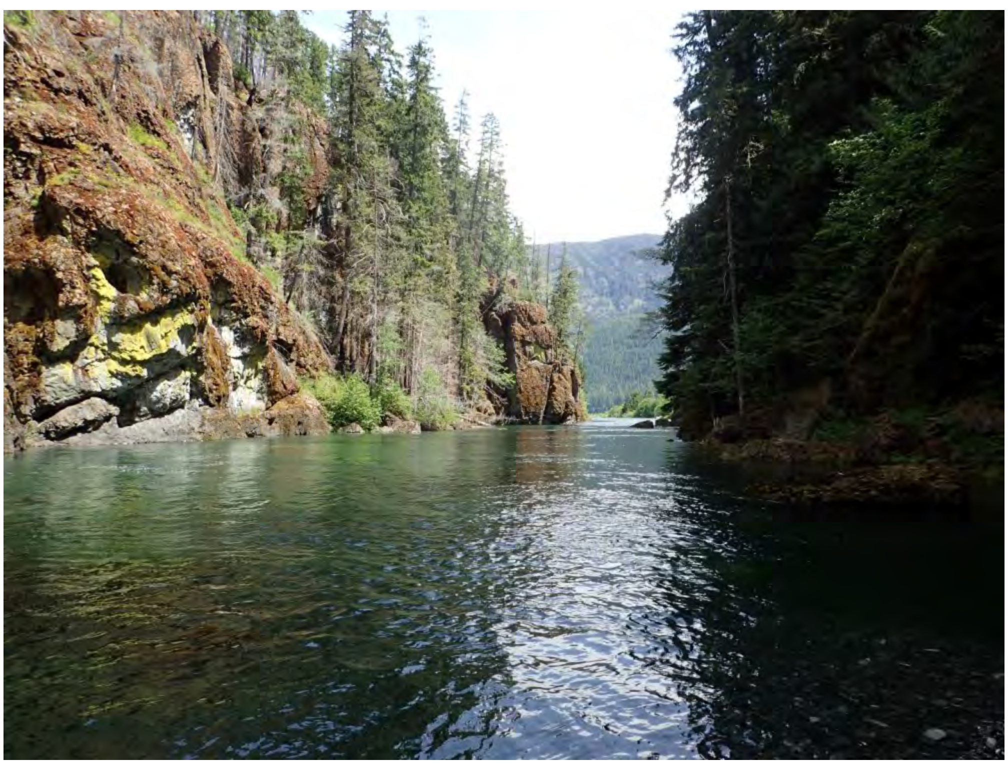


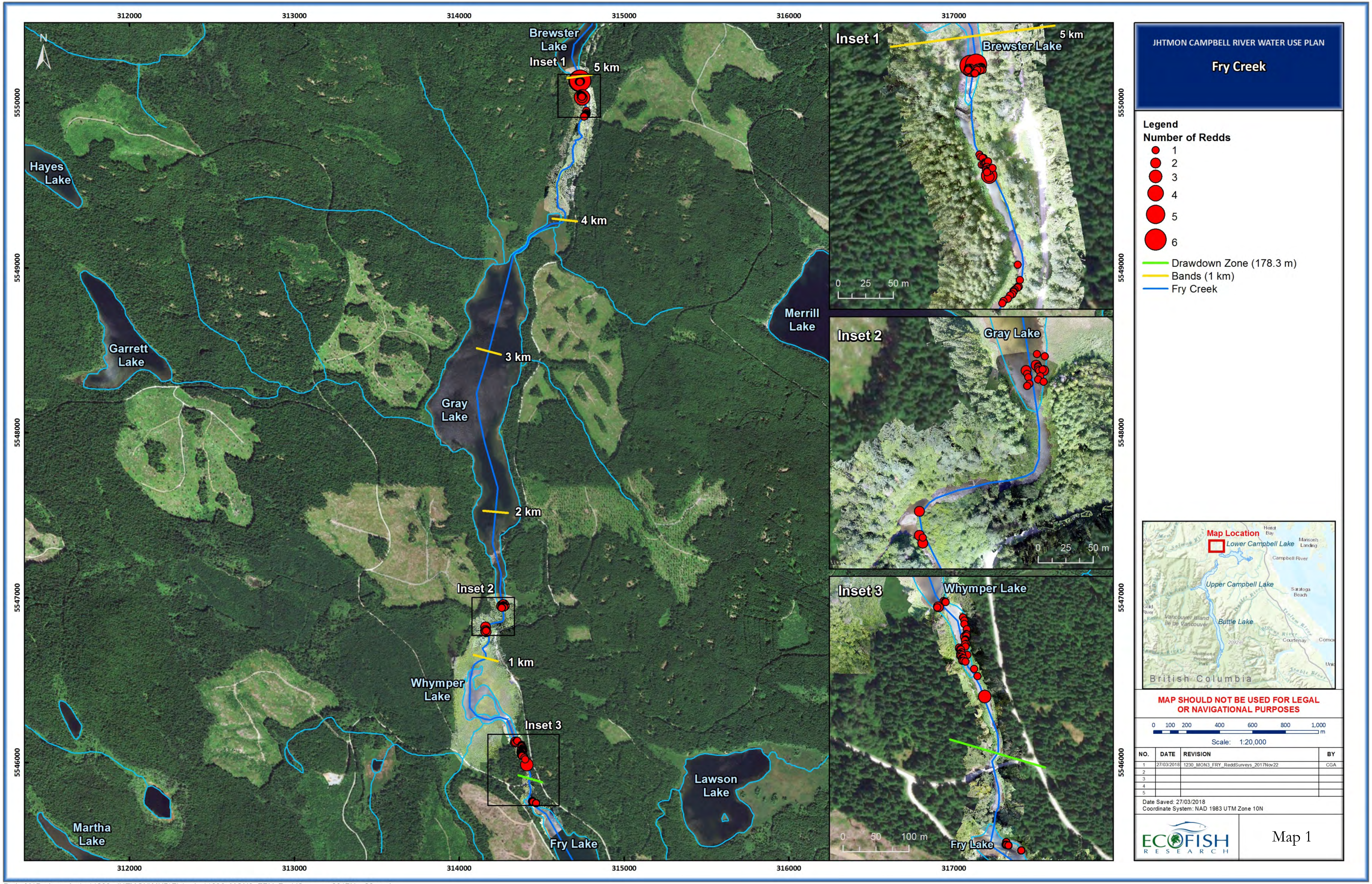
**Figure 23. Looking upstream at Phillips Creek snorkel section start on June 5, 2017.**

**Figure 24. Looking downstream at Phillips Creek snorkel section start on June 5, 2017.**

**Figure 25. Looking downstream at Phillips Creek snorkel section end on June 5, 2017.**

# Appendix D. Redd Survey Maps

## LIST OF MAPS

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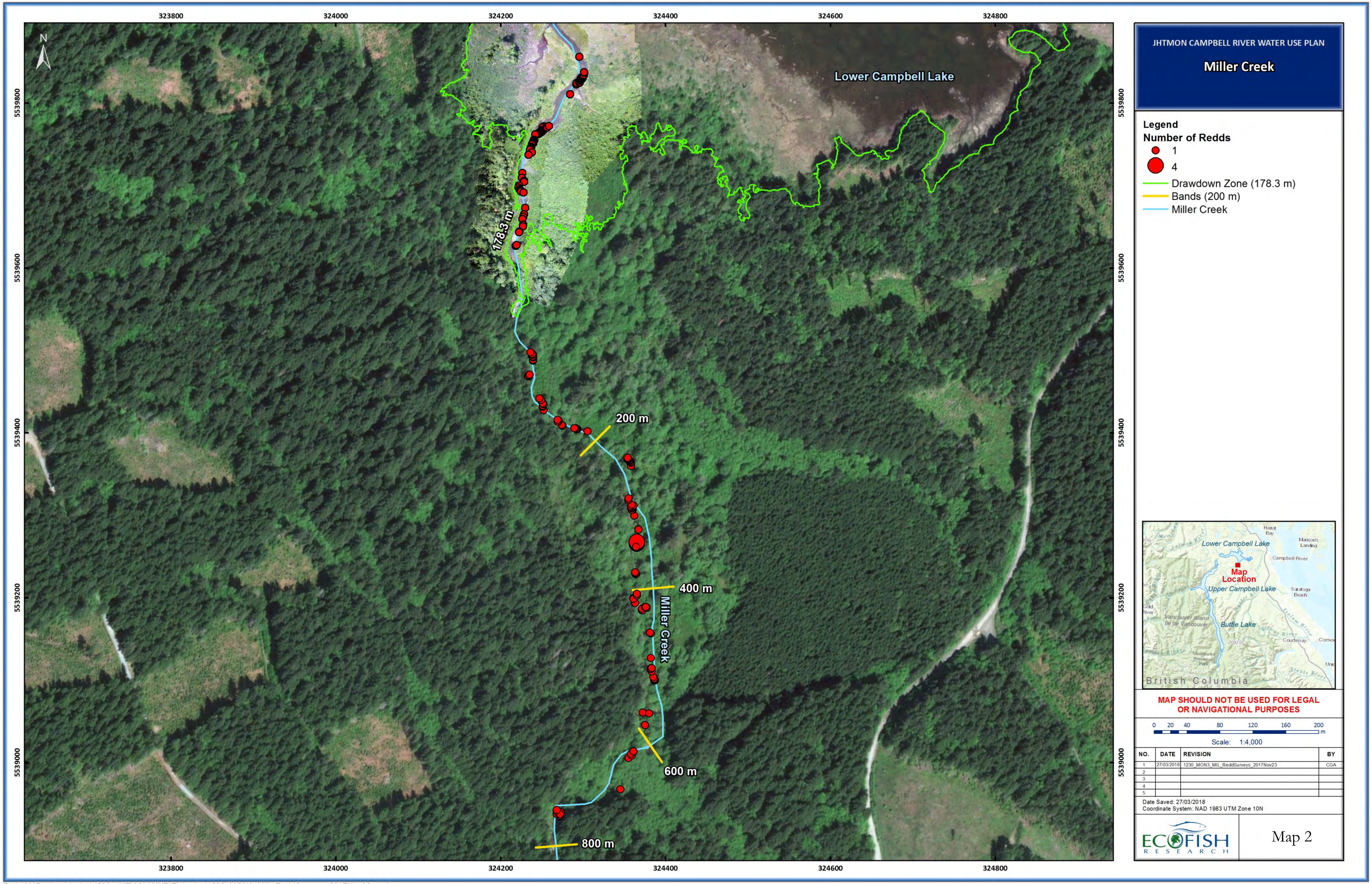
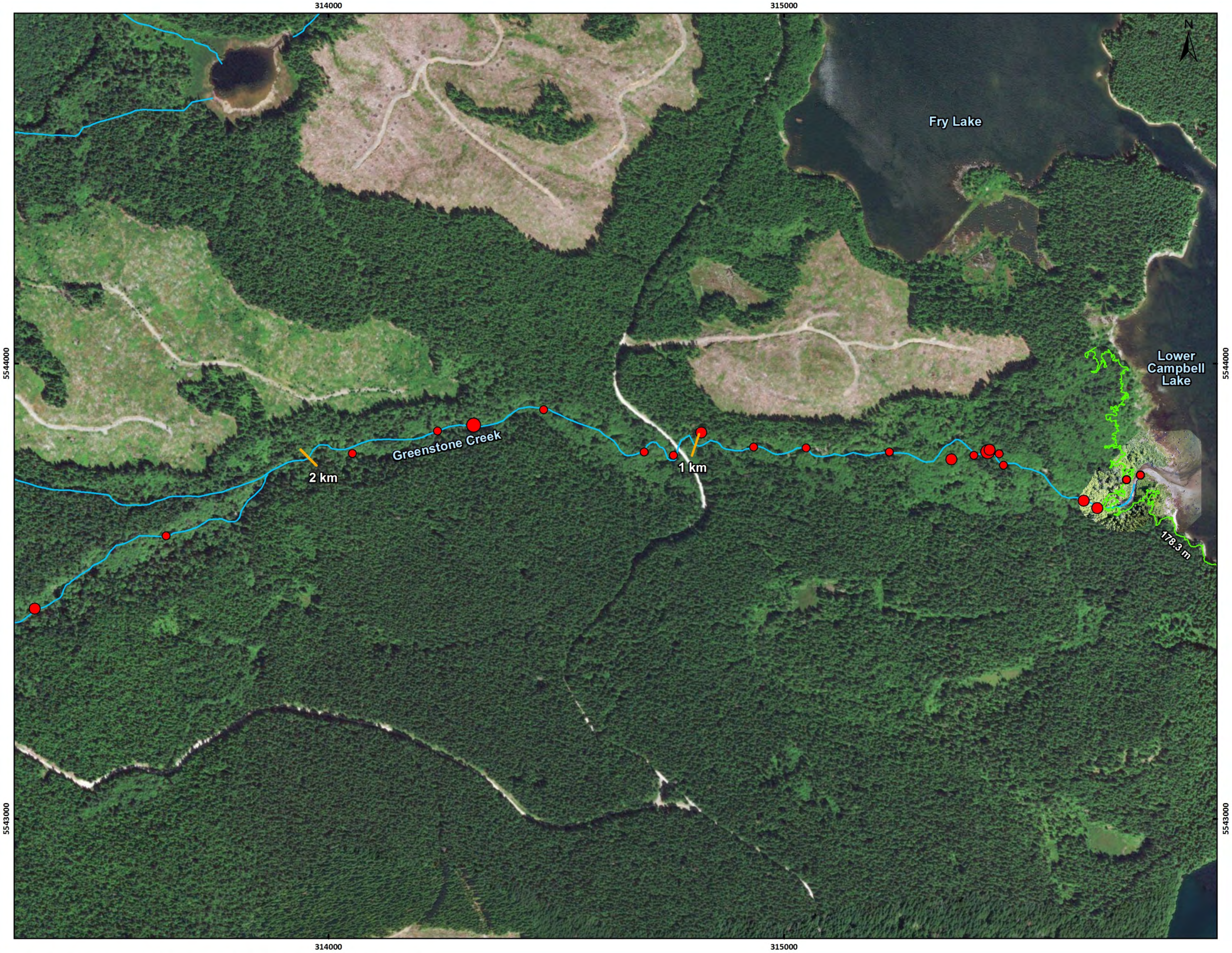



Path: M:\Projects-Active\1230_JHTMON\MXD\Fisheries\1230_MON3_MIL_ReddSurveys_2017Nov23.mxd

**JHTMON CAMPBELL RIVER WATER USE PLAN**

## Greenstone Creek




**Legend**

**Number of Redds**

- 1
- 2
- 3
- Drawdown Zone (178.3 m)
- Bands (1 km)
- Stream


**MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES**

0 50 100 200 300 400 m

Scale: 1:8,000

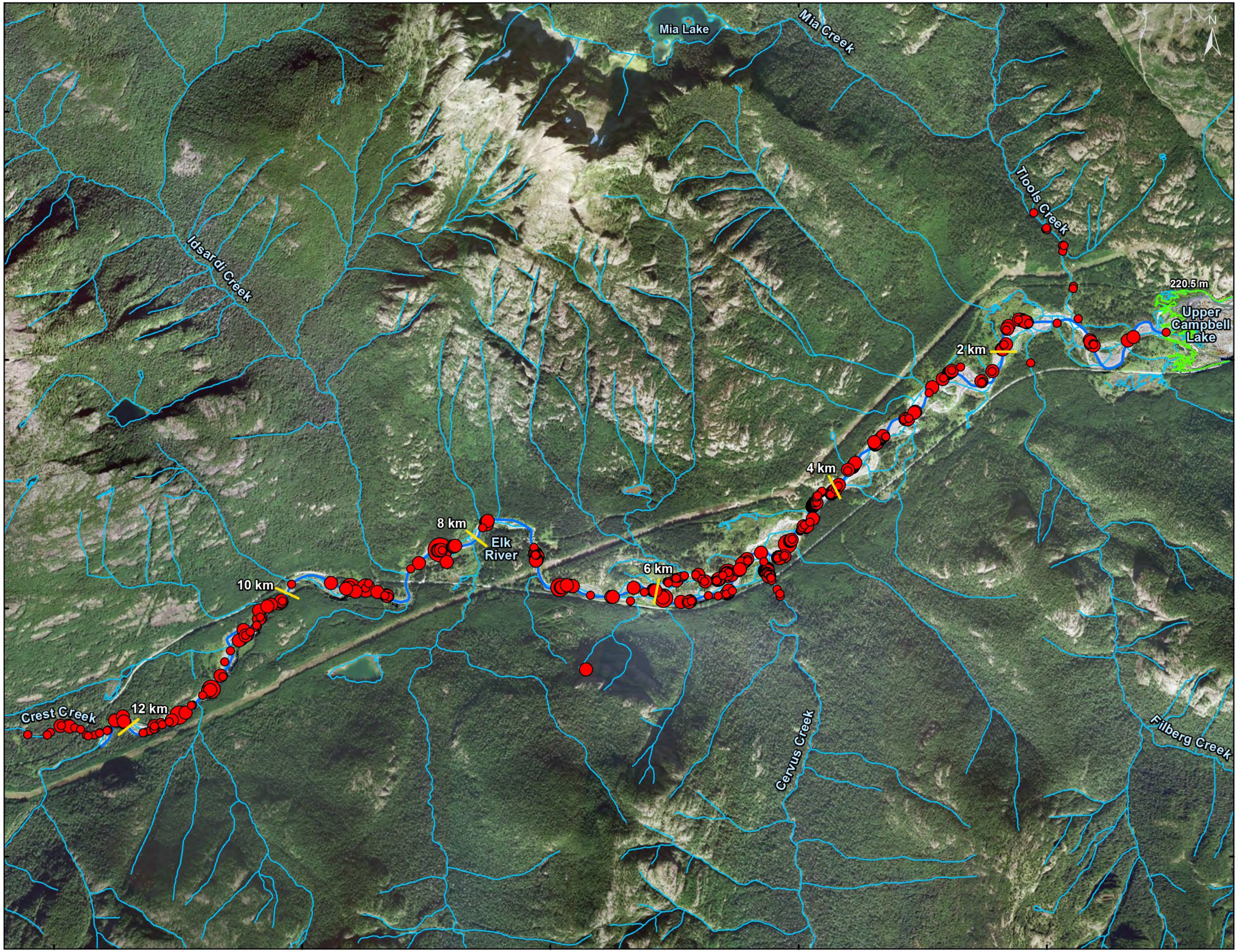
| NO. | DATE | REVISION | BY |
|---|---|---|---|
| 1 | 05/04/2018 | 1230_MON3_GRN_ReddSurveys_2017Nov24 | CGA |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

Date Saved: 05/04/2018
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 3

Path: M:\Projects-Active\1230_JHTMON\MXD\Fisheries\1230_MON3_GRN_ReddSurveys_2017Nov24.mxd




## JHTMON CAMPBELL RIVER WATER USE PLAN

## Elk River

**Legend**

**Number of Redds**

- 1 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- Drawdown Zone (220.5 m)
- Bands (2 km)
- Elk River


**MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES**

0 160 320 640 960 1,280 1,600 m

Scale: 1:30,000

| NO. | DATE | REVISION | BY |
|---|---|---|---|
| 1 | 29/03/2018 | 1230_MON3_ELK_ReddSurveys_2017Nov24 | CGA |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

Date Saved: 29/03/2018
Coordinate System: NAD 1983 UTM Zone 10N

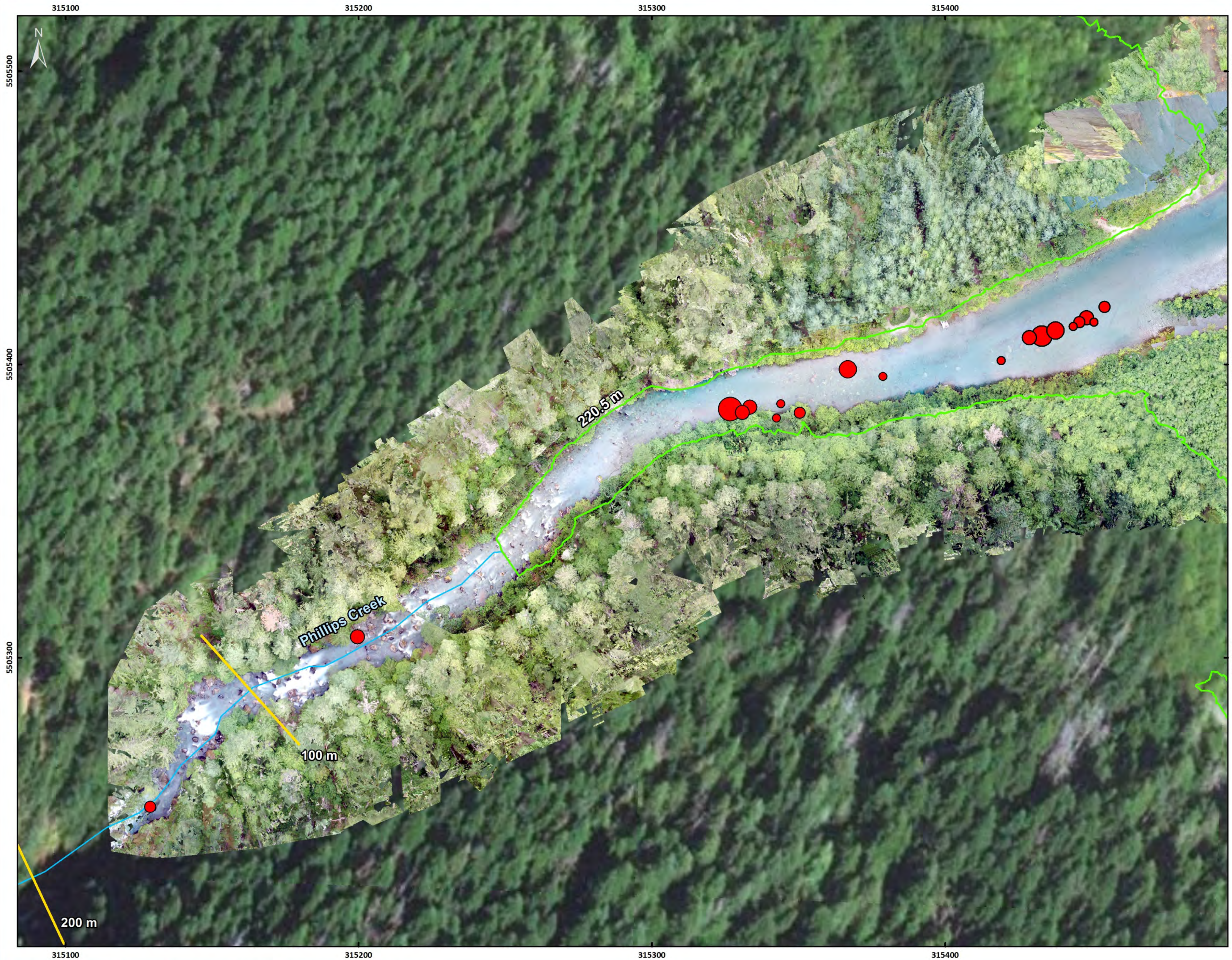
ECOFISH RESEARCH

Map 4

Path: M:\Projects-Active\1230_JHTMON\MXD\Fisheries\1230_MON3_ELK_ReddSurveys_2017Nov24.mxd


| NO. | DATE | REVISION | BY |
|---|---|---|---|
| 1 | 27/03/2018 | 1230_MON3_WOL_ReddSurveys_2017Nov24 | CGA |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

Path: M:\Projects-Active\1230_JHTMON\MXD\Fisheries\1230_MON3_WOL_ReddSurveys_2017Nov24.mxd




**JHTMON CAMPBELL RIVER WATER USE PLAN**

**Phillips Creek**

**Legend**

**Number of Redds**

- 1
- 2
- 3
- 4
- 6

- Drawdown Zone (220.5 m)
- Bands (100 m)
- Phillips Creek

**MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES**

0 10 20 40 60 m

Scale: 1:1,250

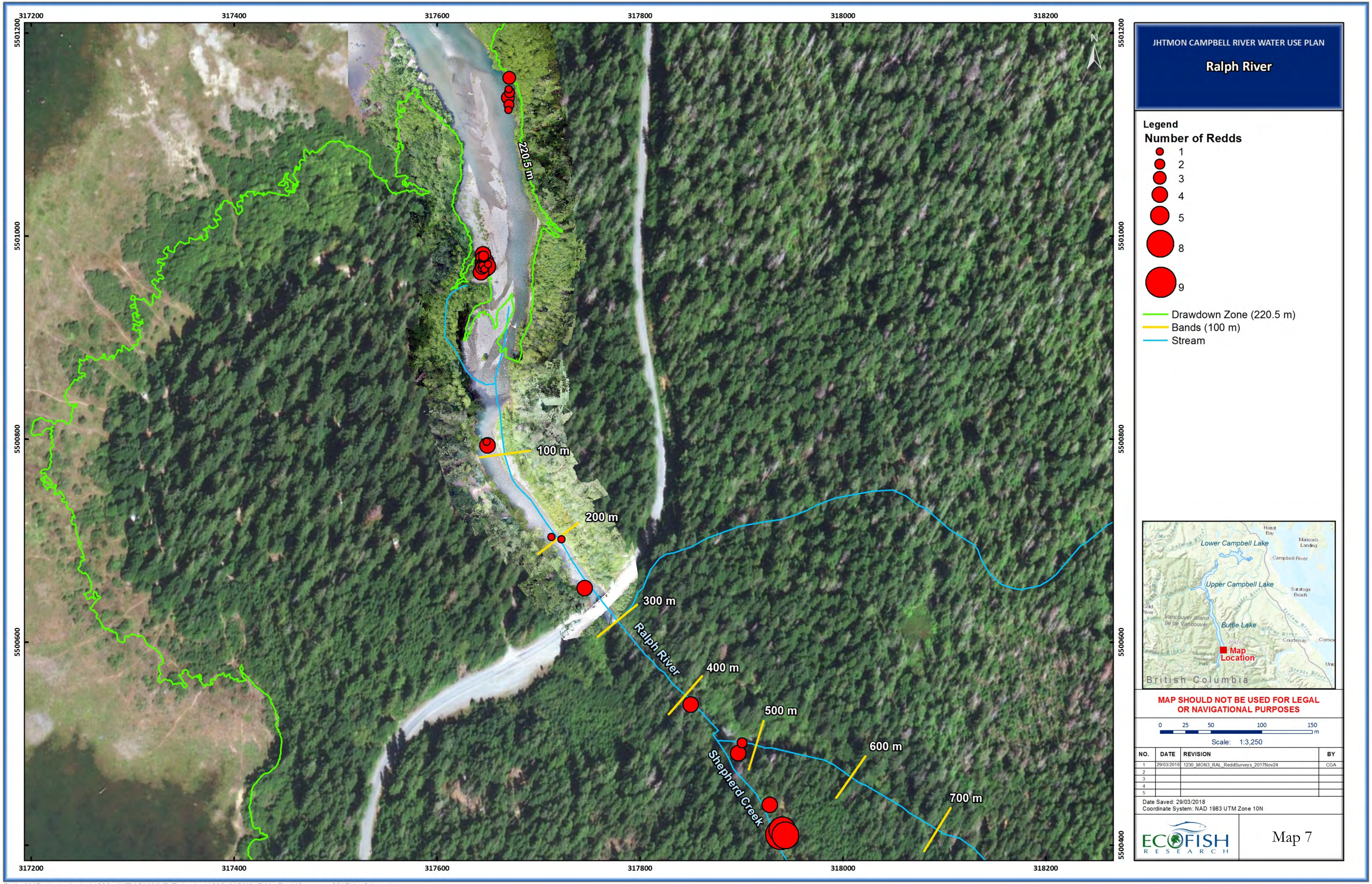
| NO. | DATE | REVISION | BY |
|---|---|---|---|
| 1 | 29/03/2018 | 1230_MON3_PHL_ReddSurveys_2017Nov24 | CGA |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

Date Saved: 29/03/2018
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 6

Path: M:\Projects-Active\1230_JHTMON\MXD\Fisheries\1230_MON3_PHL_ReddSurveys_2017Nov24.mxd




Path: M:\Projects-Active\1230_JHTMON\MXD\Fisheries\1230_MON3_RAL_ReddSurveys_2017Nov24.mxd