# Columbia River Project Water Use Plan

## Lower Columbia River Fish Management Plan

## Lower Columbia River Fish Population Indexing Surveys

## Implementation Year 10

## Reference: CLBMON-45

*Final Technical Report*

**Study Period 2016**

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**August 2017**

# CLBMON-45:
# Lower Columbia River
# Fish Population Indexing Survey
# 2016 Report

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**Prepared for:**
BC Hydro

**August 2017**

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# Executive Summary

BC Hydro has conducted flow management actions to reduce egg losses in the lower Columbia River (LCR) during the Mountain Whitefish (*Prosopium williamsoni*) and Rainbow Trout (*Oncorhynchus mykiss*) spawning seasons since the mid-1990s. These actions include decreasing flows from Hugh L. Keenleyside Dam (HLK) in early winter to encourage Mountain Whitefish spawning at lower water level elevations and to reduce egg dewatering over the winter egg incubation period. In early spring, flows are managed to provide stable or increasing water levels during the Rainbow Trout spawning season, which reduces the likelihood of Rainbow Trout eggs and other larval fish from becoming stranded during spring flow management.

In 2007, BC Hydro completed the Water Use Planning process for its hydroelectric and storage facilities on the Columbia River. The Water Use Plan Consultative Committee recommended the commissioning of the LCR Fish Population Indexing Program (CLBMON-45) to address data gaps regarding the effects of HLK operations on the downstream fish communities. CLBMON-45 represents a continuation of BC Hydro's LCR Large River Fish Indexing Program (LRFIP), first established in 2001 to gather baseline information on fish distribution, life history characteristics, and population abundance data for select index species (i.e., Mountain Whitefish, Rainbow Trout, and Walleye [*Sanders vitreus*]).

The two key management questions to be answered by CLBMON-45 are:

- What is the abundance, growth rate, survival rate, body condition, age distribution, and spatial distribution of subadult and adult Whitefish, Rainbow Trout, and Walleye in the LCR?
- What is the effect of inter-annual variability in the Whitefish and Rainbow Trout flow regimes on the abundance, growth rate, survival rate, body condition, and spatial distribution of subadult and adult Whitefish, Rainbow Trout, and Walleye in the LCR?

The study area for CLBMON-45 includes the portion of the Columbia River between HLK and the Canada-US border (approximately 56.5 km of river habitat) and the 2.8 km section of the Kootenay River from Brilliant Dam (BRD) downstream to the Columbia River confluence.

Fish were sampled by boat electroshocking at night within nearshore habitats. In addition to the mark-recapture indexing sites sampled since 2001, additional sample sites were randomly selected from 2011 to 2016 using a Generalized Random Tessellation Stratified (GRTS) survey design. All captured Mountain Whitefish, Rainbow Trout, and Walleye were measured for fork length, weighed, and implanted with a Passive Integrated Transponder (PIT) tag. Hierarchical Bayesian Models (HBMs) were used to estimate temporal and spatial variation in abundance, spatial distribution, growth, survival, and body condition. A maximum likelihood model was used to estimate mean annual length-at-age based on length-frequency data. The proportional ratio of age-1:2

Mountain Whitefish was used as an indicator of recruitment to assess annual variation and the effects of egg dewatering. A Beverton-Holt stock-recruitment model was fit to the data and egg dewatering was included as a covariate.

A new method was used to age Mountain Whitefish scales by digitally measuring the distance between growth rings (circuli) and using an algorithm to identify growth annuli and estimate age. This method was reliable for age-1 and age-2 fish and is recommended for future years. Model improvements may help improve ageing accuracy for age-3 and older Mountain Whitefish.

The estimated abundance of adult Rainbow Trout increased substantially from ~25,000 in 2002 to ~50,000 in 2015 to 2016, and high abundances in recent years coincided with a decline in body condition and survival, suggesting density dependence. Adult Mountain Whitefish abundance declined by approximately half between 2001 (~165,000) and 2014 (~77,000) and remained at similar levels between 2012 and 2016. Walleye had lower abundance in the most recent five years than in all earlier years, which corresponded with the highest observed body condition.

There was no statistically significant relationship between the Mountain Whitefish age-1:2 recruitment index and the estimated annual egg loss ($P$=0.3). This suggests that factors other than dewatering affected the inter-annual variation in recruitment. The age-1:2 index was not calculated for Rainbow Trout because age data were not available from 2013 to 2016.

In stock-recruitment analyses, there was no effect of increasing abundance of adults (“stock”) on the resulting number of age-1 recruits for Mountain Whitefish or Rainbow Trout, which was interpreted as being consistent with density-dependent survival. The effect of egg loss in the stock-recruitment model was not significant for Mountain Whitefish or Rainbow Trout, which did not support an effect of dewatering on subsequent recruitment at the observed levels of stock abundance. However, there were no years of data on the steeper part of the stock-recruitment curves, where decreases in spawners or egg losses would be expected to decrease subsequent recruitment. Therefore, the effects of egg losses at lower adult abundance are unknown based on these stock-recruitment models. These conclusions should be considered tentative because of the poor fit in the stock-recruitment relationships, and the possibility that sampling biases or environmental variability masked real effects of egg dewatering.

**Keywords:** Columbia River, Hugh L. Keenleyside Dam (HLK), Density Estimation, Fish Abundance, Hierarchical Bayesian Models (HBM)

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# 1.0 INTRODUCTION

In the mid-1990s, BC Hydro initiated water management from Hugh L. Keenleyside Dam (HLK) during the Mountain Whitefish (*Prosopium williamsoni*) and Rainbow Trout (*Oncorhynchus mykiss*) spawning seasons to reduce egg losses downstream of the dam. During the Mountain Whitefish spawning season (December to February), BC Hydro decreases flow from HLK during the peak spawning period (24 December to 21 January; Golder 2010a) to encourage spawning at lower water level elevations and reduce egg dewatering over the winter period and during the early spring when annual minimum flows typically occur. Subsequently, flows are managed (i.e., within the constraints of the Columbia River Treaty and flood protection considerations) to provide stable or increasing water levels during the middle of the Rainbow Trout spawning season (early April to late June) to protect Rainbow Trout spawners by reducing the likelihood that Rainbow Trout eggs (and other larval fishes) are stranded during spring flow management.

BC Hydro implemented a Water Use Plan (WUP; BC Hydro 2005) for the Columbia River in 2007. As part of the WUP, the Columbia River Water Use Plan Consultative Committee recommended the establishment of the Lower Columba River (LCR) Fish Indexing Program to address data gaps regarding the effects of water management at HLK (particularly during the Mountain Whitefish and Rainbow Trout spawning seasons) on downstream fish populations. The LCR Fish Indexing Program represents a continuation of the Large River Fish Indexing Program (LRFIP), a program initiated by BC Hydro in 2001 to develop a reliable and cost-effective method of indexing the fish community downstream of HLK.

In 2001, the LRFIP gathered baseline information on fish distribution, life history characteristics, and population abundance of fish species present in the LCR (Golder 2002). Between 2002 and 2006 (Golder 2003, 2004, 2005, 2006, 2007), the program was refined, based on the results of previous study years, to provide a systematic and repetitive index of fish population parameters for three index species: Mountain Whitefish, Rainbow Trout, and Walleye (*Sanders vitreus*). A detailed summary of the life history requirements for these three species was provided by Golder (2009a, 2010b).

Data collected under the LRFIP (Golder 2002, 2003, 2004, 2005, 2006, 2007) and the current program (Golder 2008, 2009a, 2010b, Ford and Thorley 2011a, Ford and Thorley 2012, Golder and Poisson 2013; Golder and Poisson 2014, 2015) will be used to identify changes in fish populations and assist in the determination of the biological and statistical significance of these changes in relation to Mountain Whitefish and Rainbow Trout spawning protection flows.

## *1.1 Study Objectives*

The objectives of CLBMON-45 (BC Hydro 2007) are:

- to extend time series data on the abundance, distribution, and biological characteristics of nearshore and shallow water fish populations in the LCR;
- to examine long-term trends in key index fish populations (i.e., Mountain Whitefish, Walleye, and Rainbow Trout) during the continued implementation of Mountain Whitefish and Rainbow Trout flows in the LCR;
- to build upon previous investigations for the further refinement of sampling strategy, sampling program, and analytical procedures to establish a long-term monitoring program for fish populations in the LCR;
- to update the existing electronic storage and retrieval system for fish population and habitat monitoring data for the Columbia River;
- to establish linkages between other biological monitoring programs being undertaken in the LCR, in particular, the Physical Habitat and Ecological Productivity Monitoring Program (CLBMON-44); and
- to identify gaps in data and understanding of current knowledge about fish populations and procedures for sampling them, and to provide recommendations for future monitoring and fisheries investigations.

## *1.2 Key Management Questions*

Key management questions to be addressed by CLBMON-45 are:

- What is the abundance, growth rate, survival rate, body condition, age distribution, and spatial distribution of subadult and adult Whitefish, Rainbow Trout, and Walleye in the LCR?
- What is the effect of inter-annual variability in the Whitefish and Rainbow Trout flow regimes on the abundance, growth rate, survival rate, body condition, and spatial distribution of subadult and adult Whitefish, Rainbow Trout and Walleye in the LCR?

## *1.3 Management Hypotheses*

Specific hypotheses to be tested under CLBMON-45 include:

- $Ho_1$: There is no change in the population levels of Whitefish in the LCR over the course of the monitoring period.
    - $Ho_{1a}$: There is no change in the abundance of adult and subadult Whitefish.
    - $Ho_{1b}$: There is no change in the mean size-at-age of subadult and adult Whitefish.
    - $Ho_{1c}$: There is no change in the mean survival of adult and subadult Whitefish.
    - $Ho_{1d}$: There is no change in the morphological (condition factor) index of body condition of adult and subadult Whitefish.
    - $Ho_{1e}$: There is no change in the distribution of adult and subadult Whitefish.

- $Ho_2$: There is no change in the population levels of Rainbow Trout in the LCR over the course of the monitoring period.
    - $Ho_{2a}$: There is no change in the abundance of adult and subadult Rainbow Trout.
    - $Ho_{2b}$: There is no change in the mean size-at-age of subadult and adult Rainbow Trout.
    - $Ho_{2c}$: There is no change in the mean survival of adult and subadult Rainbow Trout.
    - $Ho_{2d}$: There is no change in the morphological (condition factor) index of body condition of adult and subadult Rainbow Trout.
    - $Ho_{2e}$: There is no change in the distribution of adult and subadult Rainbow Trout.
- $Ho_3$: There is no change in the population levels of Walleye in the LCR over the course of the monitoring period.
    - $Ho_{3a}$: There is no change in the abundance of adult and subadult Walleye.
    - $Ho_{3b}$: There is no change in the mean size-at-age of subadult and adult Walleye.
    - $Ho_{3c}$: There is no change in the mean survival of adult and subadult Walleye.
    - $Ho_{3d}$: There is no change in the morphological (condition factor) index of body condition of adult and subadult Walleye.
    - $Ho_{3e}$: There is no change in the distribution of adult and subadult Walleye.

## *1.4 Study Area and Study Period*

The study area for the LCR Fish Indexing Program encompasses the 56.5 km section of the riverine habitat from HLK to the Canada-U.S. border (Figure 1). This study area also includes the Kootenay River below Brilliant Dam (BRD) and the Columbia-Pend d'Oreille rivers confluence below Waneta Dam. For the purposes of this study, the study area was divided into three sections. The upstream section of the Columbia River extended 10.7 km from HLK (RKm 0.0) downstream to the Kootenay River confluence (RKm 10.7). The downstream section of the Columbia River extended 48.5 km from the Kootenay River confluence downstream to the Canada-U.S. border (RKm 56.5). The Kootenay River section was established as a separate sample section that extended 2.8 km from the Kootenay-Columbia rivers confluence upstream to BRD.

In 2016, sample sites were distributed throughout the study area in locations similar to all other study years since 2001. In total, nine sites were sampled in the upstream section of the Columbia River (Appendix A, Figure A1), 15 sites were sampled in the downstream section of the Columbia River (Appendix A, Figures A2 and A3), and four sites were sampled in the Kootenay River (Appendix A, Figure A1). Site descriptions and UTM locations for all sites are listed in Appendix A, Table A1. Each of the 28 index sites was sampled four times (i.e., 4 sessions) between 3 and 29 October 2016. Field sampling also was conducted in the late summer to fall during previous study years (Table 1).

In addition to the standard indexing program described above, 20 additional sites were randomly selected for sampling in Session 5 using a Generalized Random Tessellation Stratified (GRTS) survey (see Section 2.1.5). Session 5 was completed between 27 October and 4 November 2016.

**Table 1: Summary of annual study periods and number of sites sampled for boat electroshocking surveys conducted in the lower Columbia River, 2001 to 2016.**

| Year | Start Date | End Date | Number of Sites | | | Number of Sessions | Duration (in days) |
|---|---|---|---|---|---|---|---|
| | | | Index Sites[a] | GRTS[b] | Geo-referenced Visual Survey[c] | | |
| 2001 | 13 August | 23 September | 21 | - | - | 5 | 42 |
| 2002 | 16 September | 27 October | 24 | - | - | 6 | 42 |
| 2003 | 15 September | 26 October | 23 | - | - | 6 | 42 |
| 2004 | 13 September | 30 October | 23 | - | - | 7 | 48 |
| 2005 | 19 September | 1 November | 23 | - | - | 6 | 44 |
| 2006 | 18 September | 2 November | 23 | - | - | 6 | 46 |
| 2007 | 27 September | 6 November | 23 | - | - | 5 | 41 |
| 2008 | 22 September | 3 November | 23 | - | - | 5 | 43 |
| 2009 | 28 September | 30 October | 22 | - | - | 5 | 33 |
| 2010 | 27 September | 30 October | 28 | - | - | 5 | 34 |
| 2011 | 26 September | 30 October | 28 | 20 | - | 5 | 35 |
| 2012 | 24 September | 25 October | 28 | 20 | - | 5 | 32 |
| 2013 | 2 October | 6 November | 28 | 20 | 47 | 5 | 36 |
| 2014 | 6 October | 7 November | 28 | 20 | 28 | 5 | 33 |
| 2015 | 13 October | 10 November | 28 | 20 | 28 | 5 | 29 |
| 2016 | 3 October | 4 November | 28 | 20 | 28 | 5 | 33 |

a. Index sites that were longer than one habitat type were split up in in 2002 and 2010. The same bank length was sampled in all years of the program and the difference in the number of sites samples reflects changes in site naming. The exception was a few sites that were not sampled in some years because they could not be safely accessed.

b. GRTS sites were added to the program in 2011. See Section 2.1.5 for details.

c. Geo-referenced visual surveys started in 2013. See Section 2.1.8 for details. GRTS sites were also included in the visual survey in 2013 whereas only index sites were included in the visual survey in 2014 to 2016.

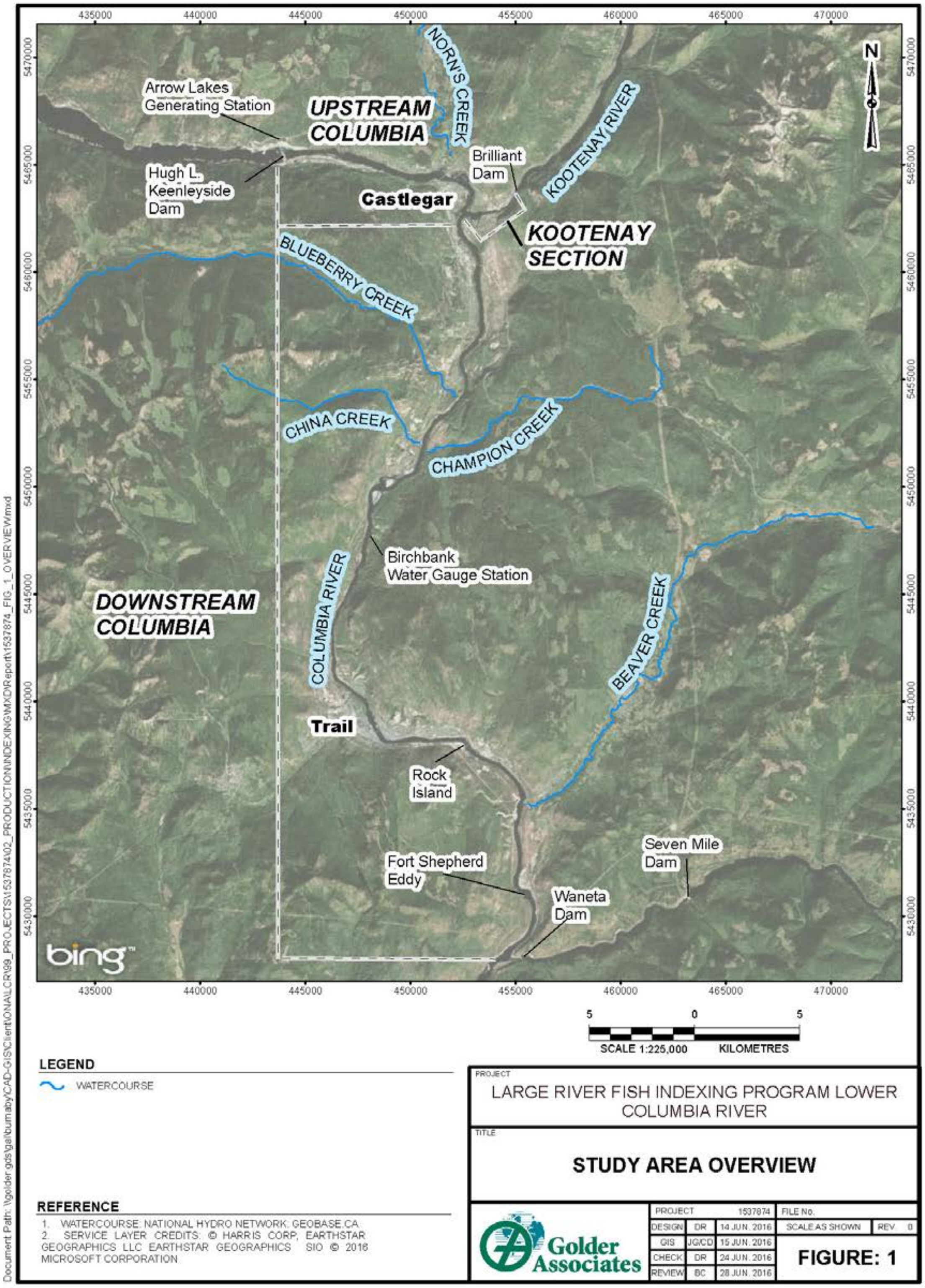

**Figure 1:** **Overview of the lower Columbia River Fish Population Indexing study area, 2016.**

# 2.0 METHODS

## *2.1 Data Collection*

### *2.1.1 Discharge*

All discharge data were obtained from BC Hydro's Temperature and Discharge database. Data used in this report included discharge for the Columbia River below HLK (combined discharge from HLK and Arrow Lakes Generating Station), the Columbia River at Birchbank (Water Survey of Canada gauging station No. 08NE049), and the Kootenay River (combined discharge through the BRD and Brilliant Expansion [BRX] plants). Discharge values throughout this report are presented as cubic metres per second ($m^3/s$).

### *2.1.2 Water Temperature*

Water temperatures for the mainstem Columbia River from 2001 to 2016 (except 2012) were obtained at hourly intervals using a Lakewood™ Universal temperature probe (accuracy ± 0.5°C) from the Water Survey of Canada gauging station at Birchbank. In 2012, water temperature data from the Birchbank station were not available for a large portion of the year because of a data logger malfunction. Columbia River water temperatures presented for 2012 were measured near Fort Shepherd (used with permission from Columbia Power Corporation; Golder 2013a). Water temperatures for the mainstem Kootenay River were obtained at hourly intervals using an Onset Tidbit™ temperature data logger (accuracy ± 0.5°C) installed approximately 1.8 km upstream of the Columbia-Kootenay rivers confluence.

All available temperature data were summarized to provide daily average temperatures. Spot measurements of water temperature were obtained at all sample sites at the time of sampling using a hull-mounted Airmar® digital thermometer (accuracy ± 0.2°C).

### *2.1.3 Habitat Conditions*

Several habitat variables were qualitatively assessed at all sample sites (Table 2). Variables selected were limited to those for which information had been obtained during previous study years and were intended as a means to detect gross changes in habitat availability or suitability in the sample sites between study years. The data collected were not intended to quantify habitat availability or imply habitat preferences.

The type and amount of instream cover for fish were qualitatively estimated at all sites (Table 2). Surface water velocities were visually estimated and categorized at each site as low (less than 0.5 m/s), medium (0.5 to 1.0 m/s), or high (greater than 1.0 m/s). Water clarity was visually estimated and categorized at each site as low (less than 1.0 m depth), medium (1.0 to 3.0 m depth), or high (greater than 3.0 m depth). To determine visibility categories, the boat operator called out depths displayed on the boats depth sounder while angling the boat from the thalweg into shore. The netters looked over the bow of the boat to become familiar with how deep they could see based on the depths relayed by the boat operator. Mean and maximum depths were estimated by the boat operator based on the boat's sonar depth display.

Habitat at each site was categorized using the Bank Habitat Types Classification System (Appendix B, Table B1; R.L.&L. 1995). Bank type length within each site was calculated using ArcView® GIS software (Appendix B, Table B2). While electrofishing, netters estimated the number of observed fish by species within each bank habitat type that were not captured. Bank habitat types less than approximately 100 m in length were combined with adjacent bank habitat types to facilitate the netters' ability to remember observed fish counts.

**Table 2: List and description of habitat variables recorded at each sample site in the lower Columbia River, 2016.**

| Variable | Description |
|---|---|
| Date | The date the site was sampled |
| Time | The time the site was sampled |
| Air Temp | Air temperature at the time of sampling (to the nearest 1°C) |
| Water Temp | Water temperature at the time of sampling (to the nearest 1°C) |
| Conductivity | Water conductivity at the time of sampling (to the nearest 10 µS) |
| Cloud Cover | A categorical ranking of cloud cover (clear=0-10% cloud cover; partly cloudy=10-50% cloud cover; mostly cloudy=50-90% cloud cover; overcast=90-100% cloud cover) |
| Weather | A general description of the weather at the time of sampling (e.g., comments regarding wind, rain, or fog) |
| Water Surface Visibility | A categorical ranking of water surface visibility (low - waves; medium - small ripples; high - flat surface) |
| Boat Model | The model of boat used during sampling |
| Range | The range of voltage used during sampling (high or low) |
| Percent | The estimated duty cycle (as a percent) used during sampling |
| Amperes | The average amperes used during sampling |
| Mode | The mode (AC or DC) and frequency (in Hz) of current used during sampling |
| Length Sampled | The length of shoreline sampled (to the nearest 1 m) |
| Time Sampled | The time of electroshocker operation (to the nearest 1 second) |
| Mean Depth | The estimated mean depth sampled (to the nearest 0.1 m) |
| Maximum Depth | The estimated maximum depth sampled (to the nearest 0.1 m) |
| Water Clarity | A categorical ranking of water clarity (high - greater than 3.0 m visibility; medium - 1.0 to 3.0 m visibility; low - less than 1 m visibility) |
| Instream Velocity | A categorical ranking of water velocity (high - greater than 1.0 m/s; medium - 0.5 to 1.0 m/s; low - less than 0.5 m/s) |
| Instream Cover | The type (i.e., interstices; woody debris; cutbank; turbulence; flooded terrestrial vegetation; aquatic vegetation; shallow water; deep water) and amount (as a percent) of available instream cover |
| Crew | The field crew that conducted the sampling |
| Sample Comments | Any additional comments regarding the sample |

### 2.1.4 Fish Capture

Fish were captured and sampled using methods similar to previous years of the project (Golder, ONA and Poisson 2016). Physiological stress on fish associated with capture and processing is greater at warmer water temperatures (Golder 2002; Gale et al. 2013). Therefore, sampling in the present study (as in during most other study years) did not commence until after water temperatures decreased below 15°C.

Boat electroshocking was conducted at all sites along the channel margin, typically within a range of 0.5 to 4.0 m water depth. Boat electroshocking employed a Smith-Root Inc. high-output Generator Powered Pulsator (GPP 5.0) electroshocker operated out of a 160 HP outboard jet-drive riverboat manned by a three-person crew. The electroshocking procedure consisted of manoeuvring the boat downstream along the shoreline of each sample site. Two crew members positioned on a netting platform at the bow of the boat netted stunned fish, while a third individual operated the boat and electroshocking unit. The two netters attempted to capture all index species. Captured fish were immediately sorted by the Bank Habitat Type they were captured in and placed into an onboard compartmentalized live-well. Index species that avoided capture and all other species that were positively identified but avoided capture were enumerated by Bank Habitat Type and recorded as “observed”. Both time sampled (seconds of electroshocker operation) and length of shoreline sampled (in kilometres) were recorded for each sample site. Electroshocking sites ranged from 0.44 to 3.79 km in length. If, because of logistical reasons, a site could not be completed, the distance that was actually sampled was estimated and recorded on the site form, and then used as the sampled length in the subsequent analyses.

To reduce fish mortalities and stress on the fish associated with capturing and handling, compressed oxygen was pumped into the livewell through an air stone.

Voltage was adjusted as needed to achieve an amperage output of ~1.75 A, at a frequency of 30 Hz direct current as these settings result in less electroshocking-induced injuries on Rainbow Trout than when using greater frequencies (60 or 120 Hz) and amperages (1.5 to 3.3. A; Golder 2004, 2005). Although electrical output is variable (i.e., depending on water conductivity, water depth, and water temperature), field crews attempted to maintain electrical output at similar levels for all sites over all sessions.

To reduce the possibility of capturing the same fish at multiple sites in one session, fish were released near the middle of the site where they were captured so they were less likely to move upstream or downstream into an adjacent site after release.

### 2.1.5 Generalized Random Tessellation Stratified Survey

In 2001, sites selected for inclusion in the LRFIP (Golder 2002) were based on sites established and data collected during surveys conducted in the early 1980’s (Ash et al. 1981) and early 1990’s (R.L.&L. 1991). During those two programs, virtually all areas of the LCR were surveyed with individual site lengths determined by the length of shoreline traversed by the boat in the amount of time it took netters to fill the livewell with fish (L. Hildebrand, Golder Associates Ltd., pers. comm.). A subsample of sites established during those original programs was selected for inclusion in the LRFIP in 2001 to provide a representative sample of general bank habitat types available throughout the LCR; however, emphasis was placed on sites known to contain higher densities of the three index species, which may result in overestimates of abundance in the entire LCR study area. This same subsample of sites has been used for annual sampling since 2001, including the continuation of the survey program as part of CLBMON-45, which was initiated in 2007. Approximately 30% of the total shoreline habitat available in the LCR was repetitively sampled each year as part of the LRFIP and CLBMON-45.

The stratified sampling design detailed above represents a repeated measures concept, where a mark-recapture program is conducted annually at each site over an approximately five week study period. The same sites are surveyed each year, resulting in annual estimates of abundance with relatively constant temporal and spatial sample design parameters. Stratified sampling programs like this may result in biased estimates because not all portions of a study area are surveyed or potentially available to be surveyed in any particular year. This bias can arise if inter-annual fish distribution changes with abundance rather than only fish density. Additionally, repetitively sampling the same sites each session (i.e., within a year) may introduce biases due to fish moving between sampled and non-sampled sections of the study areas within or between sessions.

Starting in 2011, additional sites were randomly selected using the GRTS survey design (Stevens and Olsen 2004) and sampled after field crews completed the conventional mark-recapture program. The GRTS survey was conducted to identify potential biases and to provide a better understanding of the population dynamics of the three index species.

Portions of shoreline habitat that were not sampled as part of CLBMON-45 prior to 2011 were divided up into potential sites. Upstream and downstream boundaries of each site were established using several different criteria, including historic site delineations (i.e., sites surveyed during the 1990s; R.L.&L. 1991), sampling effectiveness (e.g., overall length, ease of access, etc.), natural breaks in bank habitat type, and the location of obvious geographical boundaries (e.g., islands, tributary mouths, bridges, etc.). Established CLBMON-45 indexing sites ranged in length from 0.4 to 3.8 km; these lengths were used as general guidelines when establishing the GRTS survey sites. Overall, 62 new GRTS survey sites ranging from 0.6 to 3.9 km in length, were established in areas of the LCR that were not sampled between 2001 and 2010 (Table A2). The same habitat variables recorded for indexing sites also were recorded for GRTS survey sites (Appendix B, Table B3). In general, there was a similar range of habitat types at indexing and GRTS survey sites.

The GRTS sampling design combines the features of stratified sampling with the benefits of a totally random design, ensuring full spatial coverage and randomization so that all potential habitats are surveyed. A unique feature of the GRTS strategy is that new sites may be selected during each study year; therefore, all potential fish habitats are included within the sampling “frame”. A detailed description of the GRTS design strategy is available at http://www.epa.gov/nheerl/arm/designing/design_intro.htm.

Software used to create the GRTS design included the *spsurvey* package (Kincaid and Olsen 2011) in the statistical program R 3.4.0 (R Team 2017), and ArcGIS. Each year since 2011, the GRTS methodology was used to select a subsample of 20 sites from the 62 GRTS survey sites. In addition, 15 oversample sites also were selected to replace selected GRTS sites that were unable to be sampled due to logistical reasons. For the current project, excluded sites included those located immediately downstream of

HLK, BRD, and Waneta Dam and inside the log booms at Zellstoff Celgar (due to safety concerns), the perimeter of Waldie Island (a nature preserve), and the west shore of Zuckerberg Island (too shallow to safely navigate). Oversample sites also were used if the same site was selected more than once by the software. The use of oversample sites ensured that both randomness and spatial balance were maintained as part of the study design. Selected GRTS sites are presented in Appendix A, Table A2.

A single-pass boat electroshocking survey was conducted at each GRTS survey site between 27 October and 4 November 2016 using the same procedures described above. The GRTS surveys were always conducted after sampling at index sites was completed. Fish captured during GRTS surveys were processed in the same manner as fish captured during the conventional mark-recapture program (Section 2.1.6).

### *2.1.6 Fish Processing*

Site habitat conditions (Table 2) and the number of fish observed were recorded after sampling each site. Data collection for each captured fish included the variables in Table 3. The length (to the nearest 1 mm) and weight (to the nearest 1 g) of each fish was measured. All sampled fish were automatically assigned a unique identifying number by the database that provided a method of cataloguing associated ageing structures.

All index fish > 120 mm were marked with a Passive Integrated Transponder (PIT) tag (Plastic Infusion Process [PIP], 12 mm x 2.25 mm, model T-IP8010 polymer shell food safe Datamars FDX-B, Hallprint Pty Ltd., Australia). For fish between 120 and 160 mm FL, tags were implanted into the abdominal cavity of the fish just off the mid-line and anterior to the pelvic girdle using a single shot applicator (model MK7, Biomark Inc., Boise, Idaho, USA). For fish >160 mm FL, tags were inserted with a single shot 12 mm polymer PIT tag applicator gun (Hallprint Pty Ltd., Australia) into the dorsal musculature on the left side below the dorsal fin near the pterygiophores. Only fish that were in good condition received PIT tags whereas fish in poor physical condition (e.g., large open wounds, unable to maintain upright orientation) were not tagged. All tags, tag injectors, and scalpel blades were immersed in an antiseptic (Super Germiphene™) and rinsed with distilled water prior to insertion. Tags were checked to ensure they were inserted securely and the tag number was recorded in the LCR Fish Indexing Database.

During the 2001 to 2005 studies, fish were marked exclusively with T-bar anchor tags (i.e., PIT tags were not used). Fish captured during the present study that had previously been marked with and retained a T-bar anchor tag did not receive a second tag (i.e., a PIT tag) unless the T-bar anchor tag was not inserted properly, the tag number was illegible, or a large wound was present at the tag's insertion point (on these occasions, the T-bar anchor tag was carefully removed and a PIT tag was applied).

Table 3: List and description of variables recorded for each fish recorded in the lower Columbia River, 2016.

| Variable | Description |
|---|---|
| Species | The species recorded |
| Size Class | A general size class for observed fish (YOY = age-0; Immature = <250 mm FL; Adult = >250 mm FL) |
| Length | The fork length to the nearest 1 mm |
| Weight | The wet weight to the nearest 1 g |
| Sex and Maturity | The sex and maturity (determined where possible through external examination) |
| Scale | Whether or not a scale sample was collected for ageing purposes |
| Tag Colour/Type | The type (i.e., T-bar anchor, PIT, or PIP tag) and colour (for T bar anchor tags only) of tag applied |
| Tag Number | The number of the applied tag |
| Condition | The general condition of the fish (e.g., alive, dead, unhealthy, etc.) |
| Preserve | Details regarding sample collection (e.g., stomach contents, DNA, whole fish, etc.) |
| Habitat Type | The bank habitat type where the fish was recorded |
| Comments | Any additional comments |

Scale samples were collected from Mountain Whitefish and Rainbow Trout in accordance with the methods outlined in Mackay et al. (1990). All scales were stored in appropriately labelled coin envelopes and air-dried before processing. Scale samples were not collected from Walleye because scales are not a preferred ageing structure for Walleye (Mackay et al. 1990), which are primarily seasonal resident in the LCR and use the study area principally for feeding by adult and subadult cohorts. As a result, sensitive early life stages of Walleye are unlikely to be affected by river regulation in the study area.

### *2.1.7 Ageing*

During 2001 to 2012 study years, a subsample of Mountain Whitefish and Rainbow Trout was aged by counting growth annuli on scales following methods given in Ford and Thorley (2011a). In 2013 and 2014, scales were not aged because previous years of the study demonstrated that the length-at-age model (Section 2.2.3) accurately assigned ages to age-0 and age-1 Mountain Whitefish and Rainbow Trout based on fork length and there was a relatively large amount of error and uncertainty in the ages assigned to age-2 and older fish based on scales.

In 2015, a subsample of scales collected from 2011 to 2015 were aged by counting growth annuli but using new methods to attempt to address some of the limitations of previous scale analyses (Golder, ONA, and Poisson 2016). In 2015, while assigning ages, scale agers did not have access to information about the sampled fish such as the fork length or capture history, as they did during the 2001 to 2012 study years. Age analyses in 2015 also estimated the accuracy and variability in assigned ages. Accuracy was assessed by ageing samples whose true age was known because they were initially captured at age-0 or age-1 and recaptured in a subsequent year. Variability within and between agers was assessed by having each scale sample aged twice by two scale agers. As ages assigned in the 2015 were relatively uncertain and inaccurate (Golder, ONA, and Poisson 2016), new methods of ageing scales were trialed in the 2016 study year, as described below.

As fish grow, material deposited on the outer edge of their scales forms visible growth rings called circuli. Areas of the scale where circuli are closer together indicate slow growth during the winter and are called annuli that can be used to age fish. In previous years of the study, ages were assigned by visually identifying and counting annuli. In 2016, age was analyzed by measuring the distance between circuli and using a computer algorithm to identify annuli and assign ages. Digital photographs were taken of each scale using a Canon Microfilm Scanner 800II (Canon, Inc., Melville, NY). The distance from the first circulus to each subsequent circulus was measured to the nearest 0.01 mm on the digital images using Image-Pro Plus software, vers. 7.0 (Media Cybernetics, Inc., Rockville, MD) and the built-in calibration tool. Measurements were taken along the longest axis from the center to the edge of the scale opposite to the attachment point to the body of the fish, which is equivalent to the 360° axis used by Friedland and Haas (1996) and Beamish et al. (2004). Measurements were taken from the inside edge of each circulus. The distance from the center to the first circulus was not used in analysis of inter-circuli spacing because the approximate location of the center was considered not precise enough for the analysis. Scales were measured at the ONA's scale ageing laboratory in Penticton, BC.

Mountain Whitefish was the only species aged in 2016. Scales selected to be analyzed in 2016 included: 1) 200 samples from 2016; and 2) 35 samples from recaptured fish from various years whose true age was known due to size at initial capture and time-at-large before recapture. The recaptured fish of known age were analyzed to assess the uncertainty and bias in age assignments using the new method. One hundred scale samples were selected from 2002 and 2015 datasets and aged using the new inter-circular distance method to compare to data from previous ageing methods but these data were not analyzed or presented in this report and will be included in a future report.

Analysis of the circuli and age data is described in Section 2.2.11. The different methods used to age scales among years are summarized in Table 4. All scales collected from Mountain Whitefish and Rainbow Trout from 2001 to 2016 were archived so that they could be aged in the future if needed.

**Table 4: Scale ageing methods for fish captured in the lower Columbia River, 2001 to 2016.**

| Study Years | Capture Year of Scales Analyzed | Species Aged | Summary of Ageing Method |
|---|---|---|---|
| 2001 - 2012 | 2001 - 2012 | Mountain Whitefish and Rainbow Trout | • Visual counts of growth annuli<br>• Two to three analysts aged fish and the consensus age was used<br>• Analysts had access to fish information such as body size and capture history |
| 2013 – 2014 | None | None | • Scales were not aged |
| 2015 | 2011 - 2015 | Mountain Whitefish | • Visual counts of growth annuli<br>• Two analysts aged scale samples twice each<br>• Analysts did not have access to fish information such as body size and capture history |
| 2016 | 2002, 2015, 2016 | Mountain Whitefish | • Distance between scale circuli was measured<br>• Computer algorithm used to identify annuli and assign ages based on inter-circuli distances |

### *2.1.8 Geo-referenced Visual Enumeration Survey*

A visual enumeration survey was conducted at each index site during the week before the mark-recapture indexing surveys began. The survey consisted of a boat electroshocking pass using the same methods as the mark-recapture survey (Section 2.1.4), except that fish were only counted and not captured. Two observers were positioned in the same location as they would have been for netting, where they identified, enumerated, and estimated the length of all fishes observed. Two other individuals recorded all the observation data dictated by the observers, and recorded the geographical location of each observation using a hand-held Global Positioning System (GPS) unit. The rationale behind these geo-referenced visual enumeration surveys was that by not having to net fish and then turn to put captured fish in the livewell (and thereby not counting or capturing additional fish), continuous direct counts of observed fish would be more accurate than the intermittent observations made by netters during the mark-recapture surveys. In addition, the visual surveys provide fine-scale distribution data, which could be used to understand mesohabitat use by fishes in the LCR and better address management questions regarding spatial distribution. Fish species counted and recorded in the survey were the three index species. The only other species recorded was Northern Pike because they are an invasive species of concern in the study area (see Section 4.2.4).

During the visual surveys, observers were instructed to estimate the fork lengths of observed fishes. However, given that observers often could not see the actual fork in the tail of the fish (due to the fish position or distance) observers may have been more likely to base their estimates on total length (i.e., the measurement from the tip of the caudal fin rather than the fork). Length estimates were also likely affected by magnification by water, as objects appear larger in water than in air because of the greater refractive index of water (Luria et al. 1967). Potential biases in length estimation were assessed and corrected in the length bias model (Section 2.2.4).

### *2.1.9 Historical Data*

In addition to the data collected between 2001 and 2016, data collected in the study area between 1990 and 1996 (R.L.&L. 1995, 1997) also were used in some analyses. Studies conducted during this period involved boat electroshocking and mark-recapture programs, with protocols very similar to the 2001-2016 monitoring studies, including many of the same sample sites. There were some differences in sampling methodology between the 1990s and the current sampling program including different electrofisher settings and tag types. Despite these relatively minor differences, the 1990s data were considered comparable to data collected between 2001 and 2016 and were combined for many of the analyses in this report. Data from the 1990s were used in the analyses of length-at-age, growth and body condition but only years with large enough sample sizes were included. There were not enough data to estimate abundance or survival from the 1990s. Incorporating data from the 1990s in the analyses provided a longer time series and historical context to better address management questions about fish population trends in the LCR.

## 2.2 Data Analyses

### 2.2.1 Data Compilation and Validation

Data were entered directly into the LCR Fish Indexing Database (Attachment A) using Microsoft® Access 2007 software. The database has several integrated features to ensure that data are entered correctly, consistently, and completely.

Various input validation rules programmed into the database checked each entry to verify that the data met specific criteria for that particular field. For example, all species codes were automatically checked upon entry against a list of accepted species codes that were saved as a reference table in the database; this feature forced the user to enter the correct species code for each species (e.g., Rainbow Trout had to be entered as “RB”; the database would not accept “RT” or “rb”). Combo boxes were used to restrict data entry to a limited list of choices, which kept data consistent and decreased data entry time. For example, a combo box limited the choices for Cloud Cover to: Clear; Partly Cloudy; Mostly Cloudy; or Overcast. The user had to select one of those choices, which decreased data entry time (e.g., by eliminating the need to type out “Partly Cloudy”) and ensured consistency in the data (e.g., by forcing the user to select “Partly Cloudy” instead of typing “Part Cloud” or “P.C.”). The database contained input masks that required the user to enter data in a pre-determined manner. For example, an input mask required the user to enter the Sample Time in 24-hour short-time format (i.e., HH:mm:ss). Event procedures ensured that data conformed to the underlying data in the database. For example, after the user entered the life history information for a particular fish, the database automatically calculated the body condition of that fish. If the body condition was outside a previously determined range for that species (based on the measurements of other fish in the database), a message box would appear on the screen informing the user of a possible data entry error. This allowed the user to double-check the species, length, and weight of the fish before it was released. The database also allowed a direct connection between the PIT tag reader (AVID PowerTracker VIII) and the data entry form, which eliminated transcription errors associated with manually recording a 15-digit PIT tag number.

All raw data collected as part of the program between 2001 and 2016 are included in the LCR Fish Indexing Database (Attachment A).

For all figures in this report, sites are ordered by increasing distance from HLK (RKm 0.0) based on the upstream boundary of each site. Unless stated otherwise, black points represent sites located on the left bank (as viewed facing downstream) and red points represent sites located on the right bank (as viewed facing downstream).

### 2.2.2 Hierarchical Bayesian Analyses

The temporal and spatial variation in abundance, growth, body condition, and survival were analyzed using Hierarchical Bayesian Models (HBMs). The book ‘Bayesian Population Analysis using WinBUGS: A hierarchical perspective’ by Kéry and Schaub (2011) provides an excellent reference for hierarchical Bayesian methods and is considered the companion text for the following analyses. In short, a hierarchical Bayesian approach:

- allows complex models to be logically defined using the BUGS language (Kéry and Schaub 2011: 41);
- permits the incorporation of prior information (Kéry and Schaub 2011: 41);
- readily handles missing values;
- provides readily interpretable parameter estimates whose reliability does not depend on the sample size;
- allows derived quantities, such as the percent change in the expected weight of a 200 mm FL Mountain Whitefish at a particular site in a typical year, to be calculated (Kéry and Schaub 2011: 41);
- enables the efficient modelling of spatial and temporal variations and correlations (Kéry and Schaub 2011: 78-82); and
- permits the separation of ecological and observational processes (Kéry and Schaub 2011: 44).

HBMs were fitted to the fish indexing data using R version 3.4.0 (R Team 2017) and JAGS 4.2.0 (Plummer 2015) which interfaced with each other via the jmbr package. The technical aspects of the analyses, including the general approach, model definitions in the JAGS (Just Another Gibbs Sampler; Plummer 2003) dialect of the BUGS language, and the resultant parameter estimates are provided in Appendix C. In addition, the statistical methodology, sample code, parameter estimates, and figures of results are available online (Thorley and Muir 2017). The posterior distributions of the fixed (Kéry and Schaub 2011: 75) parameters are summarized in terms of a point estimate (mean), lower and upper 95% credible limits (2.5th and 97.5th percentiles), the standard deviation (SD), percent relative error (half the 95% credible interval as a percent of the point estimate) and significance (Kéry and Schaub 2011: 37, 42).

In general variable selection was achieved by dropping insignificant (Kéry and Schaub 2011: 37, 42) fixed (Kéry and Schaub 2011: 77–82) variables and uninformative random variables. A fixed variable was considered to be insignificant if its two-sided Bayesian p-value ≥ 0.05 (Bochkina and Richardson 2007; Lin et al. 2009) while a random variable was considered to be uninformative if its percent relative error was ≥ 80%.

The results were displayed graphically by plotting the modeled relationship between a particular variable (e.g., year) and the estimated mean values of the response variable. Uncertainty in the estimates is indicated by 95% credible intervals (CRIs), which are the Bayesian equivalent of 95% confidence intervals. If the model assumptions are correct, then there is 95% probability that the actual underlying values lie between the upper and lower bounds. An estimate is statistically significant if its 95% CRIs do not include 0. If two values have non-overlapping CRIs, then the difference between them is by definition statistically significant.

However, estimates can have overlapping CRIs but the difference between them can still be statistically significantly different. For example, the estimates of abundance depend on the differences between years as well as the abundance in a typical year. As uncertainty in the abundance in a typical year affects all the estimates, it can cause the CRIs to overlap even if the differences between years are significantly different. If it is important to establish the statistical significance of a difference or trend where the CRIs overlap, then this can be determined from the posterior probability distributions.

Statistical significance does not indicate biological importance. For example, a difference may be statistically significant but so small as to be of no consequence for the population. Conversely, the uncertainty in a difference may include 0 rendering the difference statistically insignificant while also admitting the possibility of a large and potentially impactful effect. For further information on the limitations of statistical significance, see Greenland et al. (2016).

In the plots, the mean values of the response variable with 95% CRIs are shown while the remaining variables were held constant. Unless stated otherwise, continuous and discrete fixed variables were held constant at their mean and first level values, respectively, while random variables were held constant at their typical values (i.e., the expected values of the underlying hyperdistributions; Kéry and Schaub 2011, p.77-82). Where informative, the influence of particular variables was expressed in terms of the effect size (i.e., the percent change in the response variable) with 95% CRIs (Bradford et al. 2005).

The length-at-age analysis used a maximum-likelihood (ML) model instead of a Bayesian model. The ML model was fitted to the data using a custom R script to implement an Expectation-Maximization algorithm well suited to finite mixture distributions used in the length-at-age analysis. An ML model was used because the equivalent Bayesian model was becoming prohibitively slow.

### *2.2.3 Length-At-Age*

The length-at-age of Mountain Whitefish and Rainbow Trout was estimated from annual length-frequency distributions using a finite mixture distribution model (MacDonald and Pitcher 1979). Because of low numbers of recaptured fish in the 1990s historical data, only years between 1990 and 1996 with sufficient recapture data were used for length-at-age analyses.

Key assumptions of the length-at-age model include:

- three distinguishable age-classes for each species: age-0, age-1, and age-2 and older;
- the proportion of fish in each age-class varied with year;
- the expected length increased with age-class;
- the expected length varied with year within age-class;
- the expected length varied as a linear function of day of year;
- the relationship between length and day of year varied with age-class;
- the residual variation in log-transformed length was normally distributed; and
- the standard deviation of this normal distribution varied with age-class.

Length-at-age models were used to estimate the most appropriate cut-offs between age-0, age-1 and age-2 and older individuals by year. For the purposes of estimating other population parameters by life stage, age-0 individuals were classified as fry, age-1 individuals were classified as subadult, and age-2 and older individuals were classified as adult. Walleye could not be separated by life stage due to a lack of discrete modes in the length-frequency distributions for this species. Consequently, all captured Walleye were considered adults. The results include plots of the age-class density for each year by length as predicted by the length-at-age model. Density is a measure of relative frequency for continuous values. To compare among years, mean length-at-age was plotted for age-0 and age-1 fish but confidence intervals could not be estimated for the mean estimates of length-at-age using the new ML model.

### *2.2.4 Observer Length Correction*

The bias (accuracy) and error (precision) in the observers' estimates of fish length were quantified using a model with a categorical distribution that compared the length-frequency distributions of fish whose lengths were estimated by observers during the geo-referenced visual survey, to the length-frequency distribution of fish captured and measured by netters during the mark-recapture sessions. The model calculated a multiplier for each observer that minimized the difference between the estimated fish lengths from the visual surveys, and the measured lengths from the mark-recapture sessions. This multiplier, representing the observation bias, was used to correct the estimated lengths.

Key assumptions of the length correction model include:

- the proportion of fish in each length-class varied with year;
- the expected length bias varied with observer;
- the expected length error varied with observer;
- the expected length bias and error for a given observer did not vary by year; and
- the residual variation in length was normally distributed.

The observers' estimated fish lengths were corrected for the estimated bias before being classified as fry, subadult and adult based on the model-estimated length-at-age cutoffs.

### *2.2.5 Growth*

Annual growth was estimated from inter-annual recaptured fish using the Fabens (1965) method for estimating the von Bertalanffy (1938) growth curve.

Key assumptions of the growth model include:

- the mean value of maximum length was constant;
- the growth coefficient (k) varied randomly with year; and
- the residual variation in growth was normally distributed.

Plots of growth show the effect size (percent change) relative to a typical year in the annual estimates of the mean growth coefficient. The estimated growth curve for Walleye predicted unrealistic length-at-age, which was attributed to highly variable growth even for large fish (e.g., 0-60 mm per year for 500 mm Walleye). To try to address this concern, the growth model was re-run using only Walleye less than 450 mm in fork length and these results are included in the report to represent the growth coefficient of smaller adult Walleye (mostly 300-450 mm) in the study area.

### *2.2.6 Site Fidelity*

Site fidelity was the estimated probability of a recaptured fish being caught at the same site where it was previously encountered. Site fidelity was modelled using logistic regression and estimates were used to evaluate the extent to which sites were closed within a sample period (i.e., whether fish remained at the same site between sessions). Site fidelity estimates also were used to adjust the capture efficiencies in the analysis of mark-recapture data (see Section 2.2.7).

Key assumptions of the site fidelity model include:

- observed site fidelity was described by a Bernoulli distribution; and
- expected site fidelity varied with body length.

Length as a second-order polynomial was not found to be a significant predictor for site fidelity so was not included in the model.

### *2.2.7 Capture Efficiency*

The probability of capture was estimated using a recapture-based binomial model (Kéry and Schaub 2011: 134-136, 384-388).

Key assumptions of the capture efficiency model include:

- the capture probability varied randomly by session within year;
- the probability of a marked fish remaining at a site was the estimated site fidelity; and
- the number of recaptures was described by a binomial distribution.

### *2.2.8 Abundance*

The abundance of each index fish species was estimated using the catch data from mark-recapture survey and the observer count data from geo-referenced visual surveys using an over-dispersed Poisson model (Kéry and Schaub 2011: 55-56). The model used the estimates of capture efficiency from the mark-recapture data (Section 2.2.7) to generate the estimated density of captured and uncaptured fish at each site. Observer count efficiency was estimated for the geo-referenced visual surveys, and was calculated by adjusting the capture efficiency based on the ratio of counted (visual surveys) to captured fish (four mark-recapture sessions). Count efficiency was then used in the model to estimate the total density of counted and uncounted fish present at each site. Abundance estimates represent the total number of fish in the study area.

Key assumptions of the abundance model include:

- the capture efficiency was the mean estimate from the capture efficiency model;
- the efficiency varied by visit type (mark-recapture or visual survey);
- the lineal fish density varied randomly with site, year and site within year;
- the overdispersion varied by visit type; and
- the catches and counts were described by a Poisson-gamma distribution.

Plots of annual abundance represent the estimated total number of fish at all sites combined. Plots showing the variation in abundance by site show the lineal density (fish/km) at each site.

### 2.2.9 Survival

The annual survival rate was estimated by fitting a Cormack-Jolly-Seber model (Kéry and Schaub 2011: 172-175, 220) to inter-annual recapture data using a multinomial likelihood. Survival was only estimated for adults because sparse recapture data for juveniles resulted in uninformative estimates.

Key assumptions of the survival model include:

- survival varied randomly with year; and
- the encounter probability varied with the total bank length sampled.

### 2.2.10 Body Condition

Condition was estimated via an analysis of weight-length relations (He et al. 2008). Key assumptions of the condition model include:

- weight varied with length and date;
- weight varied randomly with year;
- the relationship between length and weight varied with date;
- the relationship between length and weight varied randomly with year; and
- the residual variation in weight was log-normally distributed.

Only previously untagged fish were included in models to avoid potential effects of tagging on body condition.

### 2.2.11 Scale Ageing

Age was estimated for a subsample of Mountain Whitefish based on circuli measurements on scales (see Section 2.2.11) using an automated algorithm. The algorithm estimated age by identifying annuli based on the inter-circuli distances on the scale. The algorithm took scale growth (distance) between circuli, calculated a moving average growth rate, and then calculated a moving average of the rate of change in growth. For brevity, "rate of change in growth" is referred to as "dGrowth". An annulus was defined as a sequence of negative dGrowth values. Because of noise in the measurements, these sequences had to be of a minimum length. We estimated the window size for calculating moving averages and the minimum sequence length by tuning the algorithm to most accurately predict scale ages from recaptured fish of known age. During tuning, we found that a window size of seven circuli was best for calculating the moving average growth rate; a window size of 17 circuli was best for calculating dGrowth. Note that a larger window size leads to greater smoothing in the series. The minimum length of a sequence of negative values of dGrowth to be considered an annulus was four. Once the algorithm was tuned, it was used to age scales of unknown age from 2016. The relationship between estimated scale age and known age was described using linear regression.

Key assumptions of the scale age algorithm include:

- Growth decelerated in the fall/winter and accelerated in spring/summer; and
- The known age was the year of recapture minus the year that fish hatched, which was assumed based on size at initial capture at age-0 or age-1.

### *2.2.12 Age Ratios*

This program's management questions regard the effect of variability on the flow regime, which can result in variable amounts of egg mortality due to dewatering, on abundance of fish in the LCR. The abundance of fish in the LCR is determined in part by the number of eggs that hatch, survive, and are recruited to the subadult and adult populations. To monitor inter-annual changes in recruitment, ratios of age-1:age-2 fish were calculated and used as an index of annual recruitment. Age ratio analyses were conducted for Mountain Whitefish, which was the only species for which age data were available from 2001 to 2016.

The proportional ratio of age-1 to age-2 Mountain Whitefish (age-1:2 ratio) was calculated for each year from 2001 to 2016 using ages assigned based on scale analyses. Years with strong recruitment are expected to result in greater age-1:2 ratios than years with weaker recruitment and this ratio does not depend on estimates of capture efficiency and is not affected by violations of the assumptions of the mark-recapture models. Age-1:2 ratios were calculated using age data from three different ageing methods for 2001 to 2010, 2011-2015, and 2016, as described in detail in Section 2.1.7.

The age-1:2 ratio for a given spawning year ($r_t$) was calculated based on the abundance of age-1 ($N^1$) and age-2 ($N^2$) fish two years after the spawning year ($t+2$):

$$r_t = \frac{N^1_{t+2}}{N^1_{t+2} + N^2_{t+2}}$$

Mountain Whitefish in the LCR spawn in November and December, hatch primarily in March and April of the following year (referred to as the hatch year), and are therefore age-1 two years after the spawning year ($t+2$). To test for effects of egg loss from dewatering on the recruitment index ($r_t$), the ratio of estimated egg loss ($L_t$) affecting each spawning year was calculated:

$$L_t = \log(Q_t/Q_{t-1})$$

This ratio was used to represent egg loss because the losses during the spawning year ($Q_t$) are expected to affect the proportion of age-1 fish two years later ($N^1_{t+2)}$) whereas the proportion of age-2 fish ($N^2_{t+2}$) is expected to be affected by egg losses three years prior ($Q_{t-1}$). The ratio was logged to ensure it was symmetrical about zero (Tornqvist et al. 1985). Annual egg loss estimates were obtained from the Mountain Whitefish Egg Stranding Model, which estimates egg dewatering and mortality using hourly hydrological data, bathymetry, and information regarding spawning timing and location (Golder 2013b). The relationship between the recruitment index, $r_t$, and egg losses, $L_t$, was estimated using a hierarchical Bayesian logistic regression (Kéry 2010) loss model. Key assumptions of the final model include:

- the log odds of the proportion of age-1 fish varied linearly with the log of the ratio of the percent egg losses; and
- the numbers of age-1 fish are extra-Binomially distributed.

The relationship between egg dewatering and subsequent recruitment is expected to depend on stock abundance (Subbey et al. 2014) which might be changing over the course of the study. Consequently, preliminary analyses allowed the slope of the regression line to change through time. The change was not significant and was therefore removed from the final model. The effect of dewatering on Mountain Whitefish recruitment was expressed in terms of the predicted percent change in age-1 Mountain Whitefish abundance by egg loss in the spawn year relative to 10% egg loss in the spawn year. The egg loss in the previous year was fixed at 10%. The percent change could not be calculated relative to 0% in the spawn or previous year because $L_t$ is undefined in either case.

### *2.2.13 Stock-Recruitment Relationship*

Understanding the relationship between the number of spawning adults, which is sometimes referred to as the “stock,” and the resulting number of individuals recruited to the catchable population of fish (“recruitment”) is one of the most important issues in fisheries biology and management (Myers 2001). At low spawner abundance, recruitment is expected to be driven by density-independent factors and the number of recruits will increase with the number of spawners. At high spawner abundance, density-dependent factors such as competition for limited resources can result in a decrease in per capita recruitment with increasing numbers of spawners. For the LCR, the relationship between the adults (“stock”) and the resultant number of subadults the following year (“recruitment”) was estimated using a Bayesian Beverton-Holt stock-recruitment model (Walters and Martell 2004):

$$R = \frac{\alpha S}{1 + \beta S}$$

where $S$ is the estimated number of adults (stock), $R$ is the estimated number of age-1 subadults (recruits), $\alpha$ is the recruits per spawner at low density and $\beta$ determines the density-dependence.

With respect to the Mountain Whitefish and Rainbow Trout protection flows, it is important to understand if and when egg losses due to dewatering affect the number of recruits in the LCR. In stock-recruitment relationships, the spawning stock of adults is used as a proxy for reproductive potential or the number of eggs deposited (Subbey et al. 2014). Mortality of incubating eggs due to dewatering could affect density-dependent mortality of eggs or rearing juveniles, which would change the stock-recruitment curve compared to in the absence of dewatering. To test for effects of dewatering on the stock-recruitment relationship, stock (number of adults) was allowed to vary with the proportional egg loss in the model because dewatering eggs would be equivalent to reducing the number of spawners. Egg loss estimates were obtained from the Mountain Whitefish Egg Stranding Model (Golder 2013b) and from Irvine et al. (2015) for Rainbow Trout.

Key assumptions of the stock-recruitment model include:

- the prior probability for the logarithm of $\alpha$ was a truncated normal distribution from log(0) to log(5);
- the stock varied with the proportional egg loss; and
- the residual variation in the number of recruits was log-normally distributed.

The stock-recruitment relationship was calculated for Mountain Whitefish and Rainbow Trout. Age ratio and stock-recruit results are presented in terms of the spawning year. For Rainbow Trout, which spawn from March to July and hatch in June to August in the LCR (Irvine et al. 2015), the spawning year is the same as the hatch year. For Mountain Whitefish, spawning occurs mostly in November to December in the LCR and hatch occurs mostly between March and April; therefore, the hatch year is one year greater than the corresponding spawning year. For both species, the age-0 life stage is defined as the first year beginning on the hatch date.

# 3.0 RESULTS

## 3.1 Physical Habitat

### 3.1.1 Columbia River Discharge

Discharge in the LCR in 2016 was near the average value from 2001 to 2015 for most of the year (Figure 2; Appendix D, Figure D1). One exception was that discharge was approximately 300 to 400 m³/s lower than average (~1500 m³/s) during February and March, when discharge ranged from ~1000 to 1100 m³/s. As in previous years of the study, discharge in the LCR followed a bimodal pattern with a peak during spring freshet and a smaller second peak during early winter associated with hydropower generation. In 2016, discharge was lower than average during the sample period (Figure 2).

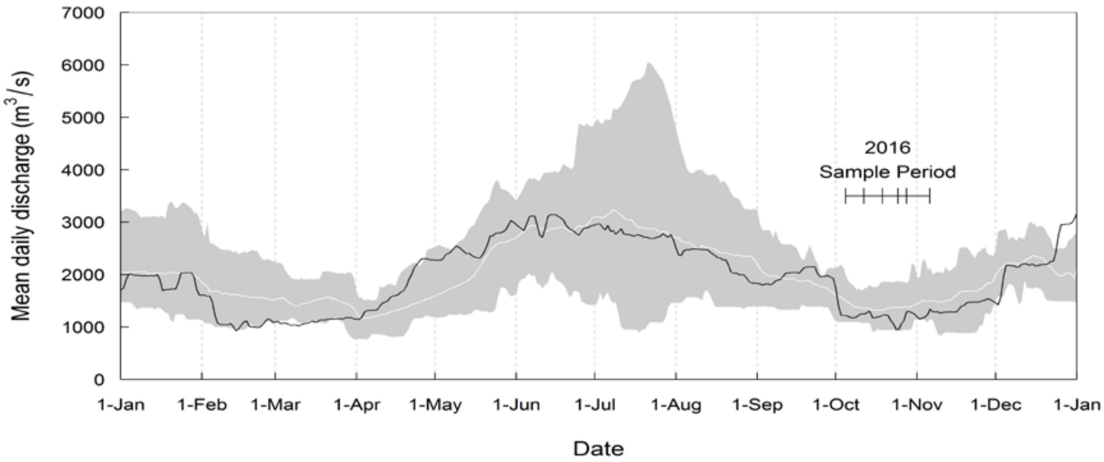

**Figure 2:** **Mean daily discharge ($m^3$/s) for the Columbia River at the Birchbank water gauging station, 2016 (black line). The shaded area represents minimum and maximum mean daily discharge values recorded at Birchbank from 2001 to 2015. The white line represents average mean daily discharge values over the same time period.**

In 2016, mean daily discharge in the Columbia River below HLK was lower in February to May than any previous study year from 2001 to 2015 (Figure 3; Appendix D, Figure D2). 2015 was one of the driest years on record and lower flows were in part attributed to Arrow Lakes Reservoir refilling for the following summer period (J. Crossman, BC Hydro, pers. comm). In April 2016, operations then transitioned upwards into stable Rainbow Trout protection flows during April and May.

Discharge in the spring increased several weeks earlier than normal during the freshet, but peak discharge during the spring and summer was similar to the average values from 2001 to 2015. Discharge below HLK was also very low from mid-October through November, which included part of the sampling period in late October and early November. The transition from October into November low flows was the result of a very wet fall, where Columbia River Treaty obligations were reduced (J. Crossman, BC Hydro, pers. comm.).

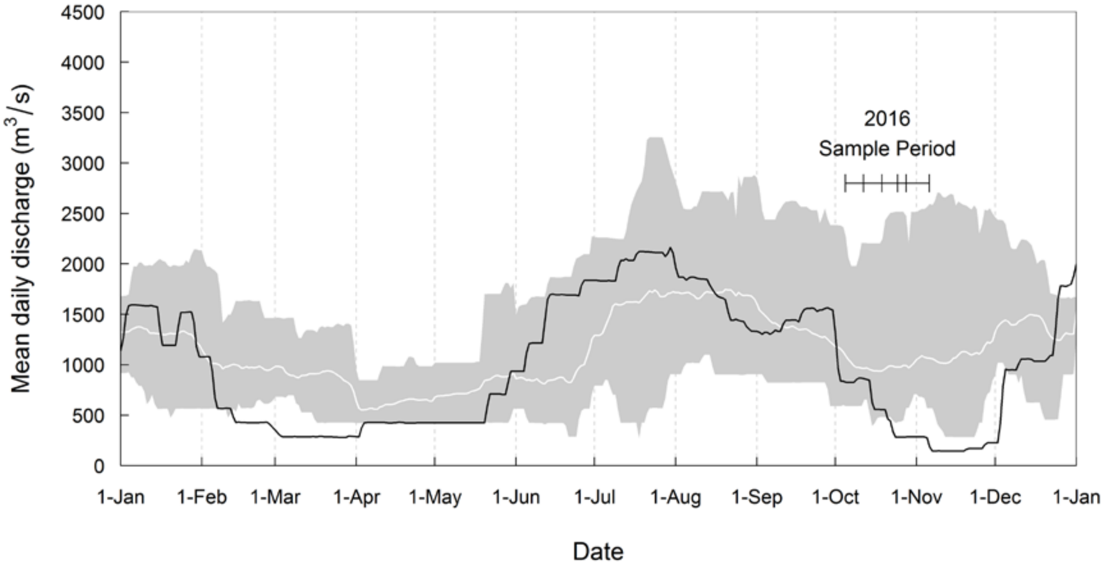

**Figure 3: Mean daily discharge (m$^3$/s) for the Columbia River at Hugh L. Keenleyside Dam, 2016 (black line). The shaded area represents minimum and maximum mean daily discharge values recorded at the dam from 2001 to 2015. The white line represents average mean daily discharge values over the same time period.**

### *3.1.2 Columbia River Temperature*

Water temperature in the Columbia River in 2016 was approximately 1°C greater than average during February to May (Figure 4), which was a period of very low discharge (Figure 2). Data were missing from October and early November when fish sampling occurred, but mean water temperature in late November was also approximately 1°C greater than average, which suggested warmer than normal water temperatures during the low discharge period in the fall. Mean water temperature during the spring and summer was similar to the 2001 to 2015 average. Spot temperature readings for the Columbia River taken at the time of sampling ranged between 10.5°C and 14.4°C (Appendix B, Table B3).

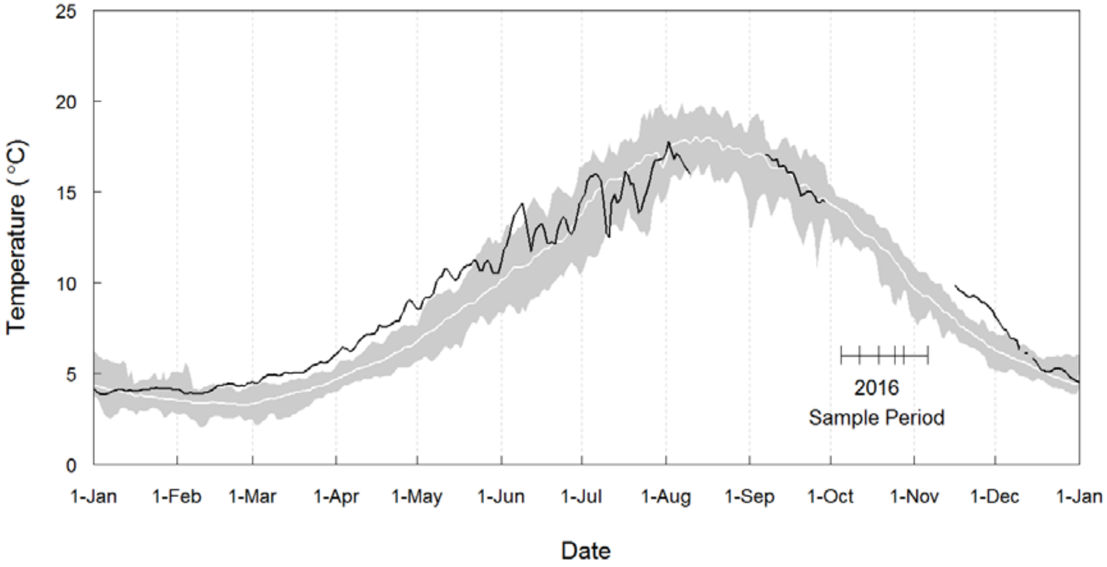

**Figure 4:** **Mean daily water temperature (°C) for the Columbia River at the Birchbank water gauging station, 2016 (black line). The shaded area represents the minimum and maximum mean daily water temperature values from 2001 to 2015. The white line represents the average mean daily water temperature during the same time period.**

### *3.1.3 Kootenay River Discharge*

In 2016, the magnitude of mean daily discharge in the Kootenay River downstream of BRD was similar to other years between 2001 and 2015 (Appendix D, Figure D4). However, the hydrograph was generally one month earlier than average with an earlier freshet in the spring, earlier decrease in the summer, and earlier increase in discharge in early winter associated with hydropower generation (Figure 5). During the sampling period, discharge was near average during early October but increased to above-average values in late October and November.

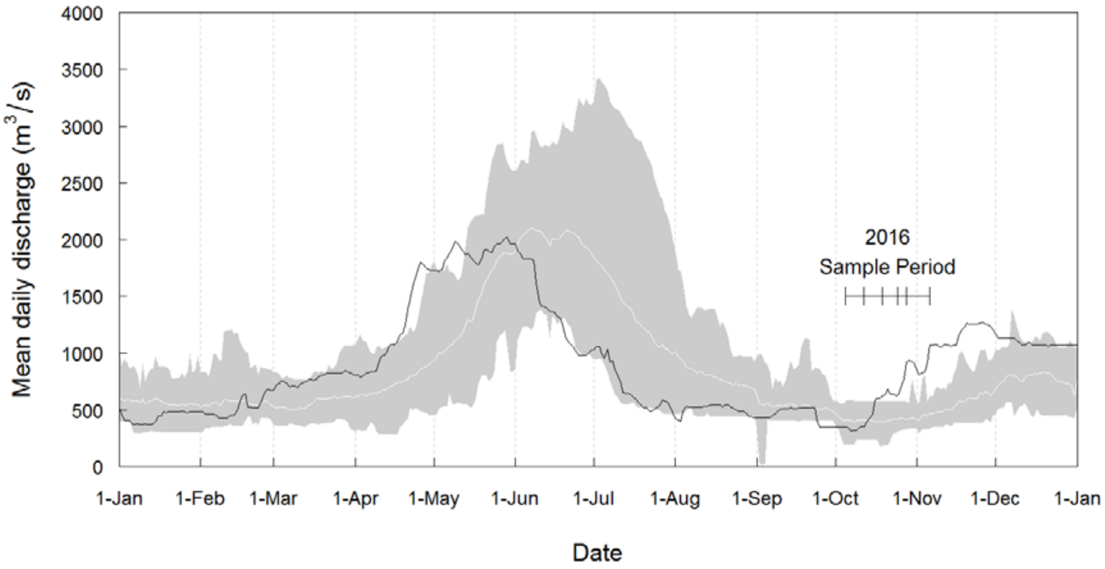

**Figure 5:** **Mean daily discharge ($m^3$/s) for the Kootenay River at BRD, 2016 (black line). The shaded area represents minimum and maximum mean daily discharge values recorded at the dam from 2001 to 2015. The white line represents average mean daily discharge values over the same time period.**

### 3.1.4 *Kootenay River Temperature*

Mean daily water temperature in the Kootenay River (downstream of BRD) was slightly (0.5-1.5°C) greater than average from January to July and during November (Figure 6). Water temperature during July to October and December were near average. Spot temperature readings for the Kootenay River taken at the time of sampling ranged between 10.9°C and 14.5°C (Appendix B, Table B3).

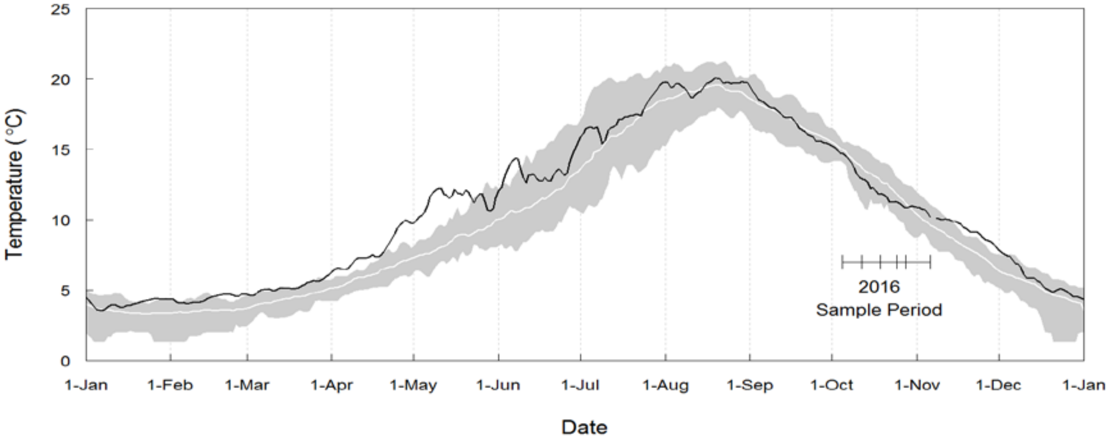

**Figure 6:** **Mean daily water temperature (°C) for the Kootenay River downstream of BRD, 2016 (black line).The shaded area represents minimum and maximum mean daily water temperature values recorded at the dam from 2001 to 2015. The white line represents average mean daily water temperature values over the same time period.**

### 3.1.5 Aquatic Vegetation

In the upstream section of the Columbia River (upstream of the Kootenay confluence), habitat vegetation data collected since 2001 indicates that aquatic vegetation comprised a small percentage of the available cover in 2001 to 2003 but a substantial portion of available cover in sites with lower velocity in all years from 2004 to 2016 (Attachment A; Appendix B, Table B3). Shallower sandy locations are dominantly Eurasian Watermilfoil (EVM; *Myriophyllum spicatum*), and small areas of invasive curly pond weed (*Potamogeton crispus*; Golder and ONA, in preparation). Sites that drop off more steeply and with more velocity contain native *Potamogeton* sp., *Chara* sp., and a native watermilfoil, (*Myriophyllum verticilatum;* Golder and ONA, in preparation).

Aquatic vegetation in the downstream section of the Columbia River and the Kootenay River are more sporadic, located in embayments off the mainstem. Although aquatic vegetation cover data were not recorded during programs conducted in the early 1990s (R.L.&L. 1995), vegetation was not a common cover type in any sections of the LCR (L. Hildebrand, Golder Associates Ltd., pers. comm.). Efforts to control the invasive EVM, and in turn, potential invasive Northern Pike habitat, started in 2017 by laying long sections of mat material in areas of high concentrations of EVM, within some of the electroshocking sites in the upstream section of the Columbia River.

## 3.2 Catch

In total, 24,428 fish were recorded in the LCR in 2016 (Table 5). This total included both captured fish and observed fish that were identified to species at both the Index and GRTS sites combined.

**Table 5: Number of fish caught and observed during boat electroshocking surveys and their frequency of occurrence in sampled sections of the LCR, 3 October to 4 November 2016. This table includes data from Index and GRTS sites.**

| **Species** | **Columbia River Upstream** | | **Kootenay River** | | **Columbia River Downstream** | | **All Sections** | |
|---|---|---|---|---|---|---|---|---|
| | ***n*[a]** | **%[b]** | ***n*[a]** | **%[b]** | ***n*[a]** | **%[b]** | ***n*[a]** | **%[b]** |
| **Sportfish** | | | | | | | | |
| Brook Trout (*Salvelinus fontinalis*) | 0 | 0 | 0 | 0 | 1 | <1 | 1 | <1 |
| Brown Trout (*Salmo trutta*) | 0 | 0 | 0 | 0 | 3 | <1 | 3 | <1 |
| Bull Trout (*Salvelinus confluentus*) | 1 | <1 | 0 | 0 | 3 | <1 | 4 | <1 |
| Burbot (*Lota lota*) | 5 | <1 | 0 | 0 | 7 | <1 | 12 | <1 |
| Kokanee (*Oncorhynchus nerka*) | 21 | <1 | 1 | <1 | 4 | <1 | 26 | <1 |
| Lake Whitefish (*Coregonus clupeaformis*) | 12 | <1 | 6 | <1 | 364 | 5 | 382 | 3 |
| Mountain Whitefish (*Prosopium wiliamsoni*) | 1965 | 60 | 1140 | 74 | 1989 | 27 | 5094 | 42 |
| Northern Pike (*Esox lucius*) | 4 | <1 | 0 | 0 | 0 | 0 | 4 | <1 |
| Rainbow Trout (*Oncorhynchus mykiss*) | 961 | 29 | 261 | 17 | 4265 | 57 | 5487 | 45 |
| Smallmouth Bass (*Micropterus dolomieu*) | 0 | 0 | 0 | 0 | 2 | <1 | 2 | <1 |
| Walleye (*Sanders vitreus*) | 308 | 9 | 117 | 8 | 786 | 11 | 1211 | 10 |
| White Sturgeon (*Acipenser transmontanus*) | 17 | <1 | 15 | <1 | 9 | <1 | 41 | <1 |
| Yellow Perch (*Perca flavescens*) | 1 | <1 | 0 | 0 | 5 | <1 | 6 | <1 |
| **Sportfish Subtotal** | **3295** | **100** | **1540** | **100** | **7438** | **100** | **12273** | **100** |

| Species | Columbia River Upstream | | Kootenay River | | Columbia River Downstream | | All Sections | |
|---|---|---|---|---|---|---|---|---|
| | ***n*[a]** | **%[b]** | ***n*[a]** | **%[b]** | ***n*[a]** | **%[b]** | ***n*[a]** | **%[b]** |
| **Non-sportfish** | | | | | | | | |
| Northern Pikeminnow (*Ptychocheilus oregonensis*) | 19 | <1 | 18 | 3 | 22 | <1 | 59 | <1 |
| Peamouth (*Mylocheilus caurinus*) | 3 | <1 | 0 | 0 | 0 | 0 | 3 | <1 |
| Redside Shiner (*Richardsonius balteatus*) | 745 | 18 | 47 | 7 | 379 | 5 | 1171 | 10 |
| Sculpin spp. (*Cottidae*) | 1498 | 36 | 372 | 57 | 6476 | 88 | 8346 | 69 |
| Sucker spp. (*Catostomidae*) | 1890 | 45 | 215 | 33 | 470 | 6 | 2575 | 21 |
| Tench (*Tinca tinca*) | 0 | 0 | 0 | 0 | 1 | <1 | 1 | <1 |
| **Non-Sportfish Subtotal** | **4155** | **100** | **652** | **100** | **7348** | **100** | **12155** | **100** |
| **Total** | **7450** | **100** | **2192** | **100** | **14786** | **100** | **24428** | **100** |

[a] Includes fish observed and identified to species; does not include intra-year recaptured fish.

[b] Percent composition of sportfish or non-sportfish catch.

[c] Not identified to species or species combined for analysis.

Summaries of catch and effort and life-history metrics were used to provide supporting information and to help set initial parameter values in some of the HBMs. Although these summaries are important, they are not presented nor specifically discussed in detail in this report. However, these metrics are provided in the appendices for reference purposes and are referred to when necessary to support or discount results of the HBMs. Metrics presented in the appendices include:

- captured and observed fish count data by site and Bank Habitat Type (Appendix B, Table B4), 2015;
- catch and percent composition by species, 2001 to 2015 (Appendix E, Table E1);
- catch-rates for all sportfish (Appendix E, Table E2) and non-sportfish (Appendix E, Table E3), 2015;
- length-frequency histograms by section for Mountain Whitefish (Appendix F, Figure F1), Rainbow Trout (Appendix F, Figure F2), and Walleye (Appendix F, Figure F3), 2015;
- length-frequency histograms by year for Mountain Whitefish (Appendix F, Figure F4), Rainbow Trout (Appendix F, Figure F5), and Walleye (Appendix F, Figure F6), all years combined; and
- length-weight relationships by year for Mountain Whitefish (Appendix F, Figure F7), Rainbow Trout (Appendix F, Figure F8), and Walleye (Appendix F, Figure F9), all years combined.

## *3.3 Length-At-Age and Growth Rate*

Outputs from the length-at-age model are presented in Table 6 and represent the most appropriate cut-offs between age-0 (fry), age-1 (subadult), and age-2 and older (adult) Mountain Whitefish and Rainbow Trout during each sample year. Length-density plots show the relative frequency of lengths by age-class (Appendix G; Figures G1 and G2). All Walleye were classified as adults by the HBMs. A comparison of von Bertalanffy growth curves for the three index species indicated that Rainbow Trout grew the fastest but reached their asymptotic length at an earlier age compared to Mountain Whitefish and Walleye (Figure 7).

**Table 6: Estimated minimum and maximum fork lengths (in mm) for each life stage by year for Mountain Whitefish and Rainbow Trout in the lower Columbia River, 1990 to 1991, 2001 to 2016. Estimates were derived from the length-at-age model (Section 2.2.3).**

| Year | Mountain Whitefish | | | Rainbow Trout | | |
|---|---|---|---|---|---|---|
| | Fry | Subadult | Adult | Fry | Subadult | Adult |
| 1990 | ≤165 | 166-276 | ≥277 | ≤184 | 185-359 | ≥360 |
| 1991 | ≤174 | 175-317 | ≥318 | ≤127 | 128-324 | ≥325 |
| 2001 | ≤150 | 151-275 | ≥276 | ≤158 | 159-342 | ≥343 |
| 2002 | ≤167 | 168-285 | ≥286 | ≤193 | 194-347 | ≥348 |
| 2003 | ≤165 | 166-286 | ≥287 | ≤201 | 202-352 | ≥353 |
| 2004 | ≤173 | 174-302 | ≥303 | ≤189 | 190-350 | ≥351 |
| 2005 | ≤177 | 178-275 | ≥276 | ≤206 | 207-360 | ≥361 |
| 2006 | ≤166 | 167-298 | ≥299 | ≤199 | 200-369 | ≥370 |
| 2007 | ≤168 | 169-291 | ≥292 | ≤196 | 197-365 | ≥366 |
| 2008 | ≤174 | 175-317 | ≥318 | ≤187 | 188-347 | ≥348 |
| 2009 | ≤165 | 166-297 | ≥298 | ≤181 | 182-349 | ≥350 |
| 2010 | ≤171 | 172-304 | ≥305 | ≤183 | 184-347 | ≥348 |
| 2011 | ≤164 | 165-283 | ≥284 | ≤183 | 184-353 | ≥354 |
| 2012 | ≤158 | 159-299 | ≥300 | ≤197 | 198-354 | ≥355 |
| 2013 | ≤173 | 174-302 | ≥303 | ≤203 | 204-354 | ≥355 |
| 2014 | ≤170 | 171-299 | ≥300 | ≤187 | 188-342 | ≥343 |
| 2015 | ≤153 | 154-283 | ≥284 | ≤204 | 205-343 | ≥344 |
| 2016 | ≤186 | 187-293 | ≥294 | ≤217 | 218-355 | ≥356 |

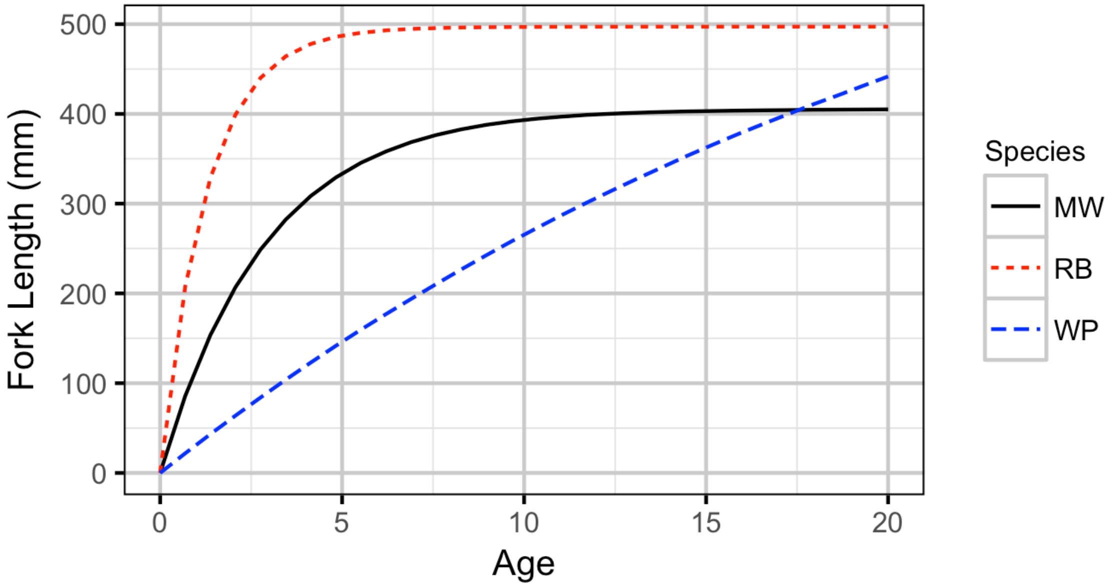

**Figure 7:** **Growth curve showing length-at-age by species as predicted by the von Bertalanffy model for the lower Columbia River, 2001-2016.**

### 3.3.1 Mountain Whitefish

The mean fork length of Mountain Whitefish fry (age-0) was greater in 2016 (149 mm) than all previous years of the study (110-132 mm; Figure 8). The length-at-age cutoff (model-estimated maximum size) for age-0 Mountain Whitefish was also greater in 2016 (187 mm) than all previous years (Table 6). However, the length-frequency plot of Mountain Whitefish suggests that very few age-0 fish were captured in 2016 (Appendix F, Figure F4) and it may be that the length-at-age model overestimated the size of age-0 fish because of a small and potentially unrepresentative sample or modelling bias. For example, the mean fork length of the 18 randomly sampled fish that were classified as age-0 based on circuli measurements (Section 3.7) was 131 mm, which is lower than the model-predicted mean of 149 mm. Of the 900 Mountain Whitefish aged between 2001 and 2012, only two were larger than 170 mm (173 and 188 mm), which also suggests that the model estimated maximum size of 187 mm in 2016 may be too large. In future years of the study, model improvements will be attempted to make the length-based estimates of the mixture distribution model more consistent with length-at-age from aged Mountain Whitefish.

Mean estimates of fork length of age-1 Mountain Whitefish were greatest in 2004 (257 mm) and 2008 (263 mm) and ranged from 217 to 241 mm in other years between 2001 and 2016 (Figure 8). The new method of modelling length-at-age, which used maximum likelihood estimation, did not allow estimates of confidence intervals. However, the results did not suggest any sustained or large trend in the length-at-age of fry or subadult Mountain Whitefish between 2001 and 2016.

The length of adult Mountain Whitefish (i.e., age-2 and older) is not presented because this group consisted of multiple age-classes.

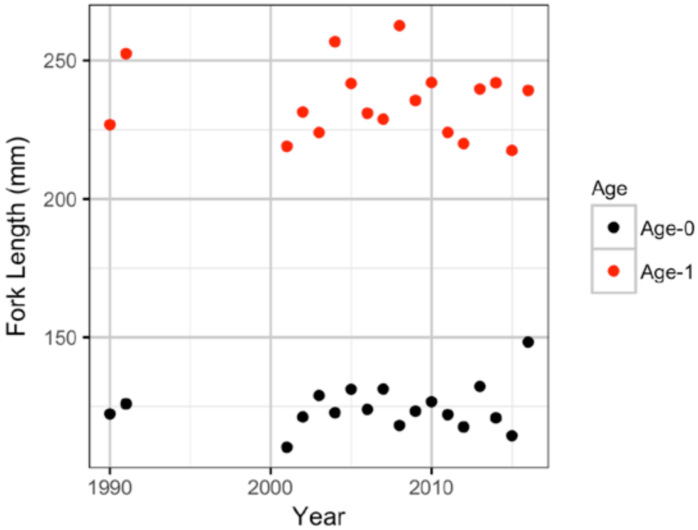

**Figure 8:** **Mean fork length of age-0 and age-1 Mountain Whitefish in the lower Columbia River, 1990 to 1991 and 2001 to 2016. The method of modelling length-at-age using maximum likelihood did not allow estimates of credible intervals.**

Analysis of annual growth of recaptured Mountain Whitefish indicated an increase in average annual growth between 2003 and 2009, and variable annual growth between 2010 and 2016, although credible intervals overlapped between most estimates (Figure 9). The growth coefficient was greater than average during the most recent three years (2014-2016) with effect sizes of nearly 50% greater than a typical year.

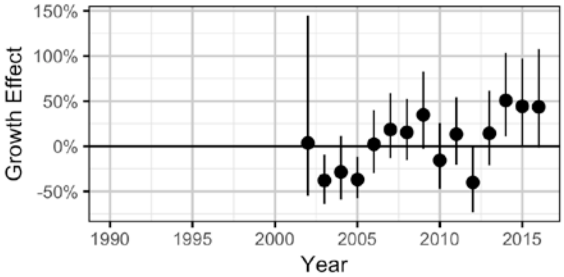

**Figure 9:** **Estimated percent change in the von Bertalanffy growth coefficient (mean with 95% CRIs) relative to a typical year for Mountain Whitefish based on recaptured individuals in the lower Columbia River, 2001 to 2016.**

### *3.3.2 Rainbow Trout*

The length-at-age model indicated an increase in the mean length of Rainbow Trout fry (age-0) increased from 107 mm in 2010 to 146 mm in 2016 (Figure 10). Mean length-at-age of fry was much lower in 1991 (56 mm) and 2001 (81 mm) than other years. Mean length-at-age of subadult (age-1) followed a similar trend as age-0 Rainbow Trout, with an increase between 2010 (265 mm) and 2016 (289 mm) and small length-at-age in 1991 (220 mm) and 2001 (250 mm; Figure 10). Length-at-age was not assessed in detail for adult Rainbow Trout (i.e., age-2 and older) because this group consisted of multiple age-classes.

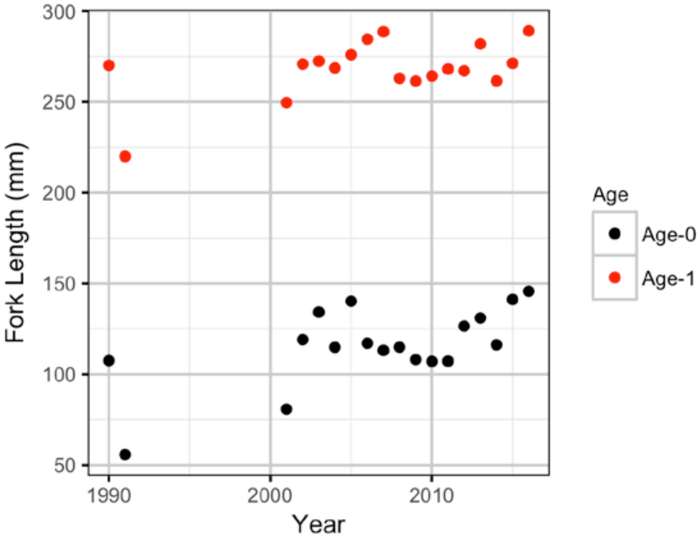

**Figure 10:** **Mean fork length of age-0 and age-1 Rainbow Trout in the lower Columbia River, 1990 to 1991 and 2001 to 2016.**

Analysis of annual growth of recaptured Rainbow Trout indicated a lower growth coefficient from 2002 to 2004 when compared to most subsequent study years (Figure 11). Estimates of the growth coefficient generally declined from a 43% effect size in 2006 to -23% in 2016.

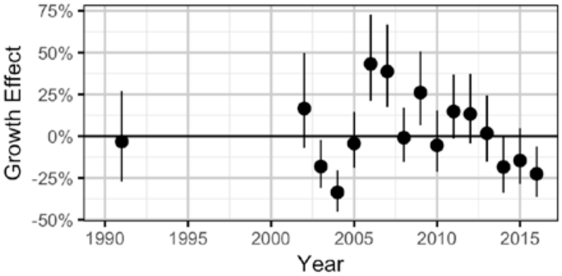

**Figure 11: Estimated percent change in the von Bertalanffy growth coefficient (mean with 95% CRIs) relative to a typical year for Rainbow Trout based on recaptured individuals in the lower Columbia River, 2001 to 2016.**

### *3.3.3 Walleye*

Analysis of annual growth of recaptured Walleye indicated generally increasing growth coefficients from 2010 (-25% effect size) to 2016 (39%) but with a very high growth coefficient (85%) in 2012 (Figure 12). Credible intervals for the growth coefficient were large because of large variability in the annual growth among recaptured Walleye of all sizes. For instance, annual growth of Walleye initially captured at ~300 mm in fork length varied from ~15 to 70 mm/year, and growth of Walleye initially captured at ~500 m ranged from ~5 to 60 mm (data not shown). Because of the large variability in annual growth, especially for the largest Walleye, the von Bertalanffy curve (Figure 7) and effect size based on the model's growth coefficient (Figure 12) were calculated using only Walleye <450 mm in fork length.

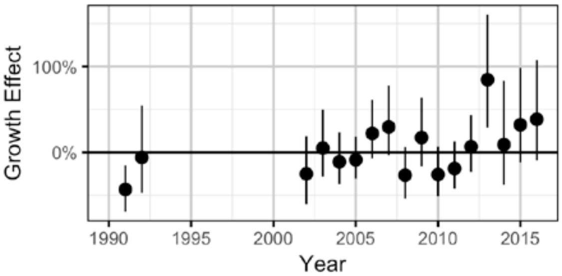

**Figure 12: Estimated percent change in the von Bertalanffy growth coefficient (mean with 95% CRIs) relative to a typical year for Walleye based on recaptured individuals in the lower Columbia River, 2001 to 2016.**

### *3.3.4 Observer Length Correction*

The length bias model used the length-frequency distribution of captured fish to estimate the bias in the estimated lengths of observed fish. The results suggested that most observers underestimated fork lengths for all three index species (Figure 13). The bias for Mountain Whitefish varied by observer with underestimates of 2 to 14% lower than captured fish of known length (Figure 14). Underestimates of Rainbow Trout lengths varied between 2 and 24%. Bias in estimated Walleye fork lengths ranged between 7 and 20%. Estimates of observer bias were used to correct estimated fork lengths before classifying fish into age-classes for abundance analyses.

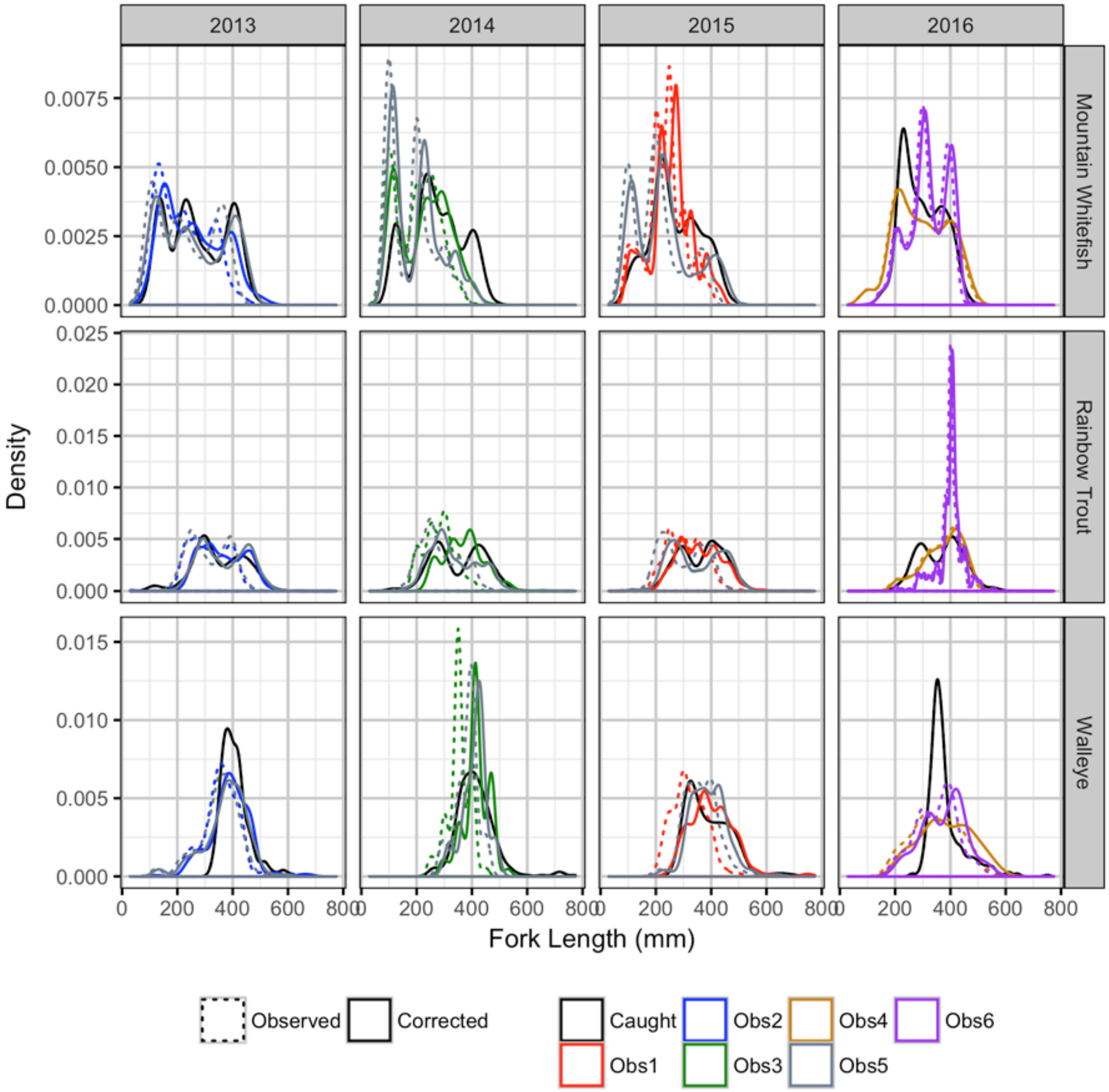

**Figure 13:** **Fork length-density plots for measured and estimated fork lengths of fish caught or observed in the lower Columbia River, 2013-2016. The black line shows fish that were caught. Observed data are shown by coloured dashed lines and corrected data are shown by coloured solid lines.**

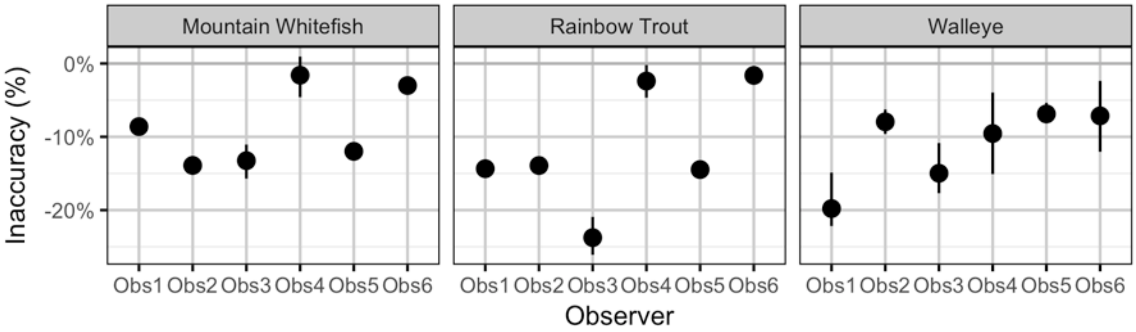

**Figure 14:** **Bias in observer estimated fork lengths of index species based on length bias model of captured (mark-recapture surveys) and estimated (geo-referenced visual surveys) length-frequency distributions from the lower Columbia River, 2013-2016.**

## 3.4 Spatial Distribution and Abundance

### 3.4.1 Site Fidelity

Site fidelity was greater for Rainbow Trout and Walleye (~50-75%) than for Mountain Whitefish (<50%; Figure 15). Site fidelity decreased with increasing fork length for all three species but the slope of this relationship was only significant for Rainbow Trout (*P* < 0.001) and not for Mountain Whitefish and Walleye (*P* > 0.5).

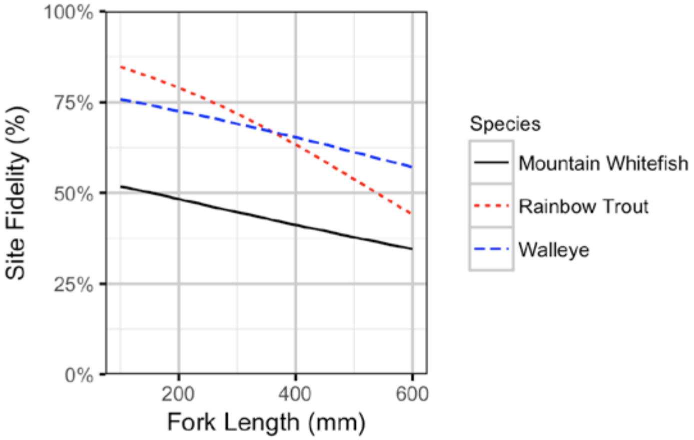

**Figure 15:** **Site fidelity, defined as the expected probability that a fish is recaptured at the same site where it was marked, by species and fork length in the lower Columbia River, 2001 to 2016.**

### *3.4.2 Efficiency*

Estimated capture efficiency was greatest for Rainbow Trout and lowest for Mountain Whitefish (Figure 16). Capture efficiency was lower for adult than subadult Rainbow Trout but similar between subadult and adult Mountain Whitefish. For most species and age-classes, capture efficiency was similar among sampling sessions and years without any apparent seasonal or temporal trends (Appendix G, Figures G3-G7). One exception was that in some but not all years, the capture efficiency of subadult Rainbow Trout and Walleye decreased in subsequent sample sessions (Appendix G, Figures G5 and G7). Estimates of capture efficiency were used to estimate total abundance in the sample sites (Section 3.4.3-3.4.5).

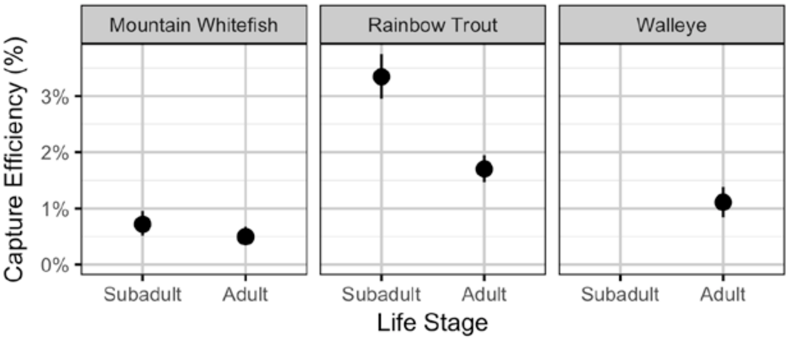

**Figure 16: Capture efficiency (mean with 95% CRIs) by species from mark-recapture data from the lower Columbia River, 2001-2016.**

### *3.4.3 Mountain Whitefish*

The estimated abundance of subadult Mountain Whitefish in index sites in the LCR was much greater in 2001 and 2002 (~140,000) than all other years (Figure 17). Estimated subadult abundance fluctuated between 21,000 and 87,000 between 2003 and 2016, with fairly stable values in the last four years (55,000 - 66,000). Estimates suggested a decline in abundance of adult Mountain Whitefish between 2001 (~165,000) and 2014 (~77,000) and similar abundance with overlapping confidence intervals between 2010 and 2016.

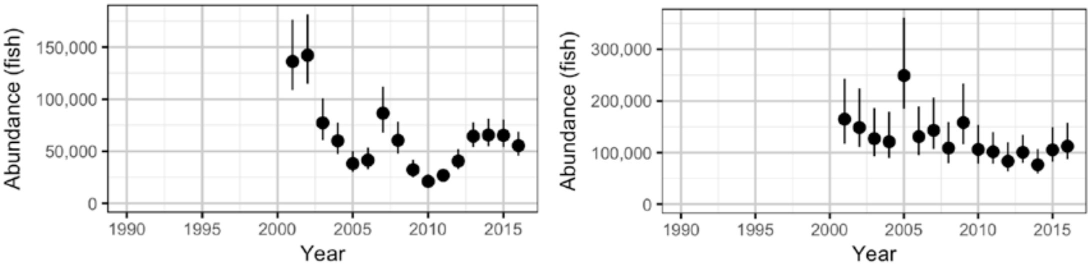

**Figure 17: Abundance (means with 95% CRIs) of subadult (left) and adult (right) Mountain Whitefish at index sample sites in the lower Columbia River, 2001-2016.**

The density of both subadult and adult Mountain Whitefish was highest near the confluence of the Columbia and Kootenay rivers and lowest near the Canada-US border (Figure 18). Subadult Mountain Whitefish densities were highest in low water velocity areas, such as Balfour Bay (RKm 2.8), just downstream of the log booms near Zellstoff-Celgar (both banks; RKm 4.5), upstream and downstream of Norn's Creek Fan (RKm 7.4), and along the left bank between Waldie Island and Tin Cup Rapids (RKm 9.2; Figure 18). Subadult Mountain Whitefish densities were low in the Kootenay River and in the Columbia River downstream of the Kootenay River confluence, river sections that typically have higher water velocities.

Adult Mountain Whitefish site-level density estimates (Figure 18) had larger credible intervals than estimates of subadult Mountain Whitefish. Density estimates were generally higher in sites known to contain suitable spawning habitat for this species. These areas include Norn's Creek Fan (RKm 7.4) downstream to CPR Island, the Kootenay River, between the Kootenay River confluence (RKm 10.6) and Kinnaird Bridge (RKm 13.4), the Genelle area (RKm 27.0), and upstream of Fort Shepherd Eddy (RKm 49.0).

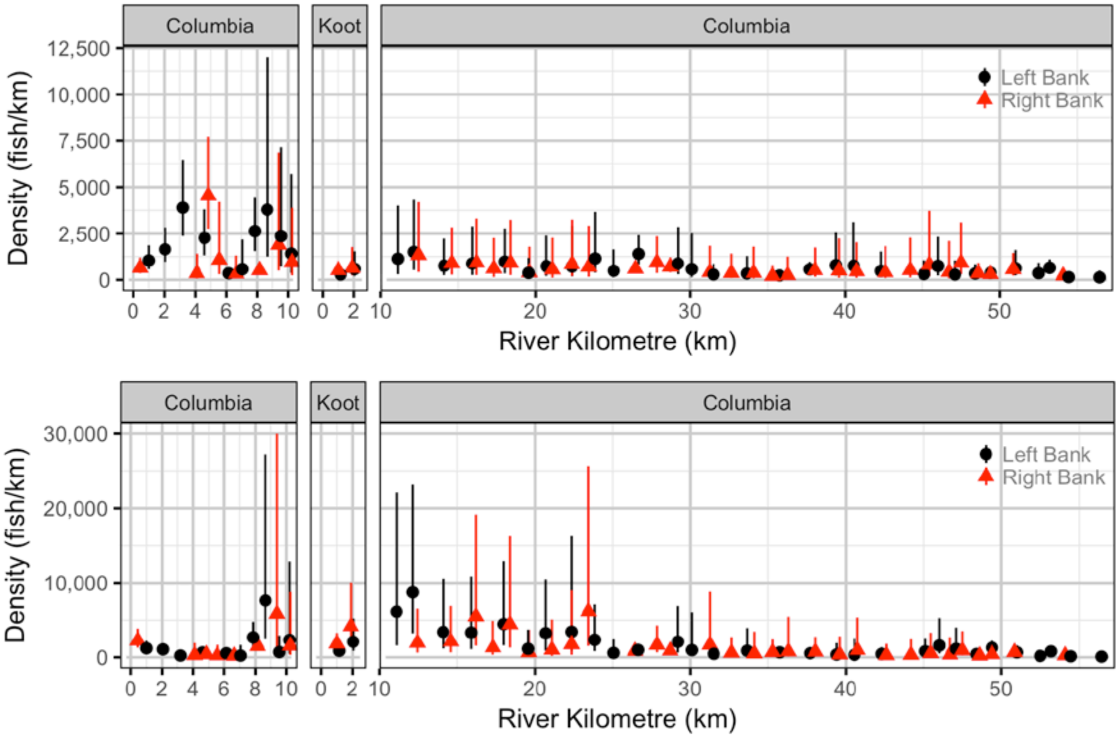

**Figure 18:** **Density (means with 95% CRIs) of subadult (top) and adult (bottom) Mountain Whitefish by river kilometre in the lower Columbia River, 2001-2016.**

### *3.4.4 Rainbow Trout*

The abundance of subadult Rainbow Trout declined from 2001 to 2005 and fluctuated with no long term increase or decrease from 2006 to 2016 (Figure 19). Adult Rainbow Trout abundance increased from ~28,000 in 2002 to the ~50,000 in 2015 and 2016.

Rainbow Trout site-level density estimates had large credible intervals (Figure 20), particularly at sites that were only sampled between 2012 and 2016 (GRTS sites). The analysis suggests higher densities of subadult Rainbow Trout in most sites between the Kootenay River confluence (RKm 10.6) and Beaver Creek (RKm 47.8) than in other sections of the study area (Figure 20). The distribution of adult Rainbow Trout was similar to that of subadults with greater densities in the Columbia River between the Kootenay River confluence and the Beaver Creek confluence and lower densities in the Columbia River upstream of the Kootenay River confluence (Figure 20). Adult Rainbow Trout densities were substantially higher near the Bear Creek confluence (Site C44.7-R), between the Champion Creek and Jordan Creek confluences (Site C23.4-L), and immediately downstream of the Kootenay River confluence (both banks; Sites C10.7-R and C10.9-L) when compared to neighbouring sites.

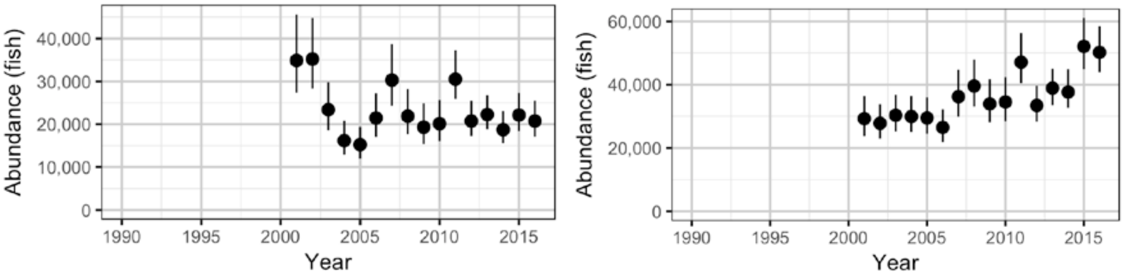

**Figure 19:** **Abundance (means with 95% CRIs) of subadult (left) and adult (right) Rainbow Trout at index sample sites in the lower Columbia River, 2001-2016.**

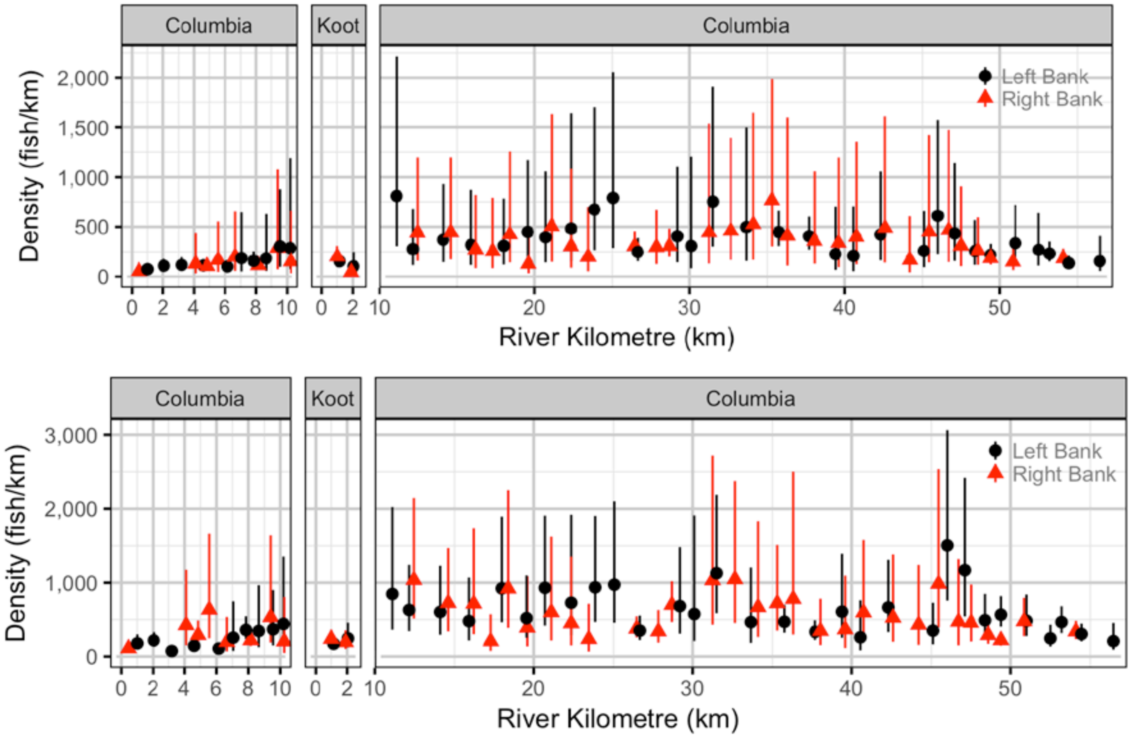

**Figure 20:** **Density (means with 95% CRIs) of subadult (top) and adult (bottom) Rainbow Trout by river kilometre in the lower Columbia River, 2001-2016.**

### 3.4.5 *Walleye*

Since 2001, Walleye abundance has fluctuated with peaks in 2003-2005 and 2011. Walleye abundance estimates were lower from 2012 to 2016 than during previous years from 2001 to 2010 (Figure 21). Density estimates for Walleye were greatest in the Kootenay River, at the three sites closest to HLK, and at the site adjacent to the Canada-US border (56.0-L; Figure 22). Density estimates for all other areas were similar and did not suggest differences in Walleye densities among sites. The density at sites sampled during the GRTS survey (not sampled prior to 2012) was comparable to the density at index sites.

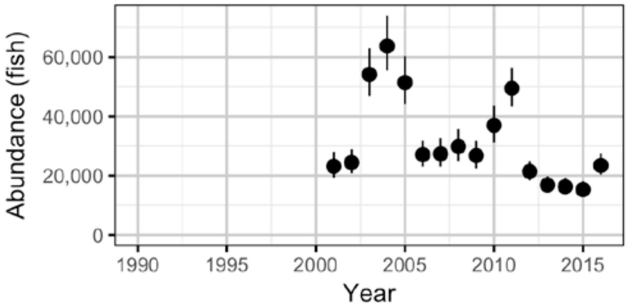

**Figure 21: Abundance (means with 95% CRIs) of adult Walleye at index sample sites in the lower Columbia River, 2001-2016.**

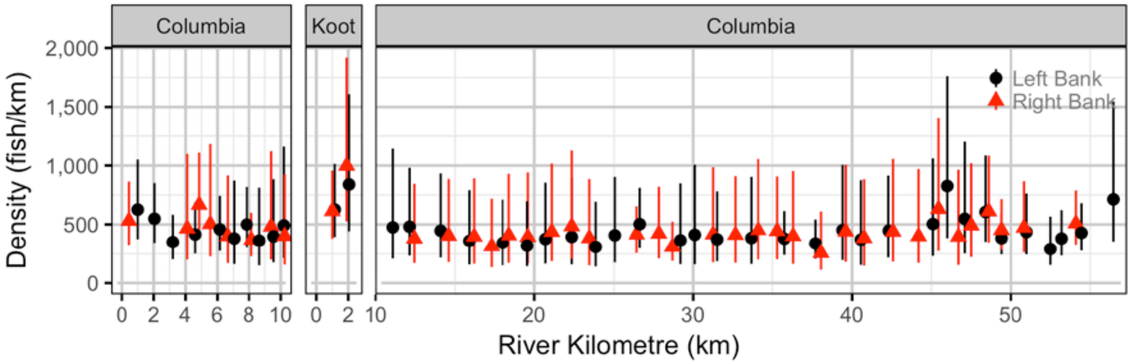

**Figure 22: Density (means with 95% CRIs) of adult Walleye by river kilometre in the lower Columbia River, 2001-2016.**

### 3.4.6 *Geo-referenced Visual Enumeration Surveys*

The visual surveys provided data regarding the within-site distribution of fish in the LCR. Maps showing the observed densities of the three index species by age-class distributed throughout sample sites are provided as an example of the spatial dataset (Appendix H). This type of map can be used to identify important fish habitats, and to compare to future years to assess the effects of flow regime variations on fish distribution and habitat usage.

## 3.5 Survival

### 3.5.1 Mountain Whitefish

For adult Mountain Whitefish, annual survival estimates varied from 25% to 90%. Adult survival generally increased between 2002 and 2008, and was relatively stable between 2009 and 2016 (60-83%; Figure 23). Credible intervals of survival estimates were greater for Mountain Whitefish than for Rainbow Trout (Section 3.5.2). The inter-annual capture efficiency, on which the survival estimate was based, was approximately 1-3% (Figure G8, Appendix G).

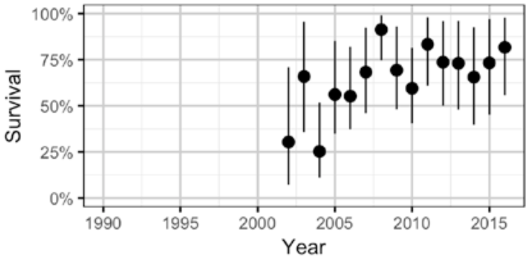

**Figure 23: Survival estimates (mean with 95% CRIs) for adult Mountain Whitefish in the lower Columbia River, 2001-2016.**

### 3.5.2 Rainbow Trout

Survival estimates of Rainbow Trout increased gradually from 31% in 2003 to 52% in 2011, but sharply declined to 32-39% in 2012 to 2016 (Figure 24). The inter-annual capture efficiency was 8% (Figure G9, Appendix G).

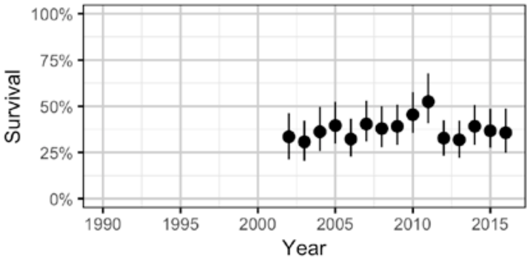

**Figure 24: Survival estimates (mean with 95% CRIs) for adult Rainbow Trout in the lower Columbia River, 2001-2016.**

### 3.5.3 Walleye

The estimated survival of Walleye was 56% in 2016 which was similar to most other years since 2001 (Figure 25). A few years including 2004, 2006, and 2013-2014 had lower survival ranging from 35 to 43%. However, credible intervals overlapped for all years. The inter-annual capture efficiency was ~2% (Figure G10, Appendix G).

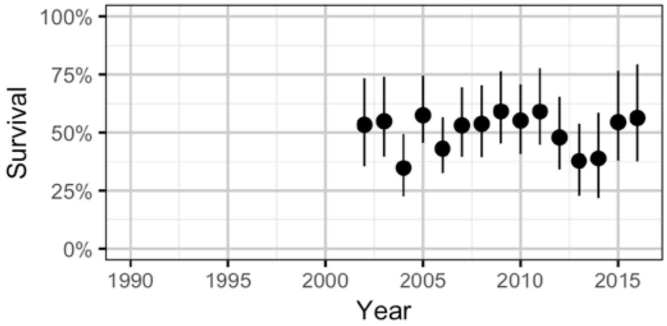

**Figure 25:** **Survival estimates (mean with 95% CRIs) for adult Walleye in the lower Columbia River, 2001-2016.**

## 3.6 Body Condition

### 3.6.1 Mountain Whitefish

The body condition of subadult Mountain Whitefish varied little (0-2%) from 2008 to 2015 but increased to 3% in 2016 (Figure 26; left panel). Adult Mountain Whitefish body condition were also stable between 2010 and 2015 (2-3%) and increased to 5% in 2016 (Figure 26; right panel). Adult body condition was much lower in the 1990s than between 2001 and 2016, with effect sizes of 7-14% lower than in a typical year.

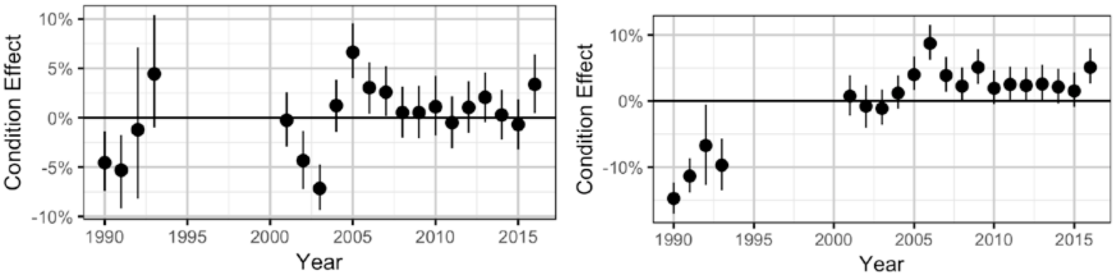

**Figure 26:** **Body condition effect size estimates (mean with 95% CRIs) for subadult (200 mm; left panel) and adult (350 mm; right panel) Mountain Whitefish in the lower Columbia River, 1990 to 1993 and 2001 to 2016.**

### 3.6.2 Rainbow Trout

The estimated body condition of subadult and adult Rainbow Trout was higher in 2002 and 2006 than in other study years (Figure 27). For subadults, body condition estimates increased from 2003 to 2006, decreased from 2006 to 2011, and were similar from 2012 to 2016. Estimates of the body condition of adult Rainbow Trout were greater in 1993, 2002, and 2006 than in other years. Adult body condition declined from 2011 to 2015, which coincided with increasing abundance estimates (Section 3.4.4).

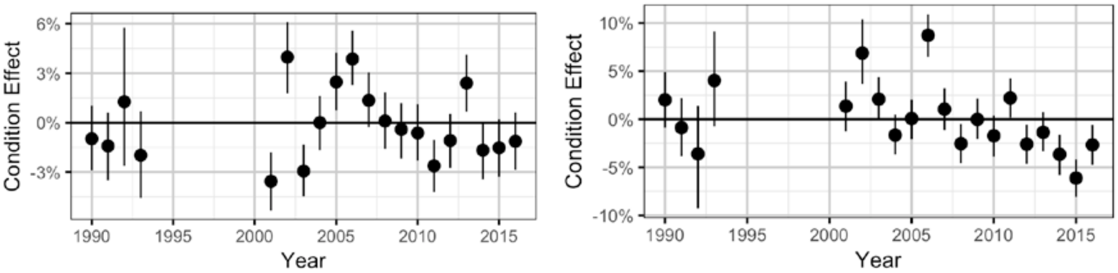

**Figure 27:** Body condition effect size estimates (mean with 95% CRIs) for subadult (250 mm; left panel) and adult (500 mm; right panel) Rainbow Trout in the lower Columbia River, 1990 to 1993 and 2001 to 2016.

### 3.6.3 *Walleye*

Walleye body condition fluctuated with no consistent trend since the early 1990s (Figure 29). However, body condition estimates in 2012 to 2016 were greater than most previous years. Overall, the results suggest fluctuating body condition of Walleye since 2001 but greater body condition in the last five years than in earlier years of the monitoring program.

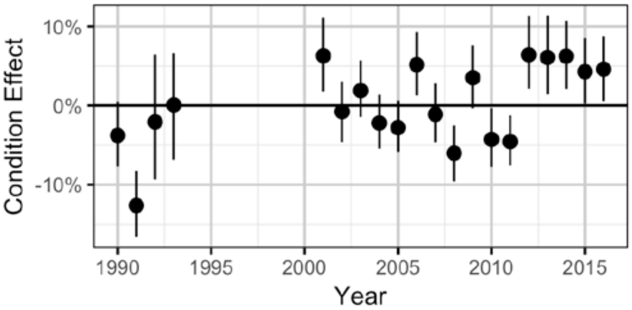

**Figure 28:** Body condition effect size estimates (median with 95% CRIs) by year for adult (600 mm) Walleye in the lower Columbia River, 1990 to 1993 and 2001 to 2016.

## 3.7 *Scale Ageing*

Ages were assigned to scale samples using an algorithm to identify growth annuli based on inter-circuli distances for recaptured Mountain Whitefish of known age. These circuli-based ages were most accurate for age-1 and age-2 Mountain Whitefish (Figure 29). Age-0 Mountain Whitefish were classified as either age-0 or age-1, whereas all of the known age-1 fish were correctly classified. Assigned ages ranged from one to two for age-2, and two to four for age-3. Both of the known age-4 recaptures were correctly aged by the algorithm, whereas age-5 and 6 Mountain Whitefish were incorrectly assigned as age-3. After maximizing the classification accuracy of the algorithm using recaptured fish of known age, the algorithm was used to age a random sample of Mountain Whitefish captured in 2016 to provide data for the analysis of the age-1:2 ratio. Age data from other years (2001 to 2015) were calculated by visual annuli counts as described in Section 2.1.7 and were obtained from the LCR Fish Population Indexing Database.

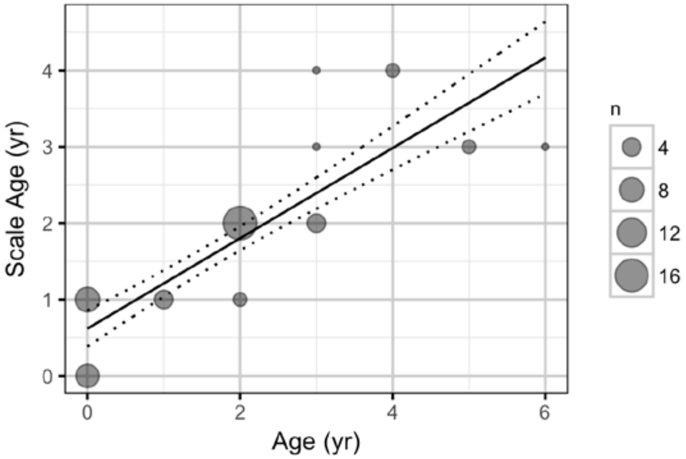

**Figure 29: Estimated scale age based on inter-circuli distances of Mountain Whitefish compared to known age based on recapture history (X axis) in the lower Columbia River.**

## 3.8 Age Ratios

The proportion of age-1 Mountain Whitefish, which was used as an indicator of annual recruitment strength, ranged from a minimum of 34% for the 2006 spawning year to a maximum of 80% in 2010 (Figure 30). The estimated proportion of egg mortality due to dewatering was greatest in 2008 (30%) and 2012 (36%) based on the egg loss model (Figure 31). Trends in the logged ratio of egg loss (Figure 32), which represents the dewatering effects on age-1 fish one year prior and on age-2 fish two years prior, were similar to those for the annual egg loss estimates (Figure 31), with the greatest estimated losses in 2002, 2008, and 2012. There was no statistically significant relationship between the age-1 recruitment index and estimated egg losses (*P*=0.3). The data suggested a weak negative relationship between age-1:2 ratio and egg loss (Figure 33) but large variability resulted in a non-significant regression slope. Although this relationship was not significant, the effect size of egg loss on recruitment is shown in Figure 34. The 2014 spawning year (2015 hatch year) had a low age-1:2 ratio (Figure 30), indicating relatively poor recruitment, even though egg loss due to dewatering was relatively low for that cohort (Figures 31 and 32).

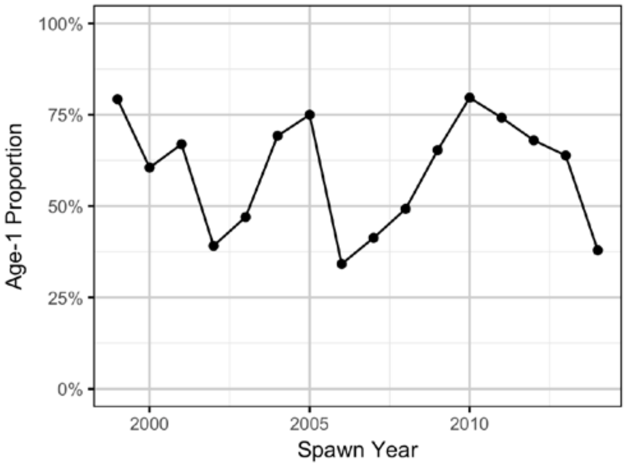

**Figure 30:** Proportion of age-1 to age-2 Mountain Whitefish in boat electroshocking catch in the lower Columbia River by spawning year, 1999 to 2014.

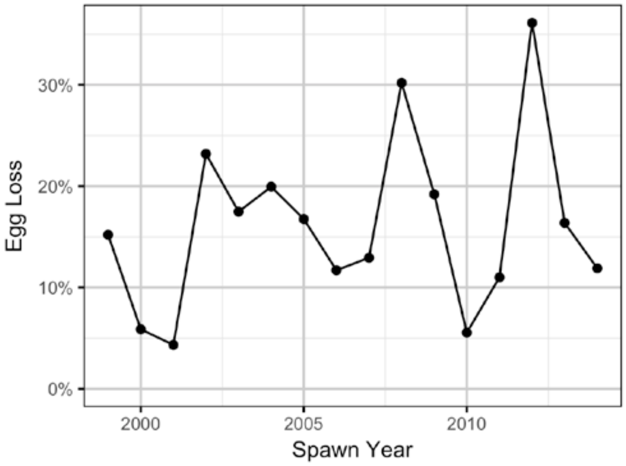

**Figure 31:** Estimated proportion of Mountain Whitefish egg loss due to dewatering in the lower Columbia River by spawning year, 1999 to 2014, based on the egg loss model.

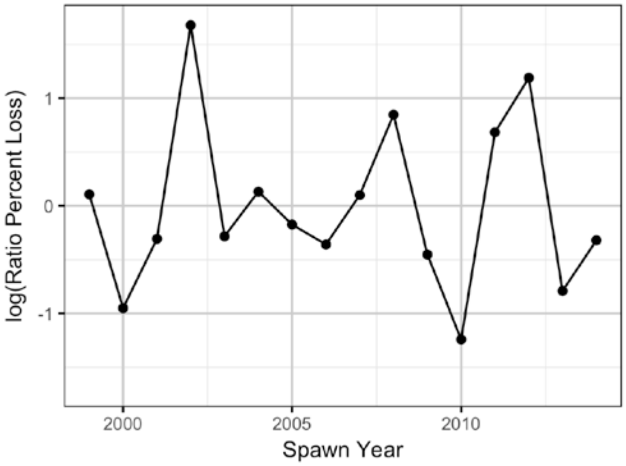

**Figure 32:** Ratio of percentage egg loss for Mountain Whitefish in the lower Columbia River by spawning year, 1999 to 2014.

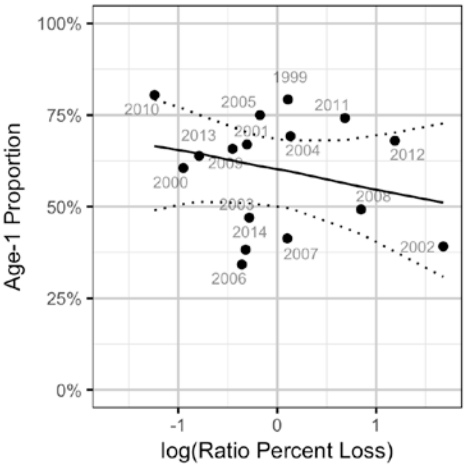

**Figure 33:** Relationship between the proportion of age-1 to age-2 Mountain Whitefish and the estimated proportion of Mountain Whitefish egg loss due to dewatering. Year labels represent the spawning year. The predicted relationship is indicated by the solid black line and dotted line represents the 95% CRIs.

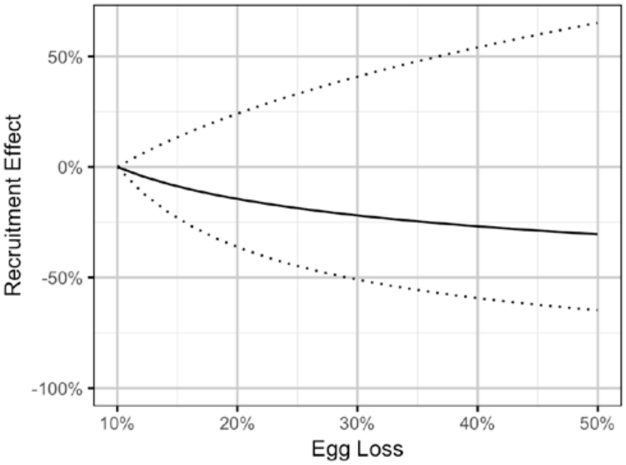

**Figure 34:** Predicted percent change in age-1 Mountain Whitefish abundance by egg loss in the spawn year relative to 10% egg loss in the spawn year (with 95% CRIs).

## *3.9 Stock-Recruitment Relationship*

### *3.9.1 Mountain Whitefish*

The Beverton-Holt stock-recruitment curve had poor fit with Mountain Whitefish data for the LCR (Figure 35).The majority of years suggested little effect of increasing abundance of adults (“stock”) on the resulting number of age-1 recruits, which is consistent with density-dependent survival and recruitment when the estimated adult population is greater than ~100,000. The exceptions were the two years (2001 and 2005) that had the greatest number of adults and greater recruitment than all other years. There were no years with data that allowed assessment of the shape of the curve at small stock size. Therefore, the productivity in terms of recruits per spawner at low stock abundance and the number of spawners below which the number of recruits is predicted to decrease is not known based on this analysis.

The impact of egg loss was modeled as an effect on the stock because dewatering would reduce the number of eggs before density-dependent mortality could occur, which is equivalent to having fewer adult spawners. The effect of egg loss on the stock was not significant (*P*>0.9), which does not support an effect of egg loss on recruitment. However, the stock-recruitment curve did not have any data on the lower part of the curve where decreased stock, or increased egg loss, would be expected to result in a large decrease in recruitment. Therefore, the data do not support an effect of egg loss on recruitment at the range of adult abundances observed, but the effects of egg loss at lower abundance are unknown based on this analysis.

The largest estimated egg loss occurred for the 2012 spawning year (36%) but the number of recruits was greater than the average recruitment predicted by the stock-recruitment curve (Figure 35). On the other hand, 2008 had the next greatest estimated egg loss (30%) and had fewer than half the estimated number of recruits than predicted by the recruitment curve, which supports a potential negative effect of egg dewatering on recruitment. Thus, we cannot rule out a possible negative effect of egg loss over the range of observed abundances because of large variability in recruitment that seems to be unrelated to spawner abundance or estimated egg loss due to dewatering.

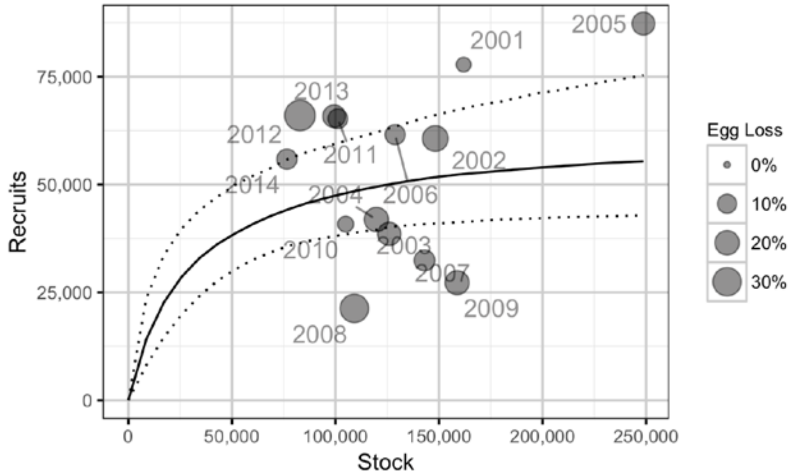

**Figure 35:** **Predicted stock-recruitment relationship between age-2+ spawners (“Stock”) and subsequent age-1 Mountain Whitefish (“Recruits”) by spawn year (with 95% CRIs). Estimated proportion of egg loss due to dewatering for each spawning year is shown by size of shaded circles.**

### *3.9.2 Rainbow Trout*

The Beverton-Holt stock-recruitment curve fit poorly with the Rainbow Trout data for the LCR (Figure 36). The stock-recruitment relationship did not suggest any effect of increasing abundance of adults (“stock”) on the resulting number of age-1 recruits one year later. There were no data points on lower part of the stock recruitment curve

(<25,000 adults) where a decrease in recruitment but an increase in recruits per spawner is predicted by the curve. As with Mountain Whitefish, no data are available to inform the number of spawners required to reach the carrying capacity for recruits, or the productivity in returns per spawner at low spawner abundance. The effect of egg loss on stock was not statistically significant (*P*>0.9). Observed egg losses were relatively small, with estimates of less than 3% in all years.

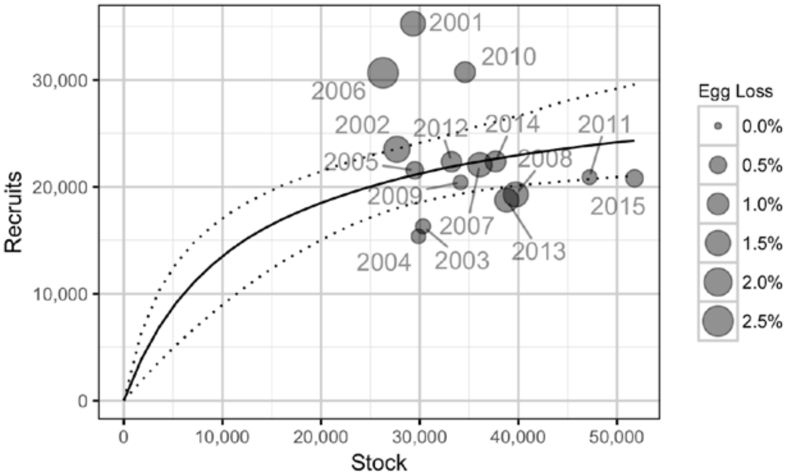

**Figure 36: Predicted stock-recruitment relationship between age-2+ spawners ("Stock") and subsequent age-1 Rainbow Trout ("Recruits") by spawn year (with 95% CRIs). Estimated proportion of egg loss due to dewatering for each spawning year is shown by size of shaded circles.**

## *3.10 Other Species*

Northern Pike (*Esox Lucius*) were first observed during the LCR Fish Indexing Program in 2010, and the number of individuals captured and observed increased in successive years from 2010 to 2013 (Table 7). Catches of Northern Pike declined in 2014 to 2016, which were years when a Northern Pike gill netting suppression program was conducted by Mountain Water Research for the Ministry of Forests Land and Natural Resources Operations (MFLNRO) and Teck Metals Ltd. (Baxter and Doutaz 2017). A total of 288 Northern Pike were removed during the gill netting program in 2014 (n=133), 2015 (n=116), and 2016 (n=39).

During the LCR Fish Indexing Program in 2015, all Northern Pike were captured in the Columbia River upstream of the Kootenay River confluence. As requested by the MFLNRO (J. Burrows, pers. comm.), all captured Northern Pike were euthanized.

**Table 7: Number of Northern Pike captured and observed in the lower Columbia River Fish Population Indexing program by year.**

| Year | # Observed | # Captured | Total # |
|---|---|---|---|
| Prior to 2010 | 0 | 0 | 0 |
| 2010 | 3 | 4 | 7 |
| 2011 | 1 | 8 | 9 |
| 2012 | 10 | 1 | 11 |
| 2013 | 90 | 45 | 135 |
| 2014 | 16 | 9 | 25 |
| 2015 | 6 | 3 | 9 |
| 2016 | 0 | 4 | 4 |

Other aquatic invasive species captured or observed within the LCR in 2016 include one Brook Trout (*Salvelinus fontinalis*), three Brown Trout (*Salmo trutta*), two Smallmouth Bass (*Micropterus dolomieu*), one Tench (*Tinca tinca*), and six Yellow Perch (*Perca flavescens*).

In 2016, eleven Burbot were recorded at index sites in the LCR, which was similar to catches from 2013 to 2015 (6-20 Burbot per year) but lower than catches from 2003 to 2013, which ranged from 39 to 247 Burbot per year (Appendix E, Table E1).

Forty-one White Sturgeon (32 adults and 9 immatures) were recorded (all observed; none captured) during the 2016 survey. Observational information for these fish is provided in Attachment A.

# 4.0 DISCUSSION

The first management question of this monitoring program assesses annual fish population metrics in the LCR. Annual estimates and observed trends or differences are summarized in the following sections. The second management question is whether variability in the Mountain Whitefish or Rainbow Trout flow regimes is related to fish population metrics. The most important aspect of flow regime variability that could affect fish populations is reduction in discharge that could dewater incubating eggs or early life stages. The effect of discharge reductions on Mountain Whitefish and Rainbow Trout populations is addressed mainly with the analyses of age ratio (Section 4.7) and stock-recruitment (Section 4.8). Variability in the flow regime could also affect populations of the index species in other ways, such as effects on availability or suitability of habitat, water temperature, or ecological interactions. These types of effects could be occurring across a range of spatial and temporal scales in the LCR and may differ among species and life stages, which make it difficult to detect relationships. Where relevant, we discuss which of the metrics (length-at-age, abundance, condition, and survival) are most likely to be affected by annual variability in the flow regime, and whether trends in fish metrics occurred in years of atypical discharge or water temperature. Assessment of the mechanisms of these relationships is speculative and not possible to assess given the observational study design of this program. Both flow regulation, including the Mountain Whitefish and Rainbow Trout protection flows, and natural variability due to weather affect the flow regime in the LCR. Therefore, variability in the flow regime is based on the resulting hydrograph from both natural and operational processes. The status of each of the specific management questions and hypotheses to be addressed by CLBMON-45 is summarized in the Executive Summary under Table I.

## 4.1 Length-at-Age and Growth

### 4.1.1 Mountain Whitefish

The model classifying age-groups based on length-frequencies suggested larger mean (149 mm) and maximum (187 mm) size of age-0 Mountain Whitefish in 2016 than all previous years. Comparison to fork lengths of aged Mountain Whitefish from 2016 and earlier years suggested that the model-predicted mean and maximum lengths of age-0 may have been biased high, which could have been related to low catch of age-0 in 2016 and/or modelling issues. However, the data do support larger size of age-0 Mountain Whitefish in 2016 than in previous years.

In future years of the study, model improvements will be attempted to make length-based predictions of age more consistent with length-at-age data. Continuing to age random samples of Mountain Whitefish is also recommended to corroborate length-at-age results that are based on length-frequency data. Length-at-age cutoffs are used to classify Mountain Whitefish as age-0, age-1, or age-2 and older; therefore, the cutoff between age-1 and age-2 affects the abundance estimates for juvenile and adults because it affects the number of fish classified into these age categories, which has implications for the analysis of spawning stock (adults) and recruitment (age-1).

Estimated mean length of age-1 Mountain Whitefish was greater in 2004 (257 mm) and 2008 (263 mm) than other study years (217 to 241 mm) but there was no consistent long-term trend. The von Bertalanffy growth model based on inter-year recaptures suggested greater than average growth in recent years, with the growth coefficient nearly 50% greater than a typical year in 2015 to 2016. Water temperature in the Columbia River from February to May of 2016 was higher than had been seen over the last 15 years (1°C greater than average) and could have supported increased growth rates and larger age-0 Mountain Whitefish that year.

### 4.1.2 Rainbow Trout

Estimates of mean length for both age-0 and age-1 Rainbow Trout increased from 2010 to 2016. The growth of inter-year recaptures suggested an opposite trend, with the von Bertalanffy growth coefficient decreasing from a 43% effect size in 2006 to -23% in 2016. These different trends could reflect differences in growth between life stages because age-0 and age-1 lengths reflect growth of younger life stages, whereas the growth coefficient represents the rate of approach to the asymptotic length independent of size, but may be influenced in this case more by adult fish that were more commonly recaptured. The decreasing trend in the growth coefficient coincided with increasing abundance of adult Rainbow Trout and may reflect density-dependence and reduced growth due to intra specific competition. Favourable environmental conditions that led to increasing abundance from 2010 to 2016 may also have contributed to increasing length-at-age for age-0 and age-1 Rainbow Trout that were not in direct competition with adults for food or other resources.

### 4.1.3 Walleye

The von Bertalanffy growth coefficient for Walleye increased from 2010 (-25% effect size) to 2016 (39%). The increasing growth coefficient estimates coincided with a decrease in abundance, with high abundance estimates in 2010 and 2011 and lower than average abundance in 2012 to 2016. This suggests a density-dependent relationship with greater growth of Walleye when abundance is low. However, there was not a consistent relationship between density and growth in all years of the study.

Predictions of length-at-age by the Bertalanffy model for Walleye were not realistic. For instance, the model predicted a mean fork length of ~150 mm at age-5 and ~260 mm at age-10 (Figure 7) whereas Walleye in Lake Roosevelt downstream of the Canada-USA border on the Columbia River are known to reach 300 mm by age-1 or age-2 (Schmuck 2016). The poor predictions of length-at-age were attributed to large variability in annual growth of Walleye across all captured sizes. Annual growth ranged from ~15 to 70 mm for 300 mm Walleye and ~5 to 60 mm for 500 mm Walleye. The wide range of observed growth for both small and larger Walleye led to wide credible intervals in growth coefficient and a fairly linear curve instead of rapid growth at smaller size and quickly attenuating growth rate at larger size. To address these issues, the growth model was re-run using only Walleye <450 mm and omitting larger fish that are typically expected by the von Bertalanffy model to have little growth but sometimes had substantial growth in the LCR. However, the analysis using only Walleye <450 mm in fork length had similar predictions of length-at-age as the full analysis but with smaller credible intervals. The growth coefficient for Walleye can still be used as a relative index of growth for this species in the LCR but future years of the study should consider alternative growth models to account for highly variable growth of Walleye in the LCR.

Overall, a lack of age data and limited number of inter-year recaptures hinder growth analyses for Walleye. During future study years, substantially more recaptures would be required to detect significant changes in Walleye growth using current methods. Walleye feed in the LCR during the summer and fall with a large numbers of individuals migrating out of the LCR into Lake Roosevelt in the late fall and early winter months (R.L.&L. 1995). The seasonal residency of a proportion of the Walleye population means that factors outside of the LCR likely also influence the growth of Walleye in the study area.

## 4.2 Abundance and Site Fidelity

### 4.2.1 Mountain Whitefish

Abundance of subadult Mountain Whitefish decreased markedly (>70%) between 2001 and 2005. If subadult Mountain Whitefish density truly declined between 2001 and 2005, one would expect either adult Mountain Whitefish densities to decline between 2002 and 2006 or adult Mountain Whitefish survival to increase between 2001 and 2005. Neither adult abundance nor survival changed enough over that time period to support a >70% reduction in the abundance of subadult Mountain Whitefish. This discrepancy could be partly explained by migration of Mountain Whitefish out of the study area, and the subsequent effect on survival and abundance estimates, which is discussed in further detail in Section 4.4.1.

Little is known about the factors influencing the abundance of Mountain Whitefish in the LCR but there is some information to suggest that predation on Mountain Whitefish by piscivorous fish species could play a role. Walleye feed on Mountain Whitefish (Wydoski and Bennett 1981), and densities of subadult Mountain Whitefish decreased from 2001 to 2005, while Walleye densities generally increased during that time period. Walleye stomach content data collected in the fall of 2009 (Golder 2010b) and 2010 (Ford and Thorley 2011a) did not indicate that young Mountain Whitefish are a major food source for Walleye. However, age-0 Mountain Whitefish may be more susceptible to Walleye predation during the early to mid-summer (i.e., when they are smaller) than during the fall (i.e., when they are larger). Mountain Whitefish were the most common prey item found in the stomachs of Northern Pike caught by gill-netting in the upstream section of the LCR, comprising 42% of the fish prey fish identified (Baxter and Doutaz 2017). Therefore, there is potential for Northern Pike to influence the abundance and distribution of Mountain Whitefish in the upper LCR.

Since 2002, more than 140,000 hatchery-reared juvenile White Sturgeon were released into the Transboundary Reach section of the LCR (J. Crossman, BC Hydro, pers. comm.). Although most of these fish would have been too small to prey on Mountain Whitefish during the early 2000s, predation by White Sturgeon may have influenced Mountain Whitefish abundance in more recent years. White Sturgeon are capable of feeding on both subadult and adult Mountain Whitefish, and as many as 12 adult Mountain Whitefish have been recorded in the stomach contents of a single adult White Sturgeon (R.L.&L. 2000).

White Sturgeon become piscivorous at approximately 500 mm FL (Scott and Crossman 1973). In the LCR, this equates to an approximately age-3 individual (Golder 2009b); therefore, predation by White Sturgeon on Mountain Whitefish is expected to have increased since approximately 2005.

One of the management questions concerns the effects of variation in flow regime on Mountain Whitefish abundance. This program estimated subadult and adult abundance but the multiple cohorts and large number of factors that can affect survival and abundance of adults likely make it difficult to detect a relationship with annual flow variation. The effects of flow variability and specifically, egg dewatering, would be most likely to be detected by measuring fry (age-0) abundance. However, reliable estimates of fry density were not possible using the current sampling method because boat electrofishing is not efficient for sampling very shallow (< 30 cm) habitats that are likely preferred by fry. The analysis of age ratios as a recruitment index (Section 4.7) provides an alternative way to assess the effects of flow variation on recruitment.

### *4.2.2 Rainbow Trout*

The abundance of subadult Rainbow Trout decreased between 2001 and 2005 whereas the abundance of adults was relatively stable during this time period. The abundance of adults nearly doubled from ~28,000 in 2002 to ~50,000 in 2016. In comparison, estimates of spawner abundance based on visual observations and an area-under-the-curve model increased nearly ten-fold from ~1600 spawners in 1999 to ~15,000 in 2015 (Baxter et al. 2016). It is not clear why spawner estimates increased more dramatically than adult population estimates and subadult abundance did not increase at all over the same time period. Possible reasons for this discrepancy include:

1) capture efficiency for adults was always low (<3%), which provided little information about annual or inter-session variation in recapture rates, and could have masked real changes in Rainbow Trout abundance;

2) at very high fish densities, the electrofishing field crew becomes overwhelmed and are able to catch or count a smaller proportion of the number of fish, which could result in underestimated abundance if the estimates of recapture rates are not precise enough to account for the change;

3) some of the adults counted during the spawner surveys migrate into the study area to spawn but leave before the fall and are therefore not sampled by the indexing program; and

4) with increasing total abundance, Rainbow Trout could be more widely distributed in the river during the non-spawning season, with little change in density in the index sites, which would result in underestimates of total abundance based on only indexing sites.

Increasing adult abundance (spawner survey and indexing) during periods of declining or similar subadult abundance (indexing study) is also reflected in the annual length frequency plots, which show increasing proportion of larger fish during the study period (Appendix F, Figure F5).

In many years, capture efficiency of subadult Rainbow Trout decreased during each successive sample session (Appendix G, Figure G5). This result may indicate a violation of the HBM's closed population assumption. By comparison, the capture efficiency of adult Rainbow Trout remained stable within each study year. Capture efficiency between study years remained constant for both age-classes.

The probability of a fish being recaptured in the same site was highest for small Rainbow Trout, among all index species and fish lengths. This indicates that subadult Rainbow Trout exhibited higher site fidelity than all other index species and life stages. High site fidelity in juvenile Rainbow Trout may reflect territorial behaviour as has been reported for this species in small streams (Imre et al. 2002). Estimated capture efficiencies were highest for subadult Rainbow Trout, which indicates that this cohort also was the easiest to catch. Site fidelity decreased with increasing fork length, indicating that older Rainbow Trout were more likely to migrate out of sample sites.

### *4.2.3 Walleye*

Walleye abundance was greater in 2003 to 2005 and 2011 than in other study years. These results likely reflect strong year-classes of Walleye present in the study area during those years. Walleye migrate into the LCR to feed in summer and fall but spawn and complete early life history in downstream regions (e.g., Lake Roosevelt and its tributaries). Abundance in the LCR depends on suitable feeding conditions but also largely on factors that influence spawning success and early life stage survival and growth outside of the study area. Based on length-frequency data and Lake Roosevelt length-at-age data (WDFW Unpublished Data), age-2 and age-3 fish are the most dominant age-classes present in the study area during most study years; therefore, the abundance of this species in the study area during any particular year is strongly influenced by the spawning success of this species during the previous two to three years. Years with high abundance (e.g., 2003-2005, 2011) generally were associated with lower than normal body condition and survival, suggesting density-dependence and resource competition in years of high abundance in the LCR. Variability in the flow regime in the LCR is less likely to be related to the abundance of Walleye than the abundance of other index species, because the abundance of Walleye in the LCR is thought to depend on spawning and early life history in Lake Roosevelt.

### *4.2.4 Other Species*

The CLBMON-45 management questions refer only to the three index species; numbers of non-index species are generally too low to draw conclusions about population trends in any case. However, electroshocking results during this program clearly demonstrate the colonization of non-native Northern Pike in the study area. Northern Pike were not documented in the study area prior to 2010, but this species has been captured or observed during electroshocking surveys every year since 2010. Attempts to suppress the growing Northern Pike population through a targeted gill-netting program in 2014 to 2016 appear to be reasonably successful with 288 individuals removed in total, and approximately 30-40% of the estimated population removed each year (Baxter and Doutaz 2017). The number of Northern Pike caught and observed by boat electrofishing during this program decreased in consecutive years from 135 in 2013 to four in 2016, which also suggests that suppression efforts decreased population size in the study area.

Northern Pike likely originated from established populations in the Pend d'Oreille River. Very high water levels in 2012 resulted in many areas with flooded terrestrial vegetation in the upper LCR, which may have provided suitable spawning habitat for Northern Pike and further facilitated an increase in their local abundance. Surveys intended to document presence or absence of larval Northern Pike did not capture any young-of-the-year during sampling in June to July of 2015 using various capture techniques (Golder 2015). However, four juvenile Northern Pike that were suspected to be age-0+ (nearly age-1) were captured during gill-netting in the spring of 2017, which indicates successful spawning by Northern Pike in the upper section of the LCR in 2016 (J. Baxter, Mountain Water Research, personal communication).

The dramatic increase in the number of Redside Shiner recorded in the section of the Columbia River upstream of the Kootenay River in 2013 suggested a significant change in the abundance of this species. However, high abundance of Redside Shiner did not persist in 2014 to 2016, when levels were similar to previous years between 2001 and 2012. Reasons for the high abundance in 2013 are unclear but possible explanations include high recruitment of a recent year-class, an increase in habitat availability or suitability in the upper section of the LCR, or inaccurate counting by different observers among years. The high abundance of Redside Shiner observed in 2013 was similar to the high abundance of this species recorded in the early 1990s (R.L.&L. 1995).

The number of Burbot captured and observed was lower from 2013 to 2016 (6-20 Burbot per year) than between 2003 and 2012 when the number recorded per year ranged from 33 to 247, with the greatest catch in 2011 (Appendix E, Table E1). Catch rates from annual gill-netting surveys in Lake Roosevelt from 2003 to 2015 were also greatest in 2011, but otherwise did not follow the same trend as electrofishing catch in the LCR, with higher gill-net catch rates in recent years than between 2003 and 2010 (Golder 2017).

## 4.3 Spatial Distribution

### 4.3.1 Mountain Whitefish

Subadult Mountain Whitefish densities were greatest in the 10-km section between HLK and the Kootenay River confluence. This result is likely related more to channel morphology than the presence or operation of the dam. Large bays and backwater areas, which are preferred habitats for subadult Mountain Whitefish, are more common near HLK than downstream of the Kootenay River confluence. Specific examples include Balfour Bay (RKm 2.6), downstream of the log booms near Zellstoff-Celgar (RKm 5.1), and upstream of Norn's Creek Fan (i.e., Lions Head RKm 7.4). These areas have exhibited increases in aquatic vegetation abundance (dominantly Eurasian water-milfoil) between 2001 and 2016 (Attachment A). Most recently, Northern Pike have been captured in these same areas. Mountain Whitefish were found to be one of the main components of Northern Pike diets in this reach, based on stomach content analysis (Baxter and Doutaz 2017). Effects of predation by Northern Pike on the distribution or survival of subadult Mountain Whitefish are not known. Fine scale distributional data are only available since 2013 and not prior to colonization by Northern Pike.

The spatial distribution of adult Mountain Whitefish during the fall sample period may be related to the location of key spawning areas for this species. Densities of adults were highest near Norn's Creek Fan, in the downstream portions of the Kootenay River, upstream of Sullivan Creek, and near the City of Trail Airport. Norn's Creek Fan, the Kootenay River, and the City of Trail Airport area are known Mountain Whitefish spawning locations (Golder 2012), whereas the site located upstream of Sullivan Creek is close to a known spawning area (i.e., Lower Cobble Island), which may indicate that Mountain Whitefish use these areas for holding purposes prior to spawning.

Although not statistically analyzed, the data did not suggest any large temporal changes in the spatial distributions of subadult and adult Mountain Whitefish between 2001 and 2016.

### 4.3.2 Rainbow Trout

Subadult Rainbow Trout densities were noticeably higher in the Columbia River between the Kootenay River confluence and Genelle, and from Birchbank downstream to the Beaver Creek confluence, compared to other portions of the study area. Ford and Thorley (2011a) suggested that these areas supported higher Rainbow Trout densities due to the more suitable habitat characteristics of these areas for this life stage and the presence of major spawning areas immediately upstream (i.e., Norn's Creek Fan, the Kootenay River, and the Genelle area; Thorley and Baxter 2012). No large changes in spatial distribution across index sites were observed during the study period.

The densities of subadult and adult Rainbow Trout at synoptic sites (i.e., sites that were not systematically sampled prior to 2011) were generally similar to indexing sites, except at synoptic sites near the Columbia-Kootenay river confluence where densities were very high. The high densities of Rainbow Trout in previously unsampled portions of the study area indicate that a large portion of the overall Rainbow Trout population is potentially missed during the typical mark-recapture sampling at index sites. Higher densities in these areas than in index sites would result in underestimates of overall population density in the LCR and might explain the discrepancy with the spawner counts. These results suggest the importance of continuing to sample in randomly sampled synoptic sites, as well as the indexing sites, to detect changes in fish abundance and distribution that may not be detected by sampling only the indexing sites.

### 4.3.3 Walleye

Walleye densities were high immediately downstream of HLK. Sculpin species and Redside Shiner are a common prey fish for Walleye based on stomach sample analyses (Ford and Thorley 2011a). In 2010, results from the spatial density HBM indicated higher Sculpin species and Redside Shiner densities in this portion of the study area (Ford and Thorley 2011a). In addition, Walleye densities are probably higher immediately downstream of HLK because they are feeding on fish entrained at the dam. Walleye densities also were high in the Kootenay River downstream of BRD to the confluence of the Columbia, likely for the same reason.

Walleye densities were similar throughout the remaining sections of the LCR. Their wide distribution throughout the study area indicates an ability to utilize a wide variety of habitats and tolerate a wide range of habitat conditions. This reflects the primary use of the LCR as a summer and fall feeding area, and as a result, this species is generally found wherever prey fish are present.

The data did not suggest any temporal change in the spatial distribution across index sites during the study period.

## 4.4 Survival

### 4.4.1 Mountain Whitefish

Estimated survival of adult Mountain Whitefish varied throughout all study years (25-90%) but has been >70% since 2011. The high survival rate of adults was not unexpected, as Mountain Whitefish are known to be a relatively long-lived species with most populations containing individuals greater than 10 years of age (McPhail 2007; Meyer et al. 2009). In comparison, estimated survival rates ranged between 63 and 91% (mean 82%) for Mountain Whitefish in Idaho (Meyer et al. 2009).

Currently, each of the management hypotheses is tested using separate HBMs, which simplifies the testing of the hypotheses. This approach also allows the model outputs to be checked for inconsistencies. When this check was conducted on subadult and adult Mountain Whitefish density estimates, the estimates generated were not compatible with survival estimates. For instance, it is not possible for an adult population of ~120,000 fish in 2014 to be supported by a subadult population in 2013 of 56,000 fish with only 25% subadult survival (14,000 fish to be recruited to the adult population) and adult survival of 29% (34,800 fish remaining in the adult population). This indicates that either the abundance or survival model (or possibly both) make at least one unreliable assumption concerning Mountain Whitefish biology or behaviour that biases the estimates. Subadult survival was not estimated in 2015 or 2016 because the estimates provide no information on inter-annual variation.

One possible explanation for the inconsistency between survival and abundance estimates is that the large-scale spawning migrations by adult Mountain Whitefish during the study period results in the loss of tagged fish from sample sites at a substantially greater rate than estimated by the site fidelity model. The site fidelity model estimates the probability that a recaptured fish is caught at the same site as encountered previously, as opposed to being recaptured at a different site. Consequently, if a fish moved from the shallow water margins, where sampling occurred, into the main channel, or moved into an area of the river where sampling was not conducted, that fish would not be available for recapture and the site fidelity model would underestimate the losses of tagged fish. This bias would result in an underestimation of capture efficiency and a concomitant overestimation of abundance.

Mountain Whitefish recapture probabilities were less than half of those for Rainbow Trout and Walleye, which further suggests that fish movements could be influencing recapture estimates. In addition, during BC Hydro's MCR Fish Population Indexing Program (CLBMON-16), recapture rates for adult Mountain Whitefish were greater in the spring than in fall from 2011 to 2016, possibly because Mountain Whitefish were moving into and out of the study area in the fall study period for spawning migrations (Golder, Poisson and ONA 2017). Based on telemetry data collected under CLBMON-48 (Golder 2009c), a substantial proportion of the adult Mountain Whitefish population in the LCR undertakes spawning related movements, often to other areas of the river during the fall study period. This would explain why abundance estimates are inconsistent with estimates of survival in the LCR and would account for lower recapture estimates for Mountain Whitefish when compared to other species in the LCR.

### *4.4.2 Rainbow Trout*

Adult survival ranged from 30 to 52% across all study years. For adult Rainbow Trout, both survival and abundance increased gradually between 2003 and 2011. However, survival decreased to 32-39% during 2012 to 2016. Lower survival during recent years coincided with high abundances, as indicated by mark-recapture estimates (Section 3.4.4) and spawner surveys (Baxter et al. 2016), which may reflect density-dependent survival and intra-specific competition for resources.

Survival of adults is unlikely to be affected directly by variability in the flow regime, although changes in productivity related to flow variability could affect growth or condition, which could ultimately affect survival. Flow variability is more likely to affect the survival of juvenile fish, through effects on habitat, displacement, or stranding. This is true for Rainbow Trout as well as Mountain Whitefish. Survival cannot be assessed using the mark-recapture data for juvenile fish because they are not effectively sampled by boat electrofishing. The effect of flow variability on survival and recruitment of juveniles can be assessed using the stock-recruitment models and age ratio analyses.

### *4.4.3 Walleye*

The estimated survival of Walleye was 56% in 2016 which was similar to most other years since 2001. Some years that had lower survival, such as 2004 (35% survival), were associated with high abundance of Walleye but there was not a consistent relationship between abundance and survival which suggest that factors other than density are likely influencing adult survival. As a large portion of the Walleye population is thought to be migratory and spend only part of the year in the LCR before moving downstream into Lake Roosevelt (R.L.&L. 1995), annual survival could be confounded by fish movements, and affected by factors outside of the study area.

## 4.5 Body Condition

### 4.5.1 Mountain Whitefish

The body condition of subadult and adult Mountain Whitefish were fairly stable (≤3% change) between 2010 and 2015 but increased in 2016. Across all years when data were available, the changes in body condition of adult Mountain Whitefish varied from -14% to 9% (compared to a typical year) between 1990 and 2016 (Figure 26). Fluctuations in body condition are known to affect reproductive potential and population productivity in other fish species (Ratz and Lloret 2003). However, it is not known what percent change in body condition is biologically significant and could affect populations of Mountain Whitefish. The Canadian Environmental Effects Monitoring (EEM) program for mining and pulp and paper effluents considers a 10% change in fish body condition to be the critical threshold for higher risk to the environment (Munkittrick et al. 2009; Environment Canada 2012). This criterion suggests that the range of 23% variation (-14 to 9%) in adult Mountain Whitefish body condition could be biologically significant. Studies of the effects of body condition on reproduction and other life-history processes are required to understand the implications of body condition variation in Mountain Whitefish and other index fish species in the LCR.

Lower body condition (approximately -10% effect size) in the early 1990s compared to between 2001 and 2016 could be related to lower water quality and industrial pollution. A number of industries including a pulp and paper mill, a fertilizer plant, and a metal smelter contributed to much poorer water quality in the 1980s and early 1990s than since the mid-1990s (MacDonald Environmental Services Ltd. 1997). Fish health monitoring studies in the early 1990s found that Mountain Whitefish had higher rates of stress-related abnormalities compared to fish from reference sites, which was thought to be related to degraded water quality (Nener et al. 1995). Reductions in industrial pollution have resulted in improved water quality and fish health in the LCR since the mid-1990s (CRIEMP 2005), which likely explains the greater body condition in 2001 to 2016 than during the early 1990s.

Body condition increased for subadult and adult Mountain Whitefish in 2016, which was characterized with near-average discharge but warmer than average water temperature during spring, summer and fall. Little is known about what factors influence changes in body condition or growth of Mountain Whitefish in the LCR. In the Skeena River, a large, unregulated river in British Columbia, food abundance was the main factor limiting growth and abundance for Mountain Whitefish (Godfrey 1955 as cited by Ford et al. 1995). Mountain Whitefish body condition also is likely related to the abundance of invertebrate prey in the LCR. With regard to the program's second management question, variability in the flow regime could affect invertebrate abundance, which in turn could affect the body condition of insectivorous fish including Mountain Whitefish. The LCR Physical Habitat and Ecological Productivity program suggested that water velocity and discharge variability can affect invertebrate productivity, especially during the Mountain Whitefish protection flow period (Olson-Rusello et al. 2015), which supports a potential pathway between flow variability, food availability, and Mountain Whitefish body condition.

Information about the relative abundance of invertebrates in the LCR has been collected (Olson-Russello et al. 2015) but is only available for five years (2008-2010, 2012, and 2014), which means that relationships between annual flow variability, invertebrates, and fish cannot be compared across the entire timespan of the fish indexing program (2001-2016).

The small spatial differences in body condition suggest that either there is little variation attributable to habitat differences among sites, or that fish do not stay within particular sites long enough to result in large inter-site differences in body condition. Therefore, sample site was not included in the body condition models for Mountain Whitefish or the other species. The low site fidelity estimates support the idea that fish movements may prevent large inter-site differences in body condition, especially for Mountain Whitefish, which had the lowest site fidelity estimates.

### *4.5.2 Rainbow Trout*

Although there was no sustained temporal trend in body condition for Rainbow Trout, body condition was greater in 2002 and 2006 for both subadult and adult Rainbow Trout compared to other study years. Both water temperature and discharge in the Columbia River were near historical averages in 2002 and 2006. Thus, the results do not suggest that variations in flow regime explain the inter-annual differences in Rainbow Trout body condition. However, the relationship between flow variability and invertebrate productivity suggested by Olson-Rusello et al. (2015) and discussed in Section 4.5.1 also has implications for Rainbow Trout. Changes in invertebrate abundance due to flow variability would be expected to affect food availability and possibly body condition of Rainbow Trout.

The 8% decrease in body condition between 2011 and 2015 coincided with high and increasing abundance of Rainbow Trout. This may indicate an increase in intra-specific competition for food that caused the decrease in body condition. The recent high abundance and low body condition also coincided with a decrease in adult survival estimates, which suggests that low body condition may lead to lower survival of Rainbow Trout in the LCR. Body condition recovered slightly from a -6% effect size in 2015 to -3% in 2016, despite similarly high estimated abundance. Body condition values of Rainbow Trout in the LCR were generally higher than those recorded downstream of Revelstoke Dam during the same time of the year (CLBMON-16; Ford and Thorley 2011b).

### *4.5.3 Walleye*

Body condition of Walleye was greater in 2012 to 2016 than in most previous years. These years of high body condition had low abundance estimates of Walleye, suggesting density-dependent growth that could be due to intraspecific competition for food and cover, similar to that reported for this species by other researchers (Hartman and Margraf 1992; Porath and Peters 1997; Forney 2011). Variability in the flow regime is less likely to have direct effects on food availability and body condition of Walleye compared to insectivorous fish species, because Walleye are piscivorous.

## *4.6 Scale Ageing*

Scales were analyzed to assign ages to Mountain Whitefish, with the main objective of providing ages to calculate the age-1:2 ratio, which was used an indicator of annual recruitment strength (Section 4.7). Ages assigned using measurements of inter-circuli distances and an algorithm to detect annuli were most accurate for age-1 and age-2. All of the known age-1 and the majority of the age-2 Mountain Whitefish were correctly classified. This suggests that this method of ageing Mountain Whitefish is appropriate for the age ratio analysis, which uses age-1 and age-2 fish.

Approximately half of the Mountain Whitefish that were assumed to be age-0 based on length were classified as age-1 by the algorithm (Figure 29). This was unexpected because age-0 Mountain Whitefish are usually accurately aged using scales. It is possible that some of the larger age-0 fish based on the length-at-age cutoffs (Table 6) were actually age-1. The assumed age, based on length cutoffs, may have resulted in small age-1 fish being incorrectly classified as age-0 because the length frequency data indicated that age-0 and age-1 fish overlapped in 2016, unlike the separate and distinct modes in previous years for these age classes that allowed accurate age assignments based only on length. Some of these fish may have been classified correctly as age-1 by the algorithm, but classified as age-0 by the length model because the estimated maximum length of age-0 was much higher in 2016 than other years (see Section 3.3.1. and 4.1.1). Therefore, the circuli measurement and ageing algorithm method may be more reliable for age-0 Mountain Whitefish than suggested by Figure 29.

Although the sample sizes for older fish were small, the data suggested that the actual age of age-5 and age-6 Mountain Whitefish were consistently underestimated. Underestimated scale ages on older fish have also been reported based on visual annuli counts from previous years of this project (Golder 2008) and studies of coregonids elsewhere (e.g. Muir et al. 2008). Underestimated ageing based on scales of older fish is attributed to slowed growth which leads to fewer circuli per year, less seasonal variation in inter-circuli distance, and annuli that are absent or difficult to discern. Analytical methods to correct biased scale ages for older fish are possible (Campana 2001) but would require a greater sample size of more reliable ages for older Mountain Whitefish, which could be obtained by larger number of inter-year recaptures, or ageing fish using otoliths, which requires lethal sampling but is known to be more accurate than scales for older fish (Barnes and Power 1984; Muir et al. 2008).

Scales from a random sample of Mountain Whitefish captured in 2016 were aged using circuli measurements and the algorithm discussed above. Mountain Whitefish captured in other years were aged using different methods (Section 2.1.7). Ageing methods from 2001 to 2012 were thought to be fairly accurate for age-0 to 3 Mountain Whitefish but were not formally validated using fish of known age. Ageing methods used for Mountain Whitefish captured from 2011 to 2015 were validated using fish of known age and the estimated ages were consistently biased (overestimated) by one year (Golder, ONA, and Poisson 2016). These ages were corrected for bias by the model and these model-corrected ages were used in the age ratio analysis. The age data used for the age ratio analysis below is thought to be sufficiently accurate for the age-classes used by the model (age-1 and 2) but we acknowledge that the three different methods used across years add some additional uncertainty to the interpretation. Additional work validating and comparing age data from the three different methods is recommended in future years.

## 4.7 Age Ratios

The proportional ratio of age-1:2 Mountain Whitefish was used as an indicator of recruitment to assess annual variation and the effects of egg dewatering. Greater egg dewatering is expected to reduce subsequent recruitment of age-1 Mountain Whitefish, which would be reflected by lower age-1:2 ratios. The age-1:2 ratio ranged from 34% to 80% between the 1999 and 2013 spawning years, which suggests substantial inter-annual variation in recruitment during the monitoring period. There was no significant relationship between the age-1:2 ratio recruitment index and the estimated annual egg loss. The weak, non-significant relationship between age-1:2 ratio and egg loss (Figure 33) and large variability in this recruitment index was likely because there were many of other factors, such as population dynamics, environmental conditions, and ecological interactions that influenced survival and recruitment more than egg dewatering during the period of study.

Mark-recapture population estimates of subadults could also be used to assess recruitment and the effects of egg dewatering. However, capture efficiencies for subadult Mountain Whitefish are low (<1%) and the mark-recapture estimates are based on several untested assumptions, such as no migration out of the study area between capture sessions. If assumptions are violated or low recapture rates are not accurately reflecting changes in capture efficiency, then it could mask trends in subadult abundance and make it difficult to detect the effects of dewatering. Because the age-1:2 ratio is based on proportions of ages in the catch, this recruitment index would not be affected by undetected changes in capture efficiency, and therefore is likely a more robust method to assess the effects of egg dewatering in the LCR. This approach could also be used for Rainbow Trout in the LCR but currently age data are only available for Rainbow Trout from 2001 to 2012, whereas scales were collected and but not analyzed for Rainbow Trout from 2013 to 2016.

## 4.8 Stock-Recruitment Relationship

For both Mountain Whitefish and Rainbow Trout, the stock-recruitment analysis indicated no relationship between the estimated number of adults and age-1 recruits, and large variability in the number of recruits produced by a particular number of adults. The lack of relationship between stock and recruitment was interpreted as being consistent with density-dependent survival and recruitment at all of the observed stock sizes. Smaller stock sizes may not have resulted in lower recruitment because the lowest observed number of adults between 2001 and 2016 was still sufficient to fully seed the habitat with eggs or fry, resulting in similar numbers of recruits as with greater stock size. In other words, it may appear that there is no relationship between spawners and recruitment if the range of spawner abundance observed is not sufficiently large (Myers and Barrowman 1996). Alternatively, errors in the measurement of either stock or recruits can mask real relationships and make recruitment appear independent of spawning stock size (Walters and Ludwig 1981). In the LCR it could be that imprecise estimates of abundance, especially for age-1 fish that have lower recapture rates, could be masking trends in abundance and relationships between adults and age-1 recruits.

For Mountain Whitefish, the effect of egg loss on stock in the model was not significant, which does not support an effect of egg loss on recruitment in the LCR. However, the only data points were on the relatively flat part of the estimated stock-recruitment curve, where a decrease in spawners or egg loss due to dewatering would not be predicted to decrease the resulting recruits substantially. Based on the estimated stock-recruitment curve, years with substantially fewer adults and/or larger egg loss would be needed to detect a decrease in recruitment related to egg loss. Therefore, the data do not support an effect of egg loss on recruitment at the range of adult abundances observed, but the effects of egg loss at lower abundance are unknown based on this analysis.

As with Mountain Whitefish, the effect of egg loss was not significant in the stock-recruitment model for Rainbow Trout. However, there were no years with stock abundance on the lower part of the curve where decreases in eggs would be expected to result in substantially lower recruitment. In addition, estimated egg loss for Rainbow Trout was relatively low (<3%) in all years. It may be that a larger proportional egg loss would be required to detect an effect on recruitment given the large variability in the stock-recruitment relationship. The Rainbow Trout Spawning Assessment Survey (Baxter et al. 2016) reported an unexpected, positive correlation between recruitment (age-1 abundance) and proportional egg loss between 1999 and 2015. This correlation was hypothesized to be because years with a hydrograph that dewatered larger proportions of eggs tended to have habitat conditions that were beneficial for survival of subsequent early life history stages. Based on the available data, there is no evidence of negative effects of egg losses less than 3% on recruitment of Rainbow Trout in the LCR. This conclusion should be considered tentative because of the poor fit in the stock-recruitment relationship, and the possibility that sampling biases or environmental variability masked real effects of egg dewatering.

Poor fit of stock-recruitment models with fisheries data is common in the literature for marine and freshwater environments. Failure of these models has been attributed to numerous possible factors, such as errors in measurement (Walters and Ludwig 1981), incorrect spatio-temporal scales (Hutchinson 2008), or environmental variability (Myers 1998). For the LCR, it is unknown how or if different environmental variables may influence survival and recruitment. It is possible to include environmental covariates, in addition to estimated egg dewatering, in the stock-recruitment model to attempt to account for variation in recruitment that is not accounted for by spawning stock size. However, this approach would only be recommended to test specific hypotheses regarding variables thought to influence recruitment and not as an exploratory assessment of all possible environmental effects on recruitment.

## *4.9 Summary*

The sampling program conducted since 2001 provides a high-quality, long-term dataset to address the first management question, which regards changes in fish population metrics over time in the LCR. Hierarchical Bayesian models suggested that the abundance of adult Rainbow Trout increased substantially between 2001 and 2016, and high abundances in recent years coincided with a decline in body condition and survival, suggesting density dependence. Data for Walleye also suggested density-dependence with a decrease in abundance and increase in body condition in recent years (2012 to 2016). The estimated abundance of Mountain Whitefish abundance declined since 2001 but was relatively stable during the most recent five years (2011-2016). The data suggested larger length-at-age of age-0 Mountain Whitefish and greater body condition in 2016 than previous years, suggesting good conditions for growth.

The second management question for this monitoring program pertains to the effects of inter-annual flow variability on fish population metrics of the index species. One of the ways that flow variability can affect fish populations is through egg dewatering during discharge reductions. The effect of egg dewatering on fish abundance was assessed through the analysis of age ratios as a recruitment index and through stock-recruitment models that included egg loss as a covariate. There was no significant relationship between the age-1:2 recruitment index and estimated egg losses. Egg loss was not a significant covariate in the stock-recruitment model for Mountain Whitefish. The stock-recruitment analysis had large variability in Mountain Whitefish recruitment for a particular level of egg loss or spawner abundance, which resulted in weak predictive ability and suggested that other unknown factors likely have a large influence on recruitment in the LCR. For Rainbow Trout, there was no evidence of negative effects of egg losses on recruitment at the observed levels of egg loss, which were less than 3% in all years. These conclusions for both Mountain Whitefish and Rainbow Trout should be considered tentative because of the poor fit in modelled relationships, and the possibility that sampling biases or environmental variability masked real effects of egg dewatering. Flow variability in the LCR is expected to have less of an effect on Walleye than Rainbow Trout and Mountain Whitefish because the abundance of Walleye is thought to depend on spawning and early life history survival outside of the study area. In addition, effects of flow variability on invertebrate productivity, if they occur, would not have direct effects on food availability that could impact the condition or growth of a piscivorous species like Walleye.

# 5.0 RECOMMENDATIONS

The following recommendations for future years of the study are provided:

- The new ageing method using circuli measurements and an algorithm to detect annuli should be used in future study years. Refinements to improve accuracy for age-0 and age-3 and older fish should be investigated, whereas age-1 and age-2 fish were reliably aged with the current model. Additional analyses to validate circuli-based ages and compare this method to the previous ageing methods are recommended to ensure comparability across all study years.
- Calculate the age-1:2 recruitment index for Rainbow Trout to assess inter-annual variation and the effects of egg dewatering. Currently, age data are only available for Rainbow Trout captured from 2001 to 2012. Ageing Rainbow Trout scales collected from 2013 to 2016 using circuli measurements is recommended to allow calculation of the age-1:2 recruitment index for all study years.
- The feasibility of implementing alternative, experimental flow regimes for a single spawning season instead of the current Mountain Whitefish and Rainbow Trout protection flows should be examined. This would provide an opportunity to monitor changes in the parameters of interest under significantly different flow regimes, which would help address the management question regarding the effects of variability in the flow regime on fish populations.

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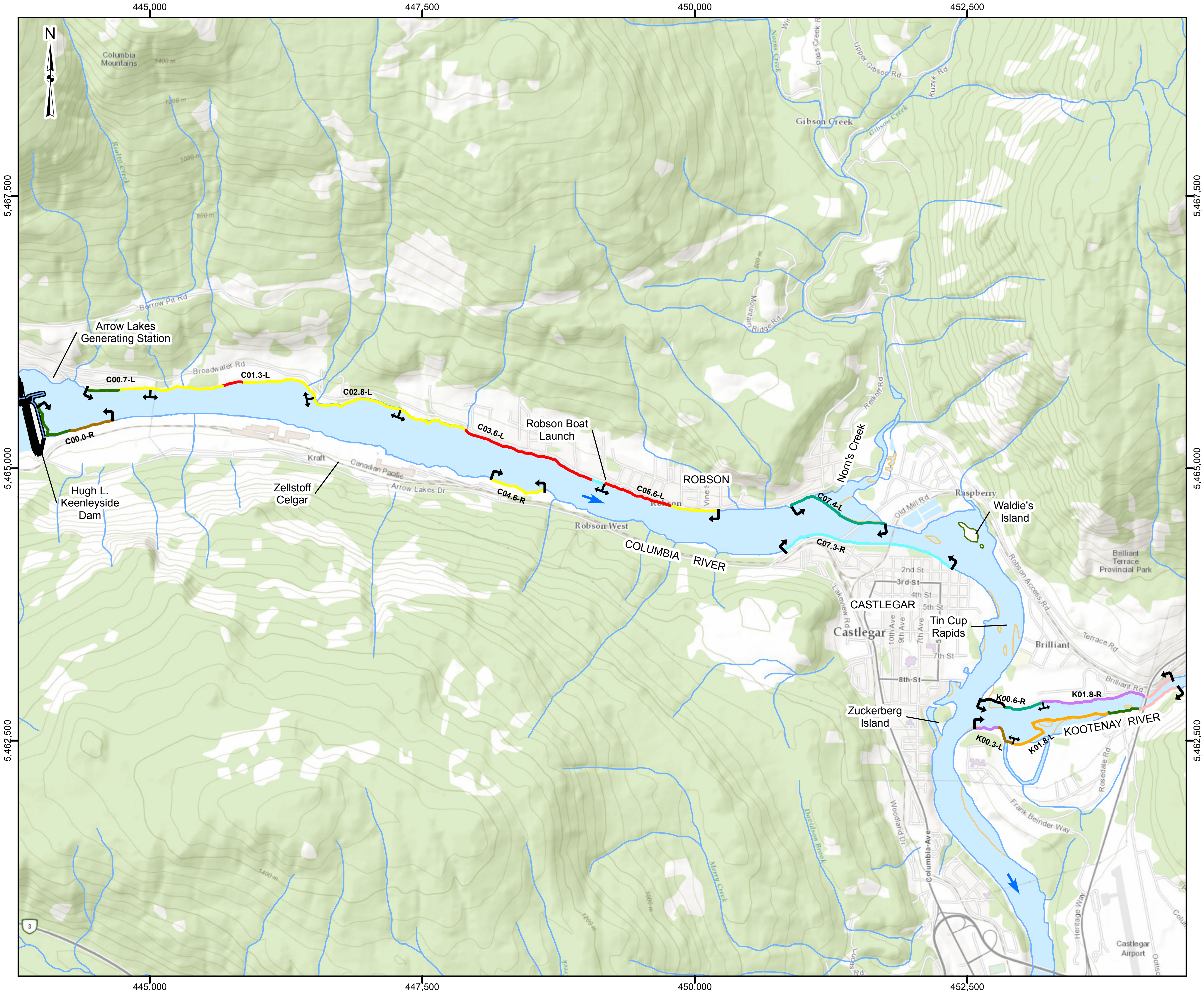
# Appendix A - Maps



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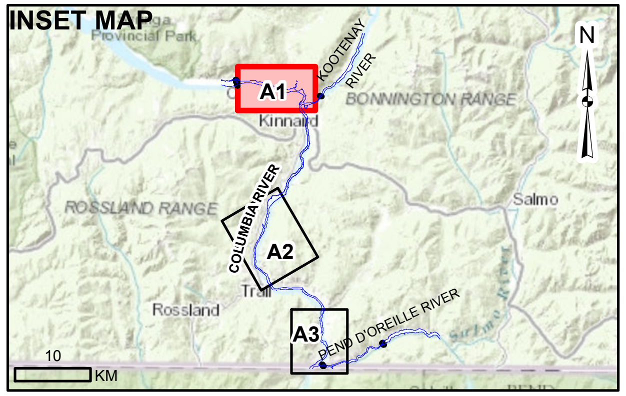
## LEGEND

| | |
|---|---|
| ● | RIVER KILOMETRE DOWNSTREAM OF HUGH L. KEENLEYSIDE DAM |
| ↱C00.0-R ↰ | BOAT ELECTROSHOCKING SITE |
| → | FLOW DIRECTION |
| — | WATERCOURSE |
| — | BREAKWATER |
| ▬ | DAM SECTION |
| — | ISLAND |
| — | SAND OR GRAVEL BAR |

### BANK HABITAT TYPE

- A1 - ARMOURED COBBLE/GRAVEL
- A1+A2 - ARMOURED COBBLE/GRAVEL/SMALL BOULDER
- A2 - ARMOURED COBBLE/SMALL BOULDER
- A2+A3 - ARMOURED COBBLE/SMALL/LARGE/BOULDER
- A3 - ARMOURED SMALL/LARGE BOULDER
- A4 - ARMOURED LARGE BOULDER
- A5 - BEDROCK BANKS
- A6 - MAN-MADE RIP-RAP
- BW - BACKWATER
- D1 - DEPOSITIONAL SAND/SILT
- D1+D2 - DEPOSITIONAL SAND/SILT/GRAVEL/COBBLE
- D2 - DEPOSITIONAL GRAVEL/COBBLE
- D3 - DEPOSITIONAL LARGE COBBLE
- EDDY - EDDY

### INSET MAP



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SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY.

PROJECTION: UTM ZONE 11 DATUM: NAD 83

600 0 600

SCALE 1:35,000 METRES

PROJECT

LARGE RIVER FISH INDEXING PROGRAM
LOWER COLUMBIA RIVER

TITLE

## UPPER SECTION OF STUDY AREA
## SAMPLE SITE LOCATIONS

Golder Associates

| PROJECT No. 1537874 | | | SCALE AS SHOWN | REV. 0 |
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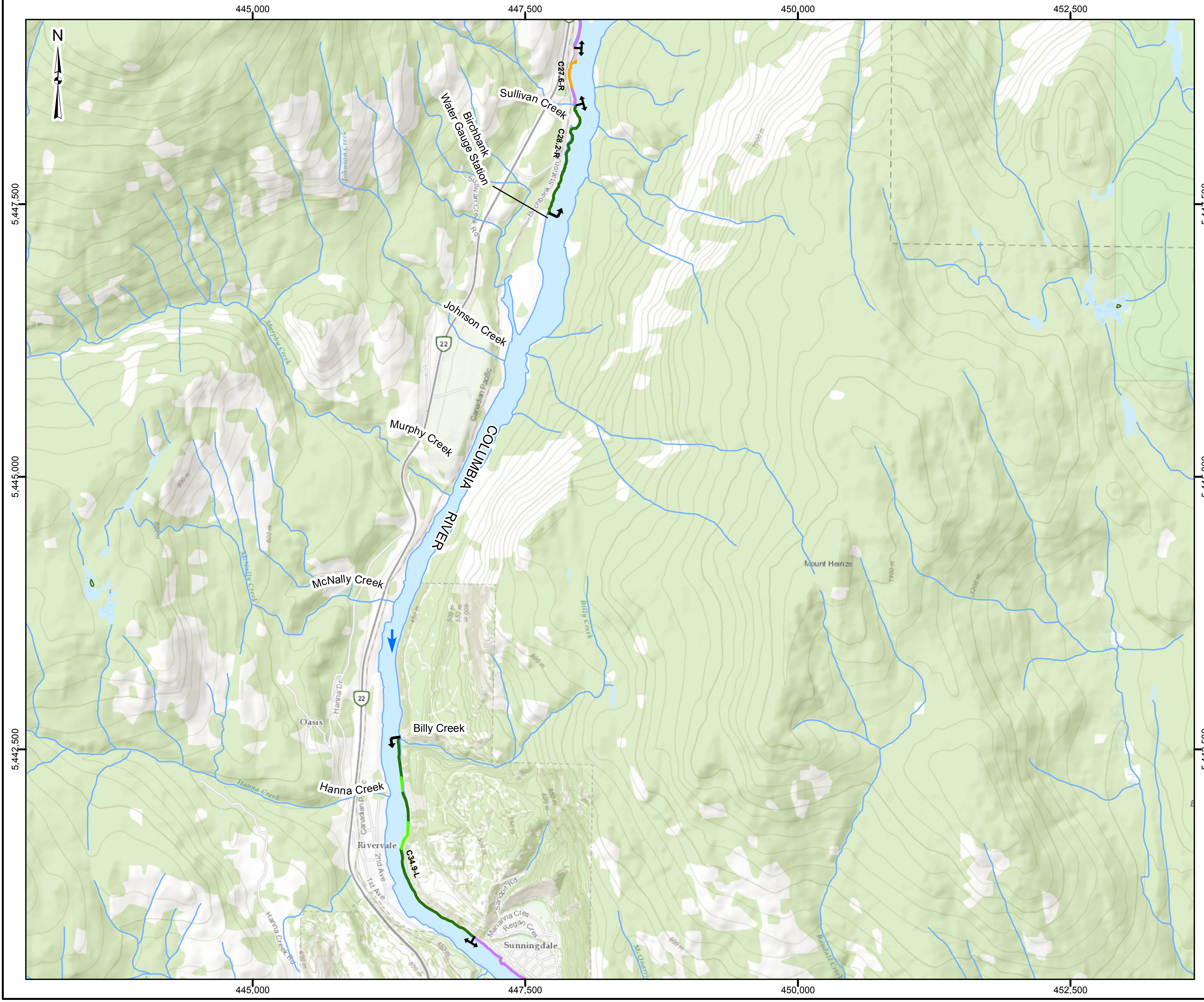


## LEGEND

● RIVER KILOMETRE DOWNSTREAM OF HUGH L. KEENLEYSIDE DAM

↱C00.0-R↰ BOAT ELECTROSHOCKING SITE

→ FLOW DIRECTION

WATERCOURSE

BREAKWATER

DAM SECTION

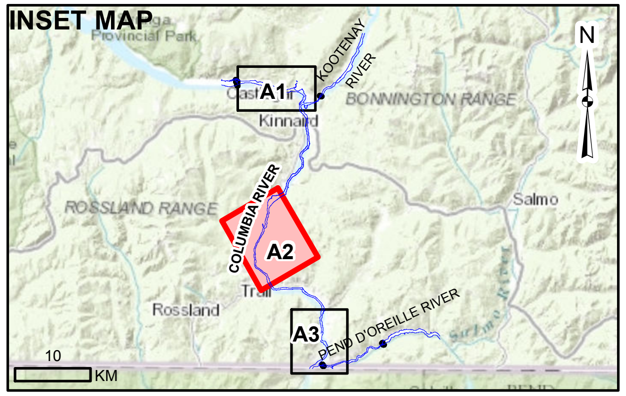
ISLAND

SAND OR GRAVEL BAR

### BANK HABITAT TYPE

- A1 - ARMOURED COBBLE/GRAVEL
- A1+A2 - ARMOURED COBBLE/GRAVEL/SMALL BOULDER
- A2 - ARMOURED COBBLE/SMALL BOULDER
- A2+A3 - ARMOURED COBBLE/SMALL/LARGE/BOULDER
- A3 - ARMOURED SMALL/LARGE BOULDER
- A4 - ARMOURED LARGE BOULDER
- A5 - BEDROCK BANKS
- A6 - MAN-MADE RIP-RAP
- BW - BACKWATER
- D1 - DEPOSITIONAL SAND/SILT
- D1+D2 - DEPOSITIONAL SAND/SILT/GRAVEL/COBBLE
- D2 - DEPOSITIONAL GRAVEL/COBBLE
- D3 - DEPOSITIONAL LARGE COBBLE
- EDDY - EDDY

### INSET MAP



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PROJECTION: UTM ZONE 11 DATUM: NAD 83

600 0 600

SCALE 1:35,000 METRES

PROJECT

LARGE RIVER FISH INDEXING PROGRAM
LOWER COLUMBIA RIVER

TITLE

## MIDDLE SECTION OF STUDY AREA
## SAMPLE SITE LOCATIONS

Golder Associates

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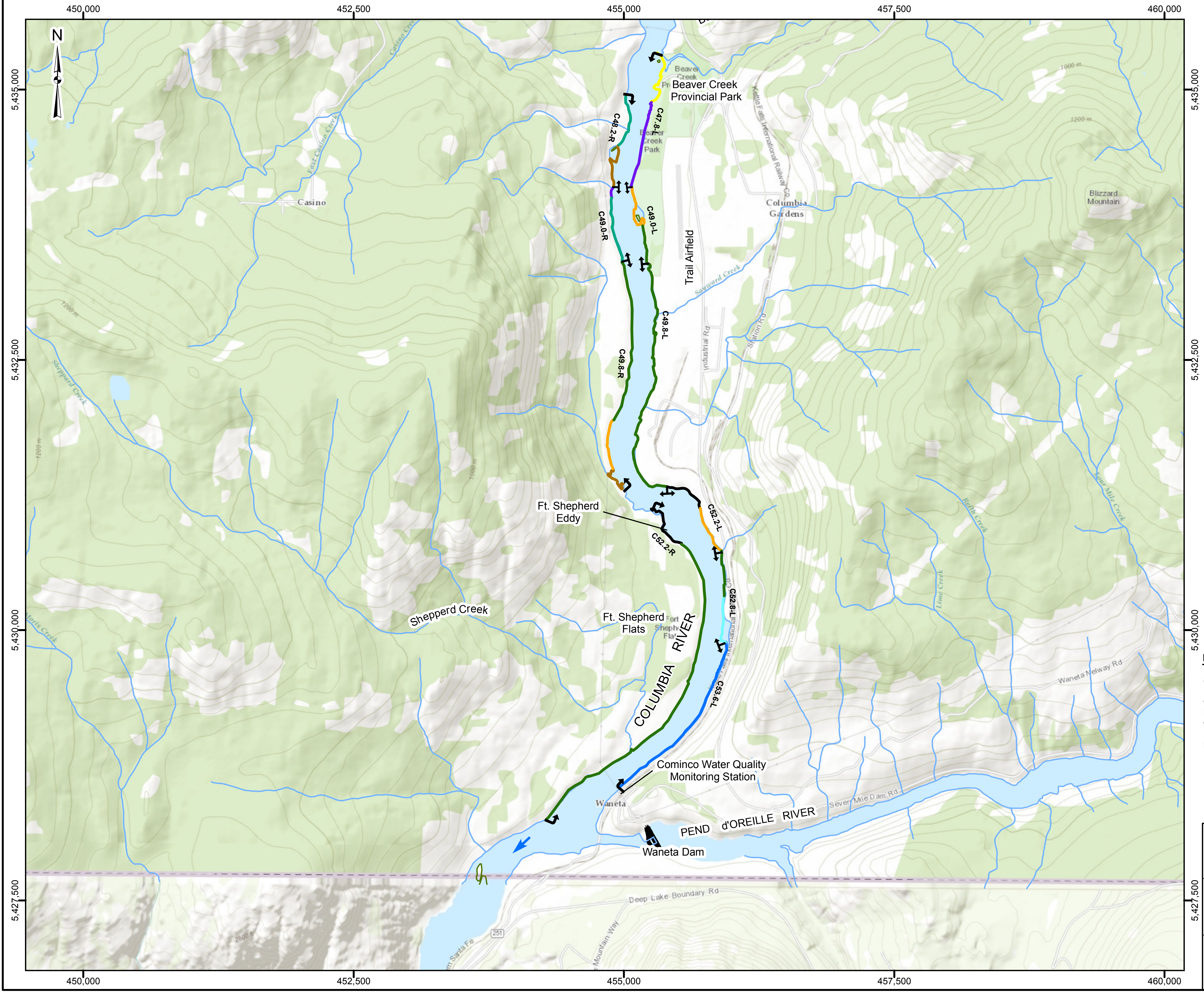


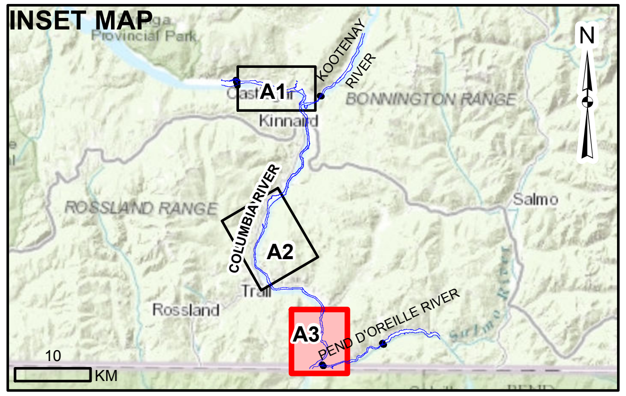
## LEGEND

● RIVER KILOMETRE DOWNSTREAM OF HUGH L. KEENLEYSIDE DAM
C00.0-R BOAT ELECTROSHOCKING SITE
FLOW DIRECTION
WATERCOURSE
BREAKWATER
DAM SECTION
ISLAND
SAND OR GRAVEL BAR

### BANK HABITAT TYPE

A1 - ARMOURED COBBLE/GRAVEL
A1+A2 - ARMOURED COBBLE/GRAVEL/SMALL BOULDER
A2 - ARMOURED COBBLE/SMALL BOULDER
A2+A3 - ARMOURED COBBLE/SMALL/LARGE/BOULDER
A3 - ARMOURED SMALL/LARGE BOULDER
A4 - ARMOURED LARGE BOULDER
A5 - BEDROCK BANKS
A6 - MAN-MADE RIP-RAP
BW - BACKWATER
D1 - DEPOSITIONAL SAND/SILT
D1+D2 - DEPOSITIONAL SAND/SILT/GRAVEL/COBBLE
D2 - DEPOSITIONAL GRAVEL/COBBLE
D3 - DEPOSITIONAL LARGE COBBLE
EDDY - EDDY

## INSET MAP



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PROJECTION: UTM ZONE 11 DATUM: NAD 83

600 0 600
SCALE 1:35,000 METRES

PROJECT

LARGE RIVER FISH INDEXING PROGRAM
LOWER COLUMBIA RIVER

TITLE

## LOWER SECTION OF STUDY AREA SAMPLE SITE LOCATIONS

Golder Associates

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Table A1 Locations and distances from Hugh L. Keenleyside Dam of boat electroshocking sites in the lower Columbia River, 2016.

| Site Designation[a] | Location (km)[b] | Bank[c] | UTM Coordinates | | |
|---|---|---|---|---|---|
| | | | Zone | Easting | Northing |
| **Columbia River Upstream** | | | | | |
| C00.0-R U/S | 0.0 | RDB | 11U | 443996 | 5465466 |
| C00.0-R D/S | 0.9 | RDB | 11U | 444649 | 5465448 |
| C00.7-L U/S | 0.7 | LDB | 11U | 444387 | 5465734 |
| C00.7-L D/S | 1.3 | LDB | 11U | 445015 | 5465719 |
| C01.3-L U/S | 1.3 | LDB | 11U | 445015 | 5465719 |
| C01.3-L D/S | 2.8 | LDB | 11U | 446504 | 5465652 |
| C02.8-L U/S | 2.8 | LDB | 11U | 446504 | 5465652 |
| C02.8-L D/S | 3.6 | LDB | 11U | 447294 | 5465482 |
| C03.6-L U/S | 3.6 | LDB | 11U | 447294 | 5465482 |
| C03.6-L D/S | 5.6 | LDB | 11U | 449206 | 5464833 |
| C04.6-R U/S | 4.6 | RDB | 11U | 448162 | 5464921 |
| C04.6-R D/S | 5.1 | RDB | 11U | 448614 | 5464820 |
| C05.6-L U/S | 5.6 | LDB | 11U | 449206 | 5464833 |
| C05.6-L D/S | 6.7 | LDB | 11U | 450212 | 5464594 |
| C07.3-R U/S | 7.3 | RDB | 11U | 450808 | 5464265 |
| C07.3-R D/S | 9.0 | RDB | 11U | 452366 | 5464096 |
| C07.4-L U/S | 7.4 | LDB | 11U | 450892 | 5464632 |
| C07.4-L D/S | 8.3 | LDB | 11U | 451742 | 5464481 |
| **Kootenay River** | | | | | |
| K00.3-L U/S | 0.3 | LDB | 11U | 453656 | 5462748 |
| K00.3-L D/S | 0.0 | LDB | 11U | 452578 | 5462650 |
| K00.6-R U/S | 0.6 | RDB | 11U | 453151 | 5462849 |
| K00.6-R D/S | 0.0 | RDB | 11U | 452627 | 5462822 |
| K01.8-L U/S | 1.8 | LDB | 11U | 454451 | 5462972 |
| K01.8-L D/S | 0.3 | LDB | 11U | 453656 | 5462748 |
| K01.8-R U/S | 1.8 | RDB | 11U | 454398 | 5463053 |
| K01.8-R D/S | 0.6 | RDB | 11U | 453151 | 5462849 |
| **Columbia River Downstream** | | | | | |
| C25.3-R U/S | 25.3 | RDB | 11U | 449606 | 5450670 |
| C25.3-R D/S | 27.6 | RDB | 11U | 448277 | 5450106 |
| C27.6-R U/S | 27.6 | RDB | 11U | 448277 | 5450106 |
| C27.6-R D/S | 28.1 | RDB | 11U | 447985 | 5448428 |
| C28.2-R U/S | 28.2 | RDB | 11U | 447985 | 5448428 |
| C28.2-R D/S | 29.2 | RDB | 11U | 447749 | 5447453 |
| C34.9-L U/S | 34.9 | LDB | 11U | 446321 | 5442589 |
| C34.9-L D/S | 36.6 | LDB | 11U | 447116 | 5440687 |
| C36.6-L U/S | 36.6 | LDB | 11U | 447116 | 5440687 |
| C36.6-L D/S | 38.8 | LDB | 11U | 448286 | 5438982 |
| C47.8-L U/S | 47.8 | LDB | 11U | 455317 | 5435244 |
| C47.8-L D/S | 49.0 | LDB | 11U | 455121 | 5434301 |
| C48.2-R U/S | 48.2 | RDB | 11U | 455021 | 5434885 |
| C48.2-R D/S | 49.0 | RDB | 11U | 455177 | 5434013 |
| C49.0-L U/S | 49.0 | LDB | 11U | 455121 | 5434301 |
| C49.0-L D/S | 49.8 | LDB | 11U | 455204 | 5433379 |
| C49.0-R U/S | 49.0 | RDB | 11U | 455177 | 5434013 |
| C49.0-R D/S | 49.8 | RDB | 11U | 454993 | 5433410 |
| C49.8-L U/S | 49.8 | LDB | 11U | 455204 | 5433379 |
| C49.8-L D/S | 52.2 | LDB | 11U | 455385 | 5431291 |
| C49.8-R U/S | 49.8 | RDB | 11U | 454993 | 5433410 |
| C49.8-R D/S | 51.9 | RDB | 11U | 454976 | 5431377 |
| C52.2-L U/S | 52.2 | LDB | 11U | 455385 | 5431291 |
| C52.2-L D/S | 52.8 | LDB | 11U | 455888 | 5430887 |
| C52.2-R U/S | 52.2 | RDB | 11U | 455350 | 5431088 |
| C52.2-R D/S | 56.0 | RDB | 11U | 454287 | 5428238 |
| C52.8-L U/S | 52.8 | LDB | 11U | 455888 | 5430887 |
| C52.8-L D/S | 53.6 | LDB | 11U | 455898 | 5429799 |

[a] U/S = Upstream limit of site; D/S = Downstream limit of site.

[b] River kilometres downstream from Hugh L. Keenleyside Dam.

[c] LDB=Left bank as viewed facing downstream; RDB = Right bank as viewed facing downstream.

Table A2 Locations of selected sites and available sites included in the Generalized Random Tessellation Stratified (GRTS) survey, 2016.

| Site Designation | Location (km)[a] | Bank[b] | Upstream UTM Coordinates | | | Downstream UTM Coordinates | | | Sites Selected in 2016 |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone | Easting | Northing | Zone | Easting | Northing | |
| **Columbia River Upstream** | | | | | | | | | |
| C01.0-R | 1.0 | RDB | 11U | 444717 | 5465448 | 11U | 447236 | 5465125 | |
| C03.6-R | 3.6 | RDB | 11U | 447236 | 5465125 | 11U | 448125 | 5464914 | |
| C05.1-R | 5.1 | RDB | 11U | 448612 | 5464808 | 11U | 449518 | 5464513 | |
| C06.0-R | 6.0 | RDB | 11U | 449518 | 5464513 | 11U | 450804 | 5464243 | X |
| C06.7-L | 6.7 | LDB | 11U | 450223 | 5464603 | 11U | 450876 | 5464645 | |
| C08.4-L | 8.4 | LDB | 11U | 451833 | 5464445 | 11U | 452304 | 5464244 | |
| C08.6-L | 8.6 | LDB | 11U | 452132 | 5464468 | 11U | 452720 | 5464206 | |
| C08.9-R | 8.9 | RDB | 11U | 452375 | 5464074 | 11U | 452797 | 5463486 | |
| C09.0-L | 9.0 | LDB | 11U | 452286 | 5462718 | 11U | 452286 | 5462718 | |
| C09.2-L | 9.2 | LDB | 11U | 452720 | 5464206 | 11U | 452987 | 5463481 | |
| C09.8-L | 9.8 | LDB | 11U | 452926 | 5463604 | 11U | 452620 | 5462860 | |
| C09.8-R | 9.8 | RDB | 11U | 452761 | 5463608 | 11U | 452416 | 5462880 | |
| **Columbia River Downstream** | | | | | | | | | |
| C10.7-R | 10.7 | LDB | 11U | 452416 | 5462880 | 11U | 452217 | 5462050 | |
| C10.8-R | 10.8 | RDB | 11U | 452154 | 5462718 | 11U | 452154 | 5462718 | |
| C10.9-L | 10.9 | LDB | 11U | 452584 | 5462607 | 11U | 453290 | 5460373 | X |
| C11.5-R | 11.5 | RDB | 11U | 452217 | 5462050 | 11U | 453103 | 5460426 | X |
| C13.4-L | 13.4 | LDB | 11U | 453290 | 5460373 | 11U | 453321 | 5459007 | X |
| C13.4-R | 13.4 | RDB | 11U | 453103 | 5460426 | 11U | 453221 | 5458057 | |
| C14.8-L | 14.8 | LDB | 11U | 453321 | 5459007 | 11U | 453210 | 5456890 | X |
| C15.8-R | 15.8 | RDB | 11U | 453221 | 5458057 | 11U | 453234 | 5457317 | |
| C16.6-R | 16.6 | RDB | 11U | 453234 | 5457317 | 11U | 452358 | 5456216 | |
| C17.0-L | 17.0 | LDB | 11U | 453210 | 5456890 | 11U | 452622 | 5455322 | X |
| C18.0-R | 18.0 | RDB | 11U | 452358 | 5456216 | 11U | 452351 | 5455401 | |
| C18.8-R | 18.8 | RDB | 11U | 452351 | 5455401 | 11U | 452122 | 5454012 | X |
| C19.0-L | 19.0 | LDB | 11U | 452622 | 5455322 | 11U | 452444 | 5454183 | |
| C20.1-L | 20.1 | LDB | 11U | 452444 | 5454182 | 11U | 451645 | 5453285 | X |
| C20.4-R | 20.4 | RDB | 11U | 452122 | 5454012 | 11U | 451093 | 5453191 | |
| C21.3-L | 21.3 | LDB | 11U | 451645 | 5453285 | 11U | 450603 | 5451637 | |
| C21.8-R | 21.8 | RDB | 11U | 451093 | 5453191 | 11U | 450495 | 5452148 | |
| C22.9-R | 22.9 | RDB | 11U | 450495 | 5452148 | 11U | 450188 | 5451058 | |
| C23.4-L | 23.4 | LDB | 11U | 450603 | 5451637 | 11U | 450368 | 5450764 | X |
| C24.0-R | 24.0 | RDB | 11U | 450188 | 5451058 | 11U | 449356 | 5450418 | |
| C24.3-L | 24.3 | LDB | 11U | 450368 | 5450764 | 11U | 449178 | 5449989 | X |
| C25.3-L | 25.3 | MID | 11U | 448978 | 5450229 | 11U | 448978 | 5450229 | |
| C26.2-L | 26.2 | MID | 11U | 448938 | 5449626 | 11U | 448938 | 5449626 | |
| C27.5-L | 27.5 | LDB | 11U | 448193 | 5449036 | 11U | 448064 | 5447758 | |
| C28.8-L | 28.8 | LDB | 11U | 448064 | 5447758 | 11U | 447820 | 5446998 | X |
| C29.2-R | 29.2 | RDB | 11U | 447715 | 5447420 | 11U | 447397 | 5446252 | |
| C29.6-L | 29.6 | LDB | 11U | 447820 | 5446998 | 11U | 447491 | 5446079 | |
| C30.5-R | 30.5 | RDB | 11U | 447397 | 5446252 | 11U | 446817 | 5444824 | X |
| C30.6-L | 30.6 | LDB | 11U | 447491 | 5446079 | 11U | 446746 | 5444432 | X |
| C32.0-R | 32.0 | RDB | 11U | 446817 | 5444824 | 11U | 446256 | 5443655 | X |
| C32.4-L | 32.4 | LDB | 11U | 446746 | 5444432 | 11U | 446353 | 5442572 | |
| C33.3-R | 33.3 | RDB | 11U | 446256 | 5443655 | 11U | 446260 | 5442116 | |
| C34.9-R | 34.9 | RDB | 11U | 446260 | 5442116 | 11U | 446294 | 5441253 | |
| C35.7-R | 35.7 | RDB | 11U | 446294 | 5441253 | 11U | 447152 | 5440472 | |
| C36.9-R | 36.9 | RDB | 11U | 447152 | 5440472 | 11U | 448305 | 5438607 | |
| C38.8-L | 38.8 | LDB | 11U | 448340 | 5439017 | 11U | 449001 | 5438233 | |
| C39.2-R | 39.2 | RDB | 11U | 448305 | 5438607 | 11U | 448995 | 5438083 | |
| C40.0-L | 40.0 | LDB | 11U | 449001 | 5438233 | 11U | 450090 | 5438405 | X |
| C40.0-R | 40.0 | RDB | 11U | 448995 | 5438083 | 11U | 450459 | 5438222 | |
| C41.1-L | 41.1 | LDB | 11U | 450090 | 5438405 | 11U | 452466 | 5438365 | X |
| C41.5-R | 41.5 | RDB | 11U | 450459 | 5438222 | 11U | 452579 | 5438015 | |
| C43.5-L | 43.5 | LDB | 11U | 452466 | 5438365 | 11U | 453245 | 5437597 | |
| C43.7-R | 43.7 | RDB | 11U | 452579 | 5438015 | 11U | 453275 | 5437384 | X |
| C44.6-L | 44.6 | LDB | 11U | 453245 | 5437597 | 11U | 454179 | 5437228 | |
| C44.7-R | 44.7 | RDB | 11U | 453275 | 5437384 | 11U | 454560 | 5436673 | |
| C45.6-L | 45.6 | LDB | 11U | 454179 | 5437228 | 11U | 454855 | 5436623 | X |
| C46.2-R | 46.2 | RDB | 11U | 454560 | 5436673 | 11U | 455141 | 5435856 | |
| C46.4-L | 46.4 | LDB | 11U | 454855 | 5436623 | 11U | 455319 | 5435321 | |
| C47.2-R | 47.2 | RDB | 11U | 455141 | 5435856 | 11U | 455017 | 5434942 | X |
| C56.0-L | 56.0 | LDB | 11U | 454774 | 5428024 | 11U | 453949 | 5427733 | X |

[a] River kilometres downstream from Hugh L. Keenleyside Dam.

[b] LDB = Left bank as viewed facing downstream; RDB = Right bank as viewed facing downstream.

# Appendix B – Habitat Summary Information

Table B1 Descriptions of categories used in the Lower Columbia River Bank Habitat Types Classification System.

| Category | Code | Description |
|---|---|---|
| Armoured/Stable | A1 | Banks generally stable and at repose with cobble/small boulder/gravel substrates predominating; uniform shoreline configuration with few/minor bank irregularities; velocities adjacent to bank generally low-moderate, instream cover limited to substrate roughness (i.e., cobble/small boulder interstices). |
| | A2 | Banks generally stable and at repose with cobble/small boulder and large boulder substrates predominating; irregular shoreline configuration generally consisting of a series of armoured cobble/boulder outcrops that produce Backwater habitats; velocities adjacent to bank generally moderate with low velocities provided in BW habitats: instream cover provided by BW areas and substrate roughness; overhead cover provided by depth and woody debris; occasionally associated with C2, E4, and E5 banks. |
| | A3 | Similar to A2 in terms of bank configuration and composition although generally with higher composition of large boulders/bedrock fractures; very irregular shoreline produced by large boulders and bed rock outcrops; velocities adjacent to bank generally moderate to high; instream cover provided by numerous small BW areas, eddy pools behind submerged boulders, and substrate interstices; overhead cover provided by depth; exhibits greater depths offshore than found in A1 or A2 banks; often associated with C1 banks. |
| | A4 | Gently sloping banks with predominantly small and large boulders (boulder garden) often embedded in finer materials; shallow depths offshore, generally exhibits moderate to high velocities; instream cover provided by “pocket eddies” behind boulders; overhead cover provided by surface turbulence. |
| | A5 | Bedrock banks, generally steep in profile resulting in deep water immediately offshore; often with large bedrock fractures in channel that provide instream cover; usually associated with moderate to high current velocities; overhead cover provided by depth. |
| | A6 | Man-made banks usually armoured with large boulder or concrete rip-rap; depths offshore generally deep and usually found in areas with moderate to high velocities; instream cover provided by rip-rap interstices; overhead cover provided by depth and turbulence. |
| Depositional | D1 | Low relief, gently sloping bank type with shallow water depths offshore; substrate consists predominantly of fines (i.e., sand/silt); low current velocities offshore; instream cover generally absent or, if present, consisting of shallow depressions produced by dune formation (i.e., in sand substrates) or embedded cobble/boulders and vegetative debris; this bank type was generally associated with bar formations or large backwater areas. |
| | D2 | Low relief, gently sloping bank type with shallow water depths offshore; substrate consists of coarse materials (i.e., gravels/cobbles); low-moderate current velocities offshore; areas with higher velocities usually producing riffle areas; overhead cover provided by surface turbulence in riffle areas; instream cover provided by substrate roughness; often associated with bar formations and shoal habitat. |
| | D3 | Similar to D2 but with coarser substrates (i.e., large cobble/small boulder) more dominant; boulders often embedded in cobble/gravel matrix; generally found in areas with higher average flow velocities than D1 or D2 banks; instream cover abundantly available in form of substrate roughness; overhead cover provided by surface turbulence; often associated with fast riffle transitional bank type that exhibits characteristics of both Armoured and Depositional bank types. |
| **SPECIAL HABITAT FEATURES** | | |
| BACKWATER POOLS | - | These areas represent discrete areas along the channel margin where backwater irregularities produce localized areas of counter-current flows or areas with reduced flow velocities relative to the mainstem; can be quite variable in size and are often an integral component of Armoured and erosional bank types. The availability and suitability of Backwater pools are determined by flow level. To warrant separate identification as a discrete unit, must be a minimum of 10 m in length; widths highly variable depending on bank irregularity that produces the pool. Three classes are identified: |
| | BW-P1 | Highest quality pool habitat type for adult and subadult cohorts for feeding/holding functions. Maximum depth exceeding 2.5 m, average depth 2.0 m or greater; high availability of instream cover types (e.g., submerged boulders, bedrock fractures, depth, woody debris); usually with Moderate to High countercurrent flows that provide overhead cover in the form of surface turbulence. |
| | BW-P2 | Moderate quality pool type for adult and subadult cohorts for feeding/holding; also provides moderate quality habitat for smaller juveniles for rearing. Maximum depths between 2.0 to 2.5 m, average depths generally in order of 1.5 m. Moderate availability of instream cover types; usually with Low to Moderate countercurrent flow velocities that provide limited overhead cover. |

Continued.

Table B1  Concluded.

| | | |
|---|---|---|
| | BW-P3 | Low quality pool type for adult/subadult classes; moderate-high quality habitat for y-o-y and small juveniles for rearing. Maximum depth <1.0 m. Low availability of instream cover types; usually with Low-Nil current velocities. |
| EDDY POOL | EDDY | Represent large (<30 m in diameter) areas of counter current flows with depths generally >5 m; produced by major bank irregularities and are available at all flow stages although current velocities within eddy are dependent on flow levels. High quality areas for adult and subadult life stages. High availability of instream cover. |
| SNYE | SN | A side channel area that is separated from the mainstem at the upstream end but retains a connection at the lower end. SN habitats generally present only at lower flow stages since area is a flowing side channel at higher flows: characterized by low-nil velocity, variable depths (generally <3 m) and predominantly depositional substrates (i.e., sand/silt/gravel); often supports growths of aquatic vegetation; very important areas for rearing and feeding. |

**Velocity Classifications:**

Low: <0.5 m/s
Moderate: 0.5 to 1.0 m/s
High: >1.0 m/s

Table B2 Length of bank habitat types at boat electroshocking sites within the lower Columbia River, 2016.

| **Section** | **Site**[a] | **Length (m) of Bank Habitat Type**[b] | | | | | | | | | | | | | | **Total Length (m)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A1+A2** | **A2+A3** | **D1** | **D2** | **D3** | **D1+D2** | **BW** | **Eddy** | |
| Upstream Columbia | C00.0-R | | 543 | | | | | | | | | | | 394 | | **937** |
| | C00.7-L | | 290 | | | | | | | 303 | | | | | | **593** |
| | C01.3-L | 200 | | | | | | | | 1401 | | | | | | **1601** |
| | C02.8-L | | | | | | | | | 882 | | | | | | **882** |
| | C03.6-L | 1276 | | | 121 | | | | | 691 | | | | | | **2087** |
| | C04.6-R | | | | | | | | | 517 | | | | | | **517** |
| | C05.6-L | 654 | | | | | | | | 447 | | | | | | **1101** |
| | C07.3-R | | | | 1705 | | | | | | | | | | | **1705** |
| | C07.4-L | | | | | | | | | | | | 998 | | | **998** |
| Upstream Columbia Total | | 2130 | 833 | | 1826 | | | | | 4241 | | | 998 | 394 | | **10 422** |
| Kootenay River | K00.3-L | | | | | | | | 230 | | | | | 207 | | **436** |
| | K00.6-R | | | | | | | | | | | | 364 | | 232 | **596** |
| | K01.8-L | | 304 | | | 387 | | | | | 1179 | | | | | **1871** |
| | K01.8-R | | | | | 326 | | | 971 | | | | | | | **1296** |
| Kootenay River Total | | | 304 | | | 713 | | | 1200 | | 1179 | | 364 | 207 | 232 | **4199** |
| Downstream Columbia | C25.3-R | 1380 | | | | 317 | | | 1029 | | | | | | | **2727** |
| | C27.6-R | | | | | 122 | | | 185 | | 306 | | | | | **613** |
| | C28.2-R | | 1131 | | | | | | | | | | | | | **1131** |
| | C34.9-L | | 1740 | 396 | | | | | | | | | | | | **2136** |
| | C36.6-L | | | | | 880 | | | 1031 | | | 483 | | | | **2395** |
| | C47.8-L | | | | | | | | 826 | 613 | | | | | | **1439** |
| | C48.2-R | | | | | | | | | | | | 495 | 514 | | **1009** |
| | C49.0-L | | 379 | | | | | | | | 550 | | | | | **930** |
| | C49.0-R | | | | | | | 101 | | | | | 618 | | | **720** |
| | C49.8-L | | 2447 | | | | | | | | | | | | | **2447** |
| | C49.8-R | | 1511 | | | | | | | | 489 | | | 391 | | **2391** |
| | C52.2-L | | | | | | | | | | 458 | | | | 431 | **889** |
| | C52.2-R | | 3272 | | | | | | | | | | | | 518 | **3790** |
| | C52.8-L | | 428 | | 464 | | | | | | | | | | | **893** |
| | C53.6-L | | | | | | 1518 | | | | | | | | | **1518** |
| Downstream Columbia Total | | 1380 | 10909 | 396 | 464 | 1320 | 1518 | 101 | 3072 | 613 | 1802 | 483 | 1113 | 905 | 949 | **25 026** |
| **Grand Total** | | **3510** | **12047** | **396** | **2290** | **2033** | **1518** | **101** | **4272** | **4854** | **2982** | **483** | **2475** | **1506** | **1181** | **39 648** |

[a] See Appendix A, Figures A1 to A3 for sample site locations.

[b] See Appendix B, Table B1 for bank habitat type descriptions.

Table B3 Summary of habitat variables recorded at boat electroshocking sites in the Middle Columbia River, 3 October to 4 November 2016.

| Section | Site[a] | Session | Air Temperature (°C) | Water Temperature (°C) | Conductivity (µS) | Cloud Cover[b] | Water Surface Visibility | Instream Velocity[c] | Water Clarity[d] | Cover Types (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Substrate Interstices | Woody Debris | Turbulence | Aquatic Vegetation | Terrestrial Vegetation | Shallow Water | Deep Water |
| Kootenay | K01.8-R | 1 | 9.0 | 14.5 | 150 | Mostly cloudy | High | High | High | 20 | 0 | 0 | 0 | 0 | 70 | 10 |
| Kootenay | K01.8-R | 2 | 3.0 | 12.2 | 140 | Clear | High | High | High | 10 | 0 | 0 | 0 | 0 | 70 | 20 |
| Kootenay | K01.8-R | 3 | 9.0 | 11.6 | 130 | Mostly cloudy | High | High | High | 0 | 0 | 0 | 0 | 0 | 85 | 15 |
| Kootenay | K01.8-R | 4 | 8.0 | 10.9 | 140 | Overcast | Medium | High | High | 10 | 0 | 0 | 0 | 0 | 70 | 20 |
| Kootenay | K01.8-L | 1 | 8.0 | 14.5 | 150 | Mostly cloudy | High | High | High | 0 | 0 | 0 | 0 | 0 | 85 | 15 |
| Kootenay | K01.8-L | 2 | 2.0 | 12.2 | 140 | Clear | Medium | High | High | 20 | 0 | 0 | 0 | 0 | 70 | 10 |
| Kootenay | K01.8-L | 3 | 5.0 | 11.6 | 130 | Partly cloudy | Medium | High | High | 0 | 0 | 0 | 0 | 0 | 90 | 10 |
| Kootenay | K01.8-L | 4 | 7.0 | 10.9 | 140 | Overcast | Medium | High | High | 10 | 0 | 0 | 0 | 0 | 75 | 15 |
| Kootenay | K00.6-R | 1 | 9.0 | 14.5 | 150 | Mostly cloudy | High | Low | High | 0 | 0 | 0 | 85 | 0 | 15 | 0 |
| Kootenay | K00.6-R | 2 | 3.9 | 12.7 | 140 | Clear | Medium | High | High | 0 | 0 | 0 | 25 | 0 | 75 | 0 |
| Kootenay | K00.6-R | 3 | 8.9 | 11.6 | 140 | Partly cloudy | High | High | High | 5 | 0 | 0 | 20 | 0 | 75 | 0 |
| Kootenay | K00.6-R | 4 | 7.0 | 10.9 | 140 | Overcast | Medium | High | High | 0 | 0 | 0 | 20 | 0 | 80 | 0 |
| Kootenay | K00.3-L | 1 | 8.0 | 14.5 | 150 | Partly cloudy | High | High | High | 15 | 0 | 0 | 0 | 0 | 80 | 5 |
| Kootenay | K00.3-L | 2 | 1.0 | 12.2 | 140 | Clear | Medium | High | High | 10 | 0 | 0 | 0 | 0 | 40 | 50 |
| Kootenay | K00.3-L | 3 | 4.0 | 11.6 | 130 | Partly cloudy | Medium | High | High | 20 | 0 | 0 | 0 | 0 | 40 | 40 |
| Kootenay | K00.3-L | 4 | 8.0 | 10.9 | 140 | Overcast | Medium | High | High | 20 | 0 | 0 | 0 | 0 | 30 | 50 |
| Lower | C56.0-L | 5 | 5.0 | 11.0 | 150 | Overcast | Medium | High | High | 10 | 0 | 0 | 0 | 0 | 20 | 70 |
| Lower | C53.6-L | 1 | 7.0 | 13.8 | 130 | Clear | Medium | High | High | 20 | 0 | 0 | 2 | 0 | 68 | 10 |
| Lower | C53.6-L | 2 | 9.0 | 12.3 | 140 | Overcast | High | High | High | 30 | 0 | 0 | 1 | 0 | 30 | 39 |
| Lower | C53.6-L | 3 | 6.0 | 11.4 | 140 | Partly cloudy | High | High | High | 50 | 0 | 0 | 2 | 0 | 0 | 48 |
| Lower | C53.6-L | 4 | 9.0 | 10.8 | 140 | Overcast | High | High | High | 20 | 0 | 0 | 0 | 0 | 10 | 70 |
| Lower | C52.8-L | 1 | 9.0 | 13.8 | 130 | Clear | High | High | High | 30 | 0 | 10 | 0 | 0 | 60 | 0 |
| Lower | C52.8-L | 2 | 8.0 | 12.3 | 140 | Overcast | Medium | High | High | 20 | 0 | 0 | 0 | 0 | 50 | 30 |
| Lower | C52.8-L | 3 | 6.0 | 11.4 | 140 | Partly cloudy | High | High | High | 20 | 0 | 0 | 0 | 0 | 20 | 60 |
| Lower | C52.8-L | 4 | 9.0 | 10.8 | 140 | Overcast | High | High | High | 30 | 0 | 0 | 0 | 0 | 25 | 45 |
| Lower | C52.2-R | 1 | 9.0 | 14.3 | 130 | Overcast | High | High | High | 5 | 0 | 0 | 0 | 0 | 90 | 5 |
| Lower | C52.2-R | 2 | 7.0 | 12.4 | 130 | Overcast | Medium | High | High | 20 | 0 | 0 | 0 | 0 | 70 | 10 |
| Lower | C52.2-R | 3 | 6.0 | 11.4 | 140 | Partly cloudy | High | High | High | 0 | 0 | 0 | 0 | 0 | 90 | 10 |
| Lower | C52.2-R | 4 | 6.0 | 11.2 | 140 | Overcast | Medium | High | High | 10 | 0 | 0 | 0 | 0 | 60 | 30 |
| Lower | C52.2-L | 1 | 8.0 | 13.8 | 130 | Clear | High | High | High | 10 | 0 | 0 | 2 | 0 | 80 | 8 |
| Lower | C52.2-L | 2 | 8.0 | 12.3 | 140 | Overcast | Medium | High | High | 20 | 0 | 0 | 0 | 0 | 50 | 30 |
| Lower | C52.2-L | 3 | 6.0 | 11.4 | 140 | Partly cloudy | High | High | High | 10 | 0 | 0 | 0 | 0 | 20 | 70 |
| Lower | C52.2-L | 4 | 9.0 | 10.8 | 140 | Overcast | High | High | High | 0 | 0 | 0 | 0 | 0 | 25 | 75 |
| Lower | C49.8-R | 1 | 9.0 | 14.3 | 130 | Partly cloudy | High | High | High | 0 | 0 | 0 | 5 | 0 | 90 | 5 |
| Lower | C49.8-R | 2 | 7.0 | 12.4 | 130 | Overcast | Medium | High | High | 5 | 0 | 0 | 5 | 0 | 80 | 10 |
| Lower | C49.8-R | 3 | 6.0 | 11.5 | 130 | Partly cloudy | High | High | High | 5 | 0 | 0 | 5 | 0 | 80 | 10 |
| Lower | C49.8-R | 4 | 6.0 | 11.2 | 140 | Overcast | Medium | High | High | 0 | 0 | 0 | 0 | 0 | 80 | 20 |
| Lower | C49.8-L | 1 | 9.0 | 13.8 | 130 | Clear | High | High | High | 0 | 0 | 0 | 5 | 0 | 85 | 10 |
| Lower | C49.8-L | 2 | 9.0 | 12.3 | 140 | Overcast | High | High | High | 0 | 0 | 0 | 2 | 0 | 85 | 13 |
| Lower | C49.8-L | 3 | 8.0 | 11.4 | 140 | Partly cloudy | High | High | High | 0 | 0 | 0 | 2 | 0 | 88 | 10 |

[a] See Appendix A, Figures A1 to A3 for sample site locations.

[b] Clear = <10%; Partly Cloudy = 10-50%; Mostly Cloudy = 50-90%; Overcast = >90%.

[c] High = >1.0 m/s; Medium = 0.5-1.0 m/s; Low = <0.5 m/s.

[d] High = >3.0 m; Medium = 1.0-3.0 m; Low = <1.0 m.

Continued...

Table B3 Continued.

| Section | Site[a] | Session | Air Temperature (°C) | Water Temperature (°C) | Conductivity (µS) | Cloud Cover[b] | Water Surface Visibility | Instream Velocity[c] | Water Clarity[d] | Cover Types (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Substrate Interstices | Woody Debris | Turbulence | Aquatic Vegetation | Terrestrial Vegetation | Shallow Water | Deep Water |
| Lower | C49.8-L | 4 | 7.0 | 10.9 | 140 | Overcast | Medium | High | Medium | 10 | 0 | 0 | 2 | 0 | 78 | 10 |
| Lower | C49.0-R | 1 | 11.0 | 14.3 | 130 | Partly cloudy | High | High | High | 10 | 0 | 0 | 0 | 0 | 80 | 10 |
| Lower | C49.0-R | 2 | 7.0 | 12.4 | 130 | Overcast | Medium | High | High | 0 | 0 | 0 | 0 | 0 | 80 | 20 |
| Lower | C49.0-R | 3 | 4.0 | 11.5 | 140 | Partly cloudy | High | High | High | 0 | 0 | 0 | 0 | 0 | 80 | 20 |
| Lower | C49.0-R | 4 | 6.0 | 11.2 | 140 | Overcast | High | High | High | 0 | 0 | 0 | 0 | 0 | 75 | 25 |
| Lower | C49.0-L | 1 | 10.0 | 13.8 | 130 | Clear | High | High | High | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Lower | C49.0-L | 2 | 11.0 | 12.3 | 140 | Overcast | High | High | High | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Lower | C49.0-L | 3 | 6.0 | 11.2 | 140 | Overcast | High | High | High | 0 | 0 | 0 | 0 | 0 | 80 | 20 |
| Lower | C49.0-L | 4 | 9.0 | 10.9 | 140 | Overcast | Medium | High | Medium | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Lower | C48.2-R | 1 | 12.0 | 14.2 | 130 | Partly cloudy | High | High | High | 0 | 0 | 0 | 10 | 0 | 80 | 10 |
| Lower | C48.2-R | 2 | 7.0 | 12.4 | 130 | Overcast | Medium | High | High | 0 | 0 | 0 | 10 | 0 | 80 | 10 |
| Lower | C48.2-R | 3 | 5.0 | 11.5 | 140 | Mostly cloudy | High | High | High | 10 | 0 | 0 | 5 | 0 | 80 | 5 |
| Lower | C48.2-R | 4 | 7.0 | 11.2 | 140 | Overcast | High | High | High | 10 | 0 | 0 | 10 | 0 | 70 | 10 |
| Lower | C47.8-L | 1 | 11.5 | 13.8 | 130 | Clear | High | High | High | 20 | 0 | 0 | 10 | 0 | 70 | 0 |
| Lower | C47.8-L | 2 | 10.0 | 12.3 | 140 | Overcast | High | High | High | 0 | 0 | 0 | 5 | 0 | 95 | 0 |
| Lower | C47.8-L | 3 | 6.5 | 11.2 | 140 | Overcast | High | High | Low | 0 | 0 | 0 | 20 | 0 | 70 | 10 |
| Lower | C47.8-L | 4 | 7.0 | 10.9 | 140 | Overcast | Medium | High | High | 20 | 0 | 0 | 5 | 0 | 50 | 25 |
| Lower | C47.2-R | 5 | 9.0 | 10.8 | 140 | Overcast | High | High | High | 0 | 0 | 0 | 0 | 0 | 90 | 10 |
| Lower | C45.6-L | 5 | 9.0 | 10.8 | 140 | Overcast | High | High | High | 25 | 0 | 0 | 0 | 0 | 60 | 15 |
| Lower | C43.7-R | 5 | 8.0 | 10.8 | 140 | Overcast | High | High | High | 30 | 0 | 0 | 0 | 0 | 30 | 40 |
| Lower | C41.1-L | 5 | 10.0 | 10.9 | 140 | Partly cloudy | High | High | High | 20 | 0 | 0 | 0 | 0 | 60 | 20 |
| Lower | C40.0-L | 5 | 8.0 | 10.9 | 140 | Partly cloudy | High | High | High | 20 | 0 | 0 | 0 | 0 | 70 | 10 |
| Middle | C36.6-L | 1 | 8.0 | 14.4 | 130 | Partly cloudy | High | High | High | 0 | 0 | 0 | 5 | 0 | 25 | 70 |
| Middle | C36.6-L | 2 | 3.0 | 12.2 | 130 | Mostly cloudy | High | High | High | 10 | 0 | 0 | 5 | 0 | 65 | 20 |
| Middle | C36.6-L | 3 | 9.0 | 11.6 | 130 | Overcast | High | High | High | 10 | 0 | 0 | 3 | 0 | 57 | 30 |
| Middle | C36.6-L | 4 | 6.0 | 11.1 | 140 | Partly cloudy | High | High | High | 15 | 0 | 0 | 2 | 0 | 48 | 35 |
| Middle | C34.9-L | 1 | 8.0 | 14.4 | 130 | Partly cloudy | High | High | High | 15 | 0 | 0 | 0 | 0 | 50 | 35 |
| Middle | C34.9-L | 2 | 2.0 | 12.2 | 130 | Clear | High | High | High | 30 | 0 | 0 | 0 | 0 | 30 | 40 |
| Middle | C34.9-L | 3 | 9.0 | 11.6 | 130 | Partly cloudy | High | High | High | 20 | 0 | 0 | 0 | 0 | 50 | 30 |
| Middle | C34.9-L | 4 | 6.0 | 11.1 | 140 | Mostly cloudy | High | High | High | 20 | 0 | 0 | 0 | 0 | 30 | 50 |
| Middle | C32.0-R | 5 | 8.0 | 10.9 | 140 | Overcast | High | High | High | 25 | 0 | 0 | 0 | 0 | 20 | 55 |
| Middle | C30.6-L | 5 | 7.0 | 10.7 | 140 | Overcast | Medium | High | High | 30 | 0 | 0 | 0 | 0 | 20 | 50 |
| Middle | C30.5-R | 5 | 8.0 | 10.9 | 140 | Overcast | High | High | High | 15 | 0 | 0 | 0 | 0 | 40 | 45 |
| Middle | C28.8-L | 5 | 8.0 | 10.7 | 140 | Overcast | Medium | High | High | 0 | 0 | 0 | 0 | 0 | 30 | 70 |
| Middle | C28.2-R | 1 | 9.0 | 14.4 | 130 | Partly cloudy | High | High | High | 0 | 0 | 0 | 0 | 0 | 95 | 5 |
| Middle | C28.2-R | 2 | 2.0 | 12.2 | 130 | Clear | High | High | High | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| Middle | C28.2-R | 3 | 9.0 | 11.6 | 130 | Partly cloudy | High | High | High | 0 | 0 | 0 | 0 | 0 | 90 | 10 |
| Middle | C28.2-R | 4 | 4.0 | 11.1 | 140 | Clear | High | High | High | 0 | 0 | 0 | 0 | 0 | 90 | 10 |
| Middle | C27.6-R | 1 | 10.0 | 14.4 | 130 | Partly cloudy | High | High | High | 10 | 0 | 0 | 0 | 0 | 80 | 10 |
| Middle | C27.6-R | 2 | 2.0 | 12.2 | 130 | Clear | High | High | High | 20 | 0 | 0 | 0 | 0 | 70 | 10 |

[a] See Appendix A, Figures A1 to A3 for sample site locations.

[b] Clear = <10%; Partly Cloudy = 10-50%; Mostly Cloudy = 50-90%; Overcast = >90%.

[c] High = >1.0 m/s; Medium = 0.5-1.0 m/s; Low = <0.5 m/s.

[d] High = >3.0 m; Medium = 1.0-3.0 m; Low = <1.0 m.

Continued...

Table B3 Continued.

| Section | Site[a] | Session | Air Temperature (°C) | Water Temperature (°C) | Conductivity (µS) | Cloud Cover[b] | Water Surface Visibility | Instream Velocity[c] | Water Clarity[d] | Cover Types (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Substrate Interstices | Woody Debris | Turbulence | Aquatic Vegetation | Terrestrial Vegetation | Shallow Water | Deep Water |
| Middle | C27.6-R | 3 | 9.8 | 11.6 | 130 | Partly cloudy | High | High | High | 5 | 0 | 0 | 0 | 0 | 75 | 20 |
| Middle | C27.6-R | 4 | 7.0 | 11.1 | 140 | Clear | High | High | High | 20 | 0 | 0 | 0 | 0 | 40 | 40 |
| Middle | C25.3-R | 1 | 10.9 | 14.3 | 130 | Partly cloudy | High | High | High | 5 | 0 | 0 | 0 | 0 | 85 | 10 |
| Middle | C25.3-R | 2 | 5.3 | 12.6 | 130 | Clear | High | High | High | 10 | 0 | 0 | 0 | 0 | 60 | 30 |
| Middle | C25.3-R | 3 | 9.8 | 11.7 | 130 | Partly cloudy | High | High | High | 10 | 0 | 0 | 0 | 0 | 70 | 20 |
| Middle | C25.3-R | 4 | 8.0 | 11.2 | 140 | Clear | High | High | High | 10 | 0 | 0 | 0 | 0 | 20 | 70 |
| Middle | C24.3-L | 5 | 9.0 | 10.7 | 140 | Overcast | High | High | High | 40 | 0 | 0 | 0 | 0 | 5 | 55 |
| Middle | C23.4-L | 5 | 10.0 | 10.7 | 140 | Overcast | High | High | High | 0 | 0 | 0 | 0 | 0 | 70 | 30 |
| Middle | C20.1-L | 5 | 3.0 | 10.5 | 140 | Clear | High | High | High | 40 | 0 | 0 | 0 | 0 | 10 | 50 |
| Upper | C18.8-R | 5 | 3.0 | 10.5 | 140 | Clear | High | High | High | 15 | 0 | 0 | 0 | 0 | 60 | 25 |
| Upper | C17.0-L | 5 | 7.0 | 10.5 | 140 | Clear | High | High | High | 20 | 0 | 0 | 0 | 0 | 30 | 50 |
| Upper | C14.8-L | 5 | 8.0 | 10.7 | 140 | Overcast | High | High | High | 10 | 0 | 0 | 0 | 0 | 60 | 30 |
| Upper | C13.4-L | 5 | 10.0 | 10.7 | 140 | Overcast | High | High | High | 10 | 0 | 0 | 0 | 0 | 80 | 10 |
| Upper | C11.5-R | 5 | 8.0 | 10.5 | 140 | Clear | High | High | High | 20 | 0 | 0 | 0 | 0 | 40 | 40 |
| Upper | C10.9-L | 5 | 10.0 | 10.7 | 140 | Overcast | High | High | High | 15 | 0 | 15 | 0 | 0 | 50 | 20 |
| Upper | C07.4-L | 1 | 15.0 | 14.1 | 120 | Partly cloudy | High | Low | High | 0 | 0 | 30 | 20 | 0 | 50 | 0 |
| Upper | C07.4-L | 2 | 6.4 | 11.6 | 110 | Clear | High | High | High | 0 | 0 | 0 | 30 | 0 | 60 | 10 |
| Upper | C07.4-L | 3 | 9.5 | 11.1 | 120 | Overcast | High | Low | High | 0 | 0 | 0 | 15 | 0 | 80 | 5 |
| Upper | C07.4-L | 4 | 7.0 | 10.5 | 130 | Overcast | High | Medium | High | 0 | 0 | 0 | 20 | 0 | 70 | 10 |
| Upper | C07.3-R | 1 | 10.0 | 14.1 | 120 | Partly cloudy | High | High | High | 20 | 0 | 5 | 0 | 0 | 75 | 0 |
| Upper | C07.3-R | 2 | 5.5 | 12.2 | 130 | Clear | High | High | High | 15 | 0 | 0 | 0 | 0 | 80 | 5 |
| Upper | C07.3-R | 3 | 9.0 | 11.5 | 130 | Overcast | High | High | High | 30 | 0 | 0 | 0 | 0 | 60 | 10 |
| Upper | C07.3-R | 4 | 9.0 | 11.0 | 130 | Overcast | High | High | High | 30 | 0 | 0 | 0 | 0 | 30 | 40 |
| Upper | C06.0-R | 5 | 11.0 | 10.7 | 140 | Overcast | Medium | Low | High | 0 | 0 | 0 | 90 | 0 | 10 | 0 |
| Upper | C05.6-L | 1 | 7.0 | 13.0 | 120 | Mostly cloudy | High | Low | High | 0 | 5 | 0 | 15 | 0 | 70 | 10 |
| Upper | C05.6-L | 2 | 2.0 | 11.8 | 120 | Clear | High | Low | High | 0 | 0 | 0 | 50 | 0 | 40 | 10 |
| Upper | C05.6-L | 3 | 9.5 | 11.5 | 130 | Overcast | High | Low | High | 0 | 0 | 0 | 85 | 0 | 10 | 5 |
| Upper | C05.6-L | 4 | 4.0 | 10.7 | 120 | Clear | High | Low | High | 0 | 0 | 0 | 90 | 10 | 0 | 0 |
| Upper | C04.6-R | 1 | 8.0 | 13.0 | 120 | Mostly cloudy | High | Low | High | 0 | 0 | 0 | 100 | 0 | 0 | 0 |
| Upper | C04.6-R | 2 | 2.0 | 11.8 | 120 | Clear | High | Low | High | 0 | 0 | 0 | 100 | 0 | 0 | 0 |
| Upper | C04.6-R | 3 | 9.5 | 11.5 | 130 | Overcast | High | Low | High | 0 | 0 | 0 | 100 | 0 | 0 | 0 |
| Upper | C04.6-R | 4 | 4.0 | 10.7 | 120 | Clear | High | Low | High | 0 | 0 | 0 | 100 | 0 | 0 | 0 |
| Upper | C03.6-L | 1 | 7.0 | 13.0 | 120 | Mostly cloudy | High | Low | High | 0 | 0 | 0 | 20 | 0 | 70 | 10 |
| Upper | C03.6-L | 2 | 6.0 | 11.8 | 120 | Clear | High | Low | High | 0 | 0 | 0 | 55 | 0 | 45 | 0 |
| Upper | C03.6-L | 3 | 9.0 | 11.1 | 130 | Overcast | High | Low | High | 5 | 0 | 0 | 40 | 0 | 50 | 5 |
| Upper | C03.6-L | 4 | 6.0 | 10.7 | 120 | Clear | High | Low | High | 15 | 0 | 0 | 40 | 0 | 30 | 15 |
| Upper | C02.8-L | 1 | 7.0 | 13.0 | 120 | Clear | High | High | High | 0 | 0 | 0 | 65 | 0 | 35 | 0 |
| Upper | C02.8-L | 2 | 7.0 | 11.8 | 120 | Clear | High | Low | High | 0 | 0 | 0 | 80 | 0 | 20 | 0 |
| Upper | C02.8-L | 3 | 9.0 | 11.1 | 130 | Overcast | High | Low | High | 0 | 0 | 0 | 80 | 0 | 20 | 0 |
| Upper | C02.8-L | 4 | 6.0 | 10.7 | 120 | Clear | High | Low | High | 0 | 0 | 0 | 15 | 0 | 20 | 65 |

Continued...

[a] See Appendix A, Figures A1 to A3 for sample site locations.

[b] Clear = <10%; Partly Cloudy = 10-50%; Mostly Cloudy = 50-90%; Overcast = >90%.

[c] High = >1.0 m/s; Medium = 0.5-1.0 m/s; Low = <0.5 m/s.

[d] High = >3.0 m; Medium = 1.0-3.0 m; Low = <1.0 m.

Table B3 Concluded.

| Section | Site[a] | Session | Air Temperature (°C) | Water Temperature (°C) | Conductivity (µS) | Cloud Cover[b] | Water Surface Visibility | Instream Velocity[c] | Water Clarity[d] | Cover Types (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Substrate Interstices | Woody Debris | Turbulence | Aquatic Vegetation | Terrestrial Vegetation | Shallow Water | Deep Water |
| Upper | C01.3-L | 1 | 9.0 | 13.0 | 120 | Clear | High | Low | High | 10 | 0 | 0 | 40 | 0 | 45 | 5 |
| Upper | C01.3-L | 2 | 7.0 | 11.8 | 120 | Partly cloudy | High | Low | High | 0 | 0 | 0 | 60 | 0 | 40 | 0 |
| Upper | C01.3-L | 3 | 9.5 | 11.1 | 130 | Overcast | High | Low | High | 0 | 0 | 0 | 40 | 0 | 50 | 10 |
| Upper | C01.3-L | 4 | 5.0 | 10.7 | 120 | Clear | High | Low | High | 0 | 0 | 0 | 70 | 0 | 20 | 10 |
| Upper | C00.7-L | 1 | 11.0 | 13.0 | 120 | Clear | High | Low | High | 15 | 0 | 0 | 2 | 0 | 75 | 8 |
| Upper | C00.7-L | 2 | 8.0 | 11.8 | 120 | Overcast | High | Low | High | 20 | 0 | 0 | 0 | 0 | 80 | 0 |
| Upper | C00.7-L | 3 | 9.5 | 11.1 | 130 | Partly cloudy | High | Low | High | 10 | 0 | 0 | 10 | 0 | 65 | 15 |
| Upper | C00.7-L | 4 | 8.0 | 10.7 | 120 | Clear | High | Low | High | 20 | 0 | 0 | 0 | 0 | 40 | 40 |
| Upper | C00.0-R | 1 | 11.1 | 13.0 | 120 | Clear | High | Low | High | 25 | 0 | 0 | 5 | 0 | 70 | 0 |
| Upper | C00.0-R | 2 | 7.0 | 11.8 | 120 | Overcast | High | Low | High | 0 | 0 | 0 | 0 | 0 | 95 | 5 |
| Upper | C00.0-R | 3 | 9.5 | 11.1 | 130 | Partly cloudy | High | Low | High | 0 | 0 | 0 | 0 | 0 | 70 | 30 |
| Upper | C00.0-R | 4 | 8.0 | 10.7 | 120 | Clear | High | Low | High | 25 | 0 | 0 | 0 | 0 | 50 | 25 |

[a] See Appendix A, Figures A1 to A3 for sample site locations.

[b] Clear = <10%; Partly Cloudy = 10-50%; Mostly Cloudy = 50-90%; Overcast = >90%.

[c] High = >1.0 m/s; Medium = 0.5-1.0 m/s; Low = <0.5 m/s.

[d] High = >3.0 m; Medium = 1.0-3.0 m; Low = <1.0 m.

Table B4 Summary of species counts adjacent to bank habitat types in the Middle Columbia River, 3 October to 4 November 2016.

| Section | Site[a] | Species | Bank Habitat Type[a] | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A1 | A2 | A3 | A4 | A5 | A6 | A1+A2 | A2+A3 | D1 | D2 | D3 | D1+D2 | BW | Eddy | |
| Upstream Columbia River | C00.0-R | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C00.0-R | Peamouth | | 1 | | | | | | | | | | | | | **1** |
| | C00.0-R | Rainbow Trout | | | | | | | | | | | | | | | **0** |
| | C00.0-R | Redside Shiner | | | | | | | | | | | | | | | **0** |
| | C00.0-R | Sculpin spp. | | | | | | | | | | | | | | | **0** |
| | C00.0-R | Sucker spp. | | 14 | | | | | | | | | | | | | **14** |
| | C00.0-R | Walleye | | | | | | | | | | | | | | | **0** |
| | C00.0-R | White Sturgeon | | | | | | | | | | | | | 1 | | **1** |
| | **Site C00.0-R Total** | | **0** | **15** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **16** |
| | C00.7-L | Kokanee | | 1 | | | | | | | | | | | | | **1** |
| | C00.7-L | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C00.7-L | Rainbow Trout | | | | | | | | | 19 | | | | | | **19** |
| | C00.7-L | Redside Shiner | | | | | | | | | | | | | | | **0** |
| | C00.7-L | Sculpin spp. | | 60 | | | | | | | | | | | | | **60** |
| | C00.7-L | Sucker spp. | | | | | | | | | | | | | | | **0** |
| | C00.7-L | Walleye | | 3 | | | | | | | 2 | | | | | | **5** |
| | C00.7-L | White Sturgeon | | | | | | | | | 2 | | | | | | **2** |
| | **Site C00.7-L Total** | | **0** | **64** | **0** | **0** | **0** | **0** | **0** | **0** | **23** | **0** | **0** | **0** | **0** | **0** | **87** |
| | C01.3-L | Lake Whitefish | | | | | | | | | 1 | | | | | | **1** |
| | C01.3-L | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C01.3-L | Northern Pike | | | | | | | | | | | | | | | **0** |
| | C01.3-L | Rainbow Trout | 38 | | | | | | | | | | | | | | **38** |
| | C01.3-L | Redside Shiner | | | | | | | | | 162 | | | | | | **162** |
| | C01.3-L | Sculpin spp. | | | | | | | | | 312 | | | | | | **312** |
| | C01.3-L | Sucker spp. | | | | | | | | | 197 | | | | | | **197** |
| | C01.3-L | Walleye | | | | | | | | | 20 | | | | | | **20** |
| | C01.3-L | White Sturgeon | | | | | | | | | 3 | | | | | | **3** |
| | **Site C01.3-L Total** | | **38** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **695** | **0** | **0** | **0** | **0** | **0** | **733** |
| | C02.8-L | Mountain Whitefish | | | | | | | | | 35 | | | | | | **35** |
| | C02.8-L | Rainbow Trout | | | | | | | | | 24 | | | | | | **24** |
| | C02.8-L | Redside Shiner | | | | | | | | | 34 | | | | | | **34** |
| | C02.8-L | Sculpin spp. | | | | | | | | | 105 | | | | | | **105** |
| | C02.8-L | Sucker spp. | | | | | | | | | 99 | | | | | | **99** |
| | C02.8-L | Walleye | | | | | | | | | 6 | | | | | | **6** |
| | C02.8-L | White Sturgeon | | | | | | | | | 1 | | | | | | **1** |
| | **Site C02.8-L Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **304** | **0** | **0** | **0** | **0** | **0** | **304** |
| | C03.6-L | Burbot | | | | 5 | | | | | | | | | | | **5** |
| | C03.6-L | Kokanee | | | | 1 | | | | | | | | | | | **1** |
| | C03.6-L | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C03.6-L | Northern Pike | | | | | | | | | | | | | | | **0** |
| | C03.6-L | Northern Pikeminnow | 4 | | | 5 | | | | | | | | | | | **9** |
| | C03.6-L | Peamouth | 2 | | | | | | | | | | | | | | **2** |
| | C03.6-L | Rainbow Trout | 82 | | | | | | | | | | | | | | **82** |
| | C03.6-L | Redside Shiner | 39 | | | | | | | | 18 | | | | | | **57** |
| | C03.6-L | Sculpin spp. | 108 | | | | | | | | 76 | | | | | | **184** |
| | C03.6-L | Sucker spp. | 315 | | | | | | | | 210 | | | | | | **525** |
| | C03.6-L | Walleye | 34 | | | | | | | | 12 | | | | | | **46** |
| | **Site C03.6-L Total** | | **584** | **0** | **0** | **11** | **0** | **0** | **0** | **0** | **316** | **0** | **0** | **0** | **0** | **0** | **911** |
| | C04.6-R | Kokanee | | | | | | | | | 9 | | | | | | **9** |
| | C04.6-R | Mountain Whitefish | | | | | | | | | 7 | | | | | | **7** |
| | C04.6-R | Northern Pikeminnow | | | | | | | | | 2 | | | | | | **2** |
| | C04.6-R | Rainbow Trout | | | | | | | | | 18 | | | | | | **18** |
| | C04.6-R | Redside Shiner | | | | | | | | | 9 | | | | | | **9** |
| | C04.6-R | Sculpin spp. | | | | | | | | | 42 | | | | | | **42** |
| | C04.6-R | Sucker spp. | | | | | | | | | 160 | | | | | | **160** |
| | C04.6-R | Walleye | | | | | | | | | 16 | | | | | | **16** |
| | C04.6-R | White Sturgeon | | | | | | | | | 2 | | | | | | **2** |
| | **Site C04.6-R Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **265** | **0** | **0** | **0** | **0** | **0** | **265** |
| | C05.6-L | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C05.6-L | Northern Pike | | | | | | | | | | | | | | | **0** |
| | C05.6-L | Northern Pikeminnow | | | | | | | | | | | | | | | **0** |
| | C05.6-L | Rainbow Trout | 26 | | | | | | | | | | | | | | **26** |
| | C05.6-L | Redside Shiner | 15 | | | | | | | | | | | | | | **15** |
| | C05.6-L | Sculpin spp. | 97 | | | | | | | | 71 | | | | | | **168** |
| | C05.6-L | Sucker spp. | | | | | | | | | 147 | | | | | | **147** |
| | C05.6-L | Walleye | 22 | | | | | | | | | | | | | | **22** |
| | **Site C05.6-L Total** | | **160** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **218** | **0** | **0** | **0** | **0** | **0** | **378** |
| | C07.3-R | Kokanee | | | | 5 | | | | | | | | | | | **5** |
| | C07.3-R | Lake Whitefish | | | | 2 | | | | | | | | | | | **2** |
| | C07.3-R | Mountain Whitefish | | | | 125 | | | | | | | | | | | **125** |
| | C07.3-R | Northern Pikeminnow | | | | 3 | | | | | | | | | | | **3** |
| | C07.3-R | Rainbow Trout | | | | 125 | | | | | | | | | | | **125** |
| | C07.3-R | Redside Shiner | | | | 39 | | | | | | | | | | | **39** |
| | C07.3-R | Sculpin spp. | | | | 77 | | | | | | | | | | | **77** |
| | C07.3-R | Sucker spp. | | | | 70 | | | | | | | | | | | **70** |
| | C07.3-R | Walleye | | | | 35 | | | | | | | | | | | **35** |
| | C07.3-R | White Sturgeon | | | | 4 | | | | | | | | | | | **4** |
| | **Site C07.3-R Total** | | **0** | **0** | **0** | **485** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **485** |
| | C07.4-L | Bull Trout | | | | | | | | | | | | 1 | | | **1** |
| | C07.4-L | Kokanee | | | | | | | | | | | | 5 | | | **5** |
| | C07.4-L | Lake Whitefish | | | | | | | | | | | | 9 | | | **9** |
| | C07.4-L | Mountain Whitefish | | | | | | | | | | | | 641 | | | **641** |
| | C07.4-L | Rainbow Trout | | | | | | | | | | | | 81 | | | **81** |
| | C07.4-L | Redside Shiner | | | | | | | | | | | | 17 | | | **17** |
| | C07.4-L | Sculpin spp. | | | | | | | | | | | | 42 | | | **42** |
| | C07.4-L | Sucker spp. | | | | | | | | | | | | 359 | | | **359** |
| | C07.4-L | Walleye | | | | | | | | | | | | 14 | | | **14** |
| | C07.4-L | White Sturgeon | | | | | | | | | | | | 3 | | | **3** |
| | C07.4-L | Yellow Perch | | | | | | | | | | | | | | | **0** |
| | **Site C07.4-L Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1172** | **0** | **0** | **1172** |
| **Upstream Columbia River Total** | | | **782** | **79** | **0** | **496** | **0** | **0** | **0** | **0** | **1821** | **0** | **0** | **1172** | **1** | **0** | **4351** |
| Kootenay | K00.3-L | Mountain Whitefish | | | | | | | | | | | | | 27 | | **27** |
| | K00.3-L | Rainbow Trout | | | | | | | | | | | | | 9 | | **9** |
| | K00.3-L | Redside Shiner | | | | | | | | | | | | | 1 | | **1** |
| | K00.3-L | Sculpin spp. | | | | | | | | | | | | | 6 | | **6** |
| | K00.3-L | Sucker spp. | | | | | | | | 7 | | | | | 8 | | **15** |
| | K00.3-L | Walleye | | | | | | | | | | | | | | | **0** |
| | **Site K00.3-L Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **7** | **0** | **0** | **0** | **0** | **51** | **0** | **58** |

[a] See Appendix A, Figures A1 to A3 for sample site locations.

[b] See Appendix B, Table B1 for bank habitat type descriptions.

Continued...

Table B4 Continued.

| Section | Site[a] | Species | Bank Habitat Type[a] | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A1 | A2 | A3 | A4 | A5 | A6 | A1+A2 | A2+A3 | D1 | D2 | D3 | D1+D2 | BW | Eddy | |
| | K00.6-R | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | K00.6-R | Northern Pikeminnow | | | | | | | | | | | | | | | **0** |
| | K00.6-R | Rainbow Trout | | | | | | | | | | | | | | 8 | **8** |
| | K00.6-R | Redside Shiner | | | | | | | | | | | | | | 11 | **11** |
| | K00.6-R | Sculpin spp. | | | | | | | | | | | | | | 23 | **23** |
| | K00.6-R | Sucker spp. | | | | | | | | | | | | | | | **0** |
| | K00.6-R | Walleye | | | | | | | | | | | | | | 12 | **12** |
| | K00.6-R | White Sturgeon | | | | | | | | | | | | 3 | | | **3** |
| | **Site K00.6-R Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **3** | **0** | **54** | **57** |
| | K01.8-L | Kokanee | | 1 | | | | | | | | | | | | | **1** |
| | K01.8-L | Lake Whitefish | | | | | | | | | | 4 | | | | | **4** |
| | K01.8-L | Mountain Whitefish | | | | | | | | | | 377 | | | | | **377** |
| | K01.8-L | Northern Pikeminnow | | | | | | | | | | | | | | | **0** |
| | K01.8-L | Rainbow Trout | | | | | | | | | | 49 | | | | | **49** |
| | K01.8-L | Redside Shiner | | 32 | | | | | | | | 3 | | | | | **35** |
| | K01.8-L | Sculpin spp. | | | | | | | | | | 253 | | | | | **253** |
| | K01.8-L | Sucker spp. | | | | | | | | | | 55 | | | | | **55** |
| | K01.8-L | Walleye | | 15 | | | | | | | | 21 | | | | | **36** |
| | K01.8-L | White Sturgeon | | | | | | | | | | 9 | | | | | **9** |
| | **Site K01.8-L Total** | | **0** | **48** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **771** | **0** | **0** | **0** | **0** | **819** |
| | K01.8-R | Lake Whitefish | | | | | | | | 2 | | | | | | | **2** |
| | K01.8-R | Mountain Whitefish | | | | | | | | 225 | | | | | | | **225** |
| | K01.8-R | Northern Pikeminnow | | | | | | | | 6 | | | | | | | **6** |
| | K01.8-R | Rainbow Trout | | | | | | | | 52 | | | | | | | **52** |
| | K01.8-R | Sculpin spp. | | | | | | | | 62 | | | | | | | **62** |
| | K01.8-R | Sucker spp. | | | | | | | | 14 | | | | | | | **14** |
| | K01.8-R | Walleye | | | | | | | | 13 | | | | | | | **13** |
| | K01.8-R | White Sturgeon | | | | | | | | 3 | | | | | | | **3** |
| | **Site K01.8-R Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **377** | **0** | **0** | **0** | **0** | **0** | **0** | **377** |
| **Kootenay Total** | | | **0** | **48** | **0** | **0** | **0** | **0** | **0** | **384** | **0** | **771** | **0** | **3** | **51** | **54** | **1311** |
| Downstream Columbia River | C25.3-R | Redside Shiner | 90 | | | | | | | | | | | | | | **90** |
| | C25.3-R | Sculpin spp. | 181 | | | | | | | | | | | | | | **181** |
| | C25.3-R | Walleye | | | | | 5 | | | | | | | | | | **5** |
| | C25.3-R | Northern Pikeminnow | | | | | | | | 2 | | | | | | | **2** |
| | C25.3-R | Lake Whitefish | | | | | | | | | | | | | | | **0** |
| | C25.3-R | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C25.3-R | Rainbow Trout | | | | | | | | | | | | | | | **0** |
| | C25.3-R | Sucker spp. | | | | | | | | | | | | | | | **0** |
| | **Site C25.3-R Total** | | **271** | **0** | **0** | **0** | **5** | **0** | **0** | **2** | **0** | **0** | **0** | **0** | **0** | **0** | **278** |
| | C27.6-R | Lake Whitefish | | | | | | | | 1 | | | | | | | **1** |
| | C27.6-R | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C27.6-R | Rainbow Trout | | | | | | | | | | | | | | | **0** |
| | C27.6-R | Sculpin spp. | | | | | 19 | | | | | | | | | | **19** |
| | C27.6-R | Sucker spp. | | | | | 1 | | | | | | | | | | **1** |
| | C27.6-R | Walleye | | | | | | | | 4 | | | | | | | **4** |
| | **Site C27.6-R Total** | | **0** | **0** | **0** | **0** | **20** | **0** | **0** | **5** | **0** | **0** | **0** | **0** | **0** | **0** | **25** |
| | C28.2-R | Lake Whitefish | | 3 | | | | | | | | | | | | | **3** |
| | C28.2-R | Mountain Whitefish | | 46 | | | | | | | | | | | | | **46** |
| | C28.2-R | Rainbow Trout | | 120 | | | | | | | | | | | | | **120** |
| | C28.2-R | Redside Shiner | | 21 | | | | | | | | | | | | | **21** |
| | C28.2-R | Sculpin spp. | | 232 | | | | | | | | | | | | | **232** |
| | C28.2-R | Sucker spp. | | 22 | | | | | | | | | | | | | **22** |
| | C28.2-R | Walleye | | 13 | | | | | | | | | | | | | **13** |
| | **Site C28.2-R Total** | | **0** | **457** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **457** |
| | C34.9-L | Kokanee | | 1 | | | | | | | | | | | | | **1** |
| | C34.9-L | Lake Whitefish | | 1 | | | | | | | | | | | | | **1** |
| | C34.9-L | Mountain Whitefish | | 54 | | | | | | | | | | | | | **54** |
| | C34.9-L | Northern Pikeminnow | | 1 | | | | | | | | | | | | | **1** |
| | C34.9-L | Rainbow Trout | | 162 | | | | | | | | | | | | | **162** |
| | C34.9-L | Redside Shiner | | 42 | | | | | | | | | | | | | **42** |
| | C34.9-L | Sculpin spp. | | 246 | | | | | | | | | | | | | **246** |
| | C34.9-L | Sucker spp. | | 23 | | | | | | | | | | | | | **23** |
| | C34.9-L | Walleye | | 34 | | | | | | | | | | | | | **34** |
| | **Site C34.9-L Total** | | **0** | **564** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **564** |
| | C36.6-L | Kokanee | | | | | | | | 1 | | | | | | | **1** |
| | C36.6-L | Lake Whitefish | | | | | | | | | | | | | | | **0** |
| | C36.6-L | Mountain Whitefish | | | | | | | | 65 | | | | | | | **65** |
| | C36.6-L | Northern Pikeminnow | | | | | | | | 1 | | | | | | | **1** |
| | C36.6-L | Rainbow Trout | | | | | | | | 151 | | | | | | | **151** |
| | C36.6-L | Sculpin spp. | | | | | 103 | | | | | | | | | | **103** |
| | C36.6-L | Sucker spp. | | | | | 36 | | | | | | | | | | **36** |
| | C36.6-L | Walleye | | | | | | | | 15 | | | | | | | **15** |
| | **Site C36.6-L Total** | | **0** | **0** | **0** | **0** | **139** | **0** | **0** | **233** | **0** | **0** | **0** | **0** | **0** | **0** | **372** |
| | C47.8-L | Brook Trout | | | | | | | | | | | | | | | **0** |
| | C47.8-L | Lake Whitefish | | | | | | | | | 28 | | | | | | **28** |
| | C47.8-L | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C47.8-L | Rainbow Trout | | | | | | | | | 59 | | | | | | **59** |
| | C47.8-L | Redside Shiner | | | | | | | | | 44 | | | | | | **44** |
| | C47.8-L | Sculpin spp. | | | | | | | | | 131 | | | | | | **131** |
| | C47.8-L | Sucker spp. | | | | | | | | | 58 | | | | | | **58** |
| | C47.8-L | Tench | | | | | | | | | 1 | | | | | | **1** |
| | C47.8-L | Walleye | | | | | | | | | 22 | | | | | | **22** |
| | C47.8-L | Yellow Perch | | | | | | | | 1 | 2 | | | | | | **3** |
| | **Site C47.8-L Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **345** | **0** | **0** | **0** | **0** | **0** | **346** |
| | C48.2-R | Lake Whitefish | | | | | | | | | | | | 10 | | | **10** |
| | C48.2-R | Mountain Whitefish | | | | | | | | | | | | 34 | | | **34** |
| | C48.2-R | Rainbow Trout | | | | | | | | | | | | 49 | | | **49** |
| | C48.2-R | Redside Shiner | | | | | | | | | | | | 8 | 13 | | **21** |
| | C48.2-R | Sculpin spp. | | | | | | | | | | | | 46 | 44 | | **90** |
| | C48.2-R | Sucker spp. | | | | | | | | | | | | 42 | | | **42** |
| | C48.2-R | Walleye | | | | | | | | | | | | 10 | | | **10** |
| | **Site C48.2-R Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **199** | **57** | **0** | **256** |
| | C49.0-L | Lake Whitefish | | 11 | | | | | | | | 12 | | | | | **23** |
| | C49.0-L | Mountain Whitefish | | 41 | | | | | | | | | | | | | **41** |
| | C49.0-L | Rainbow Trout | | | | | | | | | | | | | | | **0** |
| | C49.0-L | Redside Shiner | | 3 | | | | | | | | 4 | | | | | **7** |
| | C49.0-L | Sculpin spp. | | 236 | | | | | | | | 62 | | | | | **298** |
| | C49.0-L | Sucker spp. | | 4 | | | | | | | | 5 | | | | | **9** |
| | C49.0-L | Walleye | | 8 | | | | | | | | 7 | | | | | **15** |
| | **Site C49.0-L Total** | | **0** | **303** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **90** | **0** | **0** | **0** | **0** | **393** |

[a] See Appendix A, Figures A1 to A3 for sample site locations.

[b] See Appendix B, Table B1 for bank habitat type descriptions.

Continued...

Table B4 Concluded.

| **Section** | **Site**[a] | **Species** | **Bank Habitat Type**[a]<br>**A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A1+A2** | **A2+A3** | **D1** | **D2** | **D3** | **D1+D2** | **BW** | **Eddy** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C49.0-R | Lake Whitefish | | | | | | | 5 | | | | | | | | **5** |
| | C49.0-R | Mountain Whitefish | | | | | | | | | | | | | | | **0** |
| | C49.0-R | Rainbow Trout | | | | | | | | | | | | | | | **0** |
| | C49.0-R | Sculpin spp. | | | | | | | 27 | | | | | | | | **27** |
| | C49.0-R | Walleye | | | | | | | 10 | | | | | | | | **10** |
| | **Site C49.0-R Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **42** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **42** |
| | C49.8-L | Brown Trout | | | | | | | | | | | | | | | **0** |
| | C49.8-L | Bull Trout | | 2 | | | | | | | | | | | | | **2** |
| | C49.8-L | Burbot | | 6 | | | | | | | | | | | | | **6** |
| | C49.8-L | Lake Whitefish | | 16 | | | | | | | | | | | | | **16** |
| | C49.8-L | Mountain Whitefish | | 112 | | | | | | | | | | | | | **112** |
| | C49.8-L | Rainbow Trout | | 215 | | | | | | | | | | | | | **215** |
| | C49.8-L | Sculpin spp. | | 1818 | | | | | | | | | | | | | **1818** |
| | C49.8-L | Sucker spp. | | 37 | | | | | | | | | | | | | **37** |
| | C49.8-L | Walleye | | 50 | | | | | | | | | | | | | **50** |
| | C49.8-L | White Sturgeon | | 1 | | | | | | | | | | | | | **1** |
| | **Site C49.8-L Total** | | **0** | **2257** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **2257** |
| | C49.8-R | Lake Whitefish | | 15 | | | | | | | | 5 | | | | | **20** |
| | C49.8-R | Mountain Whitefish | | 61 | | | | | | | | | | | | | **61** |
| | C49.8-R | Northern Pikeminnow | | 1 | | | | | | | | | | | | | **1** |
| | C49.8-R | Rainbow Trout | | 85 | | | | | | | | | | | | | **85** |
| | C49.8-R | Redside Shiner | | 32 | | | | | | | | | | | | | **32** |
| | C49.8-R | Sculpin spp. | | 1002 | | | | | | | | | | | | | **1002** |
| | C49.8-R | Sucker spp. | | | | | | | | | | | | | | | **0** |
| | C49.8-R | Walleye | | 25 | | | | | | | | | | | | | **25** |
| | C49.8-R | Yellow Perch | | | | | | | | | | | | | 1 | | **1** |
| | **Site C49.8-R Total** | | **0** | **1221** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **5** | **0** | **0** | **1** | **0** | **1227** |
| | C52.2-L | Lake Whitefish | | | | | | | | | | | | | | | **0** |
| | C52.2-L | Mountain Whitefish | | | | | | | | | | | | | | 15 | **15** |
| | C52.2-L | Rainbow Trout | | | | | | | | | | | | | | 46 | **46** |
| | C52.2-L | Sculpin spp. | | | | | | | | | | | | | | 66 | **66** |
| | C52.2-L | Sucker spp. | | | | | | | | | | 3 | | | | 4 | **7** |
| | C52.2-L | Walleye | | | | | | | | | | | | | | 4 | **4** |
| | **Site C52.2-L Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **3** | **0** | **0** | **0** | **135** | **138** |
| | C52.2-R | Lake Whitefish | | 17 | | | | | | | | | | | | | **17** |
| | C52.2-R | Mountain Whitefish | | 37 | | | | | | | | | | | | | **37** |
| | C52.2-R | Rainbow Trout | | 142 | | | | | | | | | | | | | **142** |
| | C52.2-R | Sculpin spp. | | 50 | | | | | | | | | | | | | **50** |
| | C52.2-R | Smallmouth Bass | | | | | | | | | | | | | | | **0** |
| | C52.2-R | Sucker spp. | | 14 | | | | | | | | | | | | | **14** |
| | C52.2-R | Walleye | | 24 | | | | | | | | | | | | | **24** |
| | C52.2-R | White Sturgeon | | 2 | | | | | | | | | | | | | **2** |
| | **Site C52.2-R Total** | | **0** | **286** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **286** |
| | C52.8-L | Lake Whitefish | | | | | | | | | | | | | | | **0** |
| | C52.8-L | Mountain Whitefish | | | | 31 | | | | | | | | | | | **31** |
| | C52.8-L | Rainbow Trout | | | | 115 | | | | | | | | | | | **115** |
| | C52.8-L | Sculpin spp. | | | | 49 | | | | | | | | | | | **49** |
| | C52.8-L | Sucker spp. | | | | 4 | | | | | | | | | | | **4** |
| | C52.8-L | Walleye | | | | 23 | | | | | | | | | | | **23** |
| | **Site C52.8-L Total** | | **0** | **0** | **0** | **222** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **222** |
| | C53.6-L | Brown Trout | | | | | | | | | | | | | | | **0** |
| | C53.6-L | Lake Whitefish | | | | | | 10 | | | | | | | | | **10** |
| | C53.6-L | Mountain Whitefish | | | | | | 18 | | | | | | | | | **18** |
| | C53.6-L | Rainbow Trout | | | | | | 105 | | | | | | | | | **105** |
| | C53.6-L | Sculpin spp. | | | | | | 153 | | | | | | | | | **153** |
| | C53.6-L | Smallmouth Bass | | | | | | | | | | | | | | | **0** |
| | C53.6-L | Sucker spp. | | | | | | 4 | | | | | | | | | **4** |
| | C53.6-L | Walleye | | | | | | 18 | | | | | | | | | **18** |
| | C53.6-L | Yellow Perch | | | | | | 1 | | | | | | | | | **1** |
| | **Site C53.6-L Total** | | **0** | **0** | **0** | **0** | **0** | **309** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **309** |
| **Downstream Columbia River Total** | | | **271** | **5088** | **0** | **222** | **164** | **309** | **42** | **241** | **345** | **98** | **0** | **199** | **58** | **135** | **7172** |
| **Grand Total** | | | **1053** | **5215** | **0** | **718** | **164** | **309** | **42** | **625** | **2166** | **869** | **0** | **1374** | **110** | **189** | **12834** |

[a] See Appendix A, Figures A1 to A3 for sample site locations.

[b] See Appendix B, Table B1 for bank habitat type descriptions.

# Appendix C – Modelling Methods and Parameter Estimates

# Lower Columbia River Fish Population Indexing Analysis 2016

## Methods

### Data Preparation

The fish indexing data were provided by Okanagan Nation Alliance and Golder Associates in the form of an Access database. The discharge and temperature data were queried from a BC Hydro database maintained by Poisson Consulting. The Rainbow Trout egg dewatering estimates were provided by CLBMON-46 (Irvine, Baxter, and Thorley 2015) and the Mountain Whitefish egg stranding estimates by Golder Associates (2013).

The data were prepared for analysis using R version 3.3.3 (R Core Team 2017).

### Data Analysis

Hierarchical Bayesian models were fitted to the data using R version 3.3.3 (R Core Team 2017) and JAGS 4.2.0 (Plummer 2015) which interfaced with each other via the `jmbr` package. For additional information on hierarchical Bayesian modelling in the BUGS language, of which JAGS uses a dialect, the reader is referred to Kery and Schaub (2011, 41–44).

The one exception was the length-at-age analysis which used a maximum-likelihood (ML) model which was fitted to the data using TMB which interfaced with R via the `tmbr` package. An ML model was used because the equivalent Bayesian model was becoming prohibitively slow.

Unless indicated otherwise, the models used prior distributions that were *vague* in the sense that they did not affect the posterior distributions (Kery and Schaub 2011, 36). The posterior distributions were estimated from 2,000 Markov Chain Monte Carlo (MCMC) samples thinned from the second halves of three chains (Kery and Schaub 2011, 38–40). Model convergence was confirmed by ensuring that $\hat{R} < 1.1$ (Kery and Schaub 2011, 40) for each of the monitored parameters in the model(Kery and Schaub 2011, 61). Where relevant, model adequacy was confirmed by examination of residual plots.

The posterior distributions of the *fixed* (Kery and Schaub 2011, 75) parameters are summarised in terms of the point *estimate*, standard deviation (*sd*), the *z-score*, *lower* and *upper* 95% confidence/credible limits (CLs) and the *p-value* (Kery and Schaub 2011, 37, 42). The estimate is the median (50th percentile) of the MCMC samples, the z-score is sd/mean and the 95% CLs are the 2.5th and 97.5th percentiles. A p-value of 0.05 indicates that the lower or upper 95% CL is 0.

Variable selection was achieved by dropping fixed (Kery and Schaub 2011, 77–82) variables with two-sided p-values ≥ 0.05 (Kery and Schaub 2011, 37, 42) and random variables with percent relative errors ≥ 80%.

The results are displayed graphically by plotting the modeled relationships between particular variables and the response with 95% credible intervals (CIs) with the remaining variables held constant. In general, continuous and discrete fixed variables are held constant at their mean and first level values respectively while random variables are held constant at their typical values (expected values of the underlying hyperdistributions) (Kery and Schaub 2011, 77–82). Where informative the influence of particular variables is expressed in terms of the *effect size* (i.e., percent change in the response variable) with 95% CIs (Bradford, Korman, and Higgins 2005).

## Model Code

### Condition

```
model {
  bWeight ~ dnorm(5, 5^-2)
  bWeightLength ~ dnorm(3, 2^-2)

  bWeightDayte ~ dnorm(0, 2^-2)
  bWeightLengthDayte ~ dnorm(0, 2^-2)

  sWeightYear ~ dnorm(0, 2^-2)
  sWeightLengthYear ~ dnorm(0, 2^-2)
  for (i in 1:nYear) {
    bWeightYear[i] ~ dnorm(0, exp(sWeightYear)^-2)
    bWeightLengthYear[i] ~ dnorm(0, exp(sWeightLengthYear)^-2)
  }

  sWeight ~ dnorm(0, 5^-2)
  for(i in 1:length(Length)) {
    log(eWeight[i]) <- bWeight +
                       bWeightDayte * Dayte[i] +
                       bWeightYear[Year[i]] +
                       (bWeightLength +
                         bWeightLengthDayte * Dayte[i] +
                         bWeightLengthYear[Year[i]]) * Length[i]

    Weight[i] ~ dlnorm(log(eWeight[i]), exp(sWeight)^-2)
  }
..
```

### Growth

```
model {
  bK ~ dnorm (0, 5^-2)
  sKYear ~ dnorm(0, 5^-2)

  for (i in 1:nYear) {
    bKYear[i] ~ dnorm(0, exp(sKYear)^-2)
    log(eK[i]) <- bK + bKYear[i]
  }
```

```
  bLinf ~ dunif(100, 1000)
  sGrowth ~ dnorm(0, 5^-2)
  for (i in 1:length(Year)) {
    eGrowth[i] <- (bLinf - LengthAtRelease[i]) * (1 - exp(-sum(eK[Year[i]:(Ye
ar[i] + dYears[i] - 1)])))
    Growth[i] ~ dnorm(eGrowth[i], exp(sGrowth)^-2)
  }
..
```

## Observer Length Correction

```
model{
  #### Fish class terms

  for(j in 1:nAnnual){
    for(i in 1:nClass) {
      dClass[i, j] <- 1
    }
    pClass[1:nClass, j] ~ ddirch(dClass[, j])
  }

  #### Observer terms

  bLength[1] <- 1
  sLength[1] <- 1

  for(i in 2:nObserver) {
    bLength[i] ~ dunif(0.5, 2)
    sLength[i] ~ dunif(2, 10)
  }

  #### The model

  for(i in 1:length(Length)){
    eClass[i] ~ dcat(pClass[, Annual[i]])
    eLength[i] <- bLength[Observer[i]] * ClassLength[eClass[i]]
    eSLength[i] <- sLength[Observer[i]] * ClassSD
    Length[i] ~ dnorm(eLength[i], eSLength[i]^-2)
  }
..
```

## Survival

```
model{
  bEfficiency ~ dnorm(0, 5^-2)
  bEfficiencySampledLength ~ dnorm(0, 5^-2)

  bSurvival ~ dnorm(0, 5^-2)

  sSurvivalYear ~ dunif(0, 5)
```

```
  for(i in 1:nYear) {
    bSurvivalYear[i] ~ dnorm(0, sSurvivalYear^-2)
  }

  for(i in 1:(nYear-1)) {
    logit(eEfficiency[i]) <- bEfficiency + bEfficiencySampledLength * Sampled
Length[i]
    logit(eSurvival[i]) <- bSurvival + bSurvivalYear[i]

    eProbability[i,i] <- eSurvival[i] * eEfficiency[i]
    for(j in (i+1):(nYear-1)) {
      eProbability[i,j] <- prod(eSurvival[i:j]) * prod(1-eEfficiency[i:(j-1)]
) * eEfficiency[j]
    }
    for(j in 1:(i-1)) {
      eProbability[i,j] <- 0
    }
  }
  for(i in 1:(nYear-1)) {
    eProbability[i,nYear] <- 1 - sum(eProbability[i,1:(nYear-1)])
  }

  for(i in 1:(nYear - 1)) {
    Marray[i, 1:nYear] ~ dmulti(eProbability[i,], Released[i])
  }
..
```

## Site Fidelity

```
model {

  bFidelity ~ dnorm(0, 2^-2)
  bLength ~ dnorm(0, 2^-2)

  for (i in 1:length(Fidelity)) {
    logit(eFidelity[i]) <- bFidelity + bLength * Length[i]
    Fidelity[i] ~ dbern(eFidelity[i])
  }
..
```

## Capture Efficiency

```
model {

  bEfficiency ~ dnorm(0, 5^-2)

  sEfficiencySessionAnnual ~ dnorm(0, 2^-2)
  for (i in 1:nSession) {
    for (j in 1:nAnnual) {
      bEfficiencySessionAnnual[i, j] ~ dnorm(0, exp(sEfficiencySessionAnnual)
^-2)
```

```
    }
  }

  for (i in 1:length(Recaptures)) {

    logit(eEfficiency[i]) <- bEfficiency + bEfficiencySessionAnnual[Session[i
], Annual[i]]

    eFidelity[i] ~ dnorm(Fidelity[i], FidelitySD[i]^-2) T(FidelityLower[i], F
idelityUpper[i])
    Recaptures[i] ~ dbin(eEfficiency[i] * eFidelity[i], Tagged[i])
  }
..
```

## Abundance

```
model {
  bDensity ~ dnorm(5, 5^-2)

  sDensityAnnual ~ dnorm(0, 2^-2)
  for (i in 1:nAnnual) {
    bDensityAnnual[i] ~ dnorm(0, exp(sDensityAnnual)^-2)
  }

  sDensitySite ~ dnorm(0, 2^-2)
  sDensitySiteAnnual ~ dnorm(0, 2^-2)
  for (i in 1:nSite) {
    bDensitySite[i] ~ dnorm(0, exp(sDensitySite)^-2)
    for (j in 1:nAnnual) {
      bDensitySiteAnnual[i, j] ~ dnorm(0, exp(sDensitySiteAnnual)^-2)
    }
  }

  bEfficiencyVisitType[1] <- 0
  for (i in 2:nVisitType) {
    bEfficiencyVisitType[i] ~ dnorm(0, 2^-2)
  }

  sDispersion ~ dnorm(0, 2^-2)
  sDispersionVisitType[1] <- 0
  for(i in 2:nVisitType) {
    sDispersionVisitType[i] ~ dnorm(0, 2^-2)
  }

  for (i in 1:length(Fish)) {
    log(eDensity[i]) <- bDensity + bDensitySite[Site[i]] + bDensityAnnual[Ann
ual[i]] + bDensitySiteAnnual[Site[i],Annual[i]]

    eAbundance[i] <- eDensity[i] * SiteLength[i]
```

```
    logit(eEfficiency[i]) <- logit(Efficiency[i]) + bEfficiencyVisitType[Visi
tType[i]]

    log(esDispersion[i]) <- sDispersion + sDispersionVisitType[VisitType[i]]

    eDispersion[i] ~ dgamma(esDispersion[i]^-2 + 0.1, esDispersion[i]^-2 + 0.
1)
    eFish[i] <- eAbundance[i] * ProportionSampled[i] * eEfficiency[i]
    Fish[i] ~ dpois(eFish[i] * eDispersion[i])
  }
..
```

### Stock-Recruitment

```
model {

  bAlpha ~ dnorm(1, 2^-2) T(log(1), log(5))
  bBeta ~ dnorm(-5, 5^-2)
  bStockEggLoss ~ dnorm(0, 2^-2)

  sRecruits ~ dnorm(0, 5^-2)
  for(i in 1:length(Stock)){
    log(eAlpha[i]) <- bAlpha
    log(eBeta[i]) <- bBeta
    eRecruits[i] <- (eAlpha[i] * (Stock[i] + bStockEggLoss * EggLoss[i])) / (
1 + eBeta[i] * (Stock[i] + bStockEggLoss * EggLoss[i]))
    Recruits[i] ~ dlnorm(log(eRecruits[i]), exp(sRecruits)^-2)
  }
..
```

### Age-Ratios

```
model{

  bProbAge1 ~ dnorm(0, 1000^-2)
  bProbAge1Loss ~ dnorm(0, 1000^-2)

  sDispersion ~ dunif(0, 1000)
  for(i in 1:length(LossLogRatio)){
    eDispersion[i] ~ dnorm(0, sDispersion^-2)
    logit(eProbAge1[i]) <- bProbAge1 + bProbAge1Loss * LossLogRatio[i] + eDis
persion[i]
    Age1[i] ~ dbin(eProbAge1[i], Age1and2[i])
  }
..
```

## Results

### Condition

Table 1. Parameter descriptions.

| Parameter | Description |
|---|---|
| `bWeight` | Intercept of `log(eWeight)` |
| `bWeightDayte` | Effect of `Dayte` on `bWeight` |
| `bWeightLength` | Intercept of effect of `Length` on `bWeight` |
| `bWeightLengthDayte` | Effect of `Dayte` on `bWeightLength` |
| `bWeightLengthYear[i]` | Effect of `i`th `Year` on `bWeightLength` |
| `bWeightYear[i]` | Effect of `i`th `Year` on `bWeight` |
| `Dayte[i]` | Standardised day of year `i`th fish was captured |
| `eWeight[i]` | Expected `Weight` of `i`th fish |
| `Length[i]` | Log-transformed and centered fork length of `i`th fish |
| `sWeight` | Log standard deviation of residual variation in `log(Weight)` |
| `sWeightLengthYear` | Log standard deviation of `bWeightLengthYear` |
| `sWeightYear` | Log standard deviation of `bWeightYear` |
| `Weight[i]` | Recorded weight of `i`th fish |
| `Year[i]` | Year `i`th fish was captured |

## Mountain Whitefish

Table 2. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bWeight | 5.4390387 | 0.0102977 | 528.336881 | 5.4235899 | 5.4646324 | 0.0005 |
| bWeightDayte | -0.0147990 | 0.0020585 | -7.197414 | -0.0189130 | -0.0107286 | 0.0005 |
| bWeightLength | 3.1661644 | 0.0260393 | 121.474057 | 3.1057803 | 3.2094159 | 0.0005 |
| bWeightLengthDayte | -0.0076929 | 0.0055372 | -1.384208 | -0.0182591 | 0.0033349 | 0.1620 |
| sWeight | -1.8763131 | 0.0064140 | -292.541658 | -1.8889387 | -1.8638109 | 0.0005 |
| sWeightLengthYear | -2.2640210 | 0.2058377 | -10.950194 | -2.6352332 | -1.8338990 | 0.0005 |
| sWeightYear | -3.1045752 | 0.1776727 | -17.433366 | -3.4278002 | -2.7191862 | 0.0005 |

Table 3. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 12685 | 7 | 2000 | 4 | 8000 | 318.632011890411s (~5.31 minutes) | 1.09 | TRUE |

## Rainbow Trout

Table 4. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bWeight | 5.9703309 | 0.0057468 | 1038.853687 | 5.9579972 | 5.9815243 | 5e-04 |
| bWeightDayte | -0.0030932 | 0.0014834 | -2.112621 | -0.0060463 | -0.0002667 | 3e-02 |
| bWeightLength | 2.9291951 | 0.0134371 | 218.017675 | 2.9029333 | 2.9557330 | 5e-04 |
| bWeightLengthDayte | 0.0443739 | 0.0043300 | 10.260187 | 0.0361316 | 0.0527975 | 5e-04 |
| sWeight | -2.2047900 | 0.0063170 | -348.991835 | -2.2170083 | -2.1926178 | 5e-04 |

| | | | | | | |
|---|---|---|---|---|---|---|
| sWeightLengthYear | -2.8971651 | 0.2087519 | -13.834212 | -3.2729071 | -2.4457369 | 5e-04 |
| sWeightYear | -3.7442546 | 0.1811811 | -20.596907 | -4.0510794 | -3.3499532 | 5e-04 |

Table 5. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 12722 | 7 | 2000 | 4 | 16000 | 1106.17904925346s (~18.44 minutes) | 1.04 | TRUE |

### Walleye

Table 6. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bWeight | 6.2899191 | 0.0088800 | 708.22123 | 6.2699185 | 6.3045003 | 0.0005 |
| bWeightDayte | 0.0180954 | 0.0015224 | 11.88304 | 0.0149947 | 0.0210590 | 0.0005 |
| bWeightLength | 3.2204020 | 0.0227264 | 141.69706 | 3.1769167 | 3.2650029 | 0.0005 |
| bWeightLengthDayte | -0.0119018 | 0.0090645 | -1.30450 | -0.0291995 | 0.0057579 | 0.1980 |
| sWeight | -2.3175525 | 0.0077896 | -297.52032 | -2.3327386 | -2.3016806 | 0.0005 |
| sWeightLengthYear | -2.4148747 | 0.2019433 | -11.89151 | -2.7704164 | -1.9952701 | 0.0005 |
| sWeightYear | -3.2387561 | 0.1759668 | -18.34560 | -3.5366378 | -2.8606562 | 0.0005 |

Table 7. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 8447 | 7 | 2000 | 4 | 8000 | 525.920606136322s (~8.77 minutes) | 1.07 | TRUE |

## Growth

Table 8. Parameter descriptions.

| Parameter | Description |
|---|---|
| `bK` | Intercept of `log(eK)` |
| `bKYear[i]` | Effect of `i`th `Year` on `bK` |
| `bLinf` | Mean maximum length |
| `dYears[i]` | Years between release and recapture of `i`th recapture |
| `eGrowth` | Expected `Growth` between release and recapture |
| `eK[i]` | Expected von Bertalanffy growth coefficient from `i-1`th to `i`th year |
| `Growth[i]` | Observed growth between release and recapture of `i`th recapture |
| `LengthAtRelease[i]` | Length at previous release of `i`th recapture |
| `sGrowth` | Log standard deviation of residual variation in `Growth` |
| `sKYear` | Log standard deviation of `bKYear` |
| `Year[i]` | Release year of `i`th recapture |

### Mountain Whitefish

Table 9. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bK | -1.099146 | 0.1114808 | -9.860444 | -1.327204 | -0.8926646 | 5e-04 |
| bLinf | 406.500356 | 2.6677964 | 152.395582 | 401.450527 | 411.9519584 | 5e-04 |
| sGrowth | 2.557573 | 0.0508553 | 50.296204 | 2.460467 | 2.6608530 | 5e-04 |
| sKYear | -1.000056 | 0.2797959 | -3.552224 | -1.531119 | -0.4263046 | 1e-03 |

Table 10. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 219 | 4 | 2000 | 4 | 8000 | 1.5401759147644s | 1.04 | TRUE |

### Rainbow Trout

Table 11. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bK | -0.2094206 | 0.0676495 | -3.081297 | -0.3404422 | -0.0717022 | 5e-04 |
| bLinf | 497.2801363 | 2.6412130 | 188.304486 | 492.2600699 | 502.5659158 | 5e-04 |
| sGrowth | 3.4092669 | 0.0218738 | 155.873291 | 3.3655334 | 3.4526829 | 5e-04 |
| sKYear | -1.4686670 | 0.2016444 | -7.252837 | -1.8303344 | -1.0426895 | 5e-04 |

Table 12. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 987 | 4 | 2000 | 4 | 4000 | 2.68692588806152s | 1.07 | TRUE |

### Walleye

Table 13. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bK | -2.636259 | 0.2750648 | -9.502826 | -3.077111 | -2.0087887 | 5e-04 |
| bLinf | 795.329686 | 93.3051203 | 8.529336 | 630.945463 | 976.8017130 | 5e-04 |
| sGrowth | 2.875458 | 0.0468415 | 61.413297 | 2.787040 | 2.9696312 | 5e-04 |
| sKYear | -1.057749 | 0.2563667 | -4.100714 | -1.558664 | -0.5439927 | 5e-04 |

Table 14. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 247 | 4 | 2000 | 4 | 32000 | 5.34256601333618s | 1.07 | TRUE |

## Length-At-Age

Table 15. Parameter descriptions.

| Parameter | Description |
|---|---|
| `bDayte[ii]` | Effect of `ii`th age-class on linear effect of dayte on `log(eLength)` |
| `bLengthAgeYear[ii , jj]` | Effect of `ii`th age-class within `jj`th year on `eLength` |

| | |
|---|---|
| `eLength[ii]` | Expected length of `ii`th fish |
| `Length[ii]` | Observed length of `ii`th fish |
| `pAgeYear[ii, jj]` | Proportion of fish in `ii`th age-class within `jj`th year |
| `sLengthAge[ii]` | SD of residual variation in `log(eLength)` of fish in `ii`th age-class |
| `Year[ii]` | Year in which `ii`th fish was caught |

## Mountain Whitefish

Table 16. Parameter estimates from length-at-age model. Averages are taken across yearly coefficients.

| Parameter | estimate |
|---|---:|
| Average bDayte $Age-0$ | 0.003436 |
| Average bDayte $Age-1$ | 0.001149 |
| Average bDayte $Age-2+$ | 0.001387 |
| Average bLengthAgeYear $Age-0$ | 124.0000 |
| Average bLengthAgeYear $Age-1$ | 235.0000 |
| Average bLengthAgeYear $Age-2+$ | 359.0000 |
| Average pAgeYear $Age-0$ | 0.126467 |
| Average pAgeYear $Age-1$ | 0.404435 |
| Average pAgeYear $Age-2+$ | 0.469098 |

Table 17. Estimated length cutoffs (mm) by year from length-at-age model. `Age0-1` is the cuttoff between fry and subadult fish; `Age1-2+` is the cuttoff between subadult and adult fish. Reported cutoffs are for the median sampling date.

| Year | Age0-1 | Age1-2+ |
|---|---:|---:|
| 1990 | 166 | 277 |
| 1991 | 175 | 318 |
| 2001 | 151 | 276 |
| 2002 | 168 | 286 |
| 2003 | 166 | 287 |
| 2004 | 174 | 303 |
| 2005 | 178 | 276 |
| 2006 | 167 | 299 |
| 2007 | 169 | 292 |
| 2008 | 175 | 318 |
| 2009 | 166 | 298 |
| 2010 | 172 | 305 |
| 2011 | 165 | 284 |
| 2012 | 159 | 300 |
| 2013 | 174 | 303 |
| 2014 | 171 | 300 |
| 2015 | 154 | 284 |

| | | |
|---|---|---|
| 2016 | 187 | 294 |

## Rainbow Trout

Table 18. Parameter estimates from length-at-age model. Averages are taken across yearly coefficients.

| Parameter | estimate |
|---|---:|
| Average bDayte $Age-0$ | 0.0014866 |
| Average bDayte $Age-1$ | 0.0017069 |
| Average bDayte $Age-2+$ | 0.0002985 |
| Average bLengthAgeYear $Age-0$ | 113.0000000 |
| Average bLengthAgeYear $Age-1$ | 268.0000000 |
| Average bLengthAgeYear $Age-2+$ | 439.0000000 |
| Average pAgeYear $Age-0$ | 0.0578016 |
| Average pAgeYear $Age-1$ | 0.5797364 |
| Average pAgeYear $Age-2+$ | 0.3624620 |

Table 19. Estimated length cutoffs (mm) by year from length-at-age model. `Age0-1` is the cuttoff between fry and subadult fish; `Age1-2+` is the cuttoff between subadult and adult fish. Reported cutoffs are for the median sampling date.

| Year | Age0-1 | Age1-2+ |
|---|---:|---:|
| 1990 | 185 | 360 |
| 1991 | 128 | 325 |
| 2001 | 159 | 343 |
| 2002 | 194 | 348 |
| 2003 | 202 | 353 |
| 2004 | 190 | 351 |
| 2005 | 207 | 361 |
| 2006 | 200 | 370 |
| 2007 | 197 | 366 |
| 2008 | 188 | 348 |
| 2009 | 182 | 350 |
| 2010 | 184 | 348 |
| 2011 | 184 | 354 |
| 2012 | 198 | 355 |
| 2013 | 204 | 355 |
| 2014 | 188 | 343 |
| 2015 | 205 | 344 |
| 2016 | 218 | 356 |

## Observer Length Correction

Table 20. Parameter descriptions.

| Parameter | Description |
|---|---|
| `Annual[i]` | Year `i`th fish was observed |
| `bLength[i]` | Relative inaccuracy of `i`th observer |
| `ClassLength[i ]` | Mean length of fish belonging to `i`th class |
| `dClass[i]` | Prior value for the proportion of fish in the `i`th class |
| `eClass[i]` | Expected class of `i`th fish |
| `eLength[i]` | Expected length of `i`th fish |
| `eSLength[i]` | Expected SD of residual variation in length of `i`th fish |
| `Length[i]` | Observed fork length of `i`th fish |
| `Observer[i]` | Observer of `i`th fish where the first observer used a length board |
| `pClass[i]` | Proportion of fish in the `i`th class |
| `sLength[i]` | Relative imprecision of `i`th observer |

## Mountain Whitefish

Table 21. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bLength2 | 0.9136213 | 0.0051156 | 178.625152 | 0.9035760 | 0.9238427 | 5e-04 |
| bLength3 | 0.8616882 | 0.0064812 | 132.949284 | 0.8487894 | 0.8743314 | 5e-04 |
| bLength4 | 0.8683745 | 0.0125085 | 69.406983 | 0.8435491 | 0.8916728 | 5e-04 |
| bLength5 | 0.9838871 | 0.0134558 | 73.070547 | 0.9543247 | 1.0081292 | 5e-04 |
| bLength6 | 0.8798385 | 0.0038858 | 226.411954 | 0.8720420 | 0.8871658 | 5e-04 |
| bLength7 | 0.9700411 | 0.0040204 | 241.289470 | 0.9624691 | 0.9778570 | 5e-04 |
| sLength2 | 2.0143073 | 0.0236156 | 85.619843 | 2.0005247 | 2.0847834 | 5e-04 |
| sLength3 | 3.6902956 | 0.2335190 | 15.828807 | 3.2715914 | 4.2066962 | 5e-04 |
| sLength4 | 2.0195634 | 0.0315656 | 64.317618 | 2.0008278 | 2.1163382 | 5e-04 |
| sLength5 | 5.7994580 | 1.1852445 | 5.035872 | 4.1378547 | 8.7909309 | 5e-04 |
| sLength6 | 2.0040729 | 0.0064153 | 312.719540 | 2.0001292 | 2.0244321 | 5e-04 |
| sLength7 | 2.0136286 | 0.0208493 | 96.904096 | 2.0005784 | 2.0756379 | 5e-04 |

Table 22. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 11663 | 12 | 2000 | 4 | 8000 | 231.857364177704s (~3.86 minutes) | 1.07 | TRUE |

## Rainbow Trout

Table 23. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bLength2 | 0.8562601 | 0.0042386 | 202.014823 | 0.8482215 | 0.8649813 | 5e-04 |
| bLength3 | 0.8603186 | 0.0055262 | 155.699310 | 0.8502518 | 0.8718323 | 5e-04 |
| bLength4 | 0.7617854 | 0.0128469 | 59.337752 | 0.7381590 | 0.7895895 | 5e-04 |

| | | | | | | |
|---|---|---|---|---|---|---|
| bLength5 | 0.9761303 | 0.0111102 | 87.877275 | 0.9550452 | 0.9982594 | 5e-04 |
| bLength6 | 0.8548536 | 0.0029757 | 287.268881 | 0.8489767 | 0.8605222 | 5e-04 |
| bLength7 | 0.9845652 | 0.0061870 | 159.132815 | 0.9721545 | 0.9967931 | 5e-04 |
| sLength2 | 2.0153009 | 0.0233070 | 86.788981 | 2.0006449 | 2.0839448 | 5e-04 |
| sLength3 | 2.4938840 | 0.3147911 | 8.028573 | 2.0264822 | 3.2105978 | 5e-04 |
| sLength4 | 4.3694078 | 0.6307941 | 6.998507 | 3.2716412 | 5.7694546 | 5e-04 |
| sLength5 | 4.2806949 | 0.8812575 | 4.747788 | 2.3380737 | 5.6793642 | 5e-04 |
| sLength6 | 2.0098063 | 0.0146277 | 137.709381 | 2.0003867 | 2.0537921 | 5e-04 |
| sLength7 | 2.0741218 | 0.1227886 | 17.198757 | 2.0026291 | 2.4296138 | 5e-04 |

Table 24. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 11331 | 12 | 2000 | 4 | 8000 | 308.873648881912s (~5.15 minutes) | 1.07 | TRUE |

## Walleye

Table 25. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bLength2 | 0.8021716 | 0.0167514 | 48.030907 | 0.7780264 | 0.8424344 | 5e-04 |
| bLength3 | 0.9196234 | 0.0082742 | 111.136853 | 0.9037184 | 0.9352438 | 5e-04 |
| bLength4 | 0.8504446 | 0.0196170 | 43.490146 | 0.8213962 | 0.8966736 | 5e-04 |
| bLength5 | 0.9061138 | 0.0286848 | 31.605103 | 0.8511927 | 0.9644157 | 5e-04 |
| bLength6 | 0.9312984 | 0.0071767 | 129.740147 | 0.9172863 | 0.9457182 | 5e-04 |
| bLength7 | 0.9301154 | 0.0253396 | 36.689509 | 0.8777594 | 0.9791389 | 5e-04 |
| sLength2 | 3.4317672 | 1.1831261 | 2.943225 | 2.0222866 | 5.9025470 | 5e-04 |
| sLength3 | 2.3414646 | 0.5375360 | 4.675262 | 2.0135296 | 4.0519775 | 5e-04 |
| sLength4 | 2.5323496 | 0.8819812 | 3.234882 | 2.0140385 | 5.2078754 | 5e-04 |
| sLength5 | 9.5948995 | 0.4824264 | 19.613396 | 8.1976885 | 9.9873743 | 5e-04 |
| sLength6 | 2.0738182 | 0.1324764 | 15.942951 | 2.0033312 | 2.4488926 | 5e-04 |
| sLength7 | 9.2622687 | 0.6369994 | 14.345806 | 7.6120547 | 9.9715296 | 5e-04 |

Table 26. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 2224 | 12 | 2000 | 4 | 16000 | 104.354532957077s (~1.74 minutes) | 1.06 | TRUE |

## Survival

Table 27. Parameter descriptions.

| Parameter | Description |
|---|---|
| `bEfficiency` | Intercept for `logit(eEfficiency)` |
| `bEfficiencySampledLength` | Effect of `SampledLength` on `bEfficiency` |
| `bSurvival` | Intercept for `logit(eSurvival)` |

| | |
|---|---|
| `bSurvivalYear[i]` | Effect of `Year` on `bSurvival` |
| `eEfficiency[i]` | Expected recapture probability in `i`th year |
| `eSurvival[i]` | Expected survival probability from `i-1`th to `i`th year |
| `SampledLength` | Total standardised length of river sampled |
| `sSurvivalYear` | SD of `bSurvivalYear` |

## Mountain Whitefish

Table 28. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bEfficiency | -4.124880 | 0.124235 | -33.21579 | -4.3781263 | -3.890036 | 0.0005 |
| bEfficiencySampledLength | 0.3784501 | 0.1440952 | 2.608601 | 0.1062981 | 0.655473 | 0.0100 |
| bSurvival | 0.9311179 | 0.5646614 | 1.793733 | 0.1084138 | 2.378379 | 0.0220 |
| sSurvivalYear | 1.4930695 | 0.6675294 | 2.430623 | 0.7061404 | 3.287383 | 0.0005 |

Table 29. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 15 | 4 | 2000 | 4 | 16000 | 4.91605710983276s | 1.1 | TRUE |

## Rainbow Trout

Table 30. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bEfficiency | -2.487930 | 0.1038628 | -23.92374 | -2.676433 | -2.288550 | 0.0005 |
| bEfficiencySampledLength | 0.0303952 | 0.091725 | 0.3346703 | -0.148369 | 0.2091638 | 0.7550 |
| bSurvival | -0.508246 | 0.1342713 | -3.834039 | -0.780820 | -0.255130 | 0.0005 |
| sSurvivalYear | 0.3808997 | 0.1323195 | 2.9908899 | 0.1777309 | 0.6966400 | 0.0005 |

Table 31. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 15 | 4 | 2000 | 4 | 4000 | 1.27427315711975s | 1.03 | TRUE |

## Walleye

Table 32. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bEfficiency | -3.353429 | 0.1128296 | -29.72294 | -3.574324 | -3.130489 | 0.0005 |
| bEfficiencySampledLength | 0.0723255 | 0.097484 | 0.7819742 | -0.113512 | 0.2764576 | 0.4330 |
| bSurvival | 0.0588601 | 0.190118 | 0.2984865 | -0.313696 | 0.4237533 | 0.7310 |
| sSurvivalYear | 0.5275843 | 0.2150331 | 2.5934940 | 0.2234553 | 1.0756806 | 0.0005 |

Table 33. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 15 | 4 | 2000 | 4 | 4000 | 1.26076698303223s | 1.05 | TRUE |

## Site Fidelity

Table 34. Parameter descriptions.

| Parameter | Description |
|---|---|
| `bFidelity` | Intercept of `logit(eFidelity)` |
| `bLength` | Effect of length on `logit(eFidelity)` |
| `eFidelity [i]` | Expected site fidelity of `i`th recapture |
| `Fidelity[ i]` | Whether the `i`th recapture was encountered at the same site as the previous encounter |
| `Length[i]` | Length at previous encounter of `i`th recapture |

### Mountain Whitefish

Table 35. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bFidelity | -0.1793419 | 0.1944102 | -0.9388563 | -0.5581083 | 0.1863972 | 0.367 |
| bLength | -0.0965718 | 0.2030887 | -0.5000742 | -0.4873820 | 0.3149466 | 0.616 |

Table 36. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 112 | 2 | 2000 | 4 | 4000 | 0.221499919891357s | 1.01 | TRUE |

### Rainbow Trout

Table 37. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bFidelity | 0.7968407 | 0.0836815 | 9.518156 | 0.6383962 | 0.9572933 | 5e-04 |
| bLength | -0.3416541 | 0.0816499 | -4.185570 | -0.5034542 | -0.1767749 | 5e-04 |

Table 38. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 702 | 2 | 2000 | 4 | 4000 | 0.954435110092163s | 1 | TRUE |

### Walleye

Table 39. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bFidelity | 0.6948377 | 0.1418571 | 4.8819700 | 0.4084017 | 0.9747789 | 0.0005 |
| bLength | -0.0838628 | 0.1435947 | -0.6198429 | -0.3865164 | 0.1877150 | 0.5340 |

Table 40. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 212 | 2 | 2000 | 4 | 4000 | 0.291643857955933s | 1 | TRUE |

## Capture Efficiency

Table 41. Parameter descriptions.

| Parameter | Description |
|---|---|
| `Annual[i]` | Year of `i`th visit |
| `bEfficiency` | Intercept for `logit(eEfficiency)` |
| `bEfficiencySessionAnnual` | Effect of `Session` within `Annual` on `logit(eEfficiency)` |
| `eEfficiency[i]` | Expected efficiency on `i`th visit |
| `eFidelity[i]` | Expected site fidelity on `i`th visit |
| `Fidelity[i]` | Mean site fidelity on `i`th visit |
| `FidelitySD[i]` | SD of site fidelity on `i`th visit |
| `Recaptures[i]` | Number of marked fish recaught during `i`th visit |
| `sEfficiencySessionAnnual` | SD of effect of `Session` within `Annual` on `logit(eEfficiency)` |
| `Session[i]` | Session of `i`th visit |
| `Tagged[i]` | Number of marked fish tagged prior to `i`th visit |

### Mountain Whitefish

#### *Subadult*

Table 42. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bEfficiency | -4.93827 | 0.162014 | -30.51687 | -5.281714 | -4.6527581 | 5e-04 |
| sEfficiencySessionAnnual | -1.874615 | 1.2971003 | -1.682591 | -5.190868 | -0.3761219 | 9e-03 |

Table 43. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 1372 | 2 | 2000 | 4 | 40000 | 52.2466599941254s | 1.06 | TRUE |

#### *Adult*

Table 44. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bEfficiency | -5.29197 | 0.176858 | -29.98592 | -5.669844 | -4.9777022 | 5e-04 |
| sEfficiencySessionAnnual | -1.769295 | 0.9341313 | -2.025694 | -3.931266 | -0.3803537 | 1e-03 |

Table 45. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 1349 | 2 | 2000 | 4 | 40000 | 47.9335269927979s | 1.07 | TRUE |

## Rainbow Trout

### *Subadult*

Table 46. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bEfficiency | -3.364014 | 0.066833 | -50.3423 | -3.49890 | -3.237201 | 5e-04 |
| sEfficiencySessionAn nual | -0.962906 | 0.169640 1 | -5.660272 | -1.31292 7 | -0.632216 7 | 5e-04 |

Table 47. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 1422 | 2 | 2000 | 4 | 40000 | 55.0563459396362s | 1 | TRUE |

### *Adult*

Table 48. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bEfficiency | -4.05528 | 0.074750 | -54.27372 | -4.20515 0 | -3.915816 1 | 5e-04 |
| sEfficiencySessionAn nual | -1.88434 8 | 0.862607 8 | -2.406419 | -4.16749 2 | -0.938996 1 | 5e-04 |

Table 49. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 1459 | 2 | 2000 | 4 | 40000 | 49.1264290809631s | 1.05 | TRUE |

## Walleye

### *Adult*

Table 50. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bEfficiency | -4.490419 | 0.123970 | -36.2417 | -4.749816 | -4.266755 | 5e-04 |
| sEfficiencySessionAn nual | -0.517217 | 0.203375 | -2.572915 | -0.936788 5 | -0.145718 | 7e-03 |

Table 51. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 1522 | 2 | 2000 | 4 | 40000 | 51.39386510849s | 1.01 | TRUE |

## Abundance

Table 52. Parameter descriptions.

| Parameter | Description |
|---|---|
| `Annual` | Year |
| `bDensity` | Intercept for `log(eDensity)` |
| `bDensityAnnual` | Effect of `Annual` on `bDensity` |
| `bDensitySite` | Effect of `Site` on `bDensity` |
| `bDensitySiteAnnual` | Effect of `Site` within `Annual` on `bDensity` |
| `bEfficiencyVisitType` | Effect of `VisitType` on `Efficiency` |
| `eDensity` | Expected density |
| `Efficiency` | Capture efficiency |
| `esDispersion` | Overdispersion of `Fish` |
| `Fish` | Number of fish captured or counted |
| `ProportionSampled` | Proportion of site surveyed |
| `sDensityAnnual` | Log SD of effect of `Annual` on `bDensity` |
| `sDensitySite` | Log SD of effect of `Site` on `bDensity` |
| `sDensitySiteAnnual` | Log SD of effect of `Site` within `Annual` on `bDensity` |
| `sDispersion` | Intercept for `log(esDispersion)` |
| `sDispersionVisitType` | Effect of `VisitType` on `sDispersion` |
| `Site` | Site |
| `SiteLength` | Length of site |
| `VisitType` | Survey type (catch versus count) |

### Mountain Whitefish

#### *Subadult*

Table 53. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---:|---:|---:|---:|---:|---|
| bDensity | 5.7923490 | 0.170911 | 33.923028 | 5.4662141 | 6.1679499 | 0.0005 |
| bEfficiencyVisitType2 | 1.5010524 | 0.077114 | 19.489004 | 1.3533321 | 1.6573102 | 0.0005 |
| sDensityAnnual | -0.602628 | 0.201973 | -2.917420 | -0.964877 0 | -0.171470 1 | 0.0120 |
| sDensitySite | -0.269638 | 0.108314 | -2.463341 | -0.479048 5 | -0.041570 8 | 0.0240 |
| sDensitySiteAnnual | -0.865514 | 0.063489 | -13.67185 6 | -0.998185 5 | -0.748663 1 | 0.0005 |
| sDispersion | -0.721286 | 0.041050 | -17.57833 1 | -0.805672 5 | -0.644390 0 | 0.0005 |
| sDispersionVisitType2 | 0.2623007 | 0.107987 | 2.401379 | 0.0450784 | 0.4587826 | 0.0160 |

Table 54. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---:|---:|---:|---:|---:|---:|---:|---|
| 2231 | 7 | 2000 | 4 | 128000 | 398.677536010742s (~6.64 minutes) | 1.04 | TRUE |

### *Adult*

Table 55. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---:|---:|---:|---:|---:|---:|
| bDensity | 6.1813867 | 0.1410908 | 43.787478 | 5.9000158 | 6.4464737 | 0.0005 |
| bEfficiencyVisitType2 | 1.6751143 | 0.1003168 | 16.685602 | 1.4794066 | 1.8796513 | 0.0005 |
| sDensityAnnual | -1.130635 | 0.2082855 | -5.424672 | -1.522721 | -0.700828 | 0.0005 |
| sDensitySite | 0.1852506 | 0.1042943 | 1.785007 | -0.019306 6 | 0.3985994 | 0.0720 |
| sDensitySiteAnnual | -0.9001136 | 0.0764159 | -11.805926 | -1.0548468 | -0.755133 1 | 0.0005 |
| sDispersion | -0.5580963 | 0.0375540 | -14.88454 1 | -0.634029 5 | -0.488740 2 | 0.0005 |
| sDispersionVisitType2 | 0.4554857 | 0.1011566 | 4.523726 | 0.2713831 | 0.6683742 | 0.0005 |

Table 56. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---:|---:|---:|---:|---:|---:|---:|---|
| 2231 | 7 | 2000 | 4 | 32000 | 103.938536167145s (~1.73 minutes) | 1.1 | TRUE |

## Rainbow Trout

### *Subadult*

Table 57. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---:|---:|---:|---:|---:|---:|
| bDensity | 4.8498904 | 0.1133101 | 42.833328 | 4.6382208 | 5.0899914 | 5e-04 |
| bEfficiencyVisitType2 | 1.7213593 | 0.0992740 | 17.353899 | 1.5340711 | 1.9264324 | 5e-04 |
| sDensityAnnual | -1.324769 7 | 0.216746 3 | -6.079079 | -1.715743 7 | -0.847429 7 | 5e-04 |
| sDensitySite | -0.3224210 | 0.101092 9 | -3.172331 | -0.507459 2 | -0.114350 6 | 5e-04 |
| sDensitySiteAnnual | -0.9518605 | 0.061835 8 | -15.371942 | -1.0705956 | -0.8321918 | 5e-04 |
| sDispersion | -0.9713280 | 0.0415950 | -23.369747 | -1.0550184 | -0.8933246 | 5e-04 |
| sDispersionVisitType2 | 0.7254709 | 0.0936092 | 7.719914 | 0.5357961 | 0.9087836 | 5e-04 |

Table 58. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---:|---:|---:|---:|---:|---:|---:|---|
| 2231 | 7 | 2000 | 4 | 128000 | 387.966784954071s (~6.47 minutes) | 1.01 | TRUE |

### *Adult*

Table 59. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---:|---:|---:|---:|---:|---:|
| bDensity | 5.3612928 | 0.117164 9 | 45.689692 | 5.1095731 | 5.5620438 | 5e-04 |
| bEfficiencyVisitType2 | 1.1119361 | 0.077923 3 | 14.329457 | 0.9707101 | 1.2754754 | 5e-04 |
| sDensityAnnual | -1.476086 9 | 0.215917 7 | -6.796186 | -1.859221 9 | -1.022487 4 | 5e-04 |
| sDensitySite | -0.364489 1 | 0.097875 0 | -3.722088 | -0.550970 7 | -0.168110 7 | 5e-04 |
| sDensitySiteAnnual | -1.363167 1 | 0.091365 7 | -14.928837 | -1.5519328 | -1.1963810 | 5e-04 |

| | | | | | | |
|---|---|---|---|---|---|---|
| sDispersion | -0.9968726 | 0.0495450 | -20.143879 | -1.0995837 | -0.9040671 | 5e-04 |
| sDispersionVisitType2 | 0.5879117 | 0.1079024 | 5.466556 | 0.3802024 | 0.7898651 | 5e-04 |

Table 60. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 2231 | 7 | 2000 | 4 | 64000 | 195.04841709137s (~3.25 minutes) | 1.05 | TRUE |

## Walleye

### *Adult*

Table 61. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bDensity | 5.3324597 | 0.136584 2 | 39.066881 | 5.0694892 | 5.6261485 | 5e-04 |
| bEfficiencyVisitType2 | 1.3362364 | 0.094831 9 | 14.093154 | 1.1482865 | 1.5297912 | 5e-04 |
| sDensityAnnual | -0.759468 6 | 0.197375 5 | -3.803065 | -1.098460 1 | -0.313465 8 | 1e-03 |
| sDensitySite | -1.053338 7 | 0.149086 8 | -7.052889 | -1.340593 2 | -0.758082 5 | 5e-04 |
| sDensitySiteAnnual | -1.3705073 | 0.0963776 | -14.269206 | -1.573518 6 | -1.205326 0 | 5e-04 |
| sDispersion | -0.8062268 | 0.0404170 | -19.958600 | -0.8901817 | -0.7310349 | 5e-04 |
| sDispersionVisitType2 | 0.5285002 | 0.1061829 | 4.960956 | 0.3137325 | 0.7327049 | 5e-04 |

Table 62. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 2231 | 7 | 2000 | 4 | 64000 | 195.838751077652s (~3.26 minutes) | 1.02 | TRUE |

## Stock-Recruitment

Table 63. Parameter descriptions.

| Parameter | Description |
|---|---|
| `bAlpha` | Intercept for `log(eAlpha)` |
| `bBeta` | Intercept for `log(eBeta)` |
| `bStockEggLoss` | Effect of `EggLoss` on `Stock` |
| `eAlpha` | `eRecruits` per `Stock` at low `Stock` density |
| `eBeta` | Expected density-dependence |
| `EggLoss` | Calculated proportional egg loss |
| `eRecruits` | Expected `Recruits` |
| `Recruits` | Number of Age-1 recruits |
| `sRecruits` | Log SD of residual variation in `Recruits` |
| `Stock` | Number of Age-2+ spawners |

### Mountain Whitefish

Table 64. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bAlpha | 0.7633427 | 0.4281958 | 1.7740682 | 0.0360402 | 1.5457689 | 0.0005 |
| bBeta | -10.2577338 | 0.5624995 | -18.3030522 | -11.3835941 | -9.3260317 | 0.0005 |
| bStockEggLoss | 0.0717038 | 2.0206082 | 0.0066256 | -3.8805730 | 3.8913291 | 0.9810 |
| sRecruits | -0.8565672 | 0.1978407 | -4.2554059 | -1.1891157 | -0.4121321 | 0.0005 |

Table 65. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 14 | 4 | 2000 | 4 | 4000 | 0.2s | 1.03 | TRUE |

### Rainbow Trout

Table 66. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bAlpha | 0.9169246 | 0.4018138 | 2.2083730 | 0.0888277 | 1.5688870 | 0.0005 |
| bBeta | -9.3814159 | 0.5893042 | -16.0727401 | -10.7655797 | -8.5726516 | 0.0005 |
| bStockEggLoss | -0.0099327 | 2.0210123 | -0.0126477 | -3.9184809 | 3.9153188 | 0.9920 |
| sRecruits | -1.3721389 | 0.1899328 | -7.1641417 | -1.7006419 | -0.9576928 | 0.0005 |

Table 67. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 15 | 4 | 2000 | 4 | 8000 | 0.3s | 1.1 | TRUE |

## Age-Ratios

Table 68. Parameter descriptions.

| Parameter | Description |
|---|---|
| `Age1[i]` | The number of Age-1 fish in the `i`th year |
| `Age1and2[i]` | The number of Age-1 and Age-2 fish in the `i`th year |
| `bProbAge1` | Intercept for `logit(eProbAge1)` |
| `bProbAge1Loss` | Effect of `LossLogRatio` on `bProbAge1` |
| `eProbAge1[i]` | The expected proportion of Age-1 fish in the `i`th year |
| `LossLogRatio[i]` | The `log` of the ratio of the percent egg losses |
| `sDispersion` | SD of extra-binomial variation |

### Mountain Whitefish

Table 69. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bProbAge1 | 0.4178967 | 0.2032213 | 2.0408439 | 0.0131045 | 0.8231715 | 0.0420 |
| bProbAge1Loss | -0.2446400 | 0.2600279 | -0.9417909 | -0.8071290 | 0.2594519 | 0.3120 |
| sDispersion | 0.7113365 | 0.1679859 | 4.3754889 | 0.4743302 | 1.1375327 | 0.0005 |

Table 70. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 16 | 3 | 2000 | 4 | 16000 | 0.7s | 1.09 | TRUE |

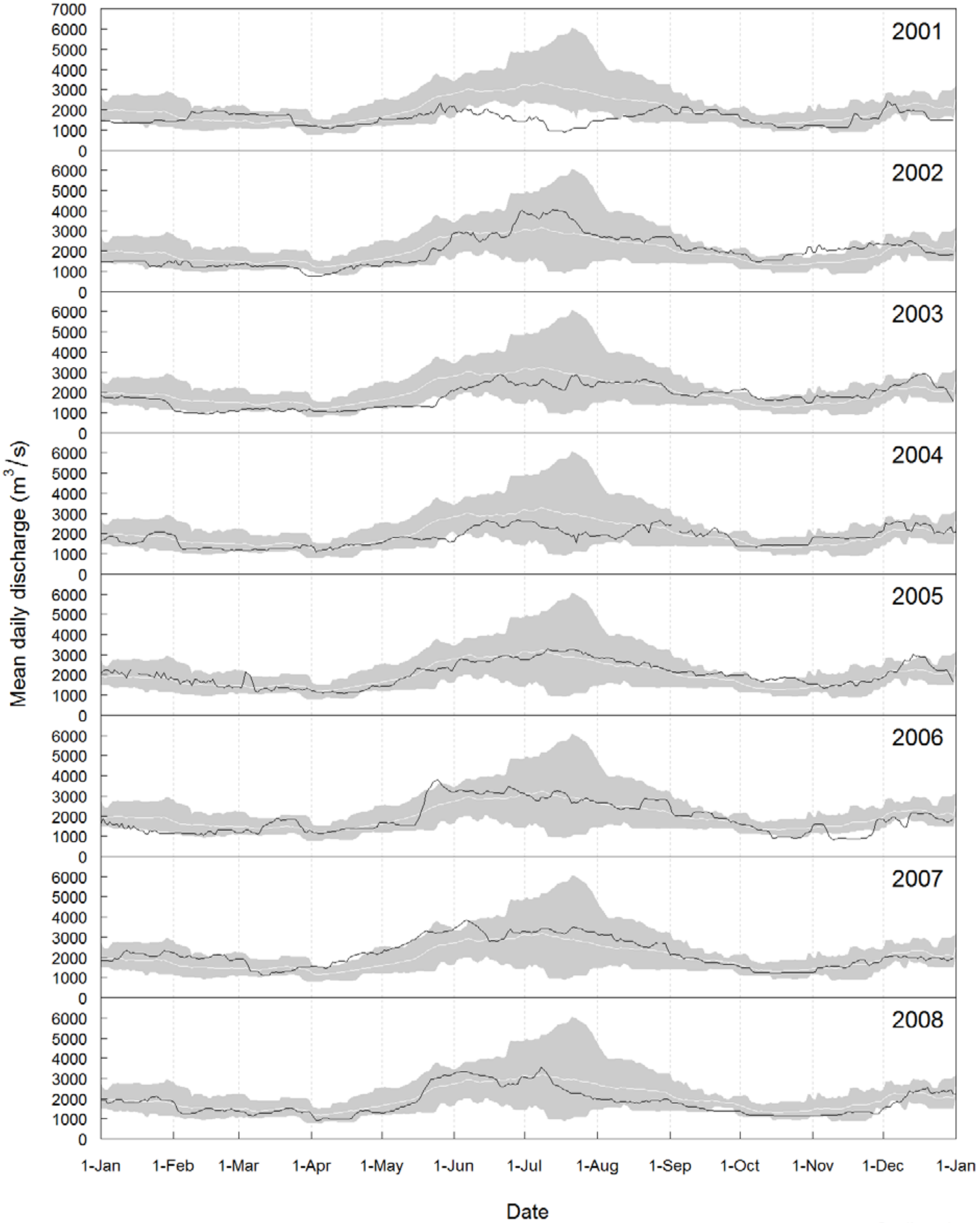
Table 71. Model coefficients.

| term | estimate | sd | zscore | lower | upper | pvalue |
|---|---|---|---|---|---|---|
| bProbAge1 | 0.4909932 | 0.1758969 | 2.805098 | 0.1485806 | 0.8466467 | 0.0005 |
| bProbAge1Loss | -0.2126246 | 0.2381382 | -0.804031 | -0.6334298 | 0.3251386 | 0.4070 |
| sDispersion | 0.6577077 | 0.1502397 | 4.519789 | 0.4447098 | 1.0165972 | 0.0005 |

Table 72. Model summary.

| n | K | nsamples | nchains | nsims | duration | rhat | converged |
|---|---|---|---|---|---|---|---|
| 16 | 3 | 2000 | 4 | 16000 | 1.12108302116394s | 1.06 | TRUE |

# Appendix D – Discharge, Temperature, and Elevation Data



Continued...

*Figure D1. Mean daily discharge (m³/s) for the Columbia River at the Birchbank water gauging station (black line), 2001 to 2016. The shaded area represents minimum and maximum mean daily discharge recorded at Birchbank during other study years between 2001 and 2016. The white line represents average mean daily discharge over the same time period.*

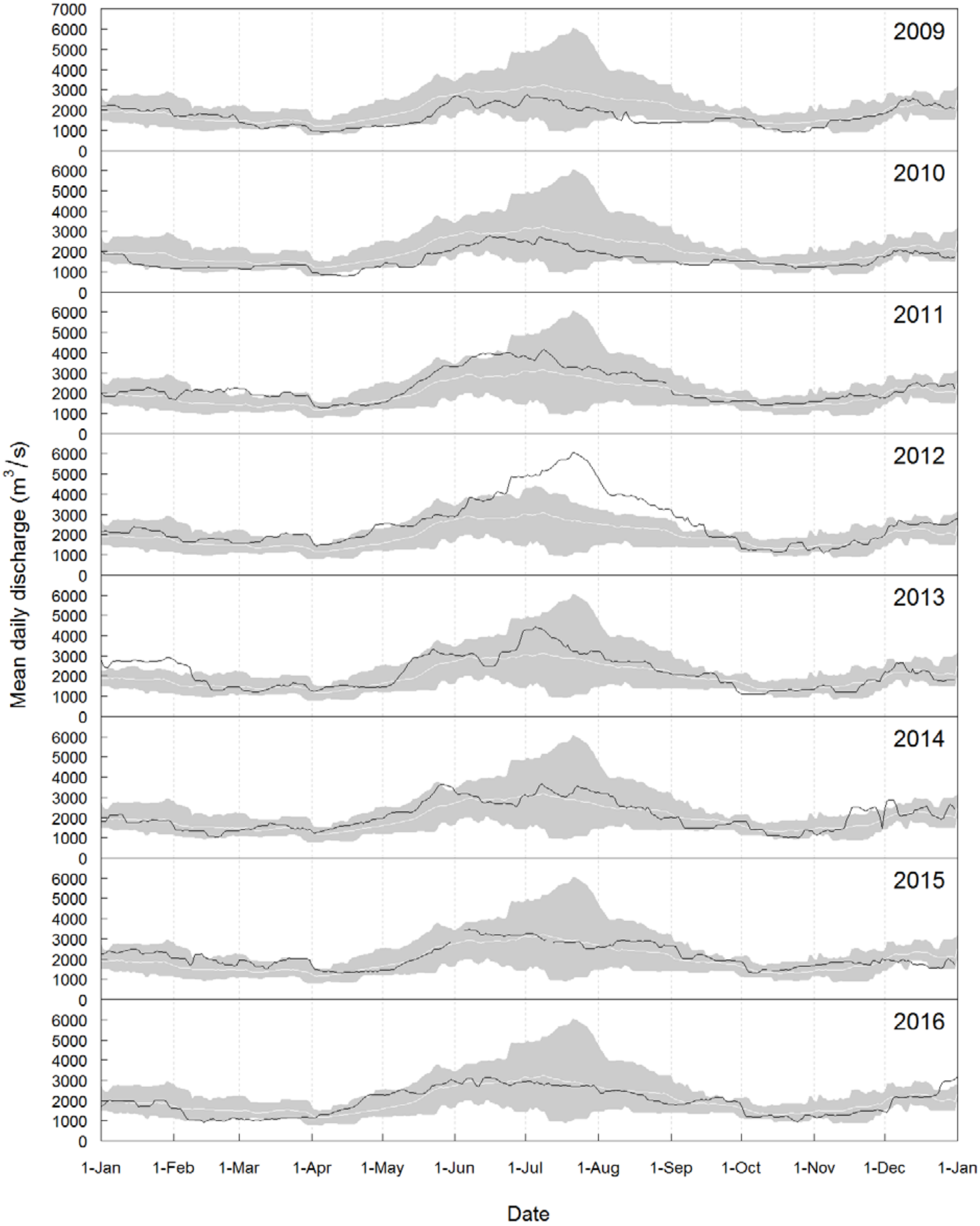
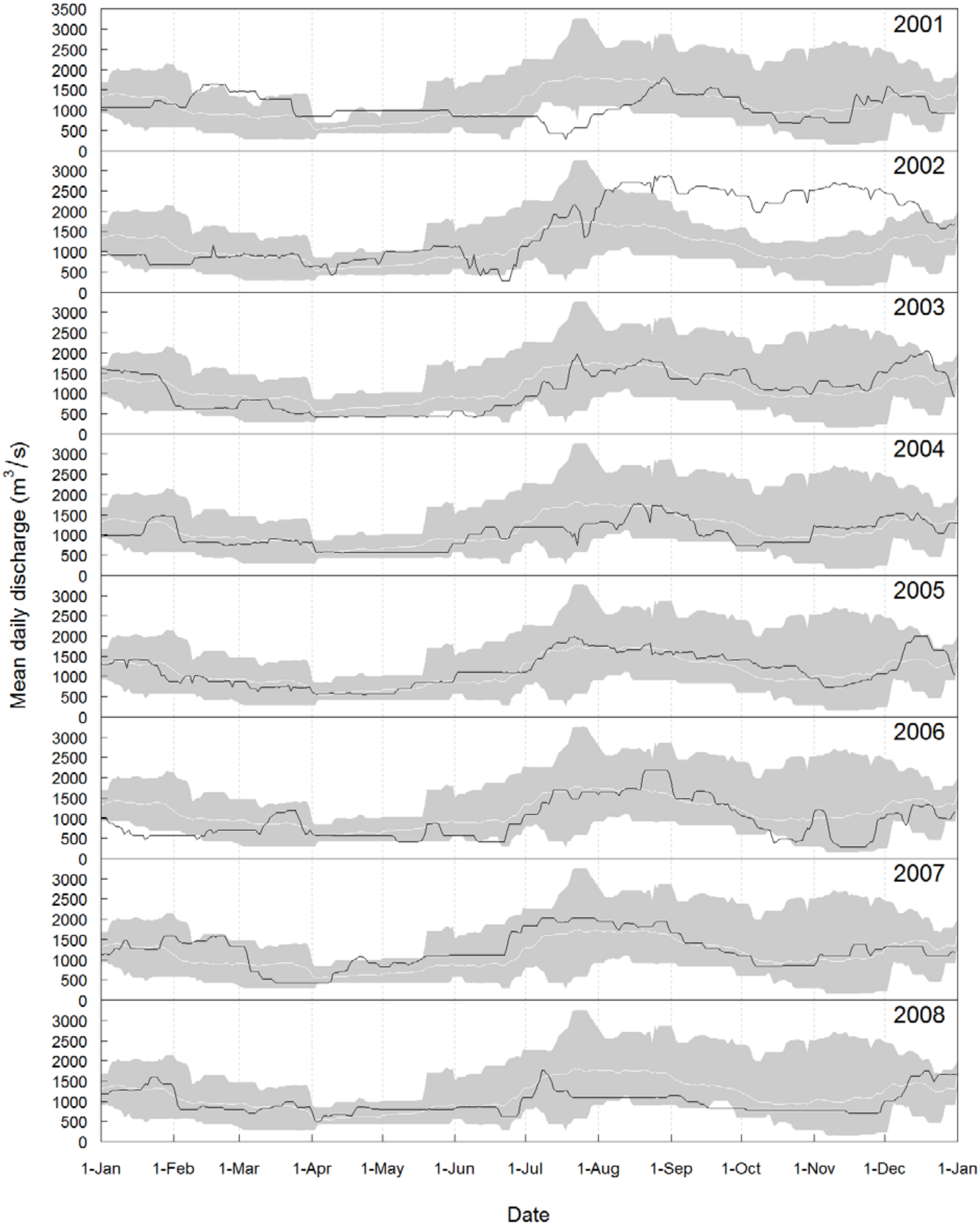


*Figure D1. Concluded.*



Continued...

*Figure D2. Mean daily discharge (m³/s) for the Columbia River at Hugh L. Keenleyside Dam (HLK), 2001 to 2016 (black line). The shaded area represents minimum and maximum mean daily discharge recorded at HLK during other study years between 2001 and 2016. The white line represents average mean daily discharge over the same time period.*

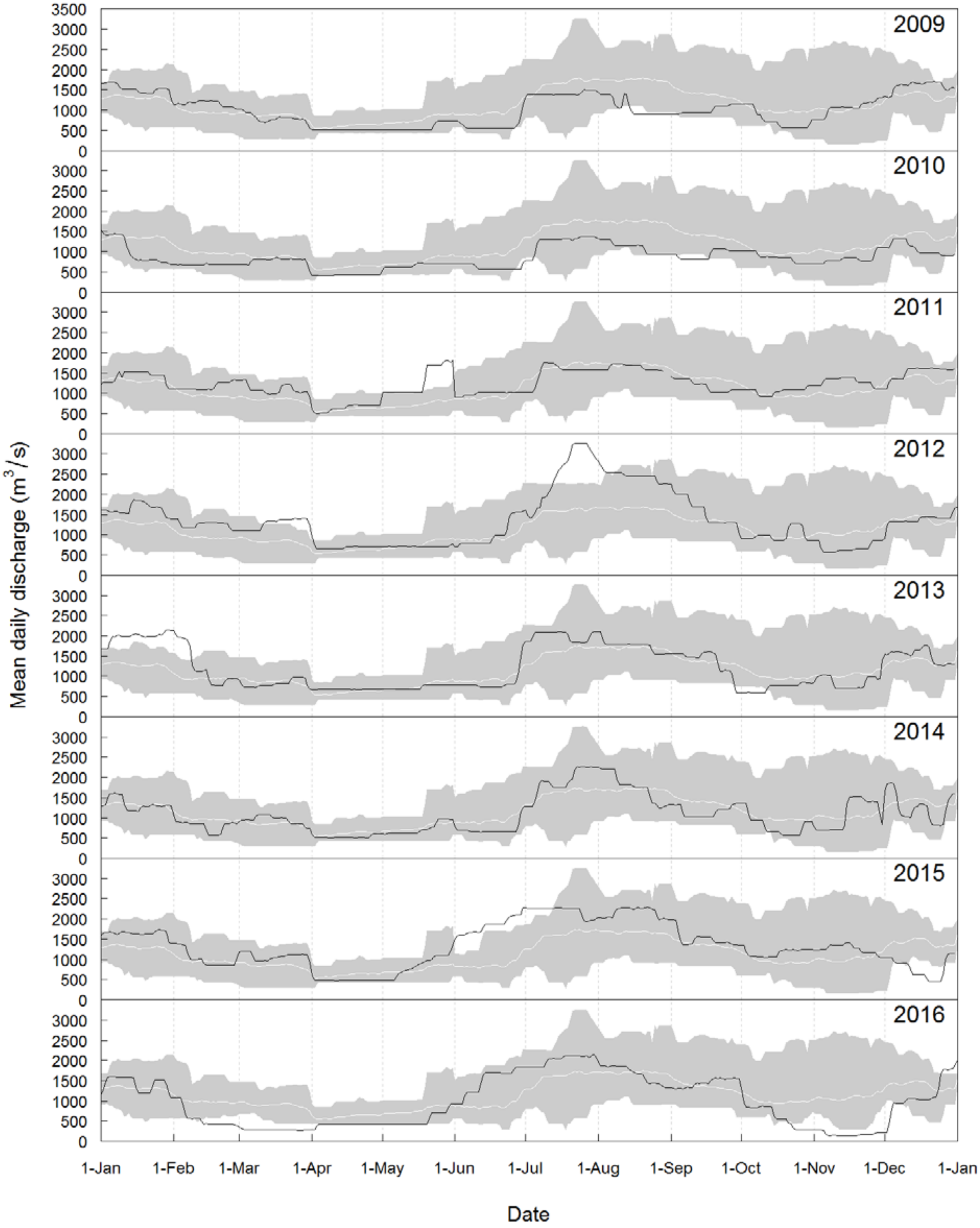
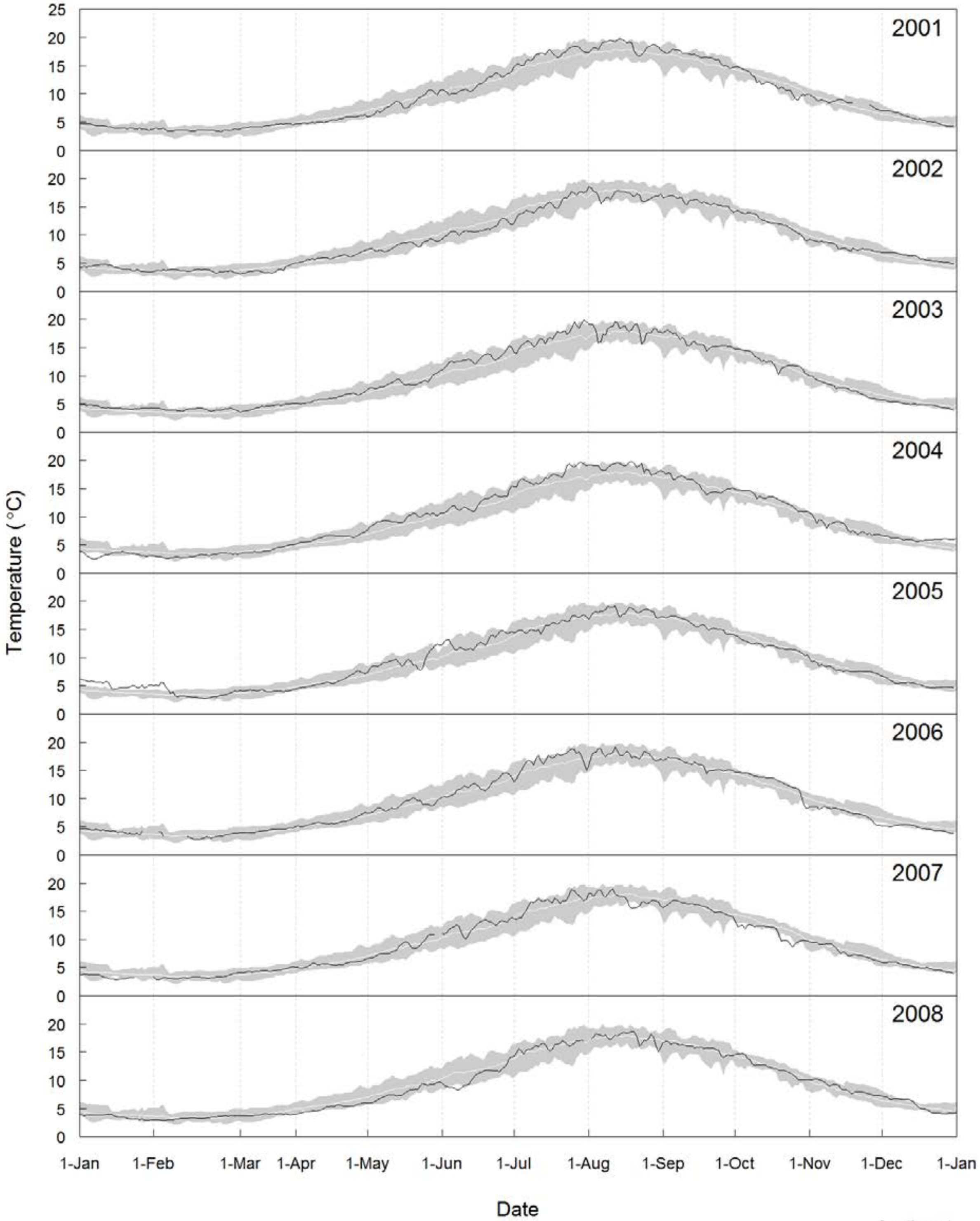


*Figure D2. Concluded.*



Continued...

*Figure D3. Mean daily water temperatures (°C) for the Columbia River (black line), 2001 to 2016. Data from all years except 2012 were recorded at the Birchbank water gauging station. Data from 2012 were recorded near Fort Shepherd. The shaded area represents minimum and maximum mean daily water temperatures during other study years between 2001 and 2016. The white line represents average mean daily water temperature over the same time period.*

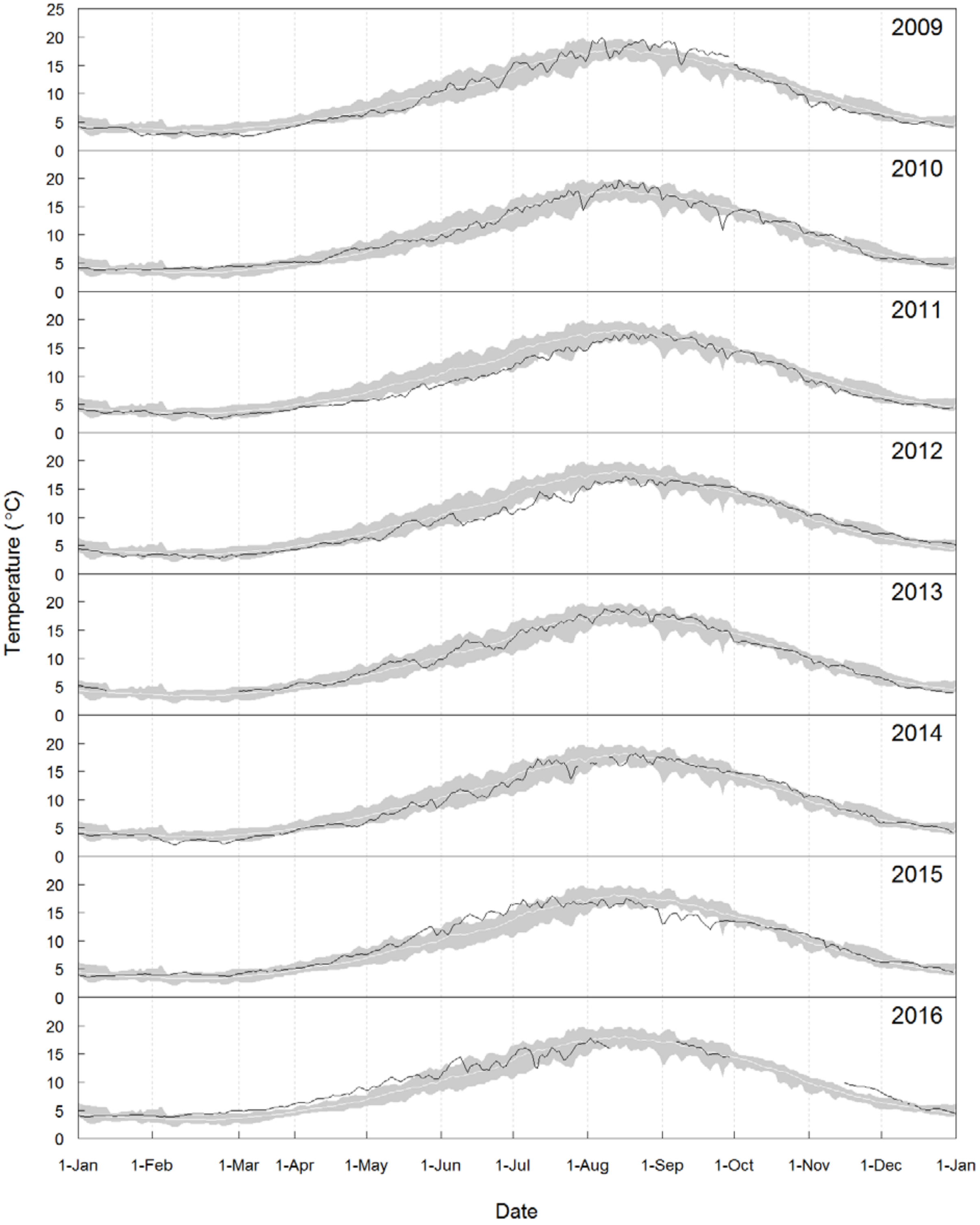
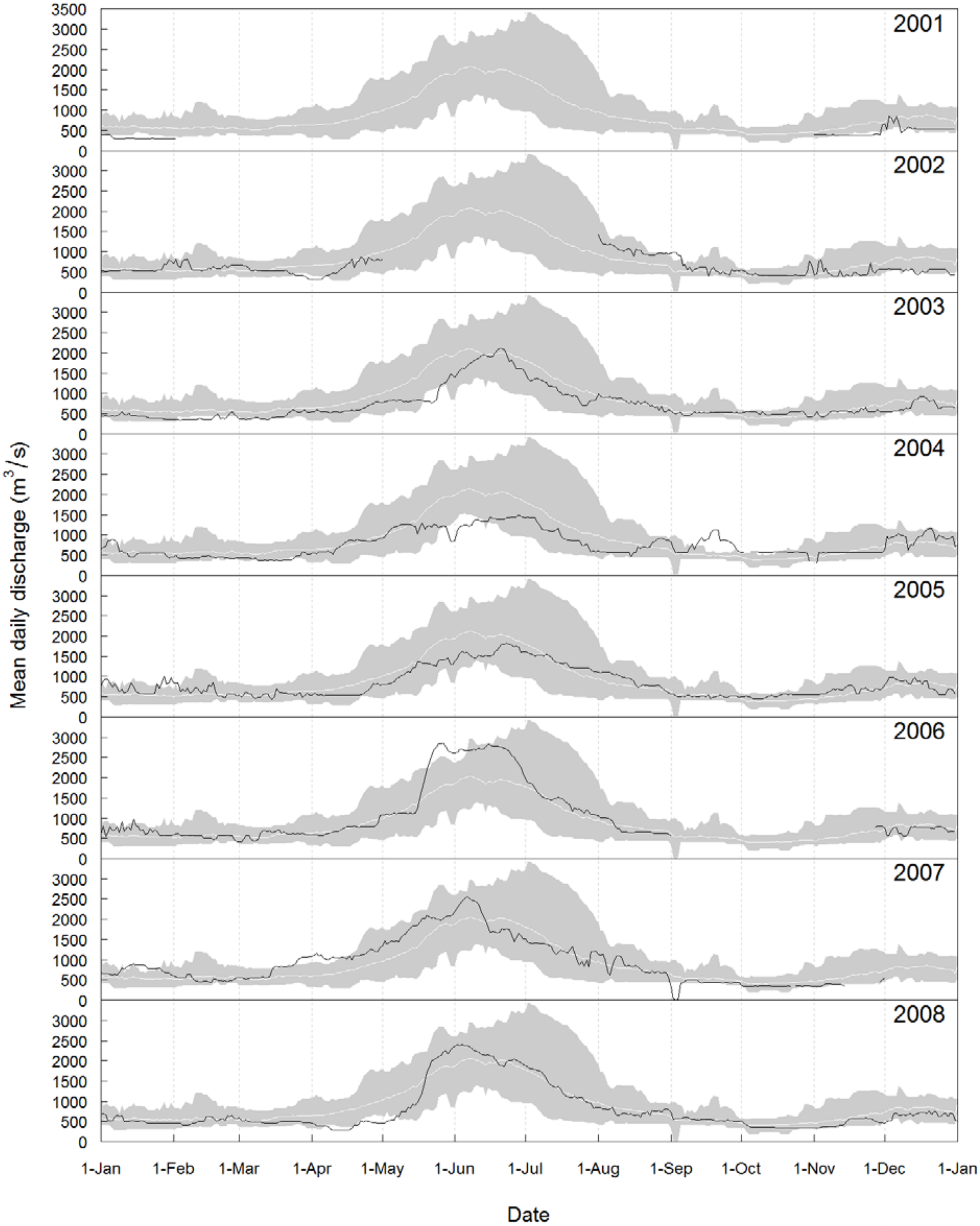


*Figure D3. Concluded.*



Continued...

*Figure D4. Mean daily discharge (m³/s) for the Kootenay River at Brilliant Dam (BRD), 2001 to 2016 (black line). The shaded area represents minimum and maximum mean daily discharge recorded at BRD during other study years between 2001 and 2016. The white line represents average mean daily discharge over the same time period.*

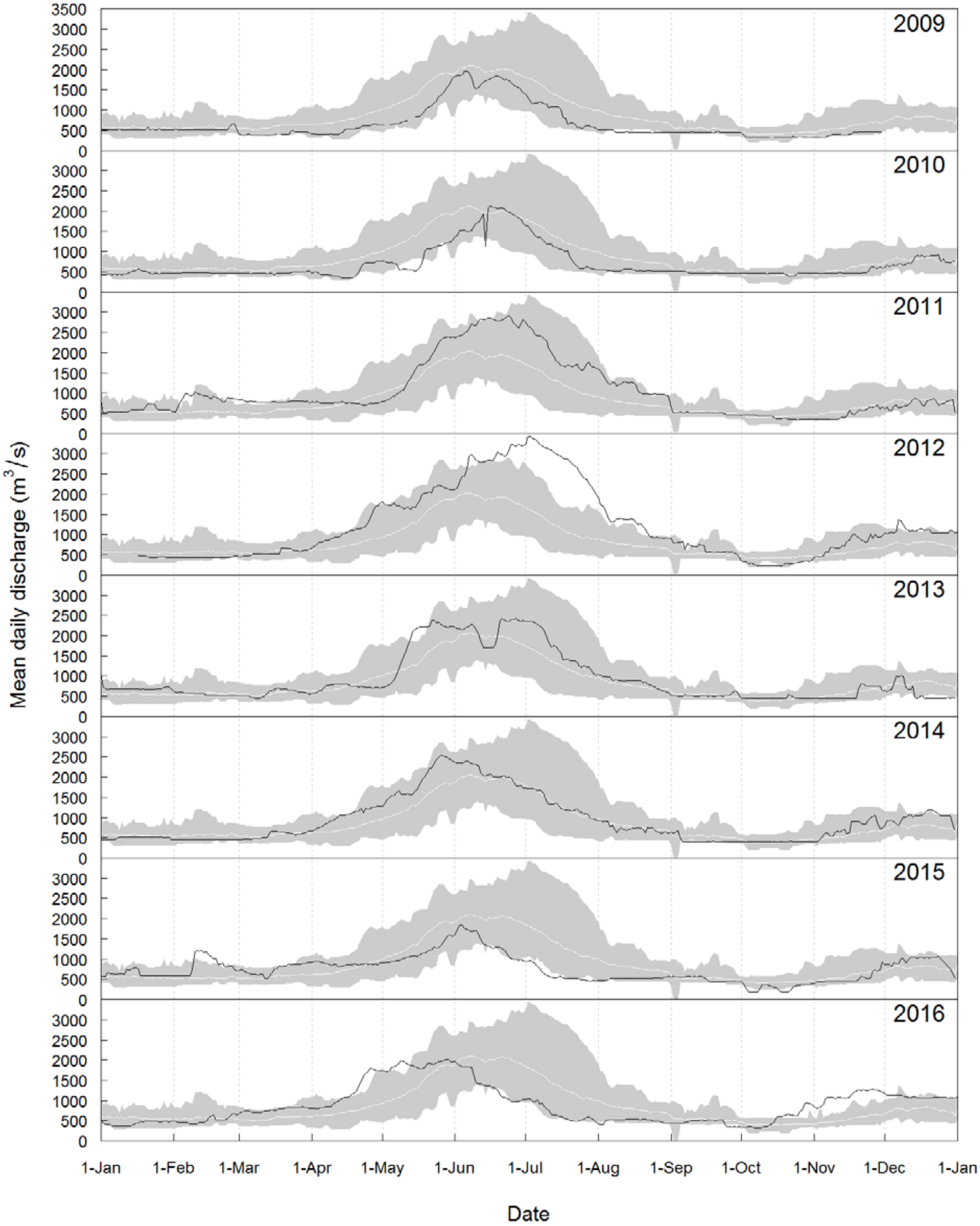
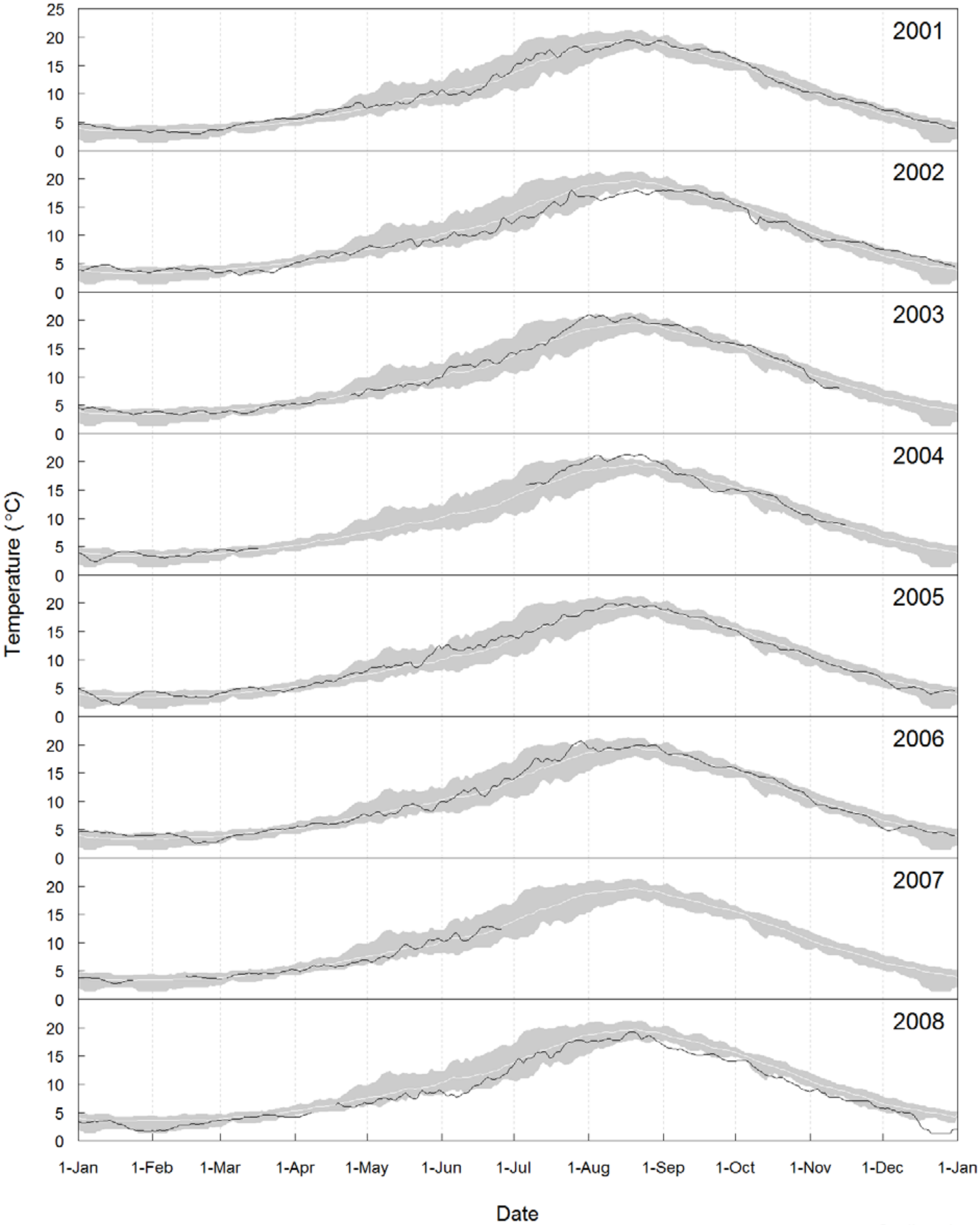


*Figure D4. Concluded.*



Continued...

*Figure D5. Mean daily water temperatures (°C) for the Kootenay River downstream of Brilliant Dam (BRD), 2001 to 2016 (black line). The shaded area represents minimum and maximum mean daily water temperatures recorded at BRD during other study years between 2001 and 2016. The white line represents average mean daily water temperature over the same time period.*

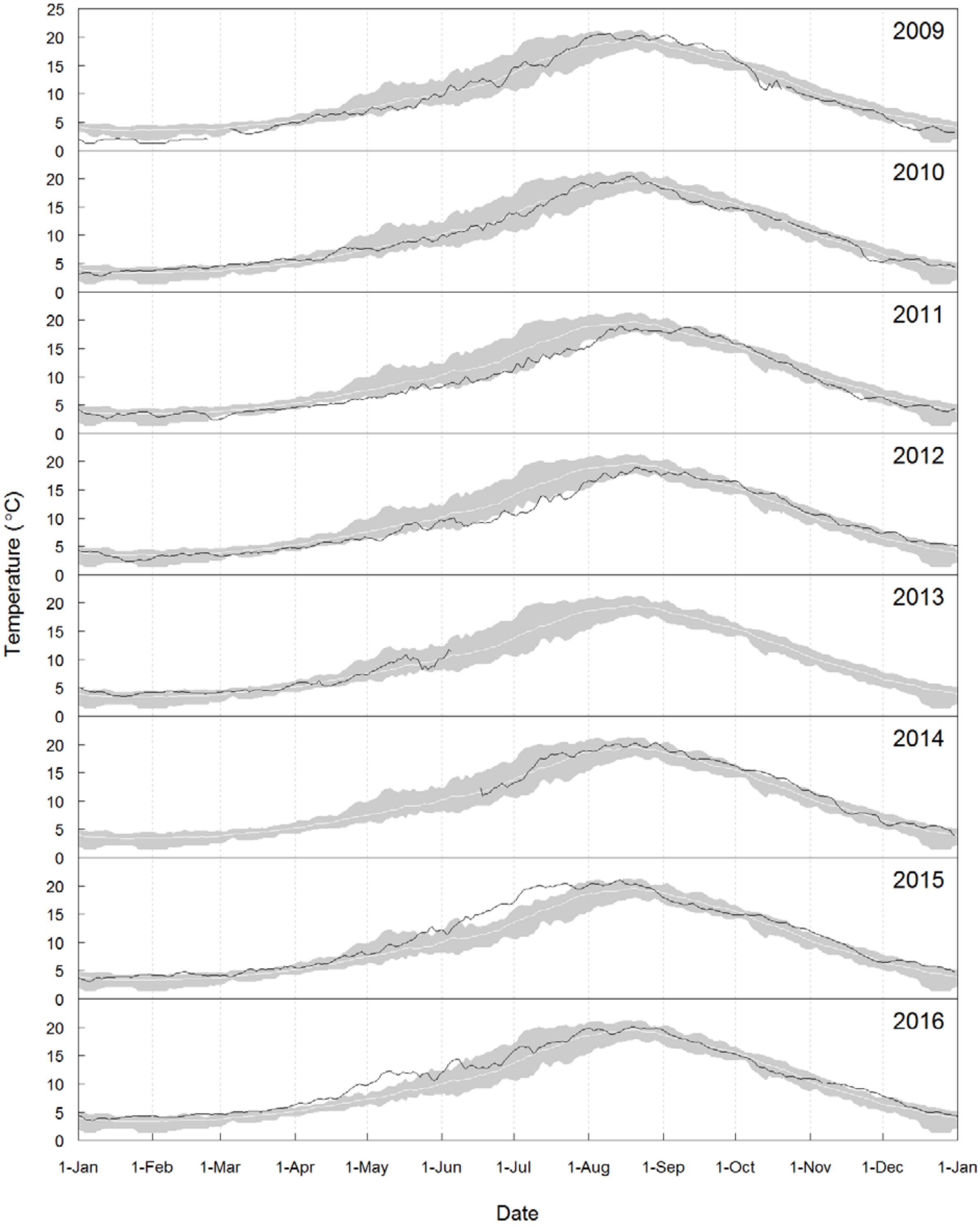


*Figure D5. Concluded.*

# Appendix E – Catch and Effort

Table E1 Number of fish caught and observed during boat electroshocking surveys and their frequency of occurrence in sampled sections of the lower Columbia River, 2001 to 2016. Data include index sites only; all data from GRTS sites were removed.

| | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | 2016 | | All Years[a] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | *n*[a] | %[b] | %[c] |
| **Sportfish** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brook Trout | 5 | <1 | 8 | <1 | 7 | <1 | 3 | <1 | 3 | <1 | 4 | <1 | 15 | <1 | 8 | <1 | 3 | <1 | 4 | <1 | 14 | <1 | 15 | <1 | 31 | <1 | 17 | <1 | 9 | <1 | 1 | <1 | 147 | <1 | |
| Brown Trout | 1 | <1 | 2 | <1 | | | 1 | <1 | 1 | <1 | 2 | <1 | 7 | <1 | 2 | <1 | 3 | <1 | 8 | <1 | 4 | <1 | 2 | <1 | 3 | <1 | 5 | <1 | 1 | <1 | 2 | <1 | 44 | <1 | |
| Bull Trout | 16 | <1 | 3 | <1 | 18 | <1 | 8 | <1 | 8 | <1 | 11 | <1 | 30 | <1 | 6 | <1 | 9 | <1 | 8 | <1 | 12 | <1 | 13 | <1 | 6 | <1 | 4 | <1 | 8 | <1 | 3 | <1 | 163 | <1 | |
| Burbot | 3 | <1 | 10 | <1 | 59 | <1 | 208 | 1 | 174 | 2 | 195 | 1 | 191 | 2 | 69 | 1 | 33 | <1 | 70 | 1 | 247 | 2 | 39 | <1 | 14 | <1 | 20 | <1 | 6 | <1 | 11 | <1 | 1349 | 1 | |
| Cutthroat Trout | 1 | <1 | 4 | <1 | 2 | <1 | | | 1 | <1 | 5 | <1 | 8 | <1 | 5 | <1 | 3 | <1 | 6 | <1 | 4 | <1 | 4 | <1 | 2 | <1 | | | | | | | 45 | <1 | |
| Kokanee | 2562 | 9 | 171 | 1 | 5180 | 19 | 120 | 1 | 32 | <1 | 898 | 7 | 506 | 4 | 148 | 1 | 1128 | 11 | 57 | 1 | 77 | 1 | 156 | 1 | 18 | <1 | 7 | <1 | 22 | <1 | 24 | <1 | 11 106 | 5 | 1 |
| Lake Trout | | | 1 | <1 | | | | | | | | | | | 1 | <1 | | | | | | | | | | | 1 | <1 | | | | | 3 | <1 | |
| Lake Whitefish | 61 | <1 | 140 | 1 | 230 | 1 | 160 | 1 | 262 | 2 | 290 | 2 | 163 | 1 | 159 | 1 | 192 | 2 | 239 | 3 | 220 | 2 | 61 | 1 | 71 | 1 | 70 | 1 | 71 | 1 | 205 | 2 | 2594 | 1 | |
| Largemouth Bass | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | <1 | | | | | 1 | <1 | |
| Mountain Whitefish | 14 916 | 52 | 12 108 | 50 | 9685 | 35 | 6020 | 38 | 5024 | 43 | 5472 | 40 | 5595 | 45 | 5221 | 44 | 3800 | 36 | 2748 | 30 | 2933 | 27 | 4648 | 41 | 4880 | 49 | 4020 | 53 | 2997 | 45 | 4315 | 45 | 94 382 | 43 | 11 |
| Northern Pike | | | | | | | | | | | | | | | | | | | 7 | <1 | 9 | <1 | 11 | <1 | 125 | 1 | 25 | <1 | 9 | <1 | 4 | <1 | 190 | <1 | |
| Rainbow Trout | 9425 | 33 | 10 221 | 42 | 8466 | 30 | 5763 | 37 | 3844 | 33 | 5338 | 39 | 4953 | 39 | 5124 | 43 | 4219 | 40 | 4420 | 48 | 5501 | 51 | 5401 | 48 | 4110 | 41 | 2937 | 39 | 3081 | 46 | 4007 | 42 | 86 810 | 39 | 10 |
| Smallmouth Bass | | | | | 4 | <1 | 3 | <1 | 4 | <1 | 53 | <1 | 16 | <1 | 1 | <1 | | | 1 | <1 | 8 | <1 | | | | | 9 | <1 | 1 | <1 | 2 | <1 | 102 | <1 | |
| Walleye | 1467 | 5 | 1478 | 6 | 4165 | 15 | 3413 | 22 | 2230 | 19 | 1421 | 10 | 1076 | 9 | 1208 | 10 | 1127 | 11 | 1588 | 17 | 1814 | 17 | 881 | 8 | 752 | 8 | 484 | 6 | 480 | 7 | 1021 | 11 | 24 605 | 11 | 3 |
| White Sturgeon | 14 | <1 | 6 | <1 | 18 | <1 | 6 | <1 | 11 | <1 | 14 | <1 | 11 | <1 | 9 | <1 | 4 | <1 | 11 | <1 | 23 | <1 | 9 | <1 | 7 | <1 | 13 | <1 | 14 | <1 | 35 | <1 | 205 | <1 | |
| Yellow Perch | | | | | 1 | <1 | 4 | <1 | 1 | <1 | 24 | <1 | 1 | <1 | | | | | 12 | <1 | 2 | <1 | | | 1 | <1 | | | 2 | <1 | 6 | <1 | 54 | <1 | |
| **Sportfish subtotal** | 28 471 | 100 | 24 152 | 100 | 27 835 | 100 | 15 709 | 100 | 11 595 | 100 | 13 727 | 100 | 12 572 | 100 | 11 961 | 100 | 10 521 | 100 | 9179 | 100 | 10 868 | 100 | 11 240 | 100 | 10 020 | 100 | 7613 | 100 | 6701 | 100 | 9636 | 100 | 221 800 | 100 | 25 |
| **Non-sportfish** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Carp spp. | 2 | <1 | | | | | 1 | <1 | 1 | <1 | 3 | <1 | 1 | <1 | 2 | <1 | | | 3 | <1 | | | | | | | | | 1 | <1 | | | 14 | <1 | |
| Dace spp. | 2 | <1 | | | | | 3 | <1 | 15 | <1 | 17 | <1 | 1 | <1 | 1 | <1 | | | 13 | <1 | 3 | <1 | 1 | <1 | | | | | | | | | 56 | <1 | |
| Northern Pikeminnow | 570 | 3 | 2371 | 10 | 969 | 3 | 1337 | 3 | 522 | 2 | 1450 | 2 | 845 | 1 | 1452 | 2 | 241 | 1 | 393 | 1 | 764 | 2 | 681 | 3 | 453 | <1 | 64 | <1 | 138 | 2 | 42 | <1 | 12 292 | 2 | 1 |
| Peamouth | 80 | <1 | 205 | 1 | 45 | <1 | 51 | <1 | 33 | <1 | 52 | <1 | 93 | <1 | 3 | <1 | 4 | <1 | 25 | <1 | 192 | <1 | 488 | 2 | 12 | <1 | 25 | <1 | 156 | 2 | 3 | <1 | 1467 | <1 | |
| Redside Shiner | 8520 | 46 | 9026 | 40 | 5710 | 20 | 4605 | 12 | 1742 | 5 | 13 121 | 17 | 3119 | 5 | 8156 | 12 | 1592 | 5 | 2269 | 7 | 4626 | 11 | 5280 | 21 | 40 151 | 41 | 3437 | 26 | 1636 | 22 | 1094 | 10 | 114 084 | 19 | 14 |
| Sculpin spp.[e] | 2724 | 15 | 7479 | 33 | 16 674 | 59 | 26 991 | 67 | 25 734 | 79 | 51 925 | 68 | 45 508 | 76 | 49 939 | 71 | 23 209 | 73 | 21 446 | 67 | 29 392 | 72 | 16 030 | 62 | 44 367 | 45 | 7856 | 59 | 4169 | 57 | 6850 | 66 | 380 293 | 63 | 46 |
| Sucker spp.[e] | 6508 | 35 | 3553 | 16 | 4779 | 17 | 7033 | 18 | 4378 | 14 | 9235 | 12 | 10 012 | 17 | 11 028 | 16 | 6896 | 22 | 7625 | 24 | 5949 | 15 | 3194 | 12 | 12 736 | 13 | 2029 | 15 | 1188 | 16 | 2441 | 23 | 98 584 | 16 | 12 |
| Tench | | | | | | | | | | | 1 | <1 | 5 | <1 | 1 | <1 | | | 2 | <1 | | | | | 2 | <1 | 1 | <1 | | | 1 | <1 | 13 | <1 | |
| **Non-sportfish subtotal** | 18 406 | 100 | 22 634 | 100 | 28 177 | 100 | 40 021 | 100 | 32 425 | 100 | 75 804 | 100 | 59 584 | 100 | 70 582 | 100 | 31 942 | 100 | 31 776 | 100 | 40 926 | 100 | 25 674 | 100 | 97 721 | 100 | 13 412 | 100 | 7288 | 100 | 10 431 | 100 | 606 803 | 100 | 73 |
| **All species** | 46 877 | | 46 786 | | 56 012 | | 55 730 | | 44 020 | | 89 531 | | 72 156 | | 82 543 | | 42 463 | | 40 955 | | 51 794 | | 36 914 | | 107 741 | | 21 025 | | 13 989 | | 20 067 | | 828 603 | | |

[a] Includes fish observed and identified to species; does not include recaptured fish.

[b] Percent composition of sportfish or non-sportfish catch.

[c] Percent composition of the total fish catch.

[d] Species combined for table or not identified to species.

Table E2 Summary of boat electroshocking sportfish catch (includes fish captured and observed and identified to species) and catch-per-unit-effort (CPUE = no. fish/km/hour) in the lower Columbia River, 3 October to 4 November 2016.

| Section | Session | Site | Date | Time Sampled (s) | Length Sampled (km) | Number Caught (CPUE = no. fish/km/hr) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Brook Trout | | Brown Trout | | Bull Trout | | Burbot | | Kokanee | | Lake Whitefish | | Mountain Whitefish | | Northern Pike | | Rainbow Trout | | Smallmouth Bass | | Walleye | | White Sturgeon | | Yellow Perch | | All Species | |
| | | | | | | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE |
| Columbia River U/S | 1 | C00.0-R | 03-Oct-16 | 947 | 0.94 | | | | | | | | | | | | | 33 | ***133.46*** | | | 4 | ***16.18*** | | | 5 | ***20.22*** | | | | | 42 | ***169.85*** |
| | | C00.7-L | 03-Oct-16 | 581 | 0.59 | | | | | | | | | 1 | ***10.5*** | | | 71 | ***745.65*** | | | 18 | ***189.04*** | | | 6 | ***63.01*** | 1 | ***10.5*** | | | 97 | ***1018.7*** |
| | | C01.3-L | 03-Oct-16 | 1694 | 1.6 | | | | | | | | | | | | | 330 | ***438.31*** | 1 | ***1.33*** | 109 | ***144.78*** | | | 16 | ***21.25*** | 1 | ***1.33*** | | | 457 | ***607*** |
| | | C02.8-L | 04-Oct-16 | 938 | 0.88 | | | | | | | | | | | | | 14 | ***61.06*** | | | 13 | ***56.7*** | | | 1 | ***4.36*** | | | | | 28 | ***122.12*** |
| | | C03.6-L | 04-Oct-16 | 2935 | 2.09 | | | | | | | 3 | ***1.76*** | | | | | 82 | ***48.12*** | | | 47 | ***27.58*** | | | 49 | ***28.76*** | | | | | 181 | ***106.22*** |
| | | C04.6-R | 04-Oct-16 | 523 | 0.51 | | | | | | | | | | | | | 5 | ***67.48*** | | | 2 | ***26.99*** | | | 12 | ***161.96*** | | | | | 19 | ***256.44*** |
| | | C05.6-L | 04-Oct-16 | 1190 | 1.1 | | | | | | | | | | | | | 18 | ***49.5*** | | | 12 | ***33*** | | | 16 | ***44*** | | | | | 46 | ***126.51*** |
| | | C07.3-R | 04-Oct-16 | 1030 | 1.7 | | | | | | | | | 2 | ***4.11*** | 1 | ***2.06*** | 97 | ***199.43*** | | | 50 | ***102.8*** | | | 14 | ***28.78*** | 2 | ***4.11*** | | | 166 | ***341.29*** |
| | | C07.4-L | 04-Oct-16 | 935 | 1 | | | | | | | | | 2 | ***7.7*** | | | 143 | ***550.59*** | | | 42 | ***161.71*** | | | 5 | ***19.25*** | | | | | 192 | ***739.25*** |
| | **Session Summary** | | | **1197** | **10.4** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **3** | ***0.87*** | **5** | ***1.45*** | **1** | ***0.29*** | **793** | ***229.32*** | **1** | ***0.29*** | **297** | ***85.89*** | **0** | ***0*** | **124** | ***35.86*** | **4** | ***1.16*** | **0** | ***0*** | **1228** | ***355.12*** |
| | 2 | C00.0-R | 10-Oct-16 | 969 | 0.94 | | | | | | | | | | | | | 28 | ***110.66*** | | | 15 | ***59.28*** | | | | | | | | | 43 | ***169.95*** |
| | | C00.7-L | 10-Oct-16 | 598 | 0.59 | | | | | | | | | | | | | 21 | ***214.27*** | | | 15 | ***153.05*** | | | | | | | | | 36 | ***367.33*** |
| | | C01.3-L | 10-Oct-16 | 1505 | 1.6 | | | | | | | | | | | 1 | ***1.5*** | 49 | ***73.26*** | | | 42 | ***62.79*** | | | 8 | ***11.96*** | 1 | ***1.5*** | | | 101 | ***151*** |
| | | C02.8-L | 10-Oct-16 | 841 | 0.88 | | | | | | | | | | | | | 11 | ***53.51*** | | | 10 | ***48.64*** | | | 6 | ***29.19*** | 1 | ***4.86*** | | | 28 | ***136.2*** |
| | | C03.6-L | 10-Oct-16 | 2152 | 2.09 | | | | | | | | | | | | | 25 | ***20.01*** | | | 111 | ***88.85*** | | | 15 | ***12.01*** | | | | | 151 | ***120.86*** |
| | | C04.6-R | 11-Oct-16 | 616 | 0.52 | | | | | | | | | | | | | 2 | ***22.48*** | | | 8 | ***89.91*** | | | 2 | ***22.48*** | | | | | 12 | ***134.87*** |
| | | C05.6-L | 11-Oct-16 | 1141 | 1.1 | | | | | | | | | | | | | 21 | ***60.23*** | | | 36 | ***103.26*** | | | 14 | ***40.16*** | | | | | 71 | ***203.65*** |
| | | C07.3-R | 11-Oct-16 | 1043 | 1.7 | | | | | | | | | | | | | 35 | ***71.06*** | | | 43 | ***87.3*** | | | 11 | ***22.33*** | 1 | ***2.03*** | | | 90 | ***182.73*** |
| | | C07.4-L | 11-Oct-16 | 946 | 1 | | | | | 1 | ***3.81*** | | | | | | | 141 | ***536.58*** | | | 25 | ***95.14*** | | | 4 | ***15.22*** | 1 | ***3.81*** | | | 172 | ***654.55*** |
| | **Session Summary** | | | **1090** | **10.4** | **0** | ***0*** | **0** | ***0*** | **1** | ***0.32*** | **0** | ***0*** | **0** | ***0*** | **1** | ***0.32*** | **333** | ***105.75*** | **0** | ***0*** | **305** | ***96.86*** | **0** | ***0*** | **60** | ***19.05*** | **4** | ***1.27*** | **0** | ***0*** | **704** | ***223.57*** |
| | 3 | C00.0-R | 17-Oct-16 | 1036 | 0.94 | | | | | | | | | | | | | 24 | ***88.72*** | | | 5 | ***18.48*** | | | 8 | ***29.57*** | | | | | 37 | ***136.78*** |
| | | C00.7-L | 17-Oct-16 | 653 | 0.59 | | | | | | | | | | | | | 19 | ***177.54*** | | | 9 | ***84.1*** | | | | | 2 | ***18.69*** | | | 30 | ***280.32*** |
| | | C01.3-L | 17-Oct-16 | 1696 | 1.58 | | | | | | | | | | | | | 42 | ***56.42*** | | | 20 | ***26.87*** | | | 12 | ***16.12*** | 1 | ***1.34*** | | | 75 | ***100.76*** |
| | | C02.8-L | 17-Oct-16 | 998 | 0.88 | | | | | | | | | | | | | 8 | ***32.79*** | | | 6 | ***24.59*** | | | 1 | ***4.1*** | | | | | 15 | ***61.49*** |
| | | C03.6-L | 18-Oct-16 | 2378 | 2.09 | | | | | | | 2 | ***1.45*** | 1 | ***0.72*** | | | 31 | ***22.45*** | | | 21 | ***15.21*** | | | 21 | ***15.21*** | | | | | 76 | ***55.05*** |
| | | C04.6-R | 18-Oct-16 | 594 | 0.52 | | | | | | | | | 9 | ***104.9*** | | | | | | | 6 | ***69.93*** | | | 5 | ***58.28*** | 2 | ***23.31*** | | | 22 | ***256.41*** |
| | | C05.6-L | 18-Oct-16 | 1131 | 1.1 | | | | | | | | | | | | | 11 | ***31.83*** | 1 | ***2.89*** | 17 | ***49.19*** | | | 9 | ***26.04*** | | | | | 38 | ***109.96*** |
| | | C07.3-R | 18-Oct-16 | 1011 | 1.7 | | | | | | | | | 3 | ***6.28*** | | | 29 | ***60.74*** | | | 43 | ***90.07*** | | | 11 | ***23.04*** | | | | | 86 | ***180.14*** |
| | | C07.4-L | 18-Oct-16 | 1037 | 1 | | | | | | | | | 1 | ***3.47*** | | | 124 | ***430.47*** | | | 21 | ***72.9*** | | | 9 | ***31.24*** | 2 | ***6.94*** | 1 | ***3.47*** | 158 | ***548.51*** |
| | **Session Summary** | | | **1170** | **10.4** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **2** | ***0.59*** | **14** | ***4.14*** | **0** | ***0*** | **288** | ***85.21*** | **1** | ***0.3*** | **148** | ***43.79*** | **0** | ***0*** | **76** | ***22.49*** | **7** | ***2.07*** | **1** | ***0.3*** | **537** | ***158.88*** |
| | 4 | C00.0-R | 23-Oct-16 | 1064 | 0.94 | | | | | | | | | | | | | 25 | ***89.99*** | | | 3 | ***10.8*** | | | 2 | ***7.2*** | 1 | ***3.6*** | | | 31 | ***111.58*** |
| | | C00.7-L | 23-Oct-16 | 691 | 0.59 | | | | | | | | | | | | | 20 | ***176.6*** | | | 2 | ***17.66*** | | | | | | | | | 22 | ***194.27*** |
| | | C01.3-L | 23-Oct-16 | 1837 | 1.6 | | | | | | | | | | | | | 23 | ***28.17*** | 1 | ***1.22*** | 27 | ***33.07*** | | | | | | | | | 51 | ***62.47*** |
| | | C02.8-L | 23-Oct-16 | 938 | 0.88 | | | | | | | | | | | | | 7 | ***30.53*** | | | 5 | ***21.81*** | | | 2 | ***8.72*** | | | | | 14 | ***61.06*** |
| | | C03.6-L | 23-Oct-16 | 2141 | 2.09 | | | | | | | | | | | | | 14 | ***11.26*** | 1 | ***0.8*** | 30 | ***24.14*** | | | 17 | ***13.68*** | | | | | 62 | ***49.88*** |
| | | C04.6-R | 24-Oct-16 | 584 | 0.52 | | | | | | | | | | | | | | | | | 19 | ***225.24*** | | | 1 | ***11.85*** | | | | | 20 | ***237.09*** |
| | | C05.6-L | 24-Oct-16 | 1068 | 1.1 | | | | | | | | | | | | | 12 | ***36.77*** | | | 14 | ***42.9*** | | | 7 | ***21.45*** | | | | | 33 | ***101.12*** |
| | | C07.3-R | 24-Oct-16 | 1165 | 1.7 | | | | | | | | | | | 1 | ***1.82*** | 33 | ***59.98*** | | | 88 | ***159.96*** | | | 15 | ***27.27*** | 1 | ***1.82*** | | | 138 | ***250.85*** |
| | | C07.4-L | 24-Oct-16 | 912 | 1 | | | | | | | | | 2 | ***7.89*** | 9 | ***35.53*** | 419 | ***1653.95*** | | | 13 | ***51.32*** | | | 5 | ***19.74*** | | | | | 448 | ***1768.42*** |
| | **Session Summary** | | | **1156** | **10.4** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **2** | ***0.6*** | **10** | ***2.99*** | **553** | ***165.59*** | **2** | ***0.6*** | **201** | ***60.19*** | **0** | ***0*** | **49** | ***14.67*** | **2** | ***0.6*** | **0** | ***0*** | **819** | ***245.24*** |
| | 5 | C06.0-R | 02-Nov-16 | 709 | 1.49 | | | | | | | | | | | | | 2 | ***6.82*** | | | 23 | ***78.38*** | | | 1 | ***3.41*** | | | | | 26 | ***88.6*** |
| | **Session Summary** | | | **709** | **1.5** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **2** | ***6.77*** | **0** | ***0*** | **23** | ***77.86*** | **0** | ***0*** | **1** | ***3.39*** | **0** | ***0*** | **0** | ***0*** | **26** | ***88.01*** |
| **Section Total All Samples** | | | | **42227** | **43.14** | **0** | | **0** | | **1** | | **5** | | **21** | | **12** | | **1969** | | **4** | | **974** | | **0** | | **310** | | **17** | | **1** | | **3314** | |
| **Section Average All Samples** | | | | **1141** | **1.17** | **0** | ***0*** | **0** | ***0*** | **0** | ***0.07*** | **0** | ***0.37*** | **1** | ***1.54*** | **0** | ***0.88*** | **53** | ***144.01*** | **0** | ***0.29*** | **26** | ***71.24*** | **0** | ***0*** | **8** | ***22.67*** | **0** | ***1.24*** | **0** | ***0.07*** | **90** | ***242.38*** |
| **Section Standard Error of Mean** | | | | | | **0** | ***0*** | **0** | ***0*** | **0.03** | ***0.1*** | **0.1** | ***0.06*** | **0.26** | ***2.84*** | **0.25** | ***0.96*** | **14.29** | ***50.35*** | **0.05** | ***0.09*** | **4.43** | ***8.82*** | **0** | ***0*** | **1.49** | ***4.58*** | **0.11** | ***0.84*** | **0.03** | ***0.09*** | **16.93** | ***54.46*** |

Table E2 Continued.

| Section | Session | Site | Date | Time Sampled (s) | Length Sampled (km) | Number Caught (CPUE = no. fish/km/hr) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Brook Trout | | Brown Trout | | Bull Trout | | Burbot | | Kokanee | | Lake Whitefish | | Mountain Whitefish | | Northern Pike | | Rainbow Trout | | Smallmouth Bass | | Walleye | | White Sturgeon | | Yellow Perch | | All Species | |
| | | | | | | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE |
| Kootenay River | 1 | K00.3-L | 05-Oct-16 | 253 | 0.44 | | | | | | | | | | | | | 15 | ***485.09*** | | | 4 | ***129.36*** | | | 9 | ***291.05*** | | | | | 28 | ***905.5*** |
| | | K00.6-R | 05-Oct-16 | 570 | 0.6 | | | | | | | | | | | | | 34 | ***357.89*** | | | 9 | ***94.74*** | | | 12 | ***126.32*** | | | | | 55 | ***578.95*** |
| | | K01.8-L | 05-Oct-16 | 1417 | 1.87 | | | | | | | | | 1 | ***1.36*** | | | 104 | ***141.29*** | | | 40 | ***54.34*** | | | 24 | ***32.61*** | 4 | ***5.43*** | | | 173 | ***235.04*** |
| | | K01.8-R | 04-Oct-16 | 1016 | 1.28 | | | | | | | | | | | 2 | ***5.54*** | 60 | ***166.09*** | | | 30 | ***83.05*** | | | 7 | ***19.38*** | 3 | ***8.3*** | | | 102 | ***282.36*** |
| | **Session Summary** | | | **814** | **4.2** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **1** | ***1.05*** | **2** | ***2.11*** | **213** | ***224.29*** | **0** | ***0*** | **83** | ***87.4*** | **0** | ***0*** | **52** | ***54.76*** | **7** | ***7.37*** | **0** | ***0*** | **358** | ***376.97*** |
| | 2 | K00.3-L | 12-Oct-16 | 239 | 0.44 | | | | | | | | | | | | | 8 | ***273.87*** | | | 6 | ***205.4*** | | | 2 | ***68.47*** | | | | | 16 | ***547.74*** |
| | | K00.6-R | 11-Oct-16 | 567 | 0.6 | | | | | | | | | | | | | 41 | ***433.86*** | | | 4 | ***42.33*** | | | 12 | ***126.98*** | 2 | ***21.16*** | | | 59 | ***624.34*** |
| | | K01.8-L | 12-Oct-16 | 1356 | 1.87 | | | | | | | | | | | | | 91 | ***129.19*** | | | 31 | ***44.01*** | | | 8 | ***11.36*** | 3 | ***4.26*** | | | 133 | ***188.82*** |
| | | K01.8-R | 12-Oct-16 | 1077 | 1.3 | | | | | | | | | | | | | 41 | ***105.42*** | | | 27 | ***69.42*** | | | 10 | ***25.71*** | | | | | 78 | ***200.56*** |
| | **Session Summary** | | | **810** | **4.2** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **181** | ***191.53*** | **0** | ***0*** | **68** | ***71.96*** | **0** | ***0*** | **32** | ***33.86*** | **5** | ***5.29*** | **0** | ***0*** | **286** | ***302.65*** |
| | 3 | K00.3-L | 19-Oct-16 | 233 | 0.44 | | | | | | | | | | | | | 20 | ***702.3*** | | | 6 | ***210.69*** | | | 1 | ***35.12*** | | | | | 27 | ***948.11*** |
| | | K00.6-R | 19-Oct-16 | 518 | 0.6 | | | | | | | | | | | | | 20 | ***231.66*** | | | 2 | ***23.17*** | | | 6 | ***69.5*** | | | | | 28 | ***324.32*** |
| | | K01.8-L | 19-Oct-16 | 1221 | 1.87 | | | | | | | | | | | 4 | ***6.31*** | 78 | ***122.98*** | | | 20 | ***31.53*** | | | 8 | ***12.61*** | 2 | ***3.15*** | | | 112 | ***176.59*** |
| | | K01.8-R | 19-Oct-16 | 1202 | 1.3 | | | | | | | | | | | | | 139 | ***320.24*** | | | 43 | ***99.07*** | | | 2 | ***4.61*** | | | | | 184 | ***423.91*** |
| | **Session Summary** | | | **794** | **4.2** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **4** | ***4.32*** | **257** | ***277.44*** | **0** | ***0*** | **71** | ***76.65*** | **0** | ***0*** | **17** | ***18.35*** | **2** | ***2.16*** | **0** | ***0*** | **351** | ***378.91*** |
| | 4 | K00.3-L | 25-Oct-16 | 184 | 0.44 | | | | | | | | | | | | | 21 | ***933.79*** | | | 4 | ***177.87*** | | | 2 | ***88.93*** | | | | | 27 | ***1200.59*** |
| | | K00.6-R | 24-Oct-16 | 589 | 0.6 | | | | | | | | | | | | | 56 | ***570.46*** | | | 3 | ***30.56*** | | | 3 | ***30.56*** | 1 | ***10.19*** | | | 63 | ***641.77*** |
| | | K01.8-L | 25-Oct-16 | 1184 | 1.87 | | | | | | | | | | | | | 310 | ***504.05*** | | | 16 | ***26.02*** | | | 7 | ***11.38*** | | | | | 333 | ***541.44*** |
| | | K01.8-R | 25-Oct-16 | 1026 | 1.3 | | | | | | | | | | | | | 102 | ***275.3*** | | | 19 | ***51.28*** | | | 4 | ***10.8*** | | | | | 125 | ***337.38*** |
| | **Session Summary** | | | **746** | **4.2** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **489** | ***561.85*** | **0** | ***0*** | **42** | ***48.26*** | **0** | ***0*** | **16** | ***18.38*** | **1** | ***1.15*** | **0** | ***0*** | **548** | ***629.64*** |
| **Section Total All Samples** | | | | **12652** | **16.82** | **0** | | **0** | | **0** | | **0** | | **1** | | **6** | | **1140** | | **0** | | **264** | | **0** | | **117** | | **15** | | **0** | | **1543** | |
| **Section Average All Samples** | | | | **791** | **1.05** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0.27*** | **0** | ***1.62*** | **71** | ***308.46*** | **0** | ***0*** | **16** | ***71.43*** | **0** | ***0*** | **7** | ***31.66*** | **1** | ***4.06*** | **0** | ***0*** | **96** | ***417.51*** |
| **Section Standard Error of Mean** | | | | | | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0.06** | ***0.08*** | **0.27** | ***0.51*** | **18.55** | ***58.63*** | **0** | ***0*** | **3.48** | ***15.83*** | **0** | ***0*** | **1.43** | ***18.35*** | **0.35** | ***1.45*** | **0** | ***0*** | **20.61** | ***75.61*** |

Table E2 Continued.

| Section | Session | Site | Date | Time Sampled (s) | Length Sampled (km) | Number Caught (CPUE = no. fish/km/hr) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Brook Trout | | Brown Trout | | Bull Trout | | Burbot | | Kokanee | | Lake Whitefish | | Mountain Whitefish | | Northern Pike | | Rainbow Trout | | Smallmouth Bass | | Walleye | | White Sturgeon | | Yellow Perch | | All Species | |
| | | | | | | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE |
| Columbia River D/S | 1 | C25.3-R | 05-Oct-16 | 1924 | 2.73 | | | | | | | | | | | 1 | 0.69 | 64 | 43.86 | | | 40 | 27.42 | | | 16 | 10.97 | | | | | 121 | 82.93 |
| | | C27.6-R | 05-Oct-16 | 353 | 0.61 | | | | | | | | | | | | | 13 | 217.34 | | | 29 | 484.84 | | | 2 | 33.44 | | | | | 44 | 735.62 |
| | | C28.2-R | 05-Oct-16 | 709 | 1.13 | | | | | | | | | | | | | 17 | 76.39 | | | 51 | 229.16 | | | 5 | 22.47 | | | | | 73 | 328.02 |
| | | C34.9-L | 06-Oct-16 | 1720 | 2.14 | | | | | | | | | | | | | 24 | 23.47 | | | 84 | 82.16 | | | 11 | 10.76 | | | | | 119 | 116.39 |
| | | C36.6-L | 06-Oct-16 | 1963 | 2.39 | | | | | | | | | | | 3 | 2.3 | 36 | 27.62 | | | 91 | 69.83 | | | 13 | 9.98 | | | | | 143 | 109.73 |
| | | C47.8-L | 07-Oct-16 | 1028 | 1.44 | 1 | 2.43 | | | | | | | | | 14 | 34.05 | 15 | 36.48 | | | 72 | 175.1 | | | 13 | 31.61 | | | | | 115 | 279.67 |
| | | C48.2-R | 06-Oct-16 | 825 | 1.01 | | | | | | | | | | | 1 | 4.32 | 14 | 60.49 | | | 36 | 155.54 | | | 8 | 34.56 | | | | | 59 | 254.91 |
| | | C49.0-L | 07-Oct-16 | 488 | 0.93 | | | | | | | | | | | | | 34 | 269.7 | | | 30 | 237.97 | | | 10 | 79.32 | | | | | 74 | 586.99 |
| | | C49.0-R | 06-Oct-16 | 491 | 0.72 | | | | | | | | | | | | | 9 | 91.65 | | | 21 | 213.85 | | | 1 | 10.18 | | | | | 31 | 315.68 |
| | | C49.8-L | 07-Oct-16 | 1614 | 2.45 | | | | | | | 2 | 1.82 | | | | | 45 | 40.97 | | | 87 | 79.2 | | | 22 | 20.03 | | | | | 156 | 142.02 |
| | | C49.8-R | 06-Oct-16 | 1337 | 2.39 | | | | | | | | | | | | | 27 | 30.42 | | | 55 | 61.96 | | | 26 | 29.29 | | | | | 108 | 121.67 |
| | | C52.2-L | 08-Oct-16 | 728 | 0.89 | | | | | | | | | | | | | 7 | 38.89 | | | 24 | 133.35 | | | | | | | | | 31 | 172.24 |
| | | C52.2-R | 06-Oct-16 | 1969 | 3.79 | | | | | | | | | | | 5 | 2.41 | 12 | 5.79 | | | 81 | 39.08 | 1 | 0.48 | 13 | 6.27 | 2 | 0.96 | | | 114 | 54.99 |
| | | C52.8-L | 08-Oct-16 | 1323 | 0.89 | | | | | | | | | | | | | 18 | 55.03 | | | 42 | 128.41 | | | 18 | 55.03 | | | | | 78 | 238.48 |
| | | C53.6-L | 08-Oct-16 | 1063 | 1.52 | | | | | | | | | | | | | 8 | 17.82 | | | 38 | 84.67 | 1 | 2.23 | 8 | 17.82 | | | | | 55 | 122.54 |
| | **Session Summary** | | | **1169** | **25** | **1** | **0.12** | **0** | **0** | **0** | **0** | **2** | **0.25** | **0** | **0** | **24** | **2.96** | **343** | **42.25** | **0** | **0** | **781** | **96.21** | **2** | **0.25** | **166** | **20.45** | **2** | **0.25** | **0** | **0** | **1321** | **162.72** |
| | 2 | C25.3-R | 12-Oct-16 | 1376 | 2.73 | | | | | | | | | | | 3 | 2.88 | 19 | 18.21 | | | 29 | 27.79 | | | 5 | 4.79 | | | | | 56 | 53.67 |
| | | C27.6-R | 12-Oct-16 | 359 | 0.61 | | | | | | | | | | | 1 | 16.44 | 27 | 443.86 | | | 14 | 230.15 | | | 2 | 32.88 | | | | | 44 | 723.32 |
| | | C28.2-R | 12-Oct-16 | 695 | 1.13 | | | | | | | | | | | | | 11 | 50.42 | | | 39 | 178.77 | | | 2 | 9.17 | | | | | 52 | 238.37 |
| | | C34.9-L | 12-Oct-16 | 1876 | 2.14 | | | | | | | | | | | | | 19 | 17.04 | | | 66 | 59.18 | | | 6 | 5.38 | | | | | 91 | 81.6 |
| | | C36.6-L | 13-Oct-16 | 1449 | 2.32 | | | | | | | | | | | | | 27 | 28.91 | | | 73 | 78.18 | | | 6 | 6.43 | | | | | 106 | 113.51 |
| | | C47.8-L | 14-Oct-16 | 998 | 1.44 | | | | | | | | | | | 2 | 5.01 | 25 | 62.63 | | | 73 | 182.87 | | | 23 | 57.62 | | | | | 123 | 308.12 |
| | | C48.2-R | 13-Oct-16 | 600 | 1.01 | | | | | | | | | | | | | 11 | 65.35 | | | 27 | 160.4 | | | 7 | 41.58 | | | | | 45 | 267.33 |
| | | C49.0-L | 14-Oct-16 | 466 | 0.93 | | | | | | | | | | | | | 25 | 207.67 | | | 16 | 132.91 | | | 6 | 49.84 | | | | | 47 | 390.42 |
| | | C49.0-R | 13-Oct-16 | 476 | 0.72 | | | | | | | | | | | | | 6 | 63.03 | | | 19 | 199.58 | | | 1 | 10.5 | | | | | 26 | 273.11 |
| | | C49.8-L | 14-Oct-16 | 1635 | 2.45 | | | | | | | 3 | 2.7 | | | 4 | 3.59 | 45 | 40.44 | | | 60 | 53.92 | | | 20 | 17.97 | | | | | 132 | 118.63 |
| | | C49.8-R | 13-Oct-16 | 1201 | 2.39 | | | | | | | | | | | | | 31 | 38.88 | | | 39 | 48.91 | | | 17 | 21.32 | | | | | 87 | 109.11 |
| | | C52.2-L | 14-Oct-16 | 178 | 0.89 | | | | | | | | | | | | | 11 | 249.97 | | | 17 | 386.31 | | | 2 | 45.45 | | | | | 30 | 681.73 |
| | | C52.2-R | 14-Oct-16 | 2295 | 3.79 | | | | | | | | | | | 5 | 2.07 | 10 | 4.14 | | | 57 | 23.59 | | | 8 | 3.31 | | | | | 80 | 33.11 |
| | | C52.8-L | 15-Oct-16 | 696 | 0.89 | | | | | | | | | | | 7 | 40.68 | 9 | 52.31 | | | 22 | 127.86 | | | 5 | 29.06 | | | | | 43 | 249.9 |
| | | C53.6-L | 15-Oct-16 | 1130 | 1.52 | | | | | | | | | | | 2 | 4.19 | 4 | 8.38 | | | 43 | 90.13 | | | 7 | 14.67 | | | | | 56 | 117.37 |
| | **Session Summary** | | | **1029** | **25** | **0** | **0** | **0** | **0** | **0** | **0** | **3** | **0.42** | **0** | **0** | **24** | **3.36** | **280** | **39.18** | **0** | **0** | **594** | **83.13** | **0** | **0** | **117** | **16.37** | **0** | **0** | **0** | **0** | **1018** | **142.46** |
| | 3 | C25.3-R | 19-Oct-16 | 1414 | 2.73 | | | | | | | | | | | 3 | 2.8 | 63 | 58.75 | | | 48 | 44.76 | | | 17 | 15.85 | | | | | 131 | 122.17 |
| | | C27.6-R | 19-Oct-16 | 372 | 0.61 | | | | | | | | | | | | | 14 | 222.1 | | | 25 | 396.62 | | | 3 | 47.59 | | | | | 42 | 666.31 |
| | | C28.2-R | 19-Oct-16 | 1 | 1.13 | | | | | | | | | | | 3 | 9557.52 | 17 | 54159.29 | | | 67 | 213451.33 | | | 10 | 31858.41 | | | | | 97 | 309026.55 |
| | | C34.9-L | 19-Oct-16 | 1889 | 2.14 | | | | | | | | | | | 1 | 0.89 | 28 | 24.94 | | | 72 | 64.12 | | | 27 | 24.04 | | | | | 128 | 113.99 |
| | | C36.6-L | 20-Oct-16 | 1554 | 2.39 | | | | | | | | | 1 | 0.97 | 5 | 4.85 | 50 | 48.46 | | | 77 | 74.64 | | | 5 | 4.85 | | | | | 138 | 133.76 |
| | | C47.8-L | 20-Oct-16 | 1197 | 1.44 | | | | | | | | | | | 8 | 16.71 | 29 | 60.57 | | | 43 | 89.81 | | | 19 | 39.68 | | | 3 | 6.27 | 102 | 213.03 |
| | | C48.2-R | 20-Oct-16 | 906 | 1.01 | | | | | | | | | | | 9 | 35.41 | 19 | 74.75 | | | 34 | 133.76 | | | 7 | 27.54 | | | | | 69 | 271.46 |
| | | C49.0-L | 20-Oct-16 | 615 | 0.93 | | | | | | | | | | | | | 23 | 144.77 | | | 23 | 144.77 | | | 6 | 37.77 | | | | | 52 | 327.3 |
| | | C49.0-R | 21-Oct-16 | 513 | 0.72 | | | | | | | | | | | 4 | 38.99 | 3 | 29.24 | | | 22 | 214.42 | | | 4 | 38.99 | | | | | 33 | 321.64 |
| | | C49.8-L | 21-Oct-16 | 1519 | 2.45 | | | 1 | 0.97 | 2 | 1.93 | 1 | 0.97 | | | 3 | 2.9 | 57 | 55.14 | | | 107 | 103.51 | | | 8 | 7.74 | | | | | 179 | 173.15 |
| | | C49.8-R | 21-Oct-16 | 1296 | 2.39 | | | | | | | | | | | 15 | 17.43 | 35 | 40.68 | | | 78 | 90.66 | | | 25 | 29.06 | | | 1 | 1.16 | 154 | 178.99 |
| | | C52.2-L | 21-Oct-16 | 811 | 0.89 | | | | | | | | | | | 1 | 4.99 | 7 | 34.91 | | | 21 | 104.74 | | | 5 | 24.94 | | | | | 34 | 169.58 |
| | | C52.2-R | 22-Oct-16 | 2279 | 3.79 | | | | | | | | | | | 4 | 1.67 | 23 | 9.59 | | | 119 | 49.6 | | | 20 | 8.34 | | | | | 166 | 69.19 |
| | | C52.8-L | 21-Oct-16 | 653 | 0.89 | | | | | | | | | | | 1 | | 11 | | | | 71 | | | | 9 | | | | | | 92 | |
| | | C53.6-L | 21-Oct-16 | 1107 | 1.52 | | | | | | | | | | | 3 | 6.42 | 3 | 6.42 | | | 41 | 87.72 | | | 8 | 17.12 | | | 1 | 2.14 | 56 | 119.81 |
| | **Session Summary** | | | **1075** | **25** | **0** | **0** | **1** | **0.13** | **2** | **0.27** | **1** | **0.13** | **1** | **0.13** | **60** | **8.04** | **382** | **51.17** | **0** | **0** | **848** | **113.59** | **0** | **0** | **173** | **23.17** | **0** | **0** | **5** | **0.67** | **1473** | **197.31** |

Table E2 Concluded.

| Section | Session | Site | Date | Time Sampled (s) | Length Sampled (km) | Number Caught (CPUE = no. fish/km/hr) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Brook Trout | | Brown Trout | | Bull Trout | | Burbot | | Kokanee | | Lake Whitefish | | Mountain Whitefish | | Northern Pike | | Rainbow Trout | | Smallmouth Bass | | Walleye | | White Sturgeon | | Yellow Perch | | All Species | |
| | | | | | | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE |
| Columbia River D/S | 4 | C25.3-R | 25-Oct-16 | 1421 | 2.73 | | | | | | | | | | | 3 | 2.78 | 42 | 38.98 | | | 91 | 84.45 | | | 8 | 7.42 | | | | | 144 | 133.63 |
| | | C27.6-R | 25-Oct-16 | 357 | 0.61 | | | | | | | | | | | | | 15 | 247.97 | | | 10 | 165.31 | | | 1 | 16.53 | | | | | 26 | 429.81 |
| | | C28.2-R | 25-Oct-16 | 154 | 1.13 | | | | | | | | | | | | | 14 | 289.62 | | | 34 | 703.37 | | | 4 | 82.75 | | | | | 52 | 1075.74 |
| | | C34.9-L | 25-Oct-16 | 1919 | 2.14 | | | | | | | | | 1 | 0.88 | | | 15 | 13.15 | | | 93 | 81.53 | | | 12 | 10.52 | | | | | 121 | 106.07 |
| | | C36.6-L | 26-Oct-16 | 1572 | 2.33 | | | | | | | | | | | 1 | 0.98 | 22 | 21.62 | | | 78 | 76.66 | | | 11 | 10.81 | | | | | 112 | 110.08 |
| | | C47.8-L | 27-Oct-16 | 1118 | 1.44 | | | | | | | | | | | 10 | 22.36 | 13 | 29.07 | | | 30 | 67.08 | | | 11 | 24.6 | | | | | 64 | 143.11 |
| | | C48.2-R | 26-Oct-16 | 820 | 1.01 | | | | | | | | | | | 1 | 4.35 | 11 | 47.81 | | | 29 | 126.06 | | | 17 | 73.9 | | | | | 58 | 252.11 |
| | | C49.0-L | 27-Oct-16 | 472 | 0.93 | | | | | | | | | | | 23 | 188.63 | 12 | 98.41 | | | 19 | 155.82 | | | 4 | 32.8 | | | | | 58 | 475.67 |
| | | C49.0-R | 26-Oct-16 | 509 | 0.72 | | | | | | | | | | | 2 | 19.65 | 5 | 49.12 | | | 10 | 98.23 | | | 17 | 166.99 | | | | | 34 | 333.99 |
| | | C49.8-L | 27-Oct-16 | 1645 | 2.45 | | | | | | | | | | | 9 | 8.04 | 23 | 20.54 | | | 63 | 56.27 | | | 33 | 29.48 | 1 | 0.89 | | | 129 | 115.23 |
| | | C49.8-R | 26-Oct-16 | 1239 | 2.39 | | | | | | | | | | | 5 | 6.08 | 20 | 24.31 | | | 45 | 54.71 | | | 16 | 19.45 | | | | | 86 | 104.55 |
| | | C52.2-L | 29-Oct-16 | 811 | 0.89 | | | | | | | | | | | 7 | 34.91 | 12 | 59.85 | | | 25 | 124.69 | | | 3 | 14.96 | | | | | 47 | 234.42 |
| | | C52.2-R | 26-Oct-16 | 2377 | 3.79 | | | | | | | | | | | 3 | 1.2 | 22 | 8.79 | | | 63 | 25.18 | | | 13 | 5.19 | | | | | 101 | 40.36 |
| | | C52.8-L | 29-Oct-16 | 602 | 0.89 | | | | | | | | | | | 10 | 67.19 | 8 | 53.75 | | | 46 | 309.08 | | | 12 | 80.63 | | | | | 76 | 510.66 |
| | | C53.6-L | 29-Oct-16 | 1101 | 1.52 | | | 1 | 2.15 | | | | | | | 5 | 10.76 | 11 | 23.66 | | | 21 | 45.17 | | | 7 | 15.06 | | | | | 45 | 96.8 |
| | **Session Summary** | | | 1074 | 25 | 0 | 0 | 1 | 0.13 | 0 | 0 | 0 | 0 | 1 | 0.13 | 79 | 10.59 | 245 | 32.85 | 0 | 0 | 657 | 88.09 | 0 | 0 | 169 | 22.66 | 1 | 0.13 | 0 | 0 | 1153 | 154.59 |
| | 5 | C10.9-L | 02-Nov-16 | 1985 | 2.18 | | | | | | | | | 2 | 1.66 | 2 | 1.66 | 196 | 163.06 | | | 133 | 110.65 | | | 9 | 7.49 | | | | | 342 | 284.52 |
| | | C11.5-R | 04-Nov-16 | 1054 | 1.87 | | | | | | | | | | | 5 | 9.13 | 39 | 71.23 | | | 90 | 164.39 | | | 16 | 29.22 | | | | | 150 | 273.98 |
| | | C13.4-L | 02-Nov-16 | 1037 | 1.39 | | | | | | | | | | | 2 | 5 | 83 | 207.29 | | | 84 | 209.79 | | | 14 | 34.97 | 1 | 2.5 | | | 184 | 459.54 |
| | | C14.8-L | 02-Nov-16 | 1969 | 2.26 | | | | | | | | | | | 5 | 4.04 | 61 | 49.35 | | | 92 | 74.43 | | | 11 | 8.9 | 1 | 0.81 | | | 170 | 137.53 |
| | | C17.0-L | 04-Nov-16 | 1925 | 1.91 | | | 1 | 0.98 | | | | | | | | | 90 | 88.12 | | | 113 | 110.64 | | | 5 | 4.9 | 2 | 1.96 | | | 211 | 206.6 |
| | | C18.8-R | 04-Nov-16 | 996 | 1.61 | | | | | | | | | | | | | 15 | 33.68 | | | 38 | 85.31 | | | 2 | 4.49 | | | | | 55 | 123.48 |
| | | C20.1-L | 04-Nov-16 | 938 | 1.27 | | | | | | | | | | | | | 13 | 39.29 | | | 50 | 151.1 | | | 7 | 21.15 | | | | | 70 | 211.54 |
| | | C23.4-L | 01-Nov-16 | 766 | 0.93 | | | | | | | | | | | 15 | 75.8 | 24 | 121.28 | | | 80 | 404.28 | | | 6 | 30.32 | | | | | 125 | 631.69 |
| | | C24.3-L | 01-Nov-16 | 885 | 1.29 | | | | | | | | | | | 11 | 34.69 | 22 | 69.37 | | | 92 | 290.11 | | | 8 | 25.23 | | | | | 133 | 419.39 |
| | | C28.8-L | 01-Nov-16 | 570 | 0.82 | | | | | 1 | 7.7 | | | | | 10 | 77.02 | 41 | 315.79 | | | 37 | 284.98 | | | 4 | 30.81 | 1 | 7.7 | | | 94 | 724.01 |
| | | C30.5-R | 30-Oct-16 | 2268 | 1.53 | | | | | | | | | | | 25 | 25.94 | 36 | 37.35 | | | 105 | 108.93 | | | 6 | 6.22 | | | | | 172 | 178.44 |
| | | C30.6-L | 02-Nov-16 | 1815 | 1.84 | | | | | | | | | | | 2 | 2.16 | 24 | 25.87 | | | 114 | 122.89 | | | 12 | 12.94 | | | | | 152 | 163.85 |
| | | C32.0-R | 30-Oct-16 | 1612 | 1.37 | | | | | | | | | | | 2 | 3.26 | 5 | 8.15 | | | 112 | 182.57 | | | 10 | 16.3 | 1 | 1.63 | | | 130 | 211.91 |
| | | C40.0-L | 30-Oct-16 | 507 | 1.14 | | | | | | | | | | | 17 | 105.89 | 13 | 80.97 | | | 15 | 93.43 | | | | | | | | | 45 | 280.29 |
| | | C41.1-L | 30-Oct-16 | 1862 | 2.41 | | | | | | | | | | | 41 | 32.89 | 25 | 20.06 | | | 118 | 94.66 | | | 10 | 8.02 | | | | | 194 | 155.64 |
| | | C43.7-R | 29-Oct-16 | 670 | 1.34 | | | | | | | | | | | 8 | 32.08 | 15 | 60.15 | | | 34 | 136.33 | | | 6 | 24.06 | | | | | 63 | 252.62 |
| | | C45.6-L | 29-Oct-16 | 713 | 0.9 | | | | | | | | | | | 5 | 28.05 | 9 | 50.49 | | | 53 | 297.34 | | | 19 | 106.59 | | | | | 86 | 482.47 |
| | | C47.2-R | 30-Oct-16 | 760 | 1.06 | | | | | | | | | | | 27 | 120.66 | 26 | 116.19 | | | 48 | 214.5 | | | 13 | 58.09 | | | | | 114 | 509.43 |
| | | C56.0-L | 27-Oct-16 | 536 | 0.94 | | | | | | | 1 | 7.15 | | | | | 2 | 14.29 | | | 13 | 92.89 | | | 5 | 35.73 | | | | | 21 | 150.05 |
| | **Session Summary** | | | 1204 | 28.1 | 0 | 0 | 1 | 0.11 | 1 | 0.11 | 1 | 0.11 | 2 | 0.21 | 177 | 18.83 | 739 | 78.63 | 0 | 0 | 1421 | 151.2 | 0 | 0 | 163 | 17.34 | 6 | 0.64 | 0 | 0 | 2511 | 267.19 |
| **Section Total All Samples** | | | | 88076 | 128.05 | 1 | | 3 | | 3 | | 7 | | 4 | | 364 | | 1989 | | 0 | | 4301 | | 2 | | 788 | | 9 | | 5 | | 7476 | |
| **Section Average All Samples** | | | | 1115 | 1.62 | 0 | 0.03 | 0 | 0.08 | 0 | 0.08 | 0 | 0.18 | 0 | 0.1 | 5 | 9.18 | 25 | 50.15 | 0 | 0 | 54 | 108.45 | 0 | 0.05 | 10 | 19.87 | 0 | 0.23 | 0 | 0.13 | 95 | 188.5 |
| **Section Standard Error of Mean** | | | | | | 0.01 | 0.03 | 0.02 | 0.03 | 0.03 | 0.1 | 0.05 | 0.1 | 0.03 | 0.03 | 0.8 | 120.84 | 2.95 | 684.67 | 0 | 0 | 3.54 | 2700.06 | 0.02 | 0.03 | 0.78 | 402.93 | 0.04 | 0.11 | 0.04 | 0.08 | 6.15 | 3908.4 |
| **All Sections Total All Samples** | | | | 142955 | 188.01 | 1 | 0 | 3 | 0 | 4 | 0 | 12 | 0 | 26 | 0 | 382 | 0.05 | 5098 | 0.68 | 4 | 0 | 5539 | 0.74 | 2 | 0 | 1215 | 0.16 | 41 | 0.01 | 6 | 0 | 12333 | 1.65 |
| **All Sections Average All Samples** | | | | | | 0 | 0.02 | 0 | 0.05 | 0 | 0.07 | 0 | 0.21 | 0 | 0.46 | 3 | 6.75 | 39 | 90.14 | 0 | 0.07 | 42 | 97.93 | 0 | 0.04 | 9 | 21.48 | 0 | 0.72 | 0 | 0.11 | 93 | 218.05 |
| **All Sections Standard Error of Mean** | | | | | | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.07 | 0.04 | 0.06 | 0.08 | 0.8 | 0.52 | 72.37 | 5.09 | 409.67 | 0.01 | 0.03 | 2.83 | 1616.18 | 0.01 | 0.02 | 0.65 | 241.14 | 0.06 | 0.31 | 0.03 | 0.06 | 6.44 | 2338.95 |

Table E3 Summary of boat electroshocking non-sportfish catch (includes fish captured and observed and identified to species) and catch-per-unit-effort (CPUE = no. fish/km/hour) in the lower Columbia River, 3 October to 4 November 2016.

| Section | Session | Site | Date | Time Sampled (s) | Length Sampled (km) | Number Caught (CPUE = no. fish/km/hr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Northern Pikeminnow | | Peamouth | | Redside Shiner | | Sculpin spp. | | Sucker spp. | | Tench | | All Species | |
| | | | | | | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE |
| Columbia River U/S | 1 | C00.0-R | 03-Oct-16 | 947 | 0.9371516 | | | 1 | ***4.06*** | 37 | ***150.09*** | 21 | ***85.18*** | 10 | ***40.56*** | | | 69 | ***279.89*** |
| | | C00.7-L | 03-Oct-16 | 581 | 0.5932888 | | | | | 24 | ***250.65*** | 8 | ***83.55*** | 5 | ***52.22*** | | | 37 | ***386.42*** |
| | | C01.3-L | 03-Oct-16 | 1694 | 1.601247 | | | | | 35 | ***46.45*** | 49 | ***65.03*** | 51 | ***67.69*** | | | 135 | ***179.17*** |
| | | C02.8-L | 04-Oct-16 | 938 | 0.8821294 | | | | | 24 | ***104.42*** | 55 | ***239.29*** | 76 | ***330.66*** | | | 155 | ***674.37*** |
| | | C03.6-L | 04-Oct-16 | 2935 | 2.087279 | 3 | ***1.76*** | | | 15 | ***8.81*** | 28 | ***16.45*** | 110 | ***64.64*** | | | 156 | ***91.67*** |
| | | C04.6-R | 04-Oct-16 | 523 | 0.5074685 | | | | | 5 | ***67.82*** | 10 | ***135.64*** | 29 | ***393.36*** | | | 44 | ***596.82*** |
| | | C05.6-L | 04-Oct-16 | 1190 | 1.100858 | 1 | ***2.75*** | | | 14 | ***38.47*** | 45 | ***123.66*** | 44 | ***120.91*** | | | 104 | ***285.8*** |
| | | C07.3-R | 04-Oct-16 | 1030 | 1.704862 | 1 | ***2.05*** | | | 3 | ***6.15*** | | | 39 | ***79.95*** | | | 43 | ***88.15*** |
| | | C07.4-L | 04-Oct-16 | 935 | 0.9981754 | | | | | 10 | ***38.57*** | 14 | ***54*** | 115 | ***443.59*** | | | 139 | ***536.17*** |
| | **Session Summary** | | | **1197** | **10.4** | **5** | ***1.45*** | **1** | ***0.29*** | **167** | ***48.29*** | **230** | ***66.51*** | **479** | ***138.52*** | **0** | ***0*** | **882** | ***255.06*** |
| | 2 | C00.0-R | 10-Oct-16 | 969 | 0.9371516 | | | | | 18 | ***71.36*** | 19 | ***75.32*** | | | | | 37 | ***146.68*** |
| | | C00.7-L | 10-Oct-16 | 598 | 0.5932888 | | | | | 1 | ***10.15*** | 3 | ***30.44*** | 1 | ***10.15*** | | | 5 | ***50.73*** |
| | | C01.3-L | 10-Oct-16 | 1505 | 1.601247 | | | | | | | 4 | ***5.98*** | 23 | ***34.36*** | | | 27 | ***40.33*** |
| | | C02.8-L | 10-Oct-16 | 841 | 0.8821294 | | | | | | | 3 | ***14.56*** | 12 | ***58.23*** | | | 15 | ***72.79*** |
| | | C03.6-L | 10-Oct-16 | 2152 | 2.087279 | | | | | | | 4 | ***3.21*** | 69 | ***55.3*** | | | 73 | ***58.51*** |
| | | C04.6-R | 11-Oct-16 | 616 | 0.5174685 | | | | | | | 6 | ***67.76*** | 27 | ***304.93*** | | | 33 | ***372.69*** |
| | | C05.6-L | 11-Oct-16 | 1141 | 1.100858 | | | | | | | 16 | ***45.86*** | 23 | ***65.92*** | | | 39 | ***111.78*** |
| | | C07.3-R | 11-Oct-16 | 1043 | 1.704862 | 2 | ***4.05*** | | | 14 | ***28.34*** | 7 | ***14.17*** | 13 | ***26.32*** | | | 36 | ***72.88*** |
| | | C07.4-L | 11-Oct-16 | 946 | 0.9981754 | | | | | 7 | ***26.69*** | 1 | ***3.81*** | 17 | ***64.81*** | | | 25 | ***95.31*** |
| | **Session Summary** | | | **1090** | **10.4** | **2** | ***0.64*** | **0** | ***0*** | **40** | ***12.7*** | **63** | ***20.01*** | **185** | ***58.75*** | **0** | ***0*** | **290** | ***92.1*** |
| | 3 | C00.0-R | 17-Oct-16 | 1036 | 0.9371516 | | | | | | | 16 | ***59.33*** | 2 | ***7.42*** | | | 18 | ***66.74*** |
| | | C00.7-L | 17-Oct-16 | 653 | 0.5932888 | | | | | 15 | ***139.38*** | 1 | ***9.29*** | 4 | ***37.17*** | | | 20 | ***185.85*** |
| | | C01.3-L | 17-Oct-16 | 1696 | 1.581247 | | | | | | | 66 | ***88.6*** | 76 | ***102.02*** | | | 142 | ***190.62*** |
| | | C02.8-L | 17-Oct-16 | 998 | 0.8821294 | | | | | | | 28 | ***114.5*** | 7 | ***28.62*** | | | 35 | ***143.12*** |
| | | C03.6-L | 18-Oct-16 | 2378 | 2.087279 | 7 | ***5.08*** | | | | | 70 | ***50.77*** | 123 | ***89.21*** | | | 200 | ***145.06*** |
| | | C04.6-R | 18-Oct-16 | 594 | 0.5174685 | 2 | ***23.42*** | | | | | 21 | ***245.95*** | 44 | ***515.33*** | | | 67 | ***784.71*** |
| | | C05.6-L | 18-Oct-16 | 1131 | 1.100858 | 3 | ***8.67*** | | | | | 45 | ***130.11*** | 95 | ***274.68*** | | | 143 | ***413.47*** |
| | | C07.3-R | 18-Oct-16 | 1011 | 1.704862 | | | | | | | 29 | ***60.57*** | 9 | ***18.8*** | | | 38 | ***79.37*** |
| | | C07.4-L | 18-Oct-16 | 1037 | 0.9981754 | | | | | | | 27 | ***93.9*** | 23 | ***79.99*** | | | 50 | ***173.89*** |
| | **Session Summary** | | | **1170** | **10.4** | **12** | ***3.55*** | **0** | ***0*** | **15** | ***4.44*** | **303** | ***89.64*** | **383** | ***113.31*** | **0** | ***0*** | **713** | ***210.95*** |
| | 4 | C00.0-R | 23-Oct-16 | 1064 | 0.9371516 | | | | | 250 | ***902.59*** | 322 | ***1162.54*** | 4 | ***14.44*** | | | 576 | ***2079.57*** |
| | | C00.7-L | 23-Oct-16 | 691 | 0.5932888 | | | | | 6 | ***52.69*** | 67 | ***588.35*** | 3 | ***26.34*** | | | 76 | ***667.38*** |
| | | C01.3-L | 23-Oct-16 | 1837 | 1.601247 | | | | | 143 | ***175.01*** | 230 | ***281.49*** | 78 | ***95.46*** | | | 451 | ***551.97*** |
| | | C02.8-L | 23-Oct-16 | 938 | 0.8821294 | | | | | 10 | ***43.51*** | 19 | ***82.66*** | 4 | ***17.4*** | | | 33 | ***143.58*** |
| | | C03.6-L | 23-Oct-16 | 2141 | 2.087279 | | | 2 | ***1.61*** | 78 | ***62.83*** | 141 | ***113.59*** | 301 | ***242.48*** | | | 522 | ***420.51*** |
| | | C04.6-R | 24-Oct-16 | 584 | 0.5174685 | | | | | 4 | ***47.65*** | 5 | ***59.56*** | 60 | ***714.75*** | | | 69 | ***821.97*** |
| | | C05.6-L | 24-Oct-16 | 1068 | 1.100858 | | | | | 10 | ***30.62*** | 62 | ***189.84*** | 146 | ***447.05*** | | | 218 | ***667.51*** |
| | | C07.3-R | 24-Oct-16 | 1165 | 1.704862 | | | | | 22 | ***39.88*** | 41 | ***74.31*** | 9 | ***16.31*** | | | 72 | ***130.5*** |
| | | C07.4-L | 24-Oct-16 | 912 | 0.9981754 | | | | | | | | | 204 | ***806.74*** | | | 204 | ***806.74*** |
| | **Session Summary** | | | **1156** | **10.4** | **0** | ***0*** | **2** | ***0.6*** | **523** | ***156.61*** | **887** | ***265.6*** | **809** | ***242.25*** | **0** | ***0*** | **2221** | ***665.06*** |
| | 5 | C06.0-R | 02-Nov-16 | 709 | 1.48665 | | | | | | | 15 | ***51.23*** | 34 | ***116.13*** | | | 49 | ***167.36*** |
| | **Session Summary** | | | **709** | **1.5** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **15** | ***50.78*** | **34** | ***115.09*** | **0** | ***0*** | **49** | ***165.87*** |
| **Section Total All Samples** | | | | **42227** | **43.1464888** | **19** | | **3** | | **745** | | **1498** | | **1890** | | **0** | | **4155** | |
| **Section Average All Samples** | | | | **1141** | **1.17** | **1** | ***1.39*** | **0** | ***0.22*** | **20** | ***54.48*** | **40** | ***109.54*** | **51** | ***138.21*** | **0** | ***0*** | **112** | ***303.84*** |
| **Section Standard Error of Mean** | | | | | | **0.22** | ***0.68*** | **0.06** | ***0.12*** | **7.74** | ***25.15*** | **10.63** | ***33.95*** | **10.46** | ***33.43*** | **0** | ***0*** | **22.25** | ***62.91*** |

Table E3 Continued.

| Section | Session | Site | Date | Time Sampled (s) | Length Sampled (km) | Number Caught (CPUE = no. fish/km/hr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Northern Pikeminnow | | Peamouth | | Redside Shiner | | Sculpin spp. | | Sucker spp. | | Tench | | All Species | |
| | | | | | | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE |
| Kootenay River | 1 | K00.3-L | 05-Oct-16 | 253 | 0.4362984 | | | | | 1 | ***32.61*** | 6 | ***195.68*** | 15 | ***489.2*** | | | 22 | ***717.5*** |
| | | K00.6-R | 05-Oct-16 | 570 | 0.5956581 | 5 | ***53.02*** | | | 11 | ***116.63*** | 6 | ***63.62*** | 64 | ***678.59*** | | | 86 | ***911.86*** |
| | | K01.8-L | 05-Oct-16 | 1417 | 1.871003 | 3 | ***4.07*** | | | 35 | ***47.53*** | 76 | ***103.2*** | 32 | ***43.45*** | | | 146 | ***198.25*** |
| | | K01.8-R | 04-Oct-16 | 1016 | 1.276347 | 5 | ***13.88*** | | | | | | | 6 | ***16.66*** | | | 11 | ***30.54*** |
| | **Session Summary** | | | **814** | **4.2** | **13** | ***13.69*** | **0** | ***0*** | **47** | ***49.49*** | **88** | ***92.66*** | **117** | ***123.2*** | **0** | ***0*** | **265** | ***279.05*** |
| | 2 | K00.6-R | 11-Oct-16 | 567 | 0.5956581 | 1 | ***10.66*** | | | | | 13 | ***138.57*** | 23 | ***245.16*** | | | 37 | ***394.39*** |
| | | K01.8-L | 12-Oct-16 | 1356 | 1.871003 | | | | | | | 193 | ***273.86*** | 22 | ***31.22*** | | | 215 | ***305.08*** |
| | | K01.8-R | 12-Oct-16 | 1077 | 1.296347 | 1 | ***2.58*** | | | | | 53 | ***136.66*** | 6 | ***15.47*** | | | 60 | ***154.71*** |
| | **Session Summary** | | | **1000** | **3.8** | **2** | ***1.89*** | **0** | ***0*** | **0** | ***0*** | **259** | ***245.37*** | **51** | ***48.32*** | **0** | ***0*** | **312** | ***295.58*** |
| | 3 | K00.6-R | 19-Oct-16 | 518 | 0.5956581 | | | | | | | 4 | ***46.67*** | 13 | ***151.68*** | | | 17 | ***198.35*** |
| | | K01.8-L | 19-Oct-16 | 1221 | 1.871003 | 3 | ***4.73*** | | | | | 10 | ***15.76*** | 3 | ***4.73*** | | | 16 | ***25.21*** |
| | | K01.8-R | 19-Oct-16 | 1202 | 1.296347 | | | | | | | 11 | ***25.41*** | | | | | 11 | ***25.41*** |
| | **Session Summary** | | | **980** | **3.8** | **3** | ***2.9*** | **0** | ***0*** | **0** | ***0*** | **25** | ***24.17*** | **16** | ***15.47*** | **0** | ***0*** | **44** | ***42.53*** |
| | 4 | K00.6-R | 24-Oct-16 | 589 | 0.5956581 | | | | | | | | | 28 | ***287.31*** | | | 28 | ***287.31*** |
| | | K01.8-R | 25-Oct-16 | 1026 | 1.296347 | | | | | | | | | 3 | ***8.12*** | | | 3 | ***8.12*** |
| | **Session Summary** | | | **808** | **1.9** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **0** | ***0*** | **31** | ***72.69*** | **0** | ***0*** | **31** | ***72.69*** |
| **Section Total All Samples** | | | | **10812** | **13.5973278** | **18** | | **0** | | **47** | | **372** | | **215** | | **0** | | **652** | |
| **Section Average All Samples** | | | | **901** | **1.13** | **2** | ***5.29*** | **0** | ***0*** | **4** | ***13.81*** | **31** | ***109.31*** | **18** | ***63.18*** | **0** | ***0*** | **54** | ***191.59*** |
| **Section Standard Error of Mean** | | | | | | **0.57** | ***4.36*** | **0** | ***0*** | **2.97** | ***10.19*** | **16.23** | ***25.48*** | **5.19** | ***64.26*** | **0** | ***0*** | **18.78** | ***82.5*** |

Table E3 Concluded.

| Section | Session | Site | Date | Time Sampled (s) | Length Sampled (km) | Number Caught (CPUE = no. fish/km/hr) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Northern Pikeminnow | | Peamouth | | Redside Shiner | | Sculpin spp. | | Sucker spp. | | Tench | | All Species | |
| | | | | | | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE | No. | CPUE |
| Columbia River D/S | 1 | C25.3-R | 05-Oct-16 | 1924 | 2.726756 | 2 | ***1.37*** | | | 11 | ***7.55*** | 97 | ***66.56*** | | | | | 110 | ***75.48*** |
| | | C27.6-R | 05-Oct-16 | 353 | 0.6127803 | | | | | | | 6 | ***99.86*** | | | | | 6 | ***99.86*** |
| | | C28.2-R | 05-Oct-16 | 709 | 1.131481 | | | | | | | 82 | ***367.98*** | 17 | ***76.29*** | | | 99 | ***444.27*** |
| | | C34.9-L | 06-Oct-16 | 1720 | 2.135852 | 1 | ***0.98*** | | | 2 | ***1.96*** | 42 | ***41.16*** | 5 | ***4.9*** | | | 50 | ***49*** |
| | | C36.6-L | 06-Oct-16 | 1963 | 2.394963 | 1 | ***0.77*** | | | | | 30 | ***22.97*** | 7 | ***5.36*** | | | 38 | ***29.1*** |
| | | C47.8-L | 07-Oct-16 | 1028 | 1.439314 | | | | | 16 | ***38.93*** | 77 | ***187.35*** | 7 | ***17.03*** | | | 100 | ***243.31*** |
| | | C48.2-R | 06-Oct-16 | 825 | 1.008599 | | | | | 21 | ***90.86*** | 13 | ***56.24*** | 15 | ***64.9*** | | | 49 | ***212*** |
| | | C49.0-L | 07-Oct-16 | 488 | 0.9297056 | | | | | 7 | ***55.54*** | 92 | ***730*** | 7 | ***55.54*** | | | 106 | ***841.09*** |
| | | C49.8-L | 07-Oct-16 | 1614 | 2.4466 | | | | | | | 342 | ***311.79*** | 27 | ***24.61*** | | | 369 | ***336.4*** |
| | | C49.8-R | 06-Oct-16 | 1337 | 2.39062 | | | | | 11 | ***12.39*** | 363 | ***408.85*** | 29 | ***32.66*** | | | 403 | ***453.91*** |
| | | C52.2-R | 06-Oct-16 | 1969 | 3.79006 | | | | | | | 1 | ***0.48*** | 7 | ***3.38*** | | | 8 | ***3.86*** |
| | | C52.8-L | 08-Oct-16 | 1323 | 0.8927717 | | | | | | | | | 2 | ***6.1*** | | | 2 | ***6.1*** |
| | | C53.6-L | 08-Oct-16 | 1063 | 1.51784 | | | | | | | 50 | ***111.56*** | 2 | ***4.46*** | | | 52 | ***116.02*** |
| | **Session Summary** | | | **1255** | **23.4** | **4** | *0.49* | **0** | *0* | **68** | *8.34* | **1195** | *146.49* | **125** | *15.32* | **0** | *0* | **1392** | *170.64* |
| | 2 | C25.3-R | 12-Oct-16 | 1376 | 2.726756 | | | | | | | 6 | ***5.76*** | | | | | 6 | ***5.76*** |
| | | C28.2-R | 12-Oct-16 | 695 | 1.131481 | | | | | | | 26 | ***119.03*** | | | | | 26 | ***119.03*** |
| | | C34.9-L | 12-Oct-16 | 1876 | 2.135852 | | | | | | | 98 | ***88.05*** | 6 | ***5.39*** | | | 104 | ***93.44*** |
| | | C36.6-L | 13-Oct-16 | 1449 | 2.319963 | | | | | | | 90 | ***96.38*** | 26 | ***27.84*** | | | 116 | ***124.23*** |
| | | C47.8-L | 14-Oct-16 | 998 | 1.439314 | | | | | | | 104 | ***260.65*** | 48 | ***120.3*** | | | 152 | ***380.94*** |
| | | C48.2-R | 13-Oct-16 | 600 | 1.008599 | | | | | | | 18 | ***107.08*** | 2 | ***11.9*** | | | 20 | ***118.98*** |
| | | C49.0-L | 14-Oct-16 | 466 | 0.9297056 | | | | | | | 6 | ***49.86*** | 2 | ***16.62*** | | | 8 | ***66.48*** |
| | | C49.0-R | 13-Oct-16 | 476 | 0.7195221 | | | | | | | 7 | ***73.58*** | | | | | 7 | ***73.58*** |
| | | C49.8-L | 14-Oct-16 | 1635 | 2.4466 | | | | | | | 803 | ***722.67*** | 1 | ***0.9*** | | | 804 | ***723.57*** |
| | | C49.8-R | 13-Oct-16 | 1201 | 2.39062 | | | | | | | 220 | ***275.85*** | 9 | ***11.28*** | | | 229 | ***287.13*** |
| | | C53.6-L | 15-Oct-16 | 1130 | 1.51784 | | | | | | | 35 | ***73.46*** | | | | | 35 | ***73.46*** |
| | **Session Summary** | | | **1082** | **18.8** | **0** | *0* | **0** | *0* | **0** | *0* | **1413** | *250.07* | **94** | *16.64* | **0** | *0* | **1507** | *266.7* |
| | 3 | C25.3-R | 19-Oct-16 | 1414 | 2.726756 | | | | | 60 | ***56.02*** | 120 | ***112.04*** | 2 | ***1.87*** | | | 182 | ***169.93*** |
| | | C28.2-R | 19-Oct-16 | 1 | 1.131481 | | | | | 21 | ***66815.09*** | 62 | ***197263.59*** | | | | | 83 | ***264078.67*** |
| | | C34.9-L | 19-Oct-16 | 1889 | 2.135852 | | | | | 58 | ***51.75*** | 61 | ***54.43*** | | | | | 119 | ***106.18*** |
| | | C36.6-L | 20-Oct-16 | 1554 | 2.394963 | | | | | | | 62 | ***59.97*** | 6 | ***5.8*** | | | 68 | ***65.78*** |
| | | C47.8-L | 20-Oct-16 | 1197 | 1.439314 | | | | | 50 | ***104.48*** | 131 | ***273.73*** | 7 | ***14.63*** | 1 | ***2.09*** | 189 | ***394.92*** |
| | | C48.2-R | 20-Oct-16 | 906 | 1.008599 | | | | | | | 47 | ***185.16*** | 23 | ***90.61*** | | | 70 | ***275.77*** |
| | | C49.0-L | 20-Oct-16 | 615 | 0.9297056 | | | | | | | 200 | ***1259.25*** | | | | | 200 | ***1259.25*** |
| | | C49.0-R | 21-Oct-16 | 513 | 0.7195221 | | | | | | | 23 | ***224.32*** | | | | | 23 | ***224.32*** |
| | | C49.8-L | 21-Oct-16 | 1519 | 2.4466 | | | | | | | 222 | ***215.05*** | 2 | ***1.94*** | | | 224 | ***216.99*** |
| | | C49.8-R | 21-Oct-16 | 1296 | 2.39062 | 1 | ***1.16*** | | | 21 | ***24.4*** | 344 | ***399.71*** | 1 | ***1.16*** | | | 367 | ***426.44*** |
| | | C52.2-L | 21-Oct-16 | 811 | 0.8889672 | | | | | | | 10 | ***49.93*** | | | | | 10 | ***49.93*** |
| | | C52.2-R | 22-Oct-16 | 2279 | 3.79006 | | | | | | | 39 | ***16.25*** | 2 | ***0.83*** | | | 41 | ***17.09*** |
| | | C52.8-L | 21-Oct-16 | 653 | 0.8927717 | | | | | | | 29 | ***179.08*** | 3 | ***18.53*** | | | 32 | ***197.61*** |
| | | C53.6-L | 21-Oct-16 | 1107 | 1.51784 | | | | | | | 50 | ***107.13*** | 2 | ***4.29*** | | | 52 | ***111.41*** |
| | **Session Summary** | | | **1125** | **24.4** | **1** | *0.13* | **0** | *0* | **210** | *27.54* | **1400** | *183.61* | **48** | *6.3* | **1** | *0.13* | **1660** | *217.7* |
| | 4 | C25.3-R | 25-Oct-16 | 1421 | 2.726756 | | | | | 24 | ***22.3*** | 36 | ***33.45*** | 1 | ***0.93*** | | | 61 | ***56.68*** |
| | | C27.6-R | 25-Oct-16 | 357 | 0.6127803 | | | | | | | 15 | ***246.84*** | 1 | ***16.46*** | | | 16 | ***263.3*** |
| | | C28.2-R | 25-Oct-16 | 154 | 1.131481 | | | | | | | 62 | ***1280.93*** | 5 | ***103.3*** | | | 67 | ***1384.23*** |
| | | C34.9-L | 25-Oct-16 | 1919 | 2.135852 | | | | | | | 66 | ***57.97*** | 16 | ***14.05*** | | | 82 | ***72.02*** |
| | | C36.6-L | 26-Oct-16 | 1572 | 2.334963 | | | | | | | 86 | ***84.35*** | 8 | ***7.85*** | | | 94 | ***92.19*** |
| | | C47.8-L | 27-Oct-16 | 1118 | 1.439314 | | | | | | | | | 4 | ***8.95*** | | | 4 | ***8.95*** |
| | | C48.2-R | 26-Oct-16 | 820 | 1.008599 | | | | | | | 12 | ***52.23*** | 20 | ***87.06*** | | | 32 | ***139.29*** |
| | | C49.8-L | 27-Oct-16 | 1645 | 2.4466 | | | | | | | 451 | ***403.41*** | 7 | ***6.26*** | | | 458 | ***409.67*** |
| | | C49.8-R | 26-Oct-16 | 1239 | 2.39062 | | | | | | | 145 | ***176.23*** | 29 | ***35.25*** | | | 174 | ***211.48*** |
| | | C52.2-L | 29-Oct-16 | 811 | 0.8889672 | | | | | | | 66 | ***329.56*** | 7 | ***34.95*** | | | 73 | ***364.52*** |
| | | C52.2-R | 26-Oct-16 | 2377 | 3.79006 | | | | | | | 10 | ***4*** | 5 | ***2*** | | | 15 | ***5.99*** |
| | | C52.8-L | 29-Oct-16 | 602 | 0.8927717 | | | | | | | 20 | ***133.97*** | | | | | 20 | ***133.97*** |
| | | C53.6-L | 29-Oct-16 | 1101 | 1.51784 | | | | | | | 18 | ***38.78*** | | | | | 18 | ***38.78*** |
| | **Session Summary** | | | **1164** | **23.3** | **0** | *0* | **0** | *0* | **24** | *3.19* | **987** | *131.01* | **103** | *13.67* | **0** | *0* | **1114** | *147.87* |
| | 5 | C10.9-L | 02-Nov-16 | 1985 | 2.18 | | | | | | | 129 | ***107.32*** | 5 | ***4.16*** | | | 134 | ***111.48*** |
| | | C11.5-R | 04-Nov-16 | 1054 | 1.87 | | | | | | | 121 | ***221.01*** | | | | | 121 | ***221.01*** |
| | | C13.4-L | 02-Nov-16 | 1037 | 1.392 | | | | | | | 61 | ***152.13*** | 8 | ***19.95*** | | | 69 | ***172.08*** |
| | | C14.8-L | 02-Nov-16 | 1969 | 2.26 | 1 | ***0.81*** | | | | | 173 | ***139.96*** | 11 | ***8.9*** | | | 185 | ***149.66*** |
| | | C17.0-L | 04-Nov-16 | 1925 | 1.906 | | | | | | | 198 | ***194.27*** | 13 | ***12.76*** | | | 211 | ***207.03*** |
| | | C18.8-R | 04-Nov-16 | 996 | 1.61324 | 1 | ***2.24*** | | | | | | | 7 | ***15.68*** | | | 8 | ***17.92*** |
| | | C20.1-L | 04-Nov-16 | 938 | 1.26591 | 15 | ***45.48*** | | | 30 | ***90.95*** | 44 | ***133.4*** | 12 | ***36.38*** | | | 101 | ***306.21*** |
| | | C23.4-L | 01-Nov-16 | 766 | 0.93 | | | | | 9 | ***45.48*** | 83 | ***419.44*** | 1 | ***5.05*** | | | 93 | ***469.97*** |
| | | C24.3-L | 01-Nov-16 | 885 | 1.28658 | | | | | | | 82 | ***259.26*** | 7 | ***22.13*** | | | 89 | ***281.39*** |
| | | C28.8-L | 01-Nov-16 | 570 | 0.82 | | | | | | | 141 | ***1086.01*** | | | | | 141 | ***1086.01*** |
| | | C30.5-R | 30-Oct-16 | 2268 | 1.52583 | | | | | 8 | ***8.32*** | 29 | ***30.17*** | 5 | ***5.2*** | | | 42 | ***43.69*** |
| | | C30.6-L | 02-Nov-16 | 1815 | 1.84 | | | | | 30 | ***32.34*** | 100 | ***107.8*** | 5 | ***5.39*** | | | 135 | ***145.53*** |
| | | C32.0-R | 30-Oct-16 | 1612 | 1.37 | | | | | | | 28 | ***45.64*** | 1 | ***1.63*** | | | 29 | ***47.27*** |
| | | C40.0-L | 30-Oct-16 | 507 | 1.13573 | | | | | | | 58 | ***362.62*** | | | | | 58 | ***362.62*** |
| | | C41.1-L | 30-Oct-16 | 1862 | 2.41 | | | | | | | 16 | ***12.84*** | 19 | ***15.24*** | | | 35 | ***28.08*** |
| | | C43.7-R | 29-Oct-16 | 670 | 1.3446 | | | | | | | 8 | ***31.97*** | | | | | 8 | ***31.97*** |
| | | C45.6-L | 29-Oct-16 | 713 | 0.901 | | | | | | | 139 | ***778.94*** | | | | | 139 | ***778.94*** |
| | | C47.2-R | 30-Oct-16 | 760 | 1.06 | | | | | | | 71 | ***317.28*** | 4 | ***17.87*** | | | 75 | ***335.15*** |
| | | C56.0-L | 27-Oct-16 | 536 | 0.94 | | | | | | | | | 2 | ***14.29*** | | | 2 | ***14.29*** |
| | **Session Summary** | | | **1204** | **28.1** | **17** | *1.81* | **0** | *0* | **77** | *8.19* | **1481** | *157.59* | **100** | *10.64* | **0** | *0* | **1675** | *178.23* |
| **Section Total All Samples** | | | | **81976** | **117.9641411** | **22** | | **0** | | **379** | | **6476** | | **470** | | **1** | | **7348** | |
| **Section Average All Samples** | | | | **1171** | **1.69** | **0** | *0.57* | **0** | *0* | **5** | *9.88* | **93** | *168.77* | **7** | *12.25* | **0** | *0.03* | **105** | *191.5* |
| **Section Standard Error of Mean** | | | | | | **0.22** | *0.65* | **0** | *0* | **1.56** | *954.37* | **15.05** | *2815.2* | **1.08** | *3.1* | **0.01** | *0.03* | **15.38** | *3769.29* |
| **All Sections Total All Samples** | | | | **135015** | **174.7079577** | ***59*** | ***0.01*** | ***3*** | ***0*** | ***1171*** | ***0.18*** | ***8346*** | ***1.27*** | ***2575*** | ***0.39*** | ***1*** | ***0*** | ***12155*** | ***1.86*** |
| **All Sections Average All Samples** | | | | | | ***0*** | ***1.07*** | ***0*** | ***0.05*** | ***10*** | ***21.27*** | ***70*** | ***151.58*** | ***22*** | ***46.77*** | ***0*** | ***0.02*** | ***102*** | ***220.75*** |
| **All Sections Standard Error of Mean** | | | | | | ***0.16*** | ***0.63*** | ***0.02*** | ***0.04*** | ***2.65*** | ***561.31*** | ***9.86*** | ***1656.39*** | ***3.8*** | ***13.8*** | ***0.01*** | ***0.02*** | ***11.57*** | ***2217.02*** |

# Appendix F – Life History

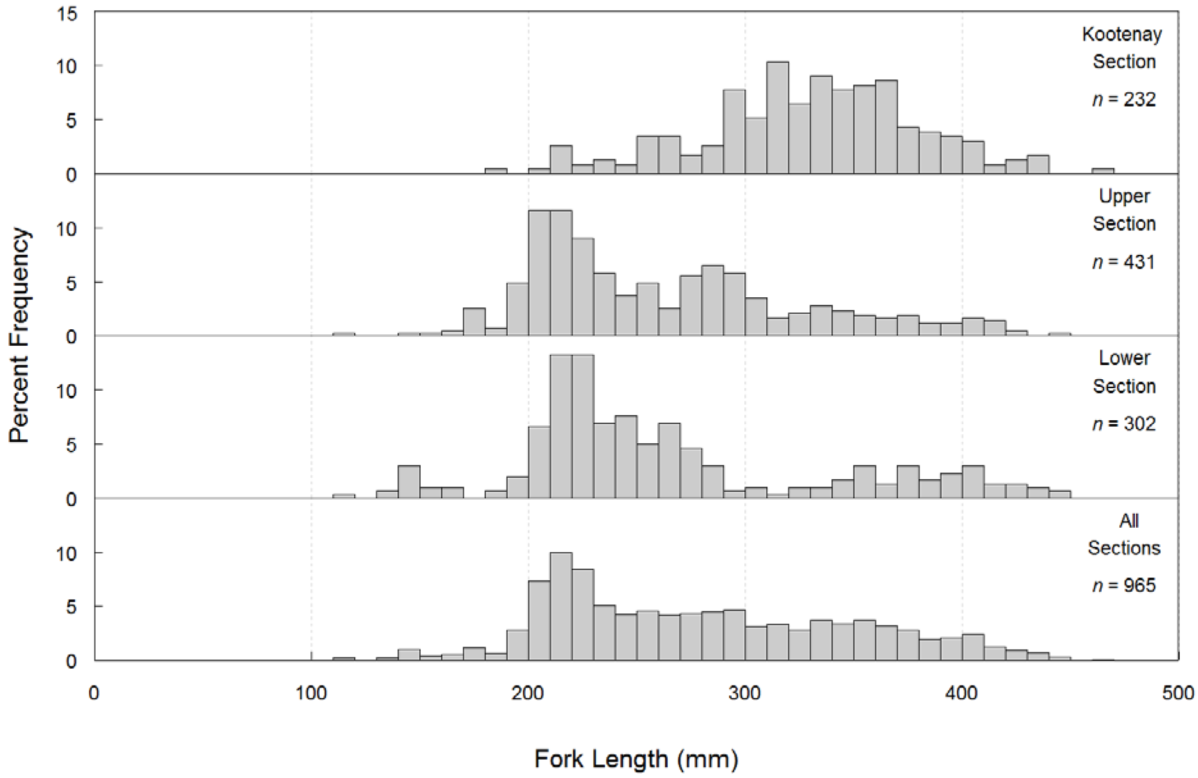


*Figure F1. Length-frequency distributions by site for Mountain Whitefish captured by boat electroshocking in sampled sections of the lower Columbia River, 3 October to 4 November 2016.*

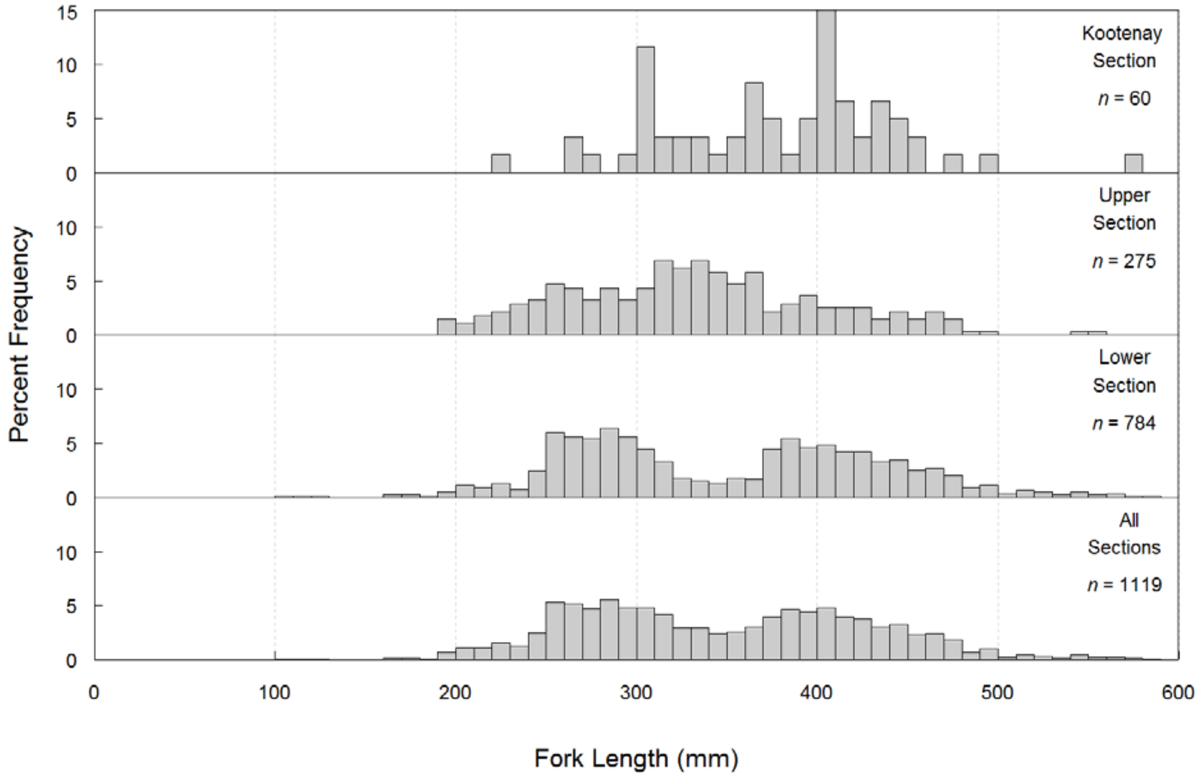


*Figure F2. Length-frequency distributions by site for Rainbow Trout captured by boat electroshocking in sampled sections of the lower Columbia River, 3 October to 4 November 2016.*

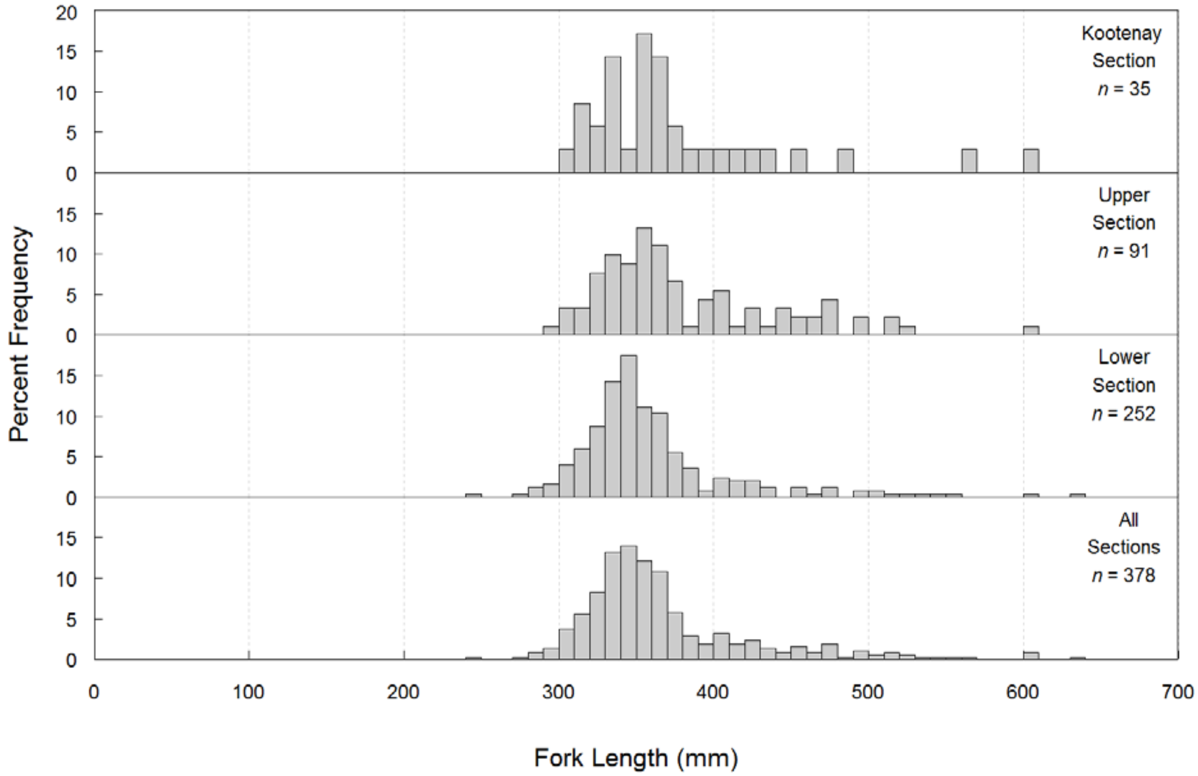
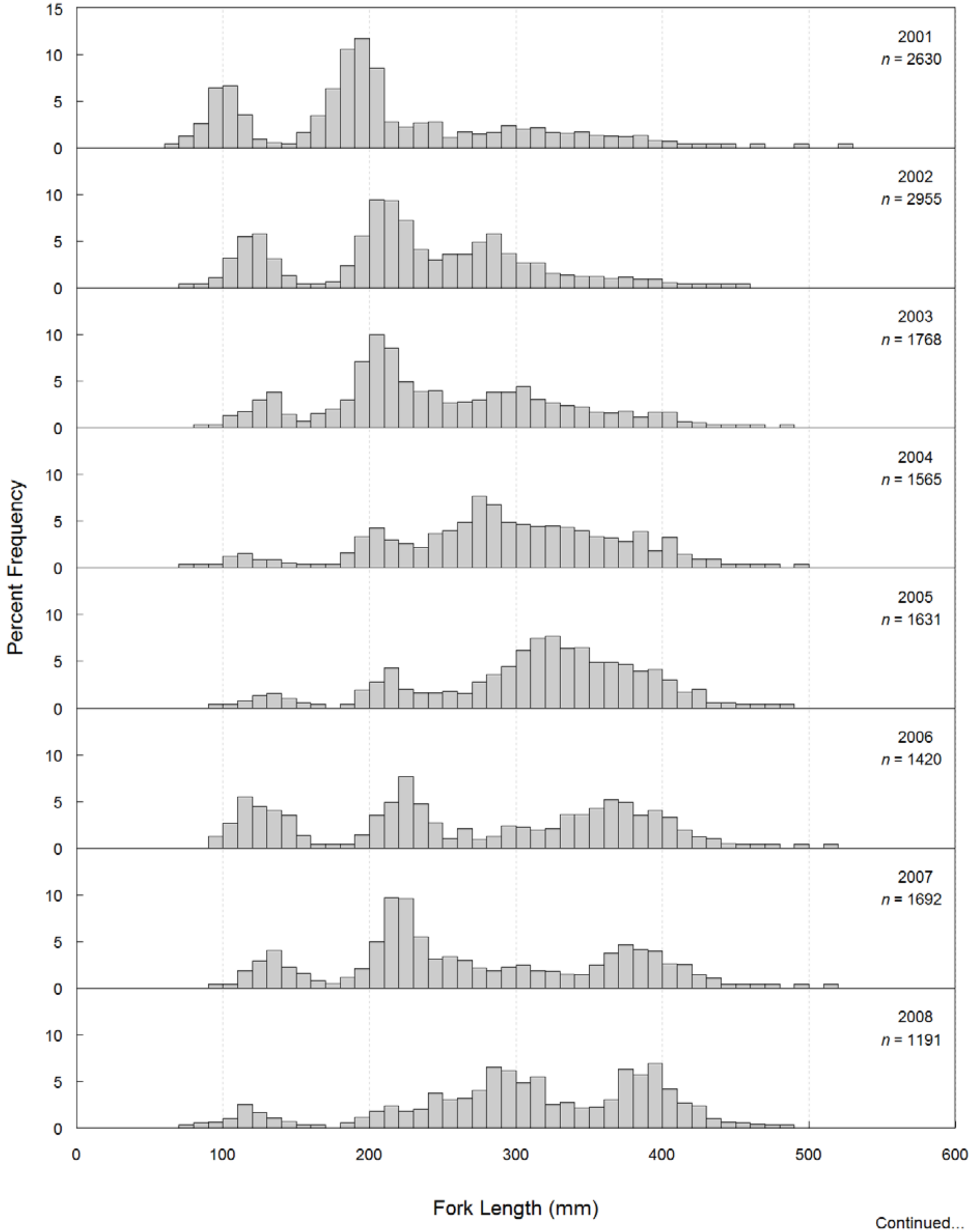


*Figure F3. Length-frequency distributions by site for Walleye captured by boat electroshocking in sampled sections of the lower Columbia River, 3 October to 4 November 2016.*



Continued...

*Figure F4. Length-frequency distributions by year for Mountain Whitefish captured by boat electroshocking in sampled sections of the lower Columbia River, 2001 to 2016.*

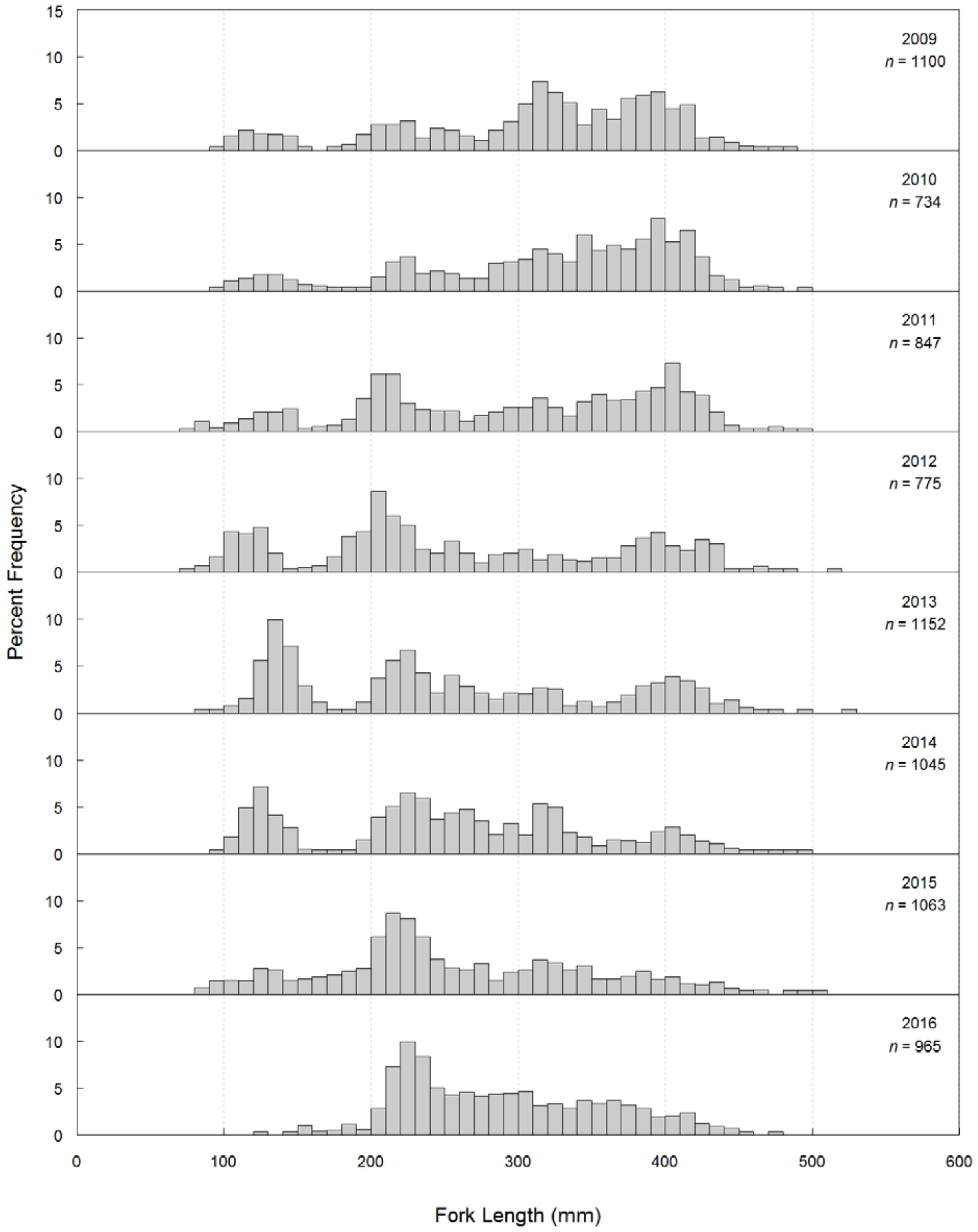
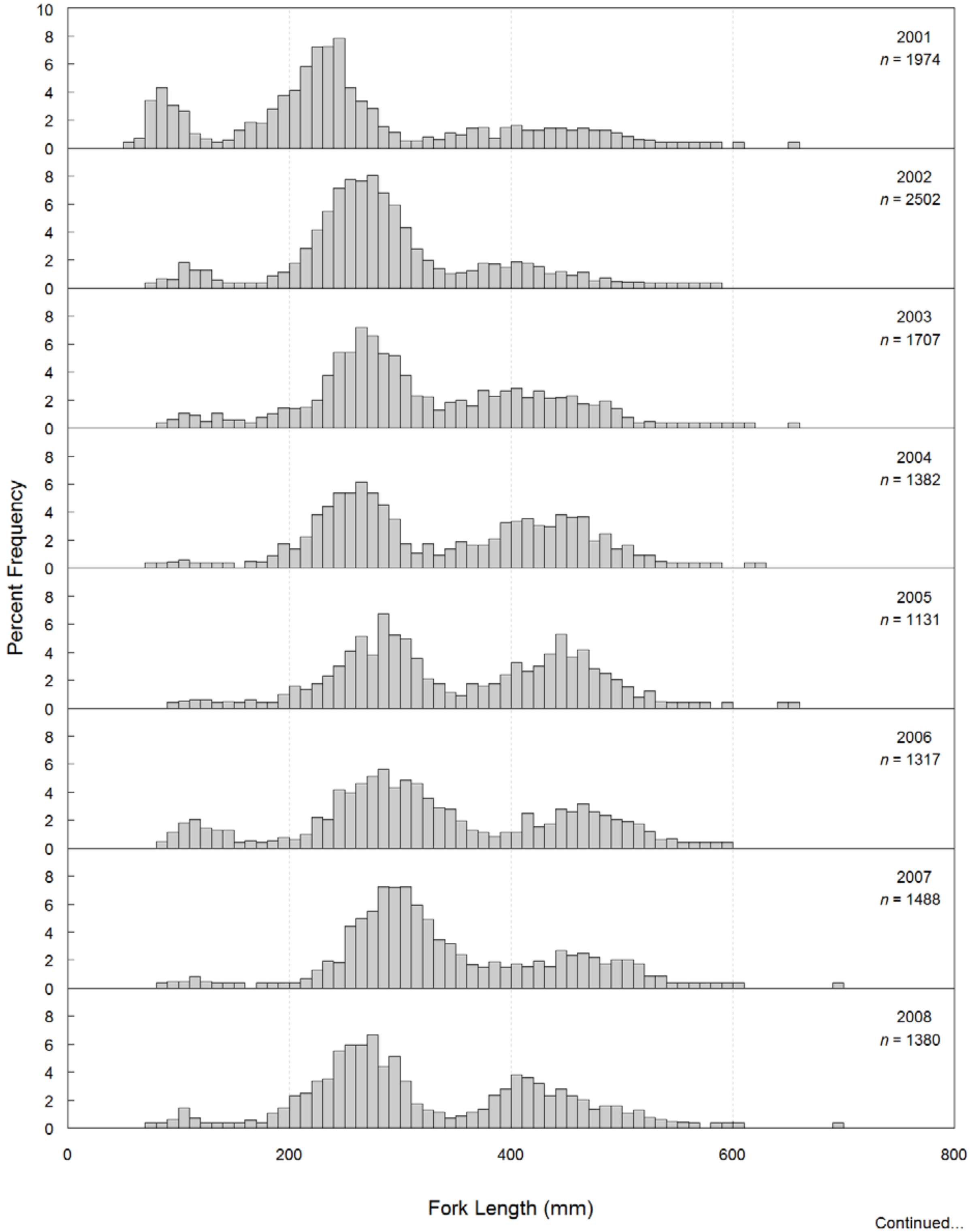


*Figure F4. Concluded.*



Continued...

*Figure F5. Length-frequency distributions by year for Rainbow Trout captured by boat electroshocking in sampled sections of the lower Columbia River, 2001 to 2016.*

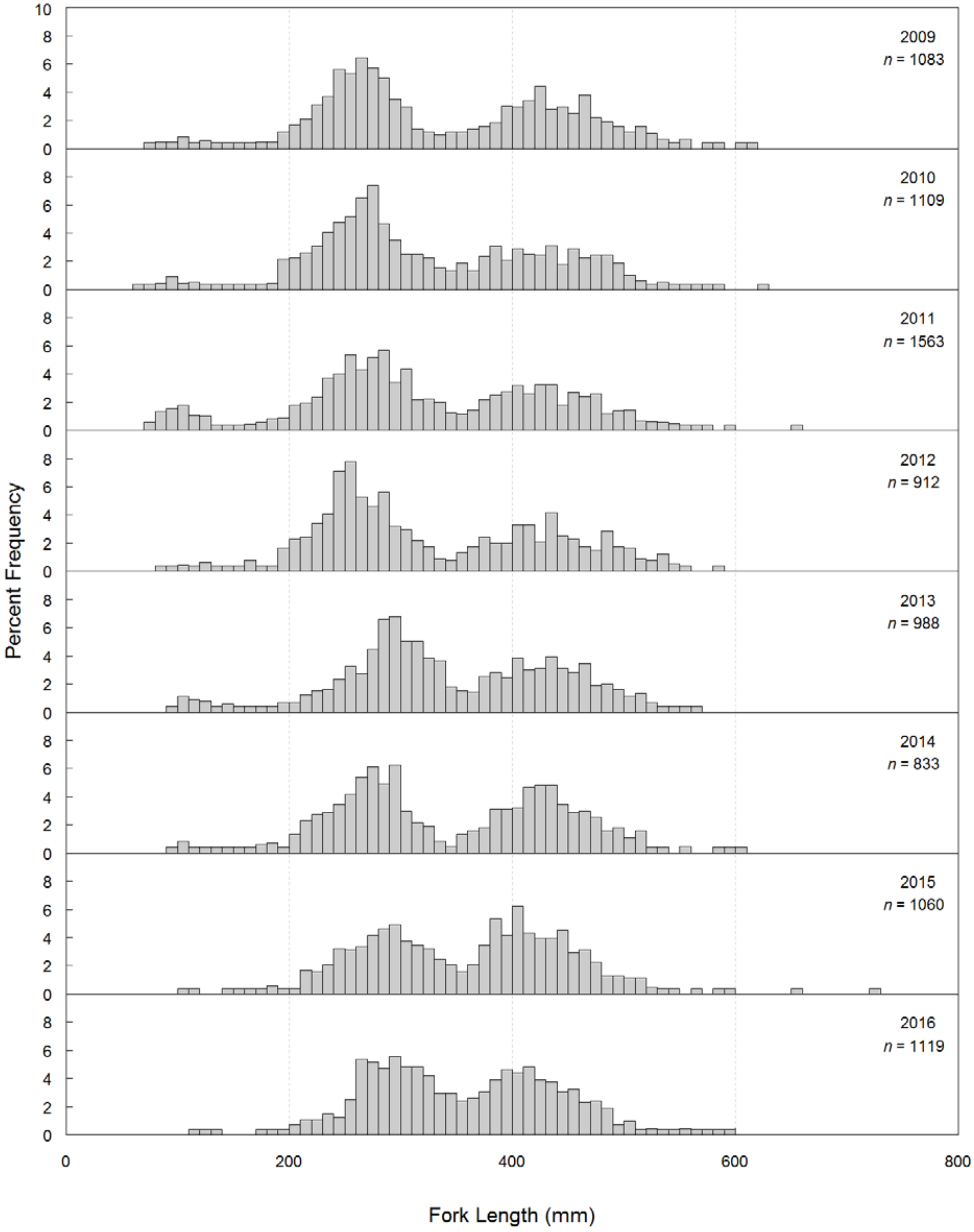
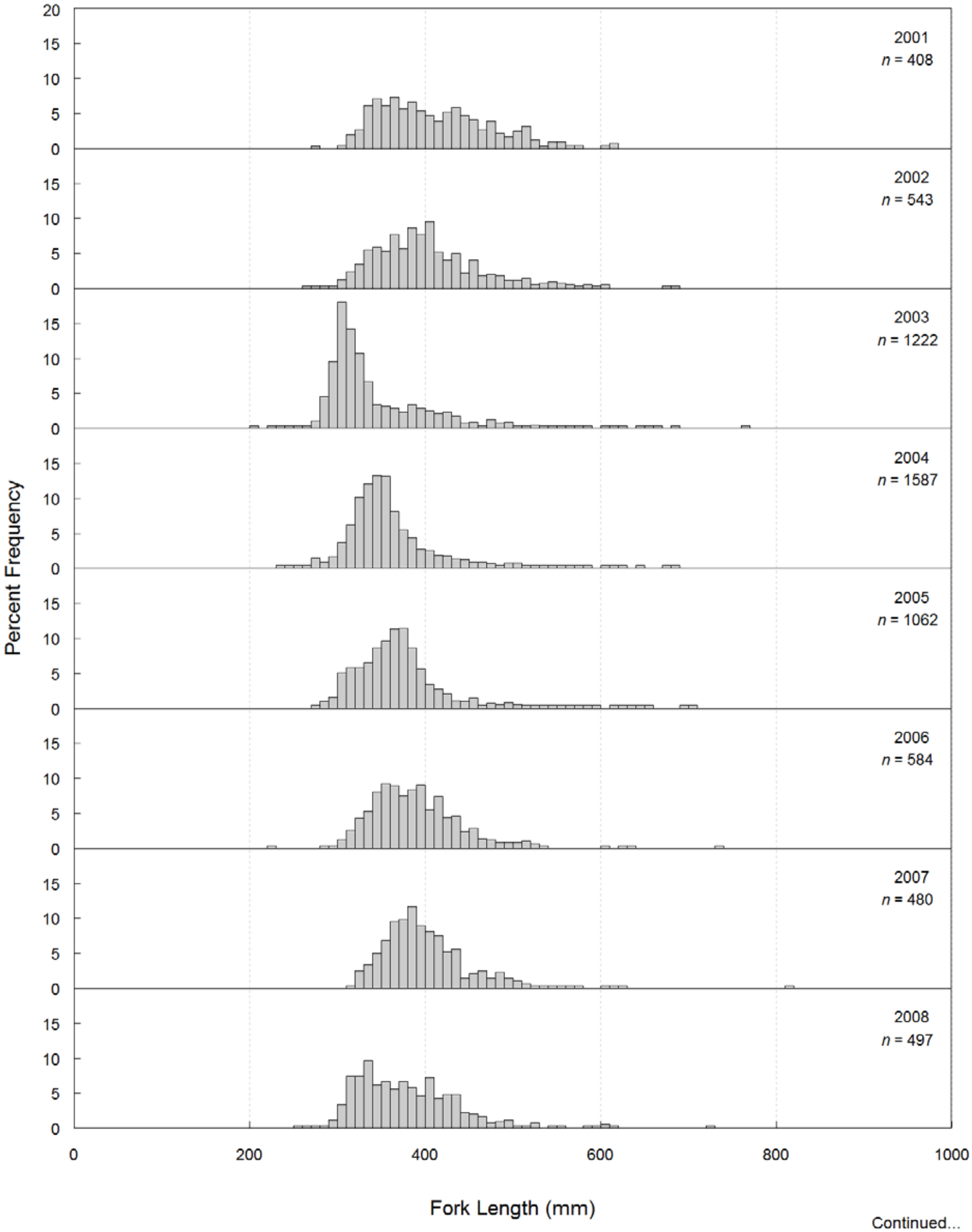


*Figure F5. Concluded.*



Continued...

*Figure F6. Length-frequency distributions by year for Walleye captured by boat electroshocking in sampled sections of the lower Columbia River, 2001 to 2016.*

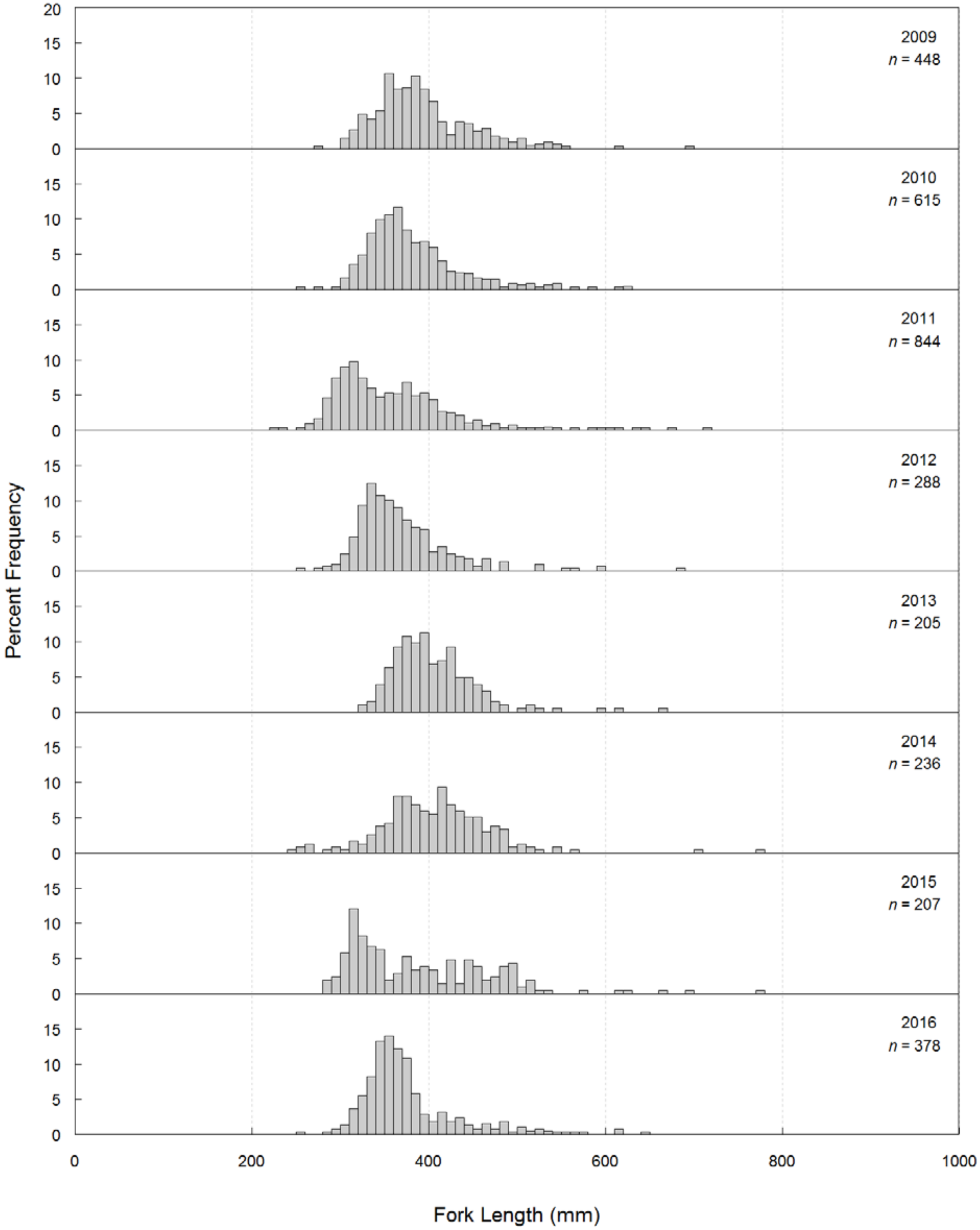
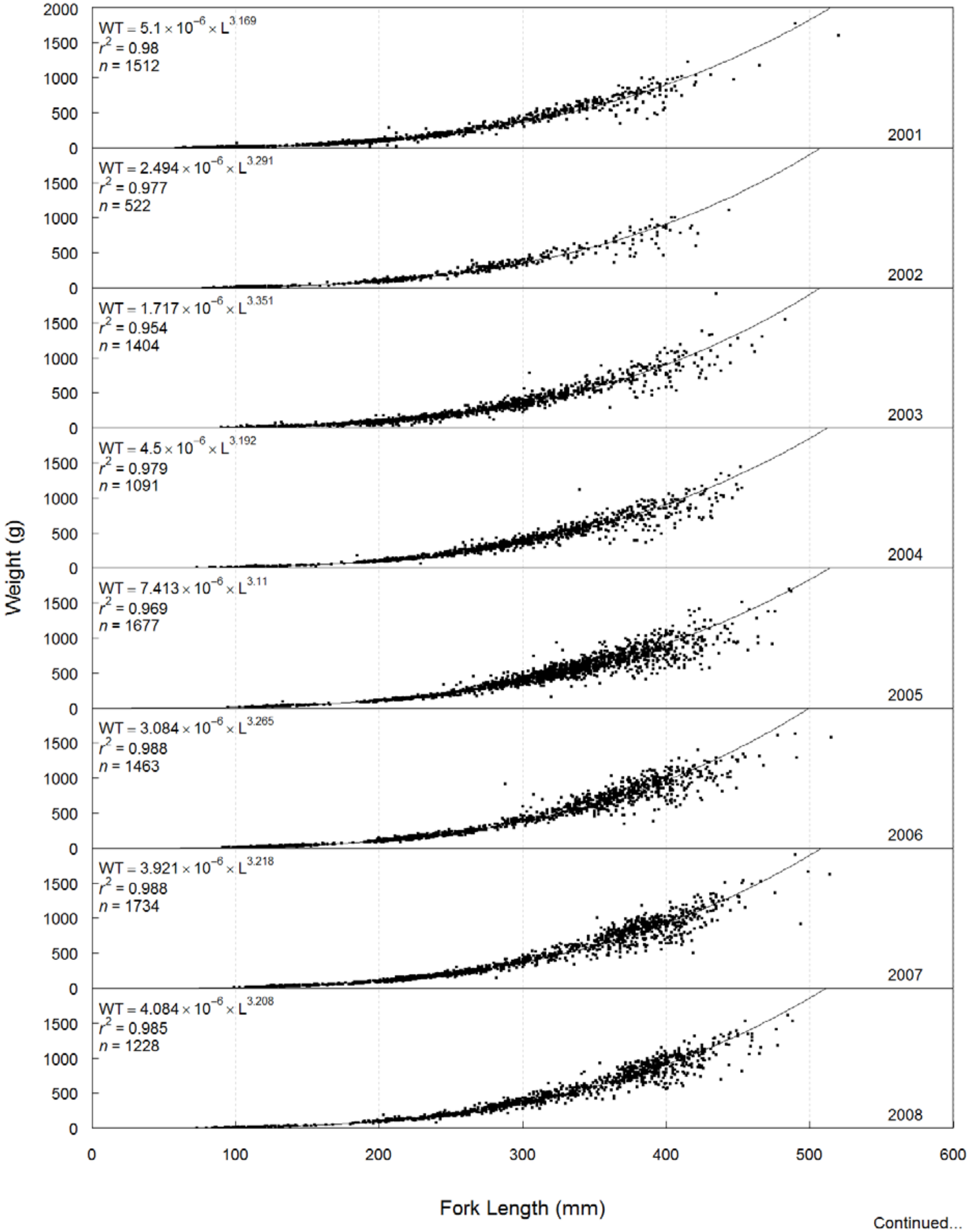


*Figure F6. Concluded.*



Continued...

*Figure F7. Length-weight regressions for Mountain Whitefish captured by boat electroshocking in the lower Columbia River, 2001 to 2016.*

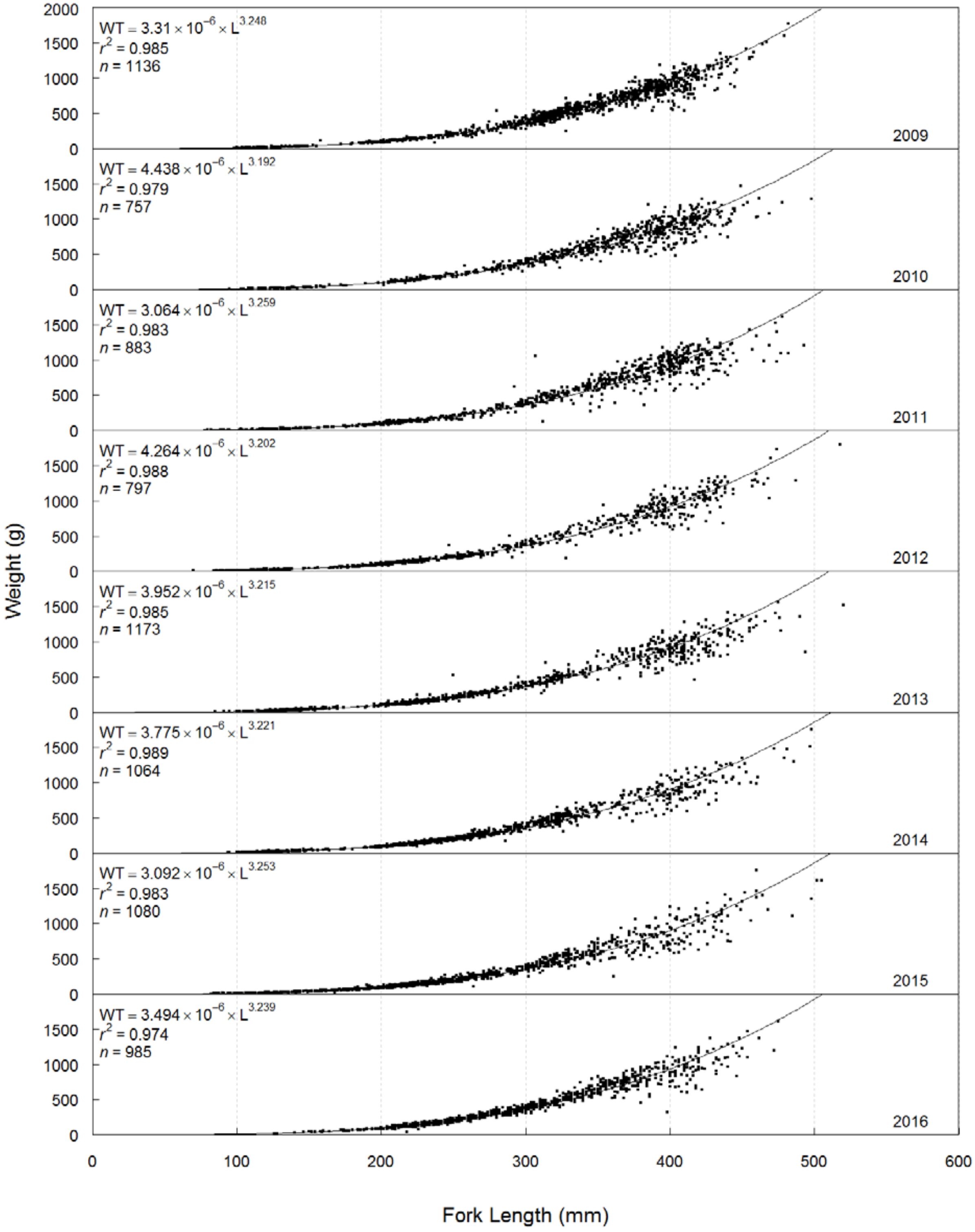
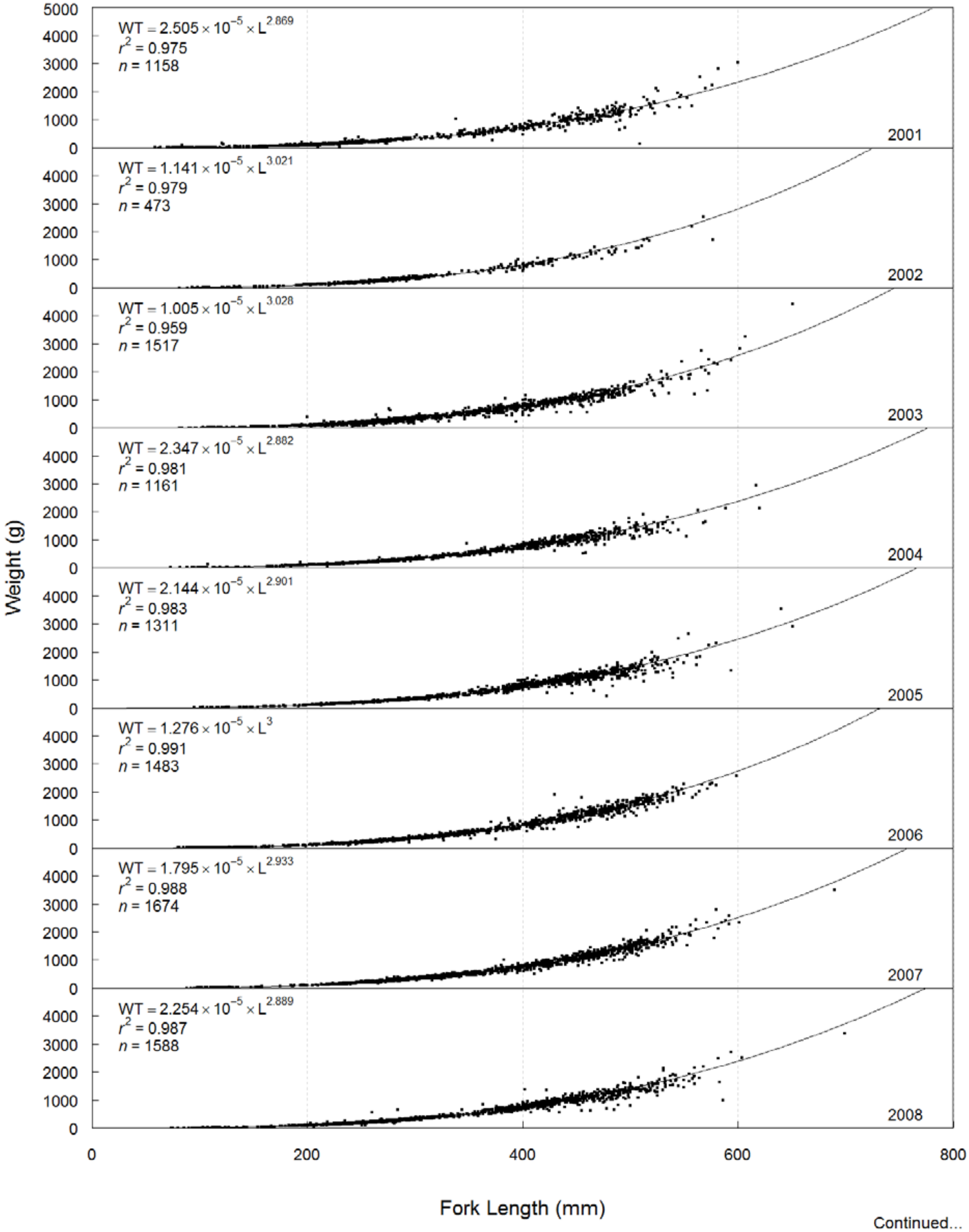


*Figure F7. Concluded.*



Continued...

*Figure F8. Length-weight regressions for Rainbow Trout captured by boat electroshocking in the lower Columbia River, 2001 to 2016.*

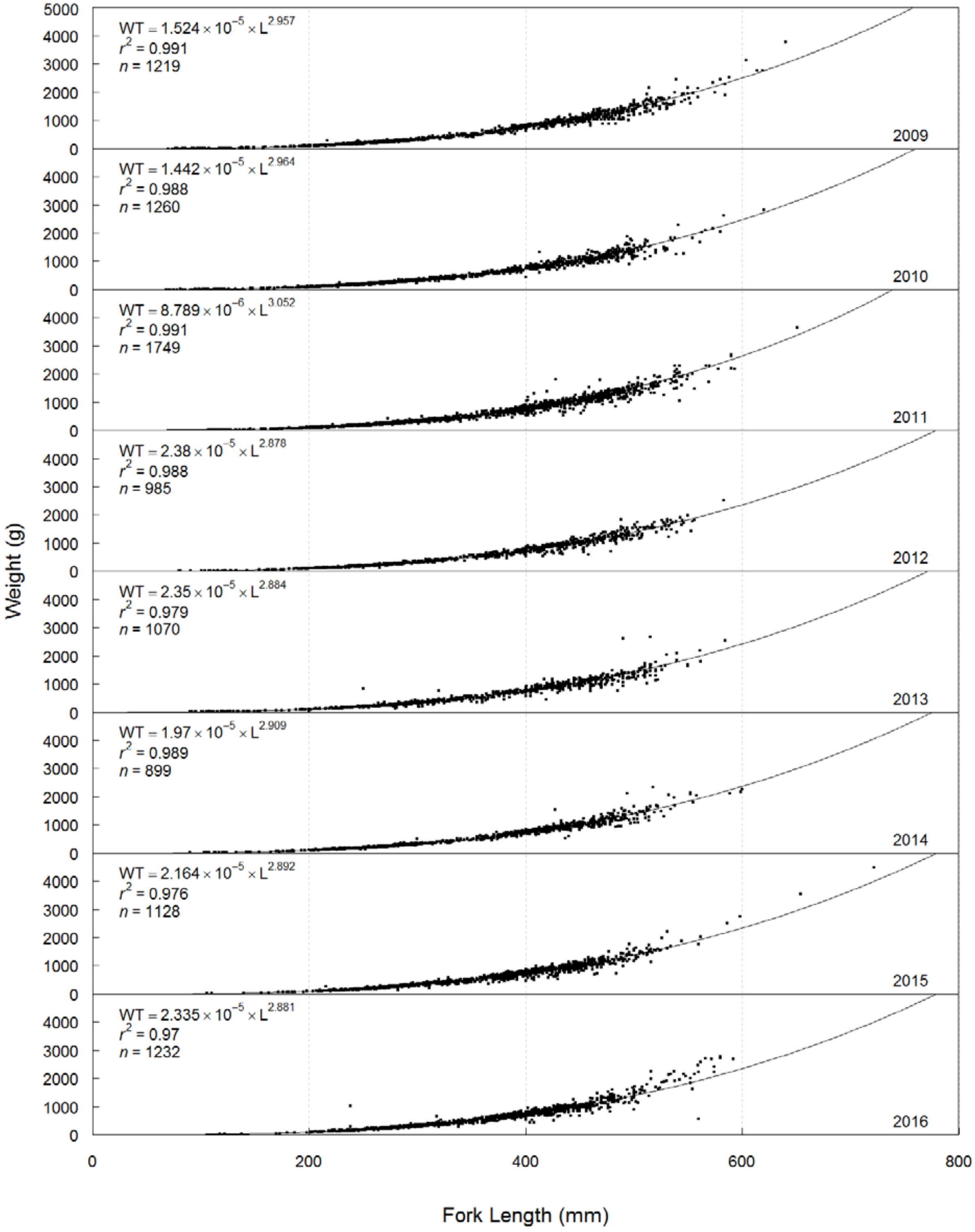
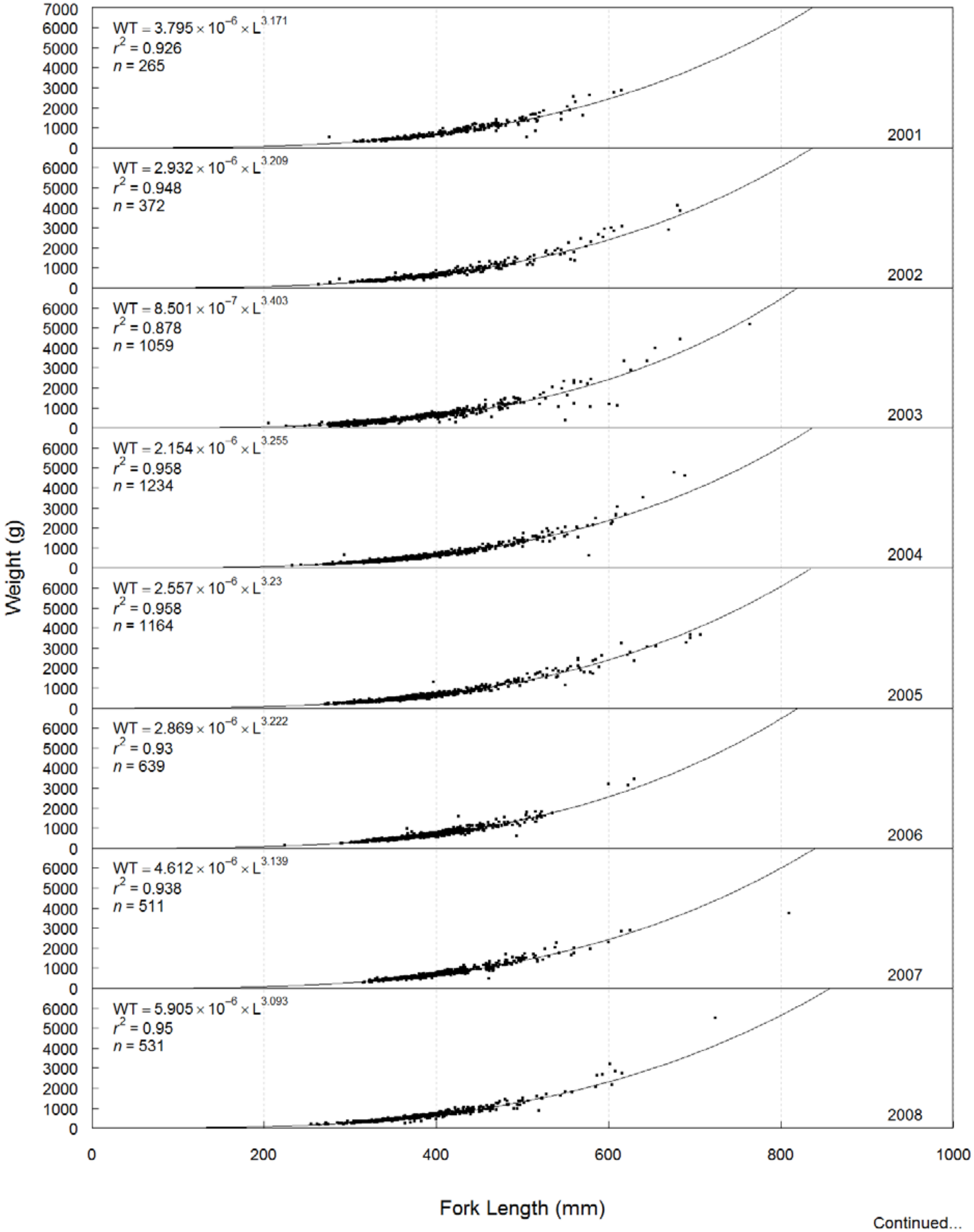


*Figure F8. Concluded.*



Continued...

*Figure F9. Length-weight regressions for Walleye captured by boat electroshocking in the lower Columbia River, 2001 to 2016.*

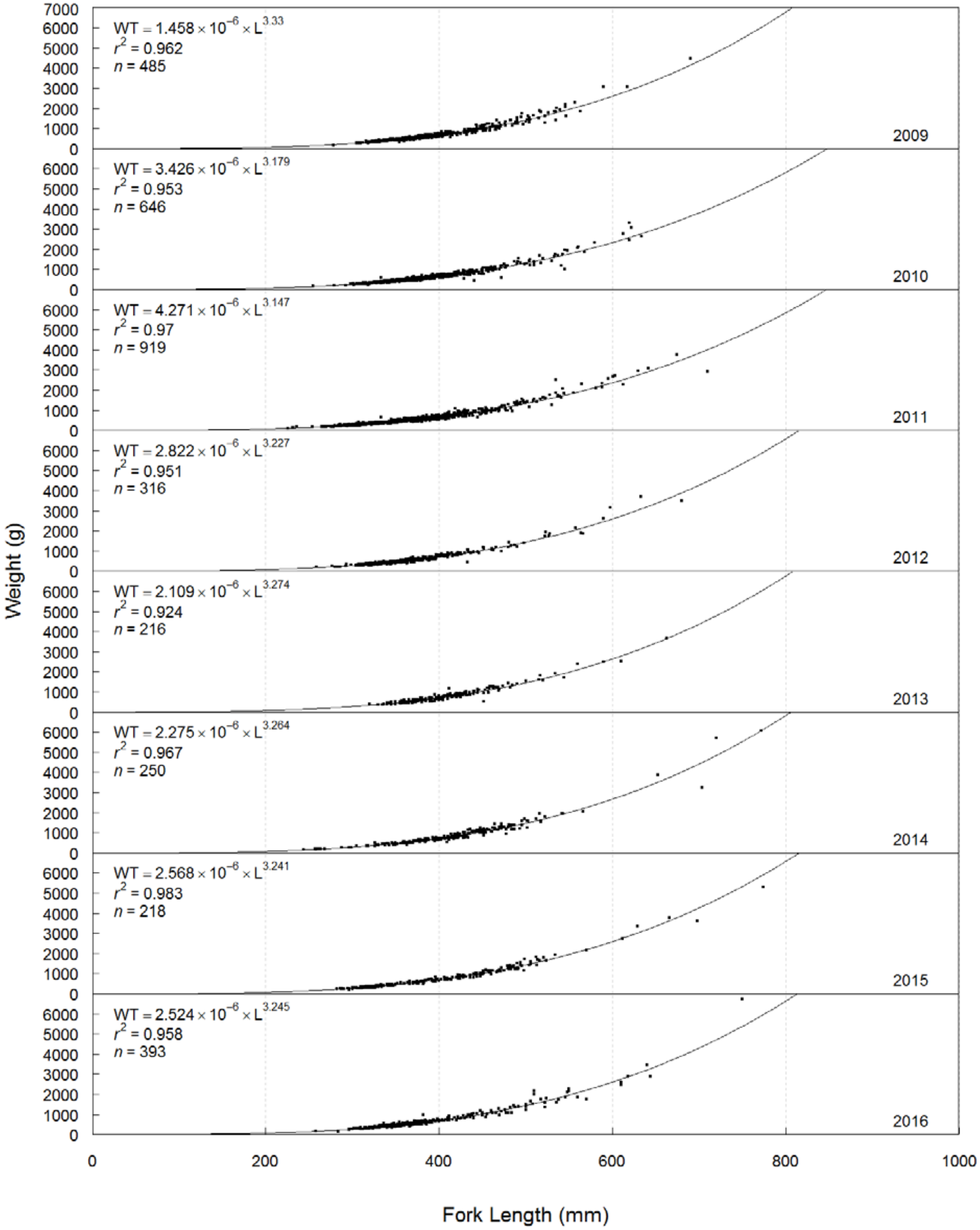


*Figure F9. Concluded.*

# Appendix G – Additional Results

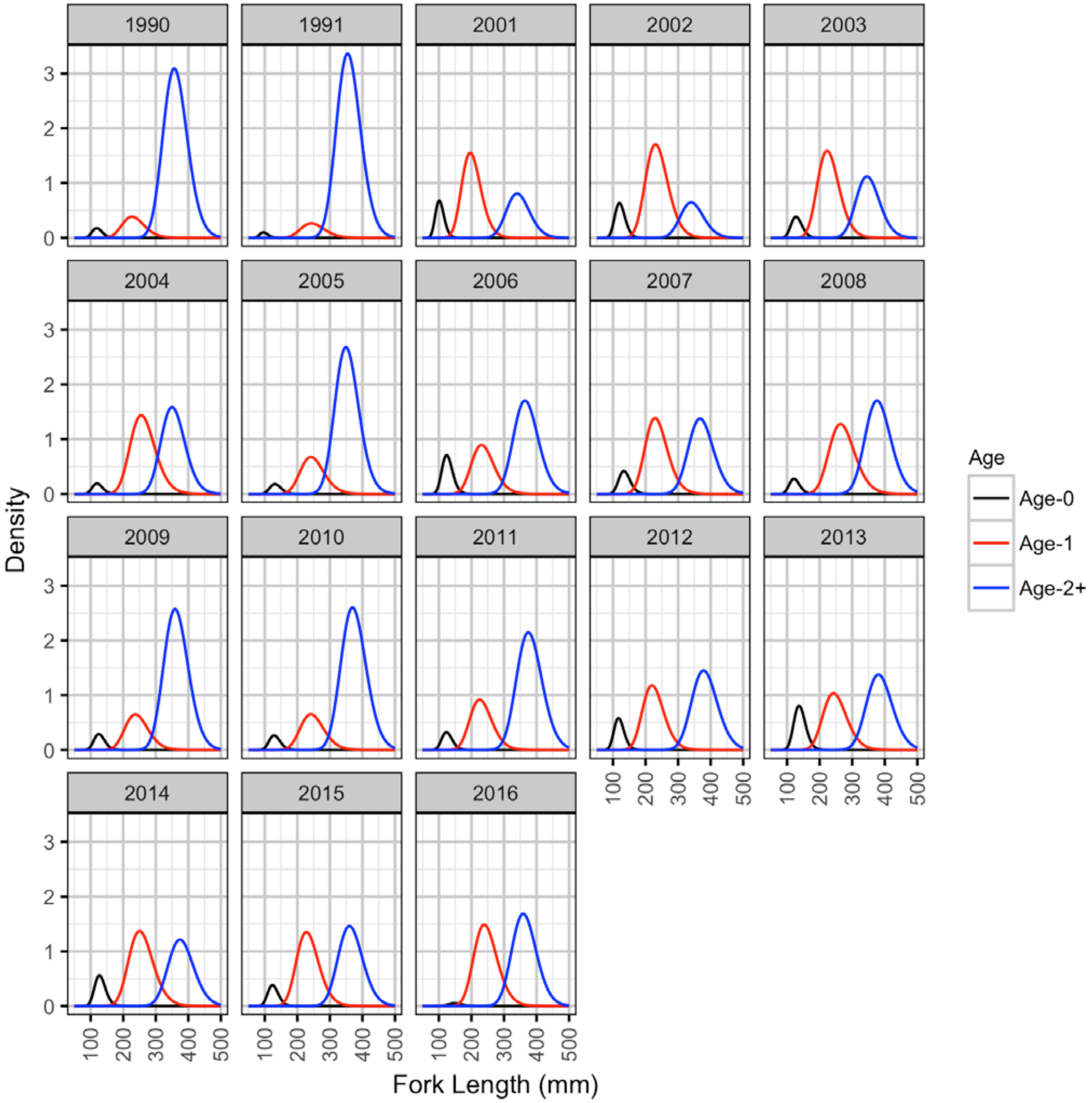


*Figure G1: Predicted length-density plot for Mountain Whitefish by life-stage and year.*

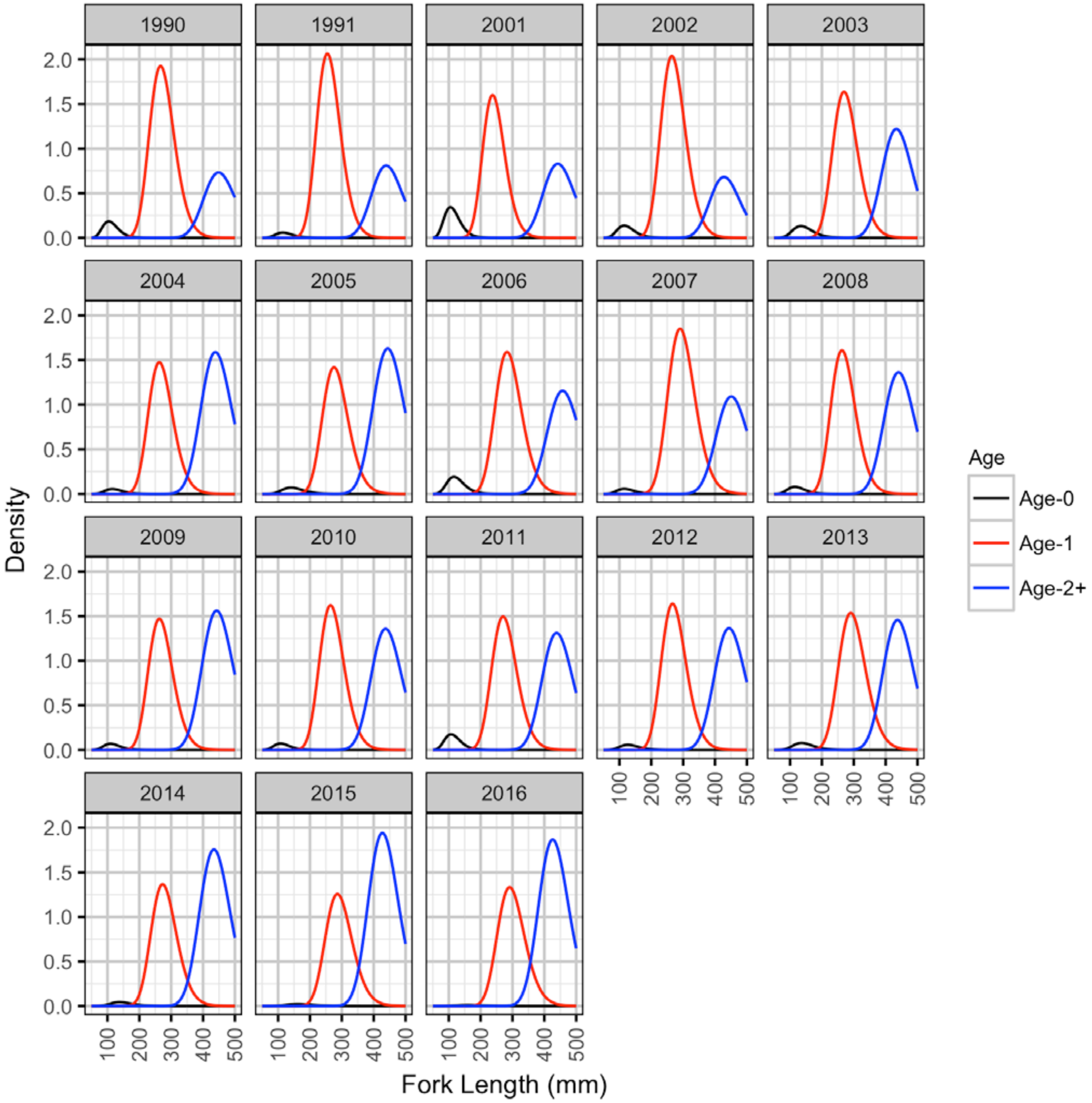


*Figure G2: Predicted length-density plot for Rainbow Trout by life-stage and year.*

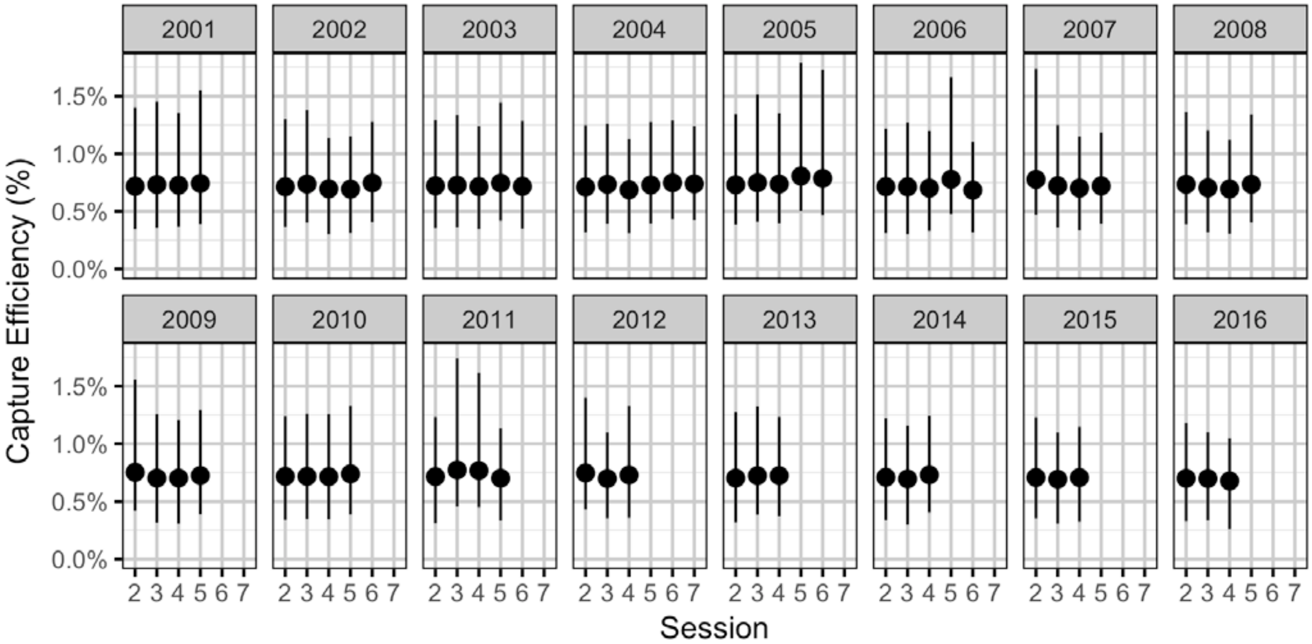


*Figure G3: Capture efficiency (mean with 95% credible intervals) of subadult Mountain Whitefish by year and sample session in the lower Columbia River, 2001-2016.*

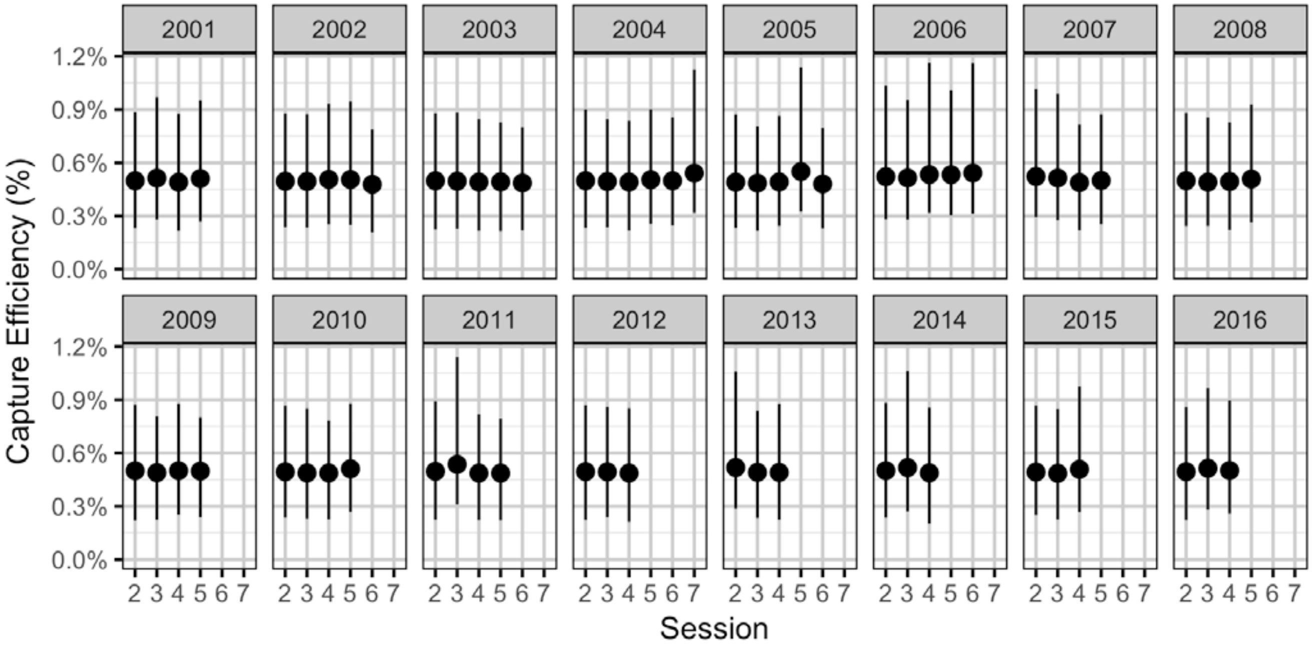


*Figure G4: Capture efficiency (mean with 95% credible intervals) of adult Mountain Whitefish by year and sample session in the lower Columbia River, 2001-2016.*

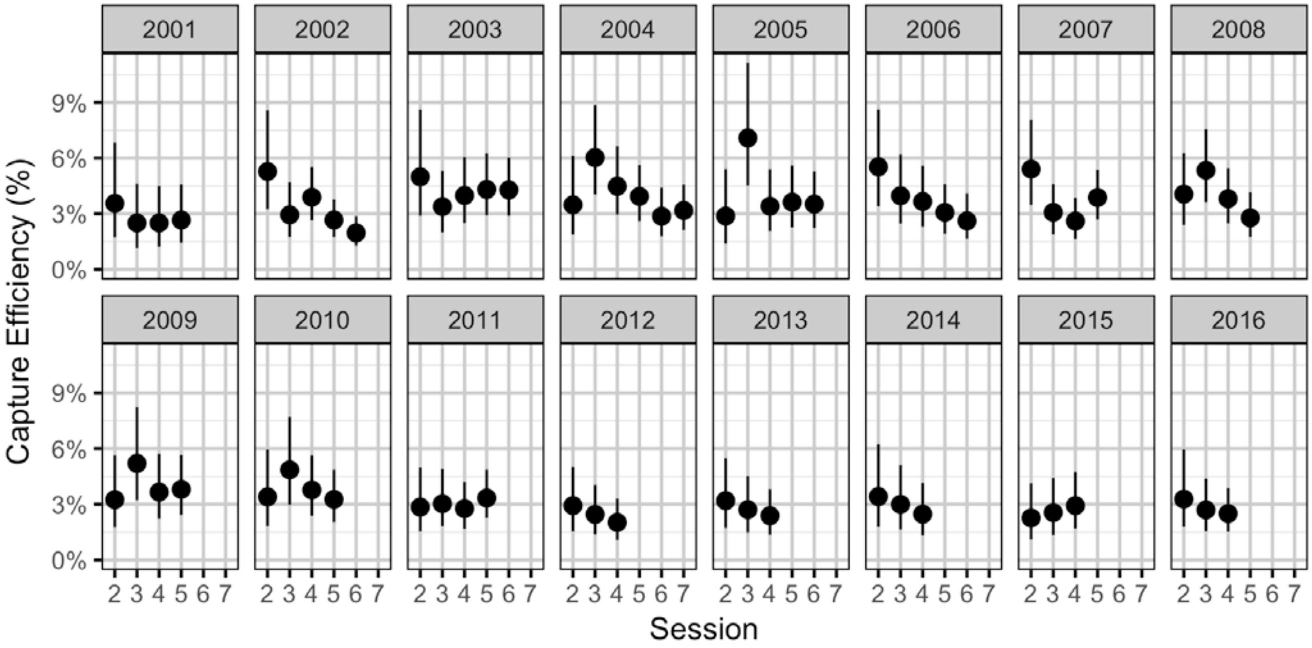


*Figure G5: Capture efficiency (mean with 95% credible intervals) of subadult Rainbow Trout by year and sample session in the lower Columbia River, 2001-2016.*

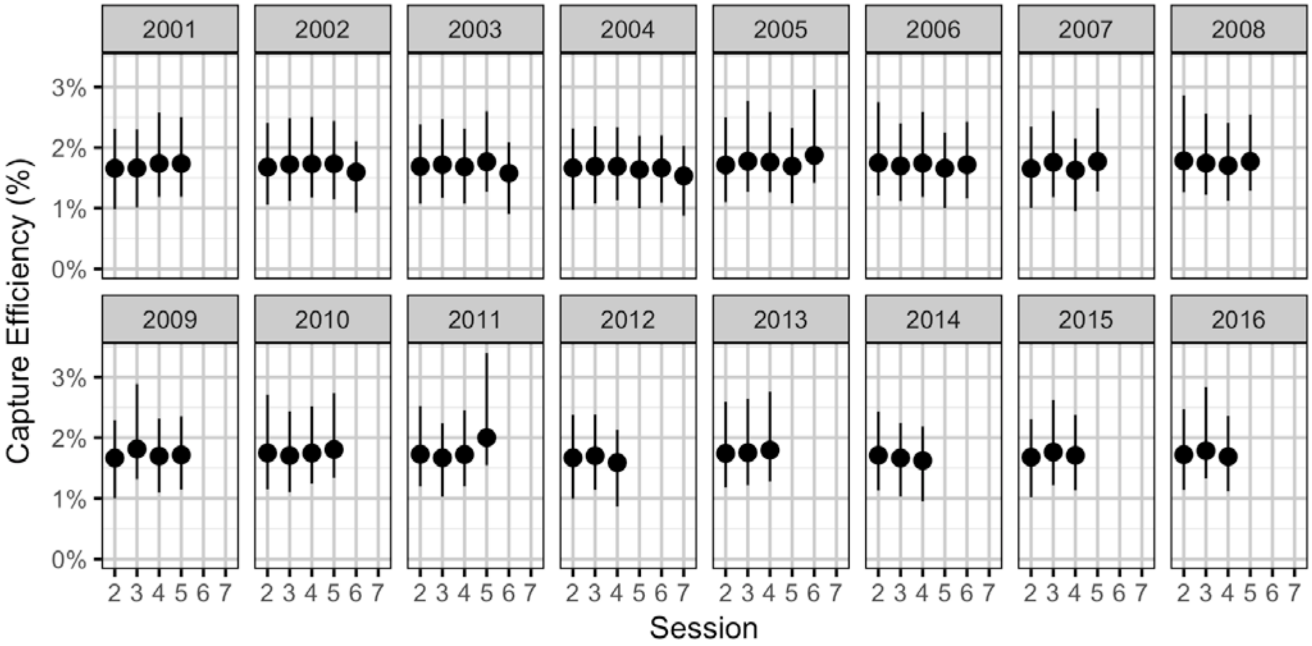


*Figure G6: Capture efficiency (mean with 95% credible intervals) of adult Rainbow Trout by year and sample session in the lower Columbia River, 2001-2016.*

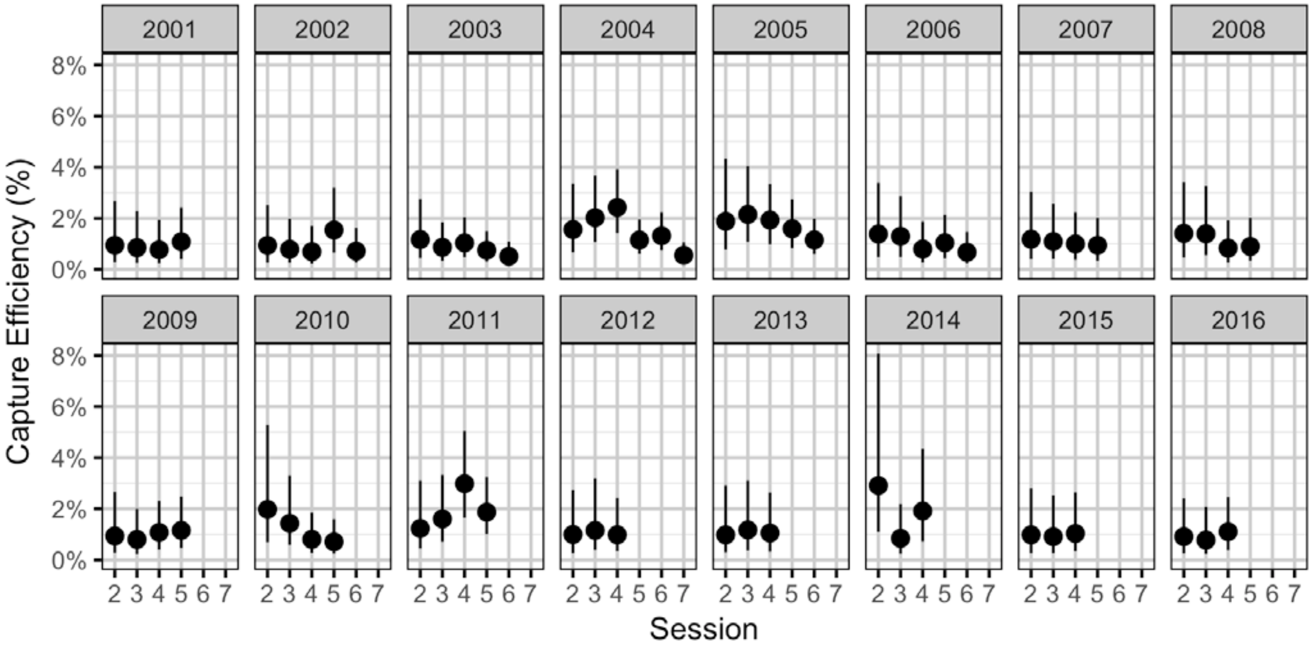


*Figure G7: Capture efficiency (mean with 95% credible intervals) of adult Walleye by year and sample session in the lower Columbia River, 2001-2016.*

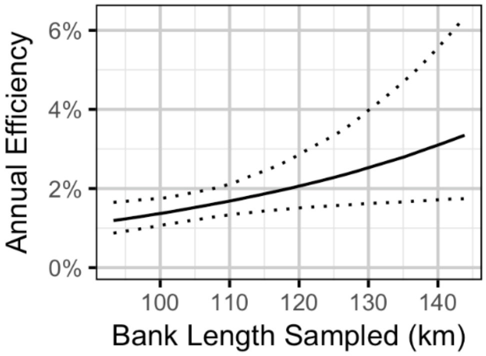


*Figure G8: Predicted annual efficiency of capture for adult Mountain Whitefish by amount of bank length sampled (km).*

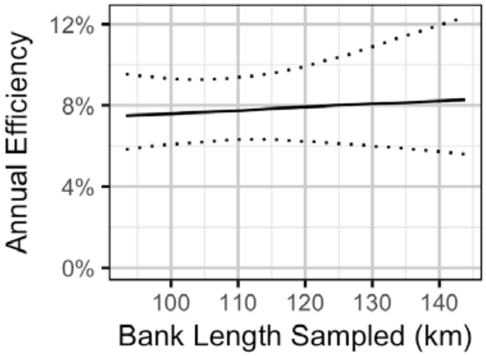


*Figure G9: Predicted annual efficiency of capture for adult Rainbow Trout by amount of bank length sampled (km).*

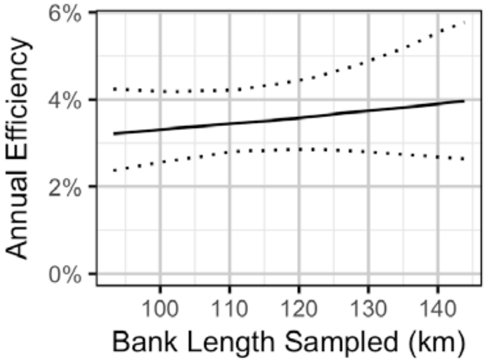


*Figure G10: Predicted annual efficiency of capture for Walleye by amount of bank length sampled (km).*

# Appendix H – Spatial Distribution Maps

This monitoring report has been completed as part of BC Hydro’s Water License Requirements. Copies are on file at BC Hydro. In order to protect sensitive information regarding the distribution of fish populations in the study area, a copy of this appendix is not available for viewing through this website. For further information concerning this study or the report, please contact Water License Requirements through the “Contact Us” button located at the top of this webpage.