Columbia River Project Water Use Plan

Revelstoke Flow Management Plan

Implementation Year 6

Reference: CLBMON-16

Middle Columbia River Fish Population Indexing Program

Study Period: 2012

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Middle Columbia River Fish Population Indexing Surveys - Synthesis Report

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Executive Summary

A year-round 142 m^3/s minimum flow release from Revelstoke Dam (REV) was implemented in December 2010 as part of BC Hydro's Water Use Plan for the Columbia River. The implementation of the minimum flow coincided with the commissioning of an additional generation unit at Revelstoke Dam (i.e., REV5) that increased the maximum generation discharge capacity of the dam from 1700 m^3/s to 2124 m^3/s. The combined effects of these changes in dam operations are referred to as a flow regime change. The key environmental objective of the minimum flow release is to increase the abundance and diversity of fish populations in the Middle Columbia River (MCR). The MCR Fish Population Indexing Program addresses four key management questions:

- Is there a change in abundance of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in growth rate of adult life stages of the most common fish species using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in body condition (measured as a function of relative weight to length) of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in spatial distribution of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?

Another objective of the program, although not specifically identified as a key management hypothesis, is to investigate and document changes in species richness or species diversity in the MCR in response to the minimum flow release. Data have been collected for the MCR Fish Population Indexing Program during four years (2007 to 2010) prior to and two years after (2011 and 2012) the flow release. In addition, data were collected from 2001 to 2006 as part of BC Hydro's Large River Fish Indexing Program, a similar program designed to monitor life history characters of fish populations in the MCR.

The study area encompassed the approximately 12 km long portion of the Columbia River between Revelstoke Dam and the Illecillewaet River confluence. Fishes were sampled by boat electroshocking at night within nearshore habitats. All captured fishes were measured for fork length and weighed. Select species were implanted with a Passive Integrated Transponder (PIT) tag for a mark-recapture study. Temporal and spatial variations in species richness, species evenness, abundance, spatial distribution, growth, and body condition were estimated using hierarchical Bayesian analyses (HBA).

There was an increase in species richness and evenness between 2001 and 2008 which was attributed to substantial increases in the abundance of several less common species. The density and/or probability of occupancy of Burbot (*Lota lota*), Lake Whitefish (*Coregonus clupeaformis*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Rainbow Trout (*Oncorhynchus mykiss*) and Sculpin species (*Cottidae* spp.) all increased, while densities of more common species such as Bull Trout (*Salvelinus confluentus*) and Mountain Whitefish (*Prosopium williamsoni*) remained relatively stable during this time period. Although the results suggest that a substantial change in the fish community occurred between 2001 and 2008, reasons for the change are unknown, and densities of most of the fish species that increased were not correlated with discharge, reservoir elevation, or water temperature.

With only two years of data following the flow regime change, it is not possible to draw strong conclusions about its effect on fish populations. In general, the abundance of most species was stable or within the range of

previously observed variability. However, there was some evidence to suggest that conditions for growth or abundance of juvenile fish in the MCR may have declined in the two years following the flow regime change. The two cohorts of juvenile Mountain Whitefish that were sampled in the MCR after the flow regime change (i.e., age-0 in 2011; age-1 and age-0 in 2012) were noticeably less abundant compared to previous years, based on density estimates and length-frequency distributions. In addition, length-at-age of age-0 and age-1 Mountain Whitefish, and body condition of Mountain Whitefish and Bull Trout all declined in the two years following the flow regime change. The similar trends in all these metrics suggest that growth was likely lower in 2011 and 2012 but the cause of the decline remains unclear. Additional years of data collection are required to assess the influence of environmental variables, and identify whether the flow regime change at REV contributed to any of the observed differences in fish populations.

Recommendations for future years of study include: 1) exploring relationships between fish population metrics from this program and variables of physical habitat attributes, primary and secondary productivity, and juvenile fishes; from other programs of the RFMP; and, 2) conducting an additional electrofishing pass during which fish would be enumerated but not captured to collect fine scale spatial distribution data.

Keywords: Inventory, Columbia River, Revelstoke Dam, Density Estimation, Hierarchical Bayesian Analysis

Table E1: Status of management questions and hypotheses after Year 6 of the Middle Columbia River Fish Population Indexing Survey (CLBMON-16).

Objectives	Management Questions	Management Hypotheses	Year 6 (2012) Status
Systematically collect fish population data prior to and following the implementation of the 142 m^3/s minimum flows and REV5 to quantitatively assess the changes in abundance, growth, diversity and distribution of fishes in the Middle Columbia River.	Is there a change in the abundance of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?	**Ho_1:** The implementation of a 142 m^3/s minimum flow release from Revelstoke Dam will not significantly affect the abundance and diversity of adult fish present in the MCR during index surveys.	Hypothesis cannot be rejected at this time. Two years of data have been collected since the implementation of the minimum flow release. Data collected to date do not suggest a substantial change in abundance or diversity of adult fish present in the MCR during indexing surveys. A hierarchical Bayesian model has been constructed that allows annual and spatial comparisons of the abundance and diversity of adult life stages of common fish species present in the MCR.

Objectives	Management Questions	Management Hypotheses	Year 6 (2012) Status
Systematically collect fish population data prior to and following the implementation of the 142 m^3/s minimum flows and REV5 to quantitatively assess the changes in abundance, growth, diversity and distribution of fishes in the Middle Columbia River.	Is there a change in growth rate of adult life stages of the most common fish species using the MCR that corresponds with the implementation of a year-round minimum flow?	**Ho_2:** The implementation of a 142 m^3/s minimum flow release from Revelstoke Dam will not significantly affect the mean growth rate of adult fish present in the MCR during index surveys.	Hypothesis cannot be rejected at this time. Two years of data have been collected since the implementation of the minimum flow release. Length-at-age for the age-0 and age-1 mountain whitefish declined after the flow regime change but inter-annual growth was not different. Whether the decline in length-at-age was due to the flow regime change remains uncertain. A negative correlation between density of age-1 mountain whitefish and the variance in discharge suggests that increased variability in discharge following the flow regime change could have contributed to the decline in length-at-age but more evidence is needed to support this relationship. Data collected to date do not suggest a substantial change in growth for other fish species present in the MCR during indexing surveys, based on hierarchical Bayesian analyses.
Systematically collect fish population data prior to and following the implementation of the 142 m^3/s minimum flows and REV5 to quantitatively assess the changes in abundance, growth, diversity and distribution of fishes in the Middle Columbia River.	Is there a change in body condition (measured as a function of relative length to weight) of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?	**Ho_3:** The implementation of a 142 m^3/s minimum flow release from Revelstoke Dam will not significantly affect the body condition of adult fish present in the MCR during index surveys.	Hypothesis cannot be rejected at this time. Two years of data have been collected since the implementation of the minimum flow release. The body condition of mountain whitefish and bull trout declined after the flow regime change but reasons for the decline are unknown. A hierarchical Bayesian Model has been constructed that allows annual and spatial comparisons of the body condition of adult life stages of common fish species present in the MCR.
Systematically collect fish population data prior to and following the implementation of the 142 m^3/s minimum flows and REV5 to quantitatively assess the changes in abundance, growth, diversity and distribution of fishes in the Middle Columbia River.	Is there a change in spatial distribution of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?	**Ho_4:** The implementation of a 142 m^3/s minimum flow release from Revelstoke Dam will not significantly alter the distribution of fish present in the MCR during index surveys.	Hypothesis cannot be rejected at this time. Two years of data have been collected since the implementation of the minimum flow release. Data collected to date do not suggest a substantial change in the distribution of any of the fish species present in the MCR during indexing surveys. A hierarchical Bayesian Model has been constructed that allows annual and spatial comparisons of the spatial distribution of adult life stages of common fish species present in the MCR.

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1.0 INTRODUCTION

BC Hydro implemented a Water Use Plan (WUP; BC Hydro 2007) for the Canadian portion of the Columbia River in 2007. As part of the WUP, the Columbia River Water Use Plan Consultative Committee (WUP CC) recommended the establishment of a year-round 142 m^3/s minimum flow release from Revelstoke Dam (REV; BC Hydro 2005). The key environmental objective of the minimum flow release is to increase the abundance and diversity of fish populations in the Middle Columbia River (MCR). Implementation of the minimum flow release coincided with the commissioning of a new and additional fifth generating unit (REV5) at REV on December 20, 2010. The addition of REV5 also increased the maximum generation discharge capacity of the REV from 1700 m^3/s to 2124 m^3/s. The combined effects of the minimum flow release and the increased maximum discharge capacity from REV are collectively referred to as the flow regime change.

The MCR includes the ~48 km long portion of the Columbia River from the outlet of REV downstream to Beaton Flats. Due to data gaps regarding the status of aquatic communities in the MCR, and uncertainty about the environmental benefits of a minimum flow release on the MCR ecosystem, the WUP CC recommended the development and implementation of the Revelstoke Flow Management Plan (RFMP). The RFMP is designed to measure the productivity of the MCR ecosystem in response to the minimum flow release, and includes the following studies, each designed to measure a specific aspect of the MCR ecosystem:

- CLBMON-15a – MCR Physical Habitat Monitoring;
- CLBMON-15b – MCR Ecological Productivity Monitoring;
- CLBMON-16 – MCR Fish Population Indexing Surveys;
- CLBMON-17 – MCR Juvenile Fish Habitat Use Assessment;
- CLBMON-18 – MCR Adult Fish Habitat Use Assessment; and,
- CLBMON-53 – MCR Juvenile Fish Stranding Assessment.

The RFMP specified four years of adult fish monitoring prior to the implementation of the minimum flow release (i.e., 2007 to 2010). Prior to 2007, adult fish abundance and population structure were monitored in the MCR under the Large River Fish Indexing Program (Golder 2002, 2003, 2004a, 2005a, 2006, 2007). These data, combined with four years of data collected as part of the RFMP, (Golder 2008, 2009, 2010, Ford and Thorley 2011a) provide 10 years of data that will be used as a baseline to help determine the effect of the minimum flow release on adult fish in the MCR. Currently, nine years of study are scheduled after the implementation of the minimum flow release (i.e., 2011 to 2019). The present study year (2012) represents the second year of monitoring following the operation of REV5 and the implementation of the minimum flow. Year Six (2012) of the RFMP requires a synthesis report including more in-depth analyses of all six years of data in relation to the management question. Previous annual reports for this monitoring program already included comprehensive analysis of all available data since 2001. Therefore, the analysis in this synthesis report will be similar to past years, using all years of available data to answer management questions, and build on analytical models from previous years.

1.1 Study Objectives

The primary objective of the MCR Fish Population Indexing Study (CLBMON-16) is to systematically collect fish population data prior to and following the flow regime change to monitor changes in abundance, growth, diversity, and distribution of fish in the MCR. Secondary objectives of the program are to:

- Build on earlier investigations to further refine the sampling strategy, sampling methodology, and analytical procedures required to establish a long-term monitoring program for fish populations in the MCR;
- Identify gaps in understanding, data, and current knowledge about fish populations; and,
- Provide recommendations for future monitoring.

The key management questions and hypotheses described in Sections 1.2 and 1.3 are excerpted from BC Hydro (2010) and focus specifically on the effects of the minimum flow release. However, the increased generation capacity of REV5 also has an equal or greater potential to result in changes to fish population metrics downstream from REV. Due to the inability to separate the effects of these two flow changes, the following would more accurately be described as questions and hypothesis related to effects of the flow regime change.

1.2 Key Management Questions

Key management questions to be addressed by CLBMON-16 include:

- Is there a change in abundance of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in growth rate of adult life stages of the most common fish species using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in body condition (measured as a function of relative weight to length) of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in spatial distribution of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?

1.3 Management Hypotheses

Specific hypotheses to be tested under CLBMON-16 include:

- Ho_1: The implementation of a 142 m^3/s minimum flow release from Revelstoke Dam will not significantly affect the abundance and diversity of adult fish present in the MCR during index surveys.
- Ho_2: The implementation of a 142 m^3/s minimum flow release from Revelstoke Dam will not significantly affect the mean growth rate of adult fish present in the MCR during index surveys.

- Ho_3: The implementation of a 142 m^3/s minimum flow release from Revelstoke Dam will not significantly affect the body condition of adult fish present in the MCR during index surveys.
- Ho_4: The implementation of a 142 m^3/s minimum flow release from Revelstoke Dam will not significantly alter the distribution of fish present in the MCR during index surveys.

1.4 Background

Revelstoke Dam is located on the Columbia River approximately 8 km upstream from the Trans-Canada Highway bridge, which crosses the Columbia River at the City of Revelstoke (Figure 1). The dam and generation facility, brought into service in 1984, were constructed primarily to generate power, using the combined storage capacity of Revelstoke Reservoir and the upstream Kinbasket Reservoir (impounded by Mica Dam in 1973). REV was not constructed as one of the Columbia River Treaty dams [i.e., Mica, Hugh L. Keenleyside (HLK), Duncan, and Libby dams]; however, operation of REV is affected by both upstream (Mica Dam) and downstream (HLK) treaty considerations. The Revelstoke Generating Station is the second largest powerplant in BC Hydro's hydroelectric power generation system, providing 21% of BC Hydro's total system capacity (http://www.bchydro.com/energy_in_bc/projects/revelstoke_unit_5.html).

REV is typically operated as a daily peaking plant with flow releases increasing through the daylight hours and peaking in the early evening (BC Hydro 1999). During periods of low power demand, flow through the generation units can be reduced to as low as 142 m^3/s (the minimum flow release). Periods of low flow can occur at any time, but mainly occur at night during the spring (March to May) and fall (September to November) when both water availability and electricity demands are typically lowest. Prior to the minimum flow release and the commissioning of REV5, discharge from REV could range from 0 to 1700 m^3/s. The commissioning of REV5 increased maximum discharge to 2124 m^3/s, an increase of 424 m^3/s. With the commissioning of REV5 (coupled with the minimum flow release), discharge from REV can now range from 142 to 2124 m^3/s.

The quantity and quality of river habitat in the MCR is influenced both by flow releases from REV and by the operation of downstream Arrow Lakes Reservoir (ALR; impounded by HLK). As ALR fills, the length of flowing river in the MCR decreases. At full pool (EL 440 m), ALR backwatering influences the MCR up to the base of REV. Typically, ALR fills to near full pool by early July and is maintained at high pool levels until late November, at which time the reservoir is drafted for downstream power production and as a requirement for flood control during the following spring freshet period. Maximum reservoir elevation, and the duration for which it is maintained, varies annually based on climate conditions, Columbia River Treaty obligations, and/or operational needs. At the minimum reservoir elevation (EL 420 m), the section of flowing river downstream of REV extends for approximately 48 km (i.e., to Arrowhead). Therefore, the influence of the minimum flow release on the MCR ecosystem is expected to be greater during the winter and spring (when reservoir levels are lower) than during the summer and fall (when reservoir levels are higher).

1.5 Study Area

The study area for CLBMON-16 encompasses the 11.7 km long section of the Columbia River from the base of REV downstream to the confluence of the Illecillewaet River (Figure 1). The study area is differentiated into two reaches. Reach 4 extends from Revelstoke Dam (RKm 238.0; as measured upstream from the Canada-U.S. border) downstream to the Jordan River confluence (RKm 231.8). Reach 3 extends from the Jordan River confluence downstream to the Illecillewaet River confluence (RKm 226.3).

Reach 2 [the Illecillewaet River confluence to the Akolkolex River confluence (RKm 206.0)] was sampled as part of CLBMON-16 in 2007, 2008, and 2009. This reach has not been sampled since 2009, as it was deemed unlikely to be influenced by the minimum flow release. Sampling in Reach 2 was removed from the Terms of Reference in 2010. Reach 1 [the Akolkolex River confluence downstream to Beaton Flats (RKM 190.0)] was not sampled as part of CLBMON-16 during any study year and also was removed from the Terms of Reference in 2010 (BC Hydro 2010).

In 2012, the sample sites covered both banks of Reaches 3 and 4 (similar to 2007, 2008, 2009, 2010, and 2011). Between 2001 and 2006 (i.e., prior to the WUP) sampling was limited to Reach 4 and the Big Eddy portion of Reach 3 (Figure 1); the portion of Reach 3 downstream of Big Eddy was not sampled during these years.

The locations of the eight sites sampled in Reach 4 and the seven sites sampled in Reach 3 in 2012 are illustrated in Appendix A, Figures A1 and A2, respectively. Site descriptions and UTM locations for all sites are listed in Appendix A, Table A1. In 2012, each site was sampled four times (i.e., four sessions) between May 28 and June 22 (spring) and four times between October 2 and 25 (fall; Table 1). Sites were sampled during the spring for the first time in 2011.

Table 2: Annual study periods for boat electroshocking surveys conducted in the Middle Columbia River, 2001 to 2012.

Year	Season	Start Date	End Date	Number of Sessions	Duration (in days)
2001	Fall	12 September	11 October	5	30
2002	Fall	22 October	14 November	4	24
2003	Fall	15 October	30 October	4	16
2004	Fall	13 October	24 October	4	12
2005	Fall	5 October	25 October	4	21
2006	Fall	2 October	24 October	4	23
2007	Fall	27 September	24 October	5	28
2008	Fall	23 September	4 November	5	43
2009	Fall	28 September	30 October	5	33
2010	Fall	4 October	29 October	4	26
2011	Spring	30 May	24 June	4	26
2011	Fall	3 October	27 October	4	25
2012	Spring	28 May	22 June	4	26
2012	Fall	2 October	25 October	4	24

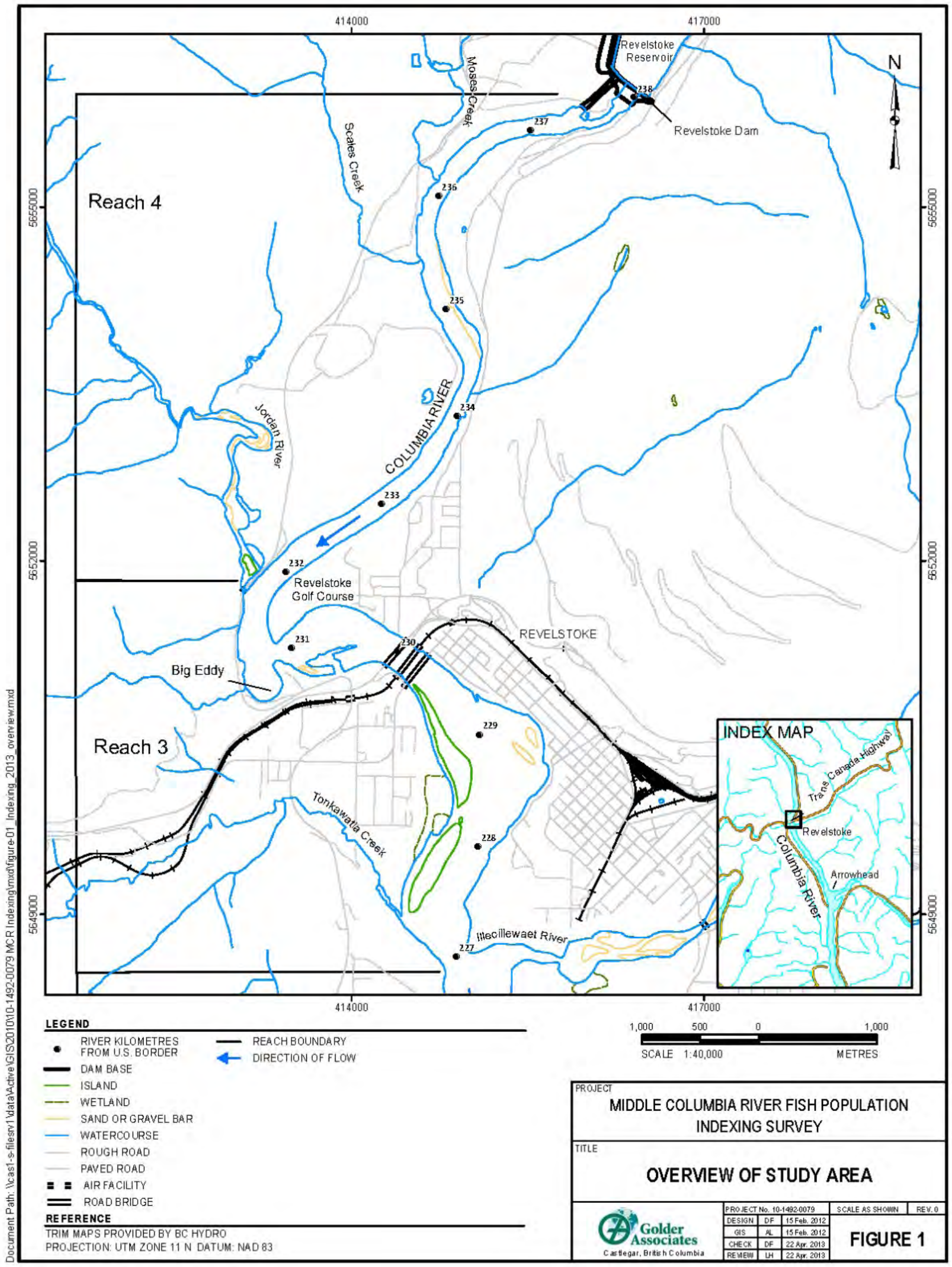

Figure 1: Overview of the Middle Columbia River study area, 2012.

2.0 METHODS

2.1 Data Collection

2.1.1 Discharge

Hourly average discharge data for the mainstem Columbia River (discharge through REV) from 2001 to 2012 were obtained from BC Hydro's Columbia-Kootenay River Temperature and Discharge Database. Discharges throughout this report are presented as cubic metres per second (m^3/s).

2.1.2 Water Elevation

Hourly water level elevation data for the mainstem Columbia River near Nakusp (RKm 132.2) from 2001 to 2012 were obtained from BC Hydro's Columbia-Kootenay River Temperature and Discharge Database. Water elevations throughout this report are presented as metres above sea level (masl).

2.1.3 Water Temperature

Water temperatures for the mainstem Columbia River were obtained from Station 2 of BC Hydro's MCR Physical Habitat Monitoring Program (CLBMON-15a), which is located approximately 4 km downstream of REV (RKm 234.0). Temperature data were collected at 10 minute intervals but daily mean values are presented in this report. Previous CLBMON-16 reports included temperature data from BC Hydro's Tailrace7 station (located approximately 7 km downstream of REV). However, the Tailrace7 station was not operational from December 1, 2011 to June 19, 2012. Therefore, data from Station 2 of the Physical Habitat Monitoring program were used in this report for all study years.

Spot measurements of water temperatures were obtained at all sample sites at the time of sampling using a hull-mounted Airmar® digital thermometer (accuracy ± 0.2°C).

2.1.4 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 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 was visually estimated at all sites. 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). Mean and maximum depths were estimated by the boat operator based on the boat's sonar depth display.

Each site was categorized into various habitat types using the Bank Habitat Types Classification System (Appendix B, Table B1; R.L.&L. 1994, 1995). Bank type length within each site was calculated using ArcView®

GIS software (Appendix B, Table B2). Netters estimated the number of fish by species and by bank habitat type. Bank habitat types less than approximately 100 m in length were combined with adjacent bank habitat types to facilitate the netters' ability to remember fish counts.

Table 3: List and description of habitat variables recorded at each sample site in the Middle Columbia River, 2012.

Variable	Description
Date	The date the site was sampled
Time	The time the site was sampled
Estimated Flow Category	A categorical ranking of Revelstoke Dam discharge (high; low; transitional)
Air Temperature	Air temperature at the time of sampling (to the nearest 1°C)
Water Temperature	Water temperature at the time of sampling (to the nearest 1°C)
Water 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 mean depth sampled (to the nearest 0.1 m)
Maximum Depth	The maximum depth sampled (to the nearest 0.1 m)
Effectiveness	A categorical ranking of how effectively the site was sampled (1 - good; 2 - moderately good; 3 - moderately poor; 4 - poor); influenced by boat operation, eddy navigation, percent of site sampled, etc.
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 sample
Sample Comments	Any additional comments regarding the sample

2.1.5 Fish Capture

In 2012, fish were captured between May 28 and June 22 (i.e., the spring season) and between October 2 and 25, (i.e., the fall season) using methods similar to previous years of the project (Golder 2002, 2003, 2004a, 2005a, 2006, 2007, 2008, 2009, 2010, Ford and Thorley 2011a, 2012).

Boat electroshocking was conducted in Reaches 3 and 4 of the study area to capture fish within nearshore habitats along the channel margins. Boat electroshocking employed a Smith-Root Inc. high-output Generator Powered Pulsator (GPP 5.0) electroshocker operated out of a 140 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 fish stunned by the electrical field. Captured fish were immediately sorted by the Bank Habitat Type they were captured in and placed into an onboard live-well. Fish that could be 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.

Kokanee (*Oncorhynchus nerka*), Redside Shiner (*Richardsonius balteatus*), and Sculpin (*Cottidae*; all species combined) were excluded from the mark-recapture component of the program. The abundance of Kokanee in the study area is highly variable and determined by recruitment processes outside of the study area and entrainment rates through REV. The distribution of Redside Shiner is generally limited to Big Eddy and the Centennial Park Boat Launch areas of Reach 3 (Figure 1), limiting the effectiveness of a mark-recapture program for this species. Sculpin species are relatively common throughout the study area; however, they are difficult to capture during boat electroshocking operations and are more amenable to other shallow water sampling techniques. Sculpin species and Redside Shiner also are being studied as part of BC Hydro’s Middle Columbia River Juvenile Habitat Use Program (CLBMON-17; Triton 2009, 2010, 2011, 2012). For the above reasons, only 50 Kokanee, 50 Redside Shiner, and 50 Sculpin species were randomly captured and processed for life history data; subsequently, these species were enumerated by the netters and recorded as “observed”.

Boat electroshocking sites varied between 519 m and 2270 m in length. If, due to logistical reasons, a site could not be fully sampled (e.g., public too close to shore, other research activities in the area, wildlife swimming in the site, etc.) the difference in distance between what was sampled and the established site length was estimated and subtracted from the site length in subsequent analyses.

Amperage output was set at 1.9 A, at a frequency of 30 Hz direct current as these settings have been shown to result in low electroshocking-induced injury rates for Rainbow Trout (*Oncorhynchus mykiss*; Golder 2004b, 2005b). Although electrical output was variable (i.e., depending on water conductivity, water depth, and water temperature), field crews attempted to maintain similar electrical output levels for all sites over all sessions.

To reduce the possibility of capturing the same fish multiple times in one session, when possible, fish were released upstream after processing, approximately halfway through the site in which they were captured.

2.1.6 Safety Communications

The operation of REV as a daily peaking plant can result in rapid and unpredictable changes in dam discharges. Real-time dam discharge rate changes were monitored by field crews via text messages automatically sent from the BC Hydro flow operations monitoring computer to the field crew's cell phone. These messages were sent when dam discharge either increased or decreased by 200 m^3/s over a range of discharge levels from 200 to 1200 m^3/s. This real-time discharge information was essential for logistical planning and allowed the crew to maximize sampling effort during the period when discharge was sufficient to allow effective sampling. To prevent the boat and crew from being stranded in shallow water during periods of low flow, sampling efforts were typically terminated upon notification of a flow reduction to a level below 200 m^3/s. Following such an event, the boat was moved to the nearest boat launch and removed from the water.

2.1.7 Fish Processing

A site form was completed at the end of each sampled site. Site habitat conditions and observed fish were recorded before processing captured fishes. Life history and other data collected for captured fishes are shown in Table 3. Fish were measured to the nearest 1 mm for fork length (FL) or total length (TL) depending on the species and weighed to the nearest 1 g using an A&D Weighing™ digital scale (Model SK-5001WP; accuracy ±1 g). Life history data were entered directly into the Middle Columbia River Fish Indexing Database (Attachment A) using a laptop computer. All fish sampled were automatically assigned a unique identifying number by the database that provided a method of cataloguing associated ageing structures.

Table 4: List and description of variables recorded for each fish captured in the Middle Columbia River, 2012.

Variable	Description
Species	The species of fish recorded
Size Class	A general size class for observed fish (YOY for age-0 fish, Immature for fish <250 mm FL, Adult for fish >250 mm FL)
Length	The fork length (FL) or total length (TL) of the fish to the nearest 1 mm
Weight	The wet weight of the fish to the nearest 1 g
Sex and Maturity	The sex and maturity of a fish (determine 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
Tag Scar	The presence of a scar from a previous tag application
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 regarding the fish

All fish (with the exception of Kokanee, Redside Shiner, and Sculpin species as detailed in Section 2.1.5) between 120 and 170 mm FL that were in good condition following processing were marked with a Passive Integrated Transponder (PIT) tag (tag model Biomark 8.9 mm BIO9.B.01). These 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) or a No. 11 surgical scalpel (depending on the size of the fish). All fish >170 mm FL that were in good condition following processing were marked with a Plastic Infusion Process (PIP) PIT tag (12 mm x 2.25 mm, model T-IP8010 polymer shell food safe Datamars FDX-B, Hallprint Pty Ltd., Australia). These 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. All tags and tag injectors 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 Middle Columbia River Fish Indexing Database.

During the 2001 to 2005 studies, fish were marked using T-bar anchor tags. 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).

Scale samples were collected from Cutthroat Trout (*Oncorhynchus clarki*), Brook Trout (*Salvelinus fontinalis*), Lake Whitefish (*Coregonus clupeaformis*), Mountain Whitefish (*Prosopium williamsoni*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Rainbow Trout, Redside Shiner, and Yellow Perch (*Perca flavescens*) in accordance with the methods outlined in Mackay et al. (1990). All scales were stored in appropriately labelled coin envelopes and air-dried before long-term storage. Scale samples were not aged during the current study, but were catalogued for potential future study.

Overall, sampling methods for the MCR fish indexing surveys were very similar between 2001 and 2012. One important change during the monitoring program was that prior to 2010, only three index species [i.e., Bull Trout (*Salvelinus confluentus*), Mountain Whitefish, and Rainbow Trout] were captured and marked, and other species were only observed and counted, whereas, from 2010 onward, all species except Kokanee, Redside Shiner, and Sculpin species were captured and marked. Another difference during the program was that there were five sampling sessions conducted in 2001 and 2007 to 2009, and four sessions in 2002 to 2006 and 2010 to 2012. There also were some changes in the sites sampled, as noted in Section 1.5, and small changes to electrofishing specifications and settings. Key changes in sampling methods from 2001 to 2012 are summarized in Table 5.

Table 5: Key changes in sampling methods for the Middle Columbia River fish population indexing study (CLBMON-16), 2001 to 2012.

Methodology Change	Years	Description
Number of sampling sessions	2002-2006, 2010-2012	Four sampling sessions
	2001, 2007-2009	Five sampling sessions
Sampling locations	2001-2007	Reach 4 and the Big Eddy portion of Reach 3 were sampled
	2007-2009	Reaches 2, 3 and 4 were sampled
	2009-2012	Reaches 3 and 4 were sampled
Fish tag type	2001-2004	T-bar anchor tags
	2005	T-bar anchor tags and PIT tags
	2006-2012	PIT tags
Species captured and tagged	2001	Bull Trout, Largescale Sucker (*Catostomus macrocheilus*), Mountain Whitefish, Rainbow Trout
	2002-2009	Bull Trout, Mountain Whitefish, Rainbow Trout
	2010-2012	All species except Kokanee, Redside Shiner, and Sculpin species
Electrofishing specifications and settings	2001-2004	Frequency was 60 Hz; boat hull as cathode
	2005-2012	Frequency was 30 Hz; cathode array droppers were added to boat hull

2.2 Data Analyses

2.2.1 Data Compilation and Validation

Data were entered directly into the Middle Columbia River 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.

2.2.2 Life Stage Assignment

Bull Trout, Rainbow Trout, Mountain Whitefish, and Largescale Sucker were assigned a life stage (i.e., fry, juvenile, or adult) based on the fork length values provided in Table 6. These values were based on length-frequency distributions and/or professional judgement. Fry were excluded from all Hierarchical Bayesian Analyses (HBAs) except for the estimations of occupancy and count density; these two analyses included observational data for which it was not always possible to reliably distinguish fry.

Table 6: Fork length (FL; in mm) based life stage classifications used in hierarchical Bayesian analyses for fish captured in the Middle Columbia River, 2001 to 2012.

Species	Fry	Juvenile	Adult
Bull Trout	<120	120 to 399	≥400
Largescale Sucker	-	<350	≥350
Mountain Whitefish	<120 (i.e., age-0)	120 to 174 (i.e., age-1)	≥175 (i.e., age-2 and older)
Rainbow Trout	<120	120 - 249	≥250

2.2.3 Hierarchical Bayesian Analysis

The temporal and spatial variation in species richness and evenness, abundance, growth, and body condition were analyzed using hierarchical Bayesian models. The book ‘Bayesian Population Analysis using WinBUGS: A hierarchical perspective’ by Kery 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 (Bayesian analysis Using Gibbs Sampling) language (Kery and Schaub 2011; p.41);
- permits the incorporation of prior information (Kery and Schaub 2011; p.41);

- readily handles missing values;
- provides readily interpretable parameter estimates whose reliability does not depend on the sample size;
- allows derived quantities to be calculated (Kery and Schaub 2011; p.41); an example would be the percent change in the expected weight of a 250 mm FL Mountain Whitefish at a particular site in a typical year;
- enables the efficient modelling of spatial and temporal variations and correlations (Kery and Schaub 2011; p.78-82); and,
- permits the separation of ecological and observational processes (Kery and Schaub 2011; p.44).

The technical aspects of the analyses, including the general approach and model definitions in the JAGS (Just Another Gibbs Sampler; Plummer 2003) dialect of the BUGS language, are provided in Appendix F. The resultant parameter estimates are tabulated in Appendix G.

The results were displayed graphically by plotting the modeled relationship between a particular variable(s) and the estimated median response (with 95% credible intervals; CRIs) 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; Kery 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).

2.2.4 Occupancy and Species Richness

Occupancy, which is the probability that a particular species was present at a site, was estimated from the temporal replication of detection data (Kery and Schaub 2011, p.414-418), i.e., each site was surveyed multiple times within a season. A species was considered to have been detected if one or more individuals of the species were caught or counted. The model estimated the probability that a species was present at a given (or typical) site in a given (or typical) year as opposed to the probability that a species was present in the entire study area. Occupancy was estimated for species which had sufficient variation in their frequency of encounter to provide information on changes through time and included the following nine species: Burbot (*Lota lota*), Kokanee, Lake Whitefish, Northern Pikeminnow, Peamouth (*Mylocheilus caurinus*), Rainbow Trout, Redside Shiner, Sculpin species, and Yellow Perch.

Key assumptions of the occupancy model included:

- occupancy (the probability of presence) varied with flow regime (period) and season;
- occupancy varied randomly with site, year, and the interaction between site and year;
- efficiency (the probability of detection) varied with the length of bank sampled;
- sites were closed (i.e., the species is present or absent at a site for all sessions within a particular season of a year), which was assessed through estimates of site fidelity (Section 2.2.7); and,
- observed presence was described by a Bernoulli distribution.

Species richness was estimated by summing the estimated occupancies for all species that had estimates of occupancy, except Kokanee. Kokanee were excluded because the large temporal variability in Kokanee presence and their abundance was not considered to be directly related to dam operations. In contrast to the traditional calculation of species richness that simply counts the number of species observed, this method excluded species that were very infrequently encountered, or nearly always encountered. For instance, Mountain Whitefish, Bull Trout, and Sucker species were not included because they were nearly always encountered. Very rarely encountered species, such as Cutthroat Trout and White Sturgeon (*Acipenser transmontanus*), were not included in estimates of richness based on the assumption that these species were always present at some unknown low density, and whether or not they were detected in a given year was due to chance, and not reflective or true presence or absence in the study area.

The traditional measure of species richness calculated as the number of species observed is based on the unrealistic assumptions that detection probability of each species is 100% and that detection probability does not change over time (Boulinier et al. 1998; Gotelli and Colwell 2001). Therefore, the number of species may not be a reliable indicator of richness over time, because it may fluctuate due to changes in detection probability or chance encounters with rare species. The method used in this study takes into account varying detection probabilities over time, and does not include very rare species, which would result in a less robust analysis due to large uncertainty in their probability of occupancy. Although the method used in this study resulted in lower estimates of richness (compared to the number of species), results were a robust index of richness that could be compared against flow regime changes. As species introductions or extirpations likely did not occur in the study area during the monitoring period, this method provides a more reliable method of evaluating changes in species richness in the fish community in the study area. Similar methods of using estimates of species occupancy to calculate species richness have previously been used to model richness of plant communities (Gelfand et al. 2005) and birds (Kery and Royle 2008). The estimates of species richness in this study should not be interpreted as the total number of species present in the study area, but can be considered an indicator of changes in the number of species at typical sites in the study area over time.

2.2.5 Count Density, Species Diversity, and Evenness

Counts of each species were obtained by summing all fish captured or observed at a particular site and sampling session. Count data were analysed using an overdispersed Poisson model (Kery and Schaub 2011, p.55-56). Unlike Kery and Schaub (2011), who used a log-normal distribution to account for the extra-Poisson variation, the current model used a gamma distribution with identical shape and scale parameters because it has a mean of 1 and therefore no overall effect on the expected count. The model did not distinguish between abundance and observer efficiency (i.e., it estimated the count, which is the product of the two). As such, it was necessary to assume that variations in observer efficiency were negligible in order to interpret estimates as relative abundance. The model estimated the number of fish expected to be captured or observed at each site per river kilometre based on the sampling data, the influence of other variables in the model, and the prior distributions of model parameters. These estimates were used as an indicator of relative density and are referred to in this report as count density, in fish counted per kilometre (count/km).

Key assumptions of the count model included:

- count density (count/km) varied with flow regime (period) and season;
- count density (count/km) varied randomly with site, year, and the interaction between site and year;
- expected counts were the product of the count density (count/km) and the length of bank sampled;
- sites were closed (i.e., the expected count at a site was constant for all the sessions in a particular season of a year); and,
- observed counts were described by a Poisson-gamma distribution.

The Shannon index of species diversity (H) was calculated using the following formula (Shannon and Weaver 1949; Krebs 1999):

$$H = -\sum_{i=1}^{S}(p_i \log(p_i))$$

Where S is the number of species and p_i is the proportion of the total number of individuals belonging to the i^{th} species, which is often referred to as the proportional abundance. Shannon's Index of evenness (E) was calculated using the formula (Pielou 1966):

$$E = H/\ln(S)$$

Shannon's diversity depends on the total number of species, as well as the evenness in the proportional abundances. By dividing Shannon's diversity by the natural logarithm of the number of species, evenness is a measure of how evenly fish are distributed among species. In this study, Shannon's diversity was calculated by using the estimated count densities from the HBA to calculate the proportional abundance of each species.

In the MCR, the total number of species present in the study area likely does not vary from year to year, although uncommon species may or may not be detected in a given site or year. For the hierarchical Bayesian model for count data, the estimated count density of uncommon species was low but was never zero, even if it was not detected in a certain year or site. This likely provides a more realistic representation of fish populations in the study area compared to an analysis that assumes densities of zero at sites or years where a species was not observed. However, this approach also means that the number of species, S, was the same for all years and sites when calculating Shannon's diversity. Therefore, the estimates of diversity among sites and years primarily reflect evenness, as the number of species is constant. Because S is constant, the denominator in the equation for evenness becomes a scaling constant that results in values between 0 and 1. Thus, for the purposes of comparing trends over time in the MCR, evenness and diversity are equivalent. For this reason, only evenness is presented in this report.

As species introductions or extirpations likely did not occur in the study area during the monitoring period, the methods used to calculate richness and evenness provide a more reliable and robust method of evaluating changes in diversity and relative abundances over time or among sites. Taken together, richness and evenness can be used to assess changes in species diversity that could be related to the effects of the flow regime change.

2.2.6 Catch Density

Catch data included all fish captured during electroshocking but did not include observed fish. The catch data were analyzed using the same overdispersed Poisson model as the count data. Estimates of relative density from this model are referred to as catch density, in units of fish captured per kilometre (catch/km).

2.2.7 Site Fidelity

Site fidelity was the estimated probability of a recaptured fish being caught at the same site at which it was previously encountered. These estimates were used to evaluate the extent to which sites are closed within a sampling season (i.e., whether fish remained at the same site between sessions) and also to adjust the capture efficiencies in the HBA using mark-recapture data (see Section 2.2.8). A binomial "t-test" (Kery 2010, p.211-213) was used to estimate the probability that intra-annual recaptures were caught at the same site as previously encountered (site fidelity) for the fall and spring seasons.

Key assumptions of the site fidelity model included:

- the log-odds of site fidelity varied with season; and,
- observed site fidelity was described by a Bernoulli distribution.

2.2.8 Absolute Density

Catch data also were analyzed using a mark-recapture-based binomial mixture model (Kery and Schaub 2011, p.134-136, 384-388) to provide estimates of capture efficiency and absolute density. The site fidelity (the probability that a recaptured fish was encountered at the same site) was used to adjust the capture efficiency for marked fish by season. Estimates of absolute abundance per kilometre from this model are referred to as absolute density, in the number of fish per kilometre (fish/km).

Key assumptions of the abundance model included:

- absolute density (fish/km) varied with flow regime (period) and season;
- absolute density (fish/km) varied randomly with site, year, and the interaction between site and year;
- efficiency (the probability of capture) varied randomly by session within year and season;

- the proportion of marked fish remaining at a site by season is described by the median estimates from the site fidelity model;
- marked and unmarked fish had the same probability of capture;
- there was no tag loss, mortality, or misidentification of fish;
- other than the straying of marked fish, sites were closed (i.e., emigration of unmarked fish was accounted for by immigration of unmarked fish);
- the abundance at a site was described by a Poisson distribution; and,
- the number of marked and unmarked fish caught at a site was described by a binomial distribution.

2.2.9 Capture Efficiency

In order to estimate capture efficiency independent of abundance, a recapture-based binomial model (Kery and Schaub 2011, p.134-136, 384-388) was fitted only to marked fish. This model was equivalent to the abundance model without the estimation of the numbers of unmarked fish.

Key assumptions of the efficiency model included:

- efficiency (the probability of capture) varied randomly by session within year and season;
- the proportion of marked fish remaining at a site by season was described by the median estimates from the site fidelity model;
- there was no tag loss, mortality, or misidentification of fish; and,
- the number of marked fish caught at a site was described by a binomial distribution.

2.2.10 Growth

Annual growth was estimated from inter-annual recaptured fish using the Fabens (1965) method for estimating the von Bertalanffy (1938) growth curve. There were enough inter-annual recapture data to estimate growth using this method for Bull Trout and Mountain Whitefish only.

Key assumptions of the growth model included:

- mean maximum length (L_∞) varied with flow regime (period);
- mean maximum length (L_∞) varied randomly with year; and,
- observed growth (change in length) was normally distributed.

Plots of annual growth show the median estimate of annual growth for a 500 mm FL Bull Trout or a 250 mm FL Mountain Whitefish. These fork lengths were selected as representative examples to illustrate changes in fork length over time for a standard size fish.

2.2.11 Length-at-Age

Length-at-age was estimated from annual length-frequency distributions from the fall season using a finite mixture distribution model (MacDonald and Pitcher 1979). Length-at-age estimates were only possible for Mountain Whitefish because age-classes were not distinguishable for Bull Trout and there were not enough data for all other species.

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

- length-at-age varied with flow regime (period);
- length-at-age varied randomly with year; and,
- length-at-age was normally distributed.

2.2.12 Body Condition

Condition was estimated via an analysis of weight-length relations (He et al. 2008).

Key assumptions of the condition model included:

- weight varied with length, flow regime (period), and season;
- weight varied randomly with site, year, and the interaction between site and year; and,
- weight was log-normally distributed.

2.2.13 Environmental Correlations

Although the management questions are concerned with changes in abundance, growth, condition, and distribution of adult life stages of common fish species related to the implementation of a year-round minimum flow, there also is interest in understanding relationships between fish population parameters and environmental variables. Knowledge of when and how discharge and water temperatures in the MCR and the elevation of ALR affect fish populations could be used to further refine operations.

To assess how the influence of environmental variables may vary by season, variables were summarized in bi-monthly periods (e.g., January to February). As discharge can affect fish populations through a range of different mechanisms, three different measures of river discharge were calculated for each bi-monthly period:

1) mean of hourly discharge;
2) mean of the hourly absolute difference in discharge, as a measure of hour-to-hour variability; and,
3) variance of the hourly discharge, as a measure of overall discharge variability.

Due to the limited short-term variability of ALR water level elevations, only the mean reservoir level was calculated for each bi-monthly period. The November to December discharge and elevation time series were lagged by one year such that fish data in a given year were correlated with temperature or elevation data from the year prior to fish sampling. This time lag was done to account for the fact that the months of November and December occur after the fall surveys and reflect habitat conditions that could impact the fish populations sampled in the spring and fall of the following year. Water temperature data were not available prior to 2007, so water temperature was excluded from the correlation analysis.

Relationships between fish density, growth, length-at-age, condition, and the discharge and elevation variables were assessed using Pearson correlation. Instead of comparing absolute values of fish population metrics and environmental variables each year, the analysis assessed correlations between the year-to-year differences in these values (i.e., correlations were assessed between the changes in fish metrics and environmental variables from one year to the next). This approach was less likely to result in spurious correlations caused by time series data that followed similar trends by chance. To partially account for multiple comparisons, significance was assessed at the 0.001 level. Only significant correlations are presented and discussed in this report.

3.0 RESULTS

3.1 Discharge

In 2012, mean daily discharge in the MCR was above average for most of the year, and often approached or exceeded the maximum value observed since 2001 (Figure 2). Above average snow pack loads (Province of British Columbia River Forecast Centre 2013) and seasonally warm air temperatures (Environment Canada 2013) resulted in record high water discharges at REV. Discharge was exceptionally high during late July and early August when the spillway at REV was used for the first time since 1997. Similar to previous study years, discharge in 2012 exhibited large hourly fluctuations, a reflection of the primary use of the facility for daily peaking operations (Appendix C, Figure C1).

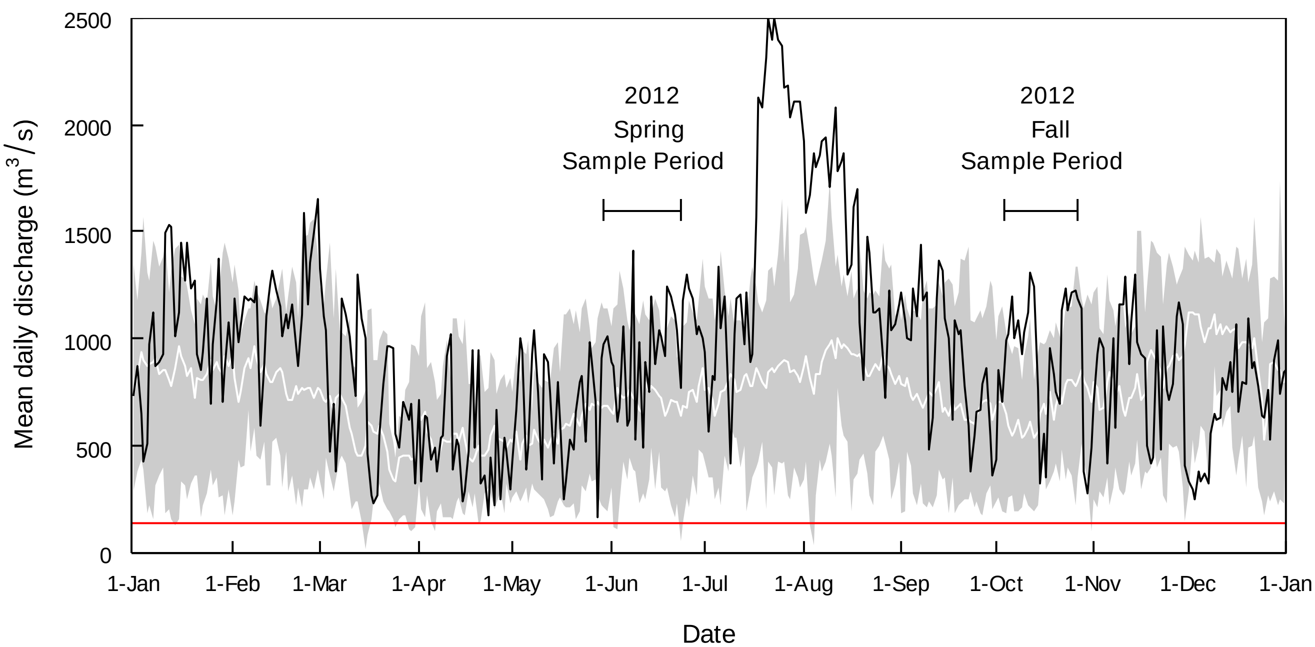

Figure 2: Mean daily discharge (m^3/s) for the Columbia River at Revelstoke Dam, 2012. The shaded area represents minimum and maximum mean daily discharge values recorded at the dam from 2001 to 2011. The white line represents average mean daily discharge values over that same time period. The red line represents the minimum flow of 142 m^3/s.

During the spring 2012 sample period, discharge decreased to minimum flows during most, but not all, sampling nights (Appendix C, Figure C2). Peak discharges during the days were slightly lower in Session 1 when compared to Sessions 2, 3, and 4 (Appendix C, Figure C2).

During the fall 2012 sample period, discharge varied among sample sessions (Appendix C, Figure C3). In Sessions 2 and 3, discharge decreased to less than 200 m^3/s each night. In Sessions 1 and 4, nightly decreases in discharge were smaller, with discharge remaining above 500 m^3/s on most nights. Peak flows were similar in all four sample sessions of the fall sample period, reaching daily maximums of approximately

1500 m^3/s. Since the implementation of the minimum flow release, discharge from REV rarely declines to 142 m^3/s due to operational considerations (BC Hydro, personal communication). The lowest discharges are typically between 140 and 160 m^3/s. In 2012, 0.5% of hourly discharge measurements were less than 150 m^3/s and 6.1% were less than 160 m^3/s.

During both the spring and fall sample period, discharge typically increased in the morning, varied throughout the day, and decreased in the evening. Overall, discharges were higher during the spring sample period than during the fall sample period. Although maximum discharges during the July and August period were much greater in 2012 than in previous years, discharge during the spring and fall sample periods was generally within the range previously experienced.

3.2 Water Elevation

In 2012, water elevations in ALR were near average from January to the end of May, increased to above the 10-year maximum in July and August, and were slightly above average during the fall (Appendix C, Figure C4). The high ALR water elevations in 2012 resulted in backwatering effects in the downstream portions of Reach 3 during both the spring and fall sample periods. ALR levels increased over the duration of the spring sample period, which resulted in greater backwatering effects in the MCR during each successive sample session. Water elevation in ALR remained stable during the fall sample period.

Overall, water elevations in ALR were lower from 2001 to 2006 and higher from 2007 to 2012 (Appendix C, Figure C4).

3.3 Water Temperature

Water temperature data are not available for the MCR prior to 2007. Water temperatures in 2012 were similar to the average values recorded since 2007 during January to June (Figure 3), but warmer than average during July through September, when REV discharge also was above average. During the spring sample period, daily average temperature ranged from 5.4 to 7.9°C. Spot temperature readings taken at the time of sampling ranged between 5.0 and 7.9°C (Attachment A). During the fall 2012 sample period, daily average water temperature gradually declined from 11.0 to 9.2°C. Spot water temperature readings taken at the time of sampling ranged between 8.0 and 11.1°C (Attachment A).

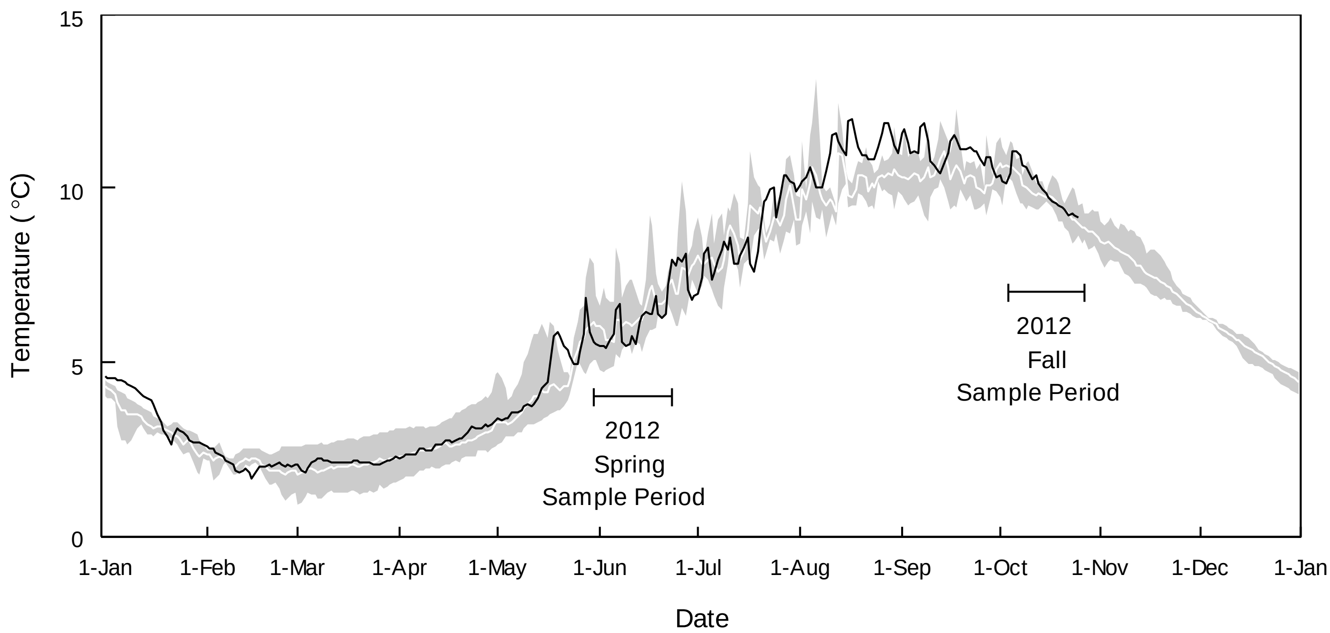

Figure 3: Mean daily water temperature (°C) for the Columbia River at Station 2 of the Physical Habitat Monitoring Program (CLBMON-15a), 2012. The shaded area represents minimum and maximum mean daily water temperature values recorded at Station 2 from 2007 to 2011. The white line represents average mean daily water temperature values over that same time period.

3.4 Catch

Overall, 8371 fishes, comprising 13 taxa, were recorded in the MCR during the spring 2012 sample period (Appendix D, Table D1) and 8982 fishes, comprising 12 taxa, were recorded during the fall 2012 sample period (Appendix D, Table D2). These values include captured and observed fish identified to species.

Various metrics were used to provide background information and to help set initial parameter value estimates in some of the HBAs. Although these summaries are important, they are not presented or 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 HBAs. Metrics presented in the appendices include:

- captured and observed fish count data by site and Bank Habitat Type during the spring (Appendix B, Table B4) and fall (Appendix B, Table B5) sample periods, 2012;
- catch-rates for all sportfish (Appendix D, Table D2) and non-sportfish (Appendix D, Table D3) during the spring sample period;
- catch-rates for all sportfish (Appendix D, Table D4) and non-sportfish (Appendix D, Table D5) during the fall sample period, 2012 data;
- inter-site movement summaries for Bull Trout (Appendix D, Figure D1), Largescale Sucker (Appendix D, Figure D2), Mountain Whitefish (Appendix D, Figure D3), and Rainbow Trout (Appendix D, Figure D4), all years combined;

- catch and recapture data summaries by species for the spring (Appendix D, Table D6) and fall (Appendix D, Table D7);
- length-frequency histograms for Bull Trout (Appendix E, Figure E1) and Mountain Whitefish (Appendix E, Figure E2) from 2001 to 2012, and for Rainbow Trout from 2007 to 2012 (Appendix E, Figure E3);
- length-frequency histograms for Kokanee (Appendix E, Figure E4), Lake Whitefish (Appendix E, Figure E5), Largescale Sucker (Appendix E, Figure E6), Northern Pikeminnow (Appendix E, Figure E7), Prickly Sculpin (*Cottus asper*; Appendix E, Figure E8), and Redside Shiner (Appendix E, Figure E9) for 2010 to 2012 (where applicable);
- length-weight relationships for Bull Trout (Appendix E, Figure E10) and Mountain Whitefish (Appendix E, Figure E11) from 2001 to 2012, and for Rainbow Trout from 2007 to 2012 (Appendix E, Figure E12); and,
- length-weight relationships for Kokanee (Appendix E, Figure E13), Lake Whitefish (Appendix E, Figure E14), Largescale Sucker (Appendix E, Figure E15), Northern Pikeminnow (Appendix E, Figure E16), Prickly Sculpin (Appendix E, Figure E17), Redside Shiner (Appendix E, Figure E18), and Yellow Perch (Appendix E, Figure E19) for 2010 to 2012.

All raw data collected as part of the program between 2001 and 2012 are included in the Middle Columbia River Fish Indexing Database (Attachment A).

For all plots in this report, sites are ordered left to right by increasing distance from REV based on the upstream boundary of each site; red symbols denote sites located on the right bank (as viewed facing downstream); black symbols denote sites located on the left bank. For year-based figures, black symbols denote fall sample periods; red symbols denote spring sample periods.

3.5 Species Richness and Diversity

Yearly estimates of species richness (Figure 4) represent the number of species present at a typical site. Species richness increased from 2001 to 2005, due to increasing probabilities of occupancy of several species, including Burbot, Lake Whitefish, Redside Shiner, and Sculpin species (Appendix G, Figures G1-G9). In recent years, estimates of species richness varied, with greater richness in 2008, 2010 and 2011, and lower richness in 2009 and 2012. Species richness was lower in the spring than in the fall (2011 and 2012), which was associated with lower probability of occupancy by Burbot, Lake Whitefish, and Northern Pikeminnow. Site estimates of species richness (Figure 4) represent the number of species estimated to be present at each site in a typical year. Species richness was noticeably lower at Site 232.6-R (immediately upstream of the Jordan River confluence) when compared to neighbouring sites. Downstream of Big Eddy (RKm 231.2), species richness was lower along the right bank than along the left bank. Overall, species richness was greater in Reach 3 than in Reach 4.

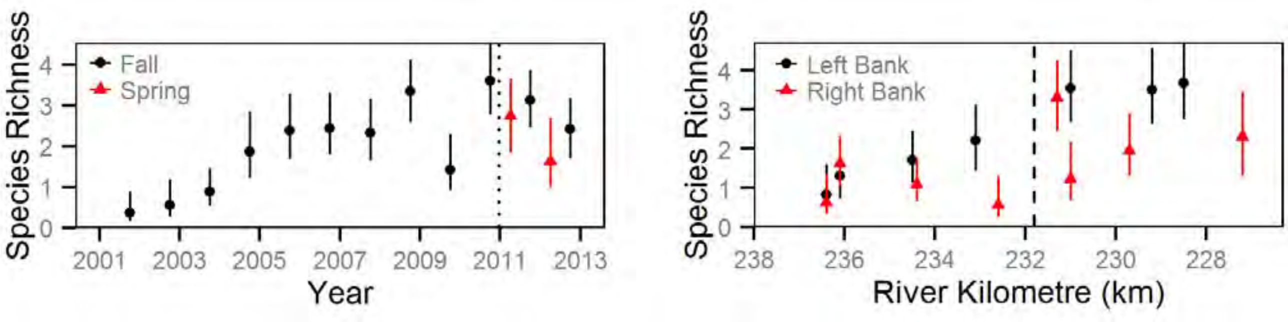

Figure 4: Species richness estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

Species evenness increased from 2001 to 2008 (Figure 5) then fluctuated from 2008 to 2012 with no obvious directional trend. In both 2011 and 2012, species evenness was lower in the spring than in the fall, although credible intervals overlapped for all four estimates. Downstream of the Jordan River, evenness was greater on the left bank than on the right bank. Site 233.1-L had particularly high evenness relative to adjacent sites (Figure 5). This pattern of greater evenness at Site 233.1-L was noted by Ford and Thorley (2011a), who stated that this result was due mainly to lower Mountain Whitefish densities in this site when compared to neighbouring sites (see Section 3.6.4).

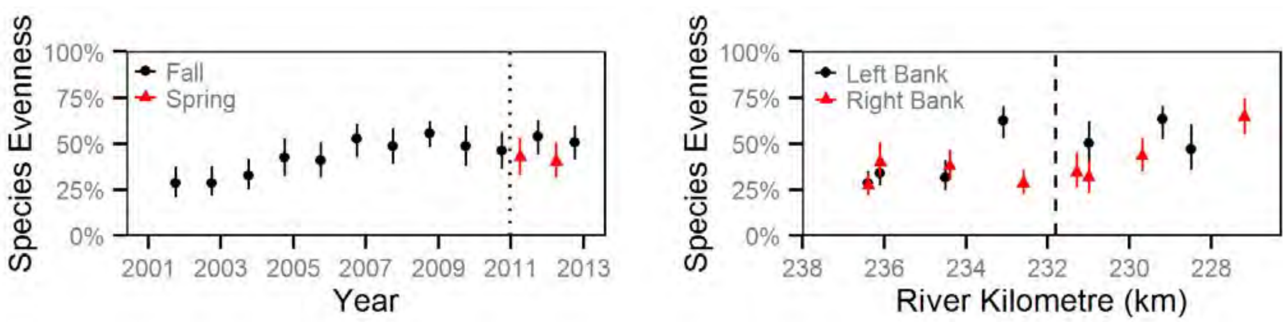

Figure 5: Species evenness estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.6 Spatial Distribution and Abundance

Three different indicators of abundance were estimated for fish species in the MCR:

1) count density estimates from a HBA using count data (i.e., the number of fish caught and observed per river kilometre) as an indicator of relative lineal density;

2) catch density estimates from a HBA using catch data (i.e., the number of fish captured per river kilometre) as an indicator of relative lineal density; and,

3) absolute density estimates from a HBA of mark-recapture data as an indicator of absolute lineal density.

Estimates of catch density and absolute density were only possible for Bull Trout, Mountain Whitefish (both age-1 and age-2 and older individuals combined), and Rainbow Trout. Catch density also was estimated for Largescale Sucker. Only count density was estimated for Burbot, Northern Pikeminnow, Sculpin species, and Sucker species. Extremely low and/or variable count data for Brook Trout, Cutthroat Trout, Kokanee, Lake Whitefish, Peamouth, Pygmy Whitefish (*Prosopium coulteri*), Redside Shiner, White Sturgeon, and Yellow Perch resulted in unreliable estimates of density for these species and therefore, are not provided.

Capture efficiencies for Bull Trout, age-1 Mountain Whitefish and age-2 and older Mountain Whitefish combined are reported together in Section 3.6.9. Site fidelity, which is the estimated probability of a recaptured fish being caught at the same site it was previously encountered in, is presented in Section 3.6.10.

3.6.1 Bull Trout

Count density, (Figure 6) catch density (Figure 7) and absolute density (Figure 8) estimates suggest that the number of Bull Trout in the MCR increased between 2001 and 2007, and was similar from 2007 to 2011. Catch and absolute densities of Bull Trout were lower in 2012 than in the previous six years, although the credible intervals overlapped. Bull Trout densities were highest immediately downstream of REV (between RKm 236 and 237) and downstream of the Jordan River confluence (between RKm 231 and 232), a result consistent with previous study years. Count, catch, and absolute density of Bull Trout did not vary significantly with the flow regime change (all $P>0.8$) or season (all $P>0.3$).

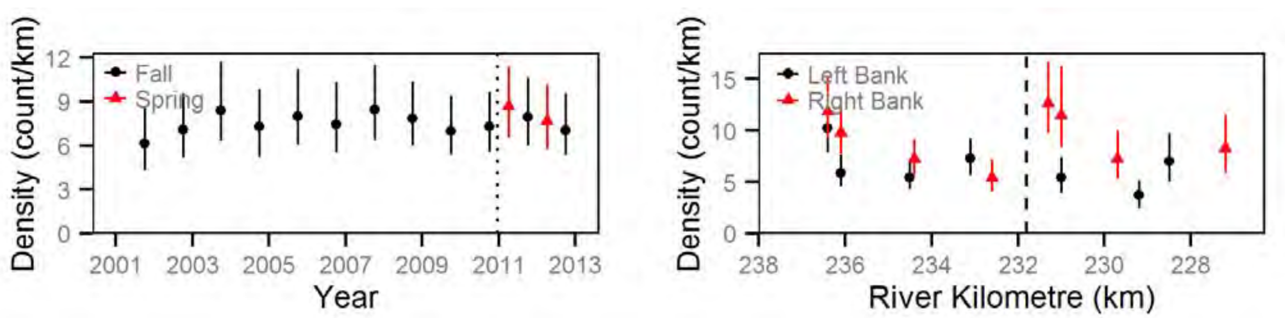

Figure 6: Count density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Bull Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

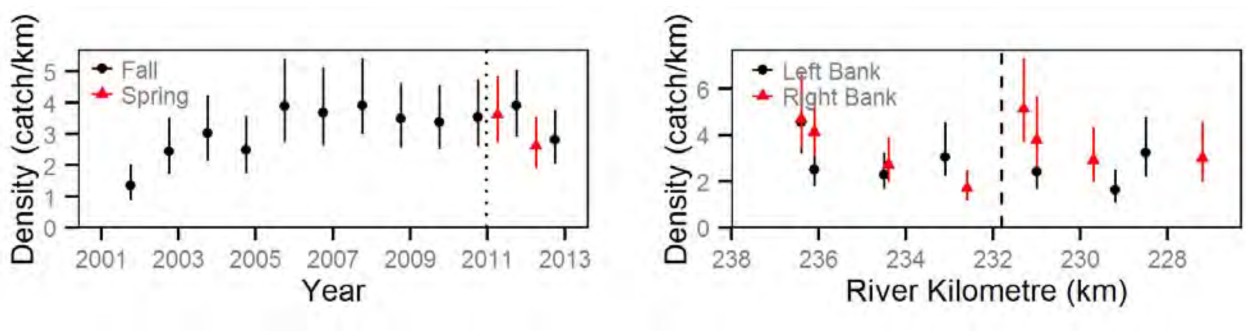

Figure 7: Catch density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Bull Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

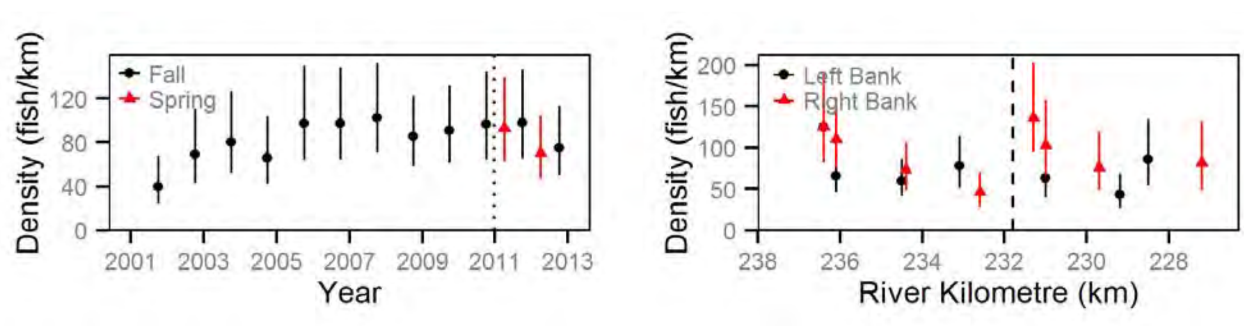

Figure 8: Absolute density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Bull Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.6.2 Burbot

Overall, count densities for Burbot were low compared to count densities of most other species caught during all study years. Count density estimates suggest that Burbot abundance may have been higher in 2008 and 2011 than in other study years (Figure 9). Count density varied significantly by season (P<0.001), with higher densities in the fall than in the spring in 2011 and 2012. Burbot density did not vary significantly with flow regime (P=0.3).

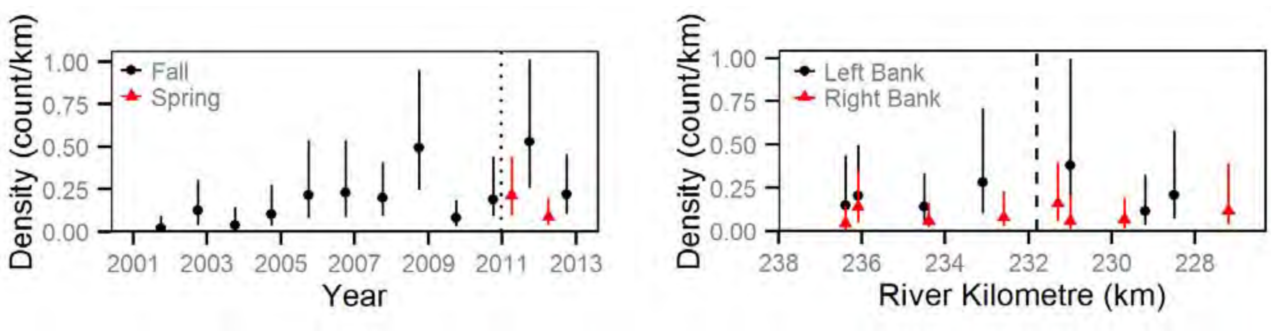

Figure 9: Count density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Burbot in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.6.3 Kokanee

The model estimating Kokanee count density did not converge because of extremely variable counts for this species across sites, years, and seasons. The probability of occupancy at a typical site also varied substantially among years (Appendix G, Figure G2).

3.6.4 Mountain Whitefish

Count density for all size-cohorts combined suggested stable Mountain Whitefish densities between 2001 and 2012 (Figure 10). Season was a significant predictor of count density for Mountain Whitefish (P<0.001), with higher densities in the spring than in the fall. The seasonal difference in Mountain Whitefish density was likely driven by age-1 fish, which were more abundant in spring than in fall (Figures 11 and 12; P<0.001 for both catch and absolute density models). The absolute density of adult (age-2 and older; Figure 14) Mountain Whitefish was not different between seasons (P=0.4) but catch density (Figure 13) was greater in spring than in fall (P<0.001).

There were no consistent directional trends in the density or abundance of age-1 or age-2 and older Mountain Whitefish between 2001 and 2012. Flow regime was not a significant predictor of density for any age groups (all P>0.6). Prior to 2007, Mountain Whitefish less than approximately 180 mm FL were rarely marked, preventing the model from generating density estimates for age-1 cohorts between 2001 and 2006 (Figure 12).

Densities of Mountain Whitefish (all size-cohorts combined) were generally greater along the right bank from upstream of the Jordan River confluence to the Tonkawatla Creek confluence and lower along the left bank from the upstream end of the Revelstoke Golf Club to the Centennial Park Boat Launch (Figure 10). High densities of Mountain Whitefish at sites on the right bank near the Jordan River confluence were related to large abundance estimates for age-2 and older fish at these sites (Figures 13 and 14). Site-level density estimates for age-1 Mountain Whitefish were more variable but suggest similar density patterns (Figures 11 and 12).

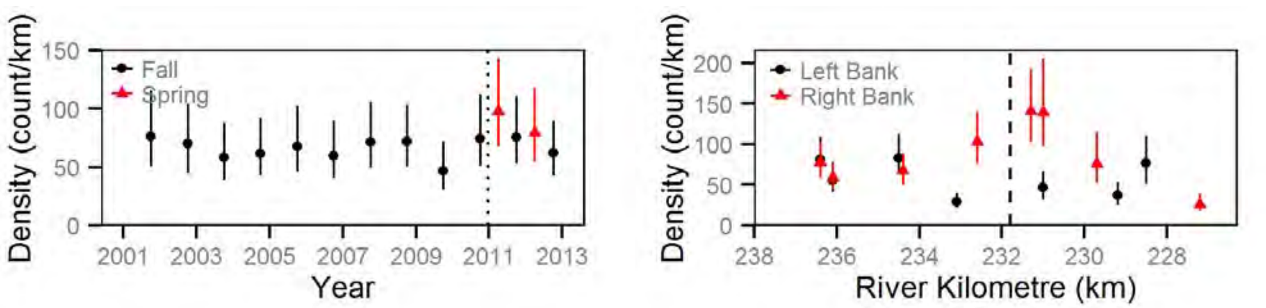

Figure 10: Count density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Mountain Whitefish (all size-cohorts combined) in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

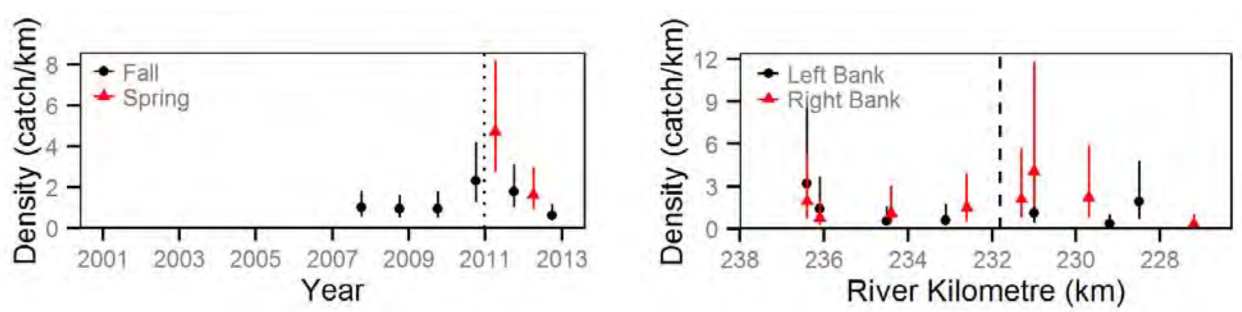

Figure 11: Catch density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for age-1 Mountain Whitefish in the Middle Columbia River study area, 2007 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

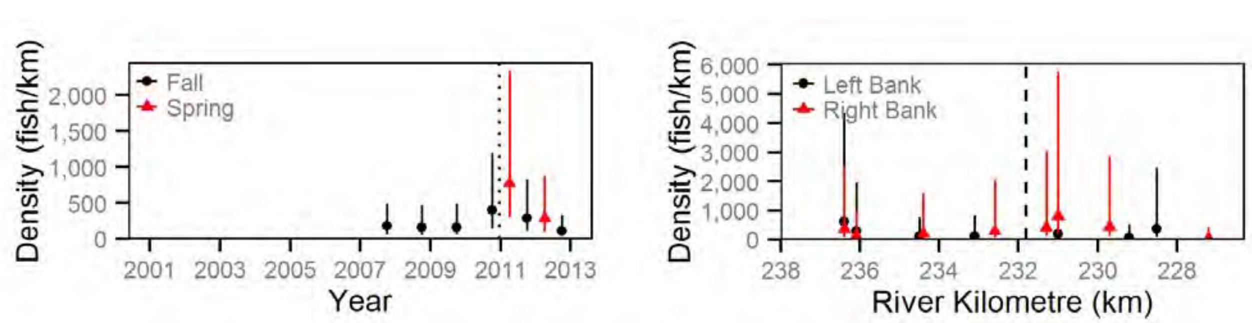

Figure 12: Absolute density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for age-1 Mountain Whitefish in the Middle Columbia River study area, 2007 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

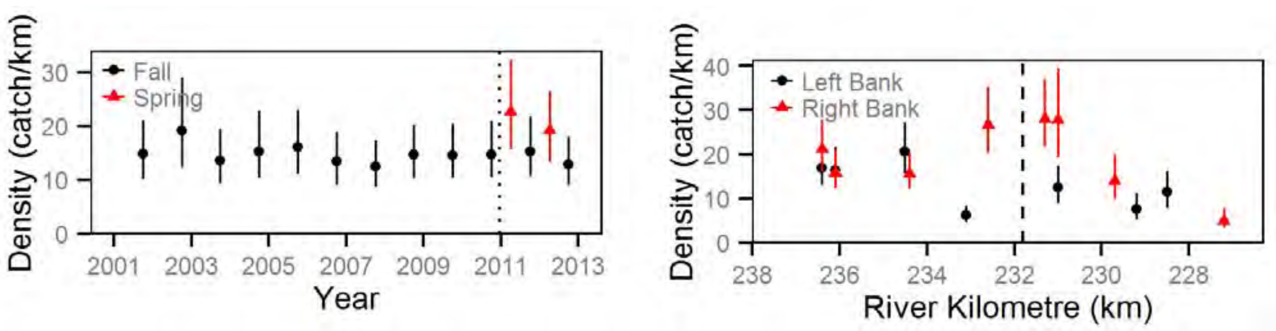

Figure 13: Catch density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for age-2 and older Mountain Whitefish in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

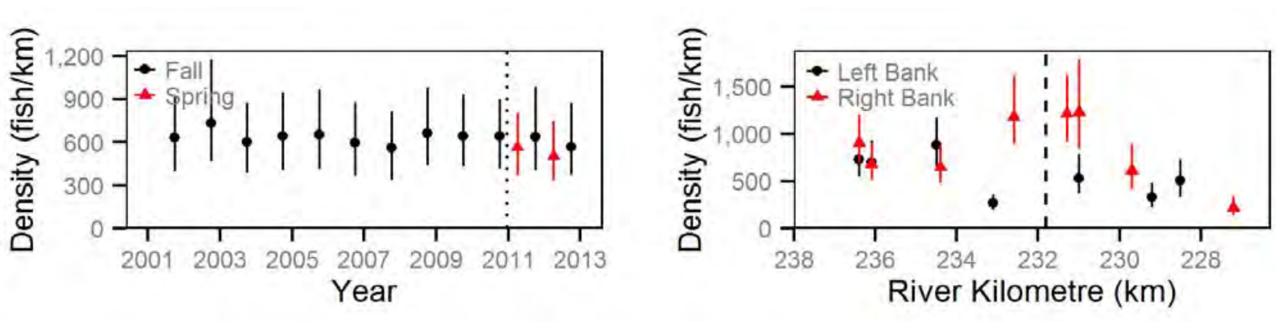

Figure 14: Absolute density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for age 2 and older Mountain Whitefish in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.6.5 Rainbow Trout

Rainbow Trout count density estimates suggested a gradual increase between 2001 and 2008 (Figure 15); however, this result is based on a small sample size as Rainbow Trout were rarely captured from between 2001 and 2006 because sampling was limited to Reach 4 and to the Big Eddy portion of Reach 3 during those study years. Count density of Rainbow Trout was low in 2009, increased in 2010 and 2011, and declined in 2012.

Rainbow Trout catch density and absolute density were only estimated for 2007 to 2012 because catches were very low prior to 2007. Catch density (Figure 16) and absolute density (Figure 17) estimates showed a similar trend to count density estimates (Figure 15), with lower values in 2009 and 2012, and greater values in 2007, 2008, and 2011. In 2011 and 2012, density estimates were very similar between spring and fall sessions; season was not a significant predictor of density (P>0.4 for count, catch, and absolute density models).

Rainbow Trout densities were greater in Reach 3 than in Reach 4, and generally greater at sites on the left bank than sites on the right bank (Figures 15 to 17). The left bank of Reach 3 is predominantly rip-rap substrate (Appendix A, Figure A2).

For Rainbow Trout, flow regime was not a significant predictor of count density (*P*=0.2), catch density (*P*=0.8), or absolute density (*P*=0.9).

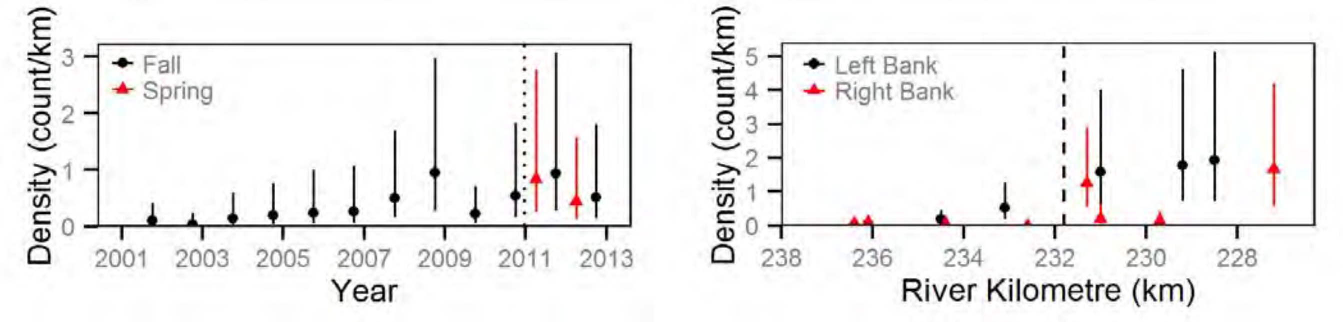

Figure 15: Count density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Rainbow Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

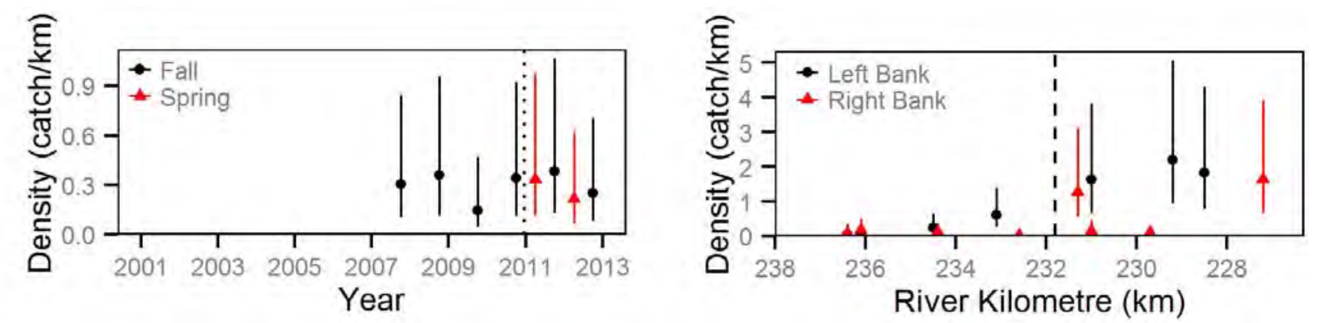

Figure 16: Catch density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Rainbow Trout in the Middle Columbia River study area, 2007 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

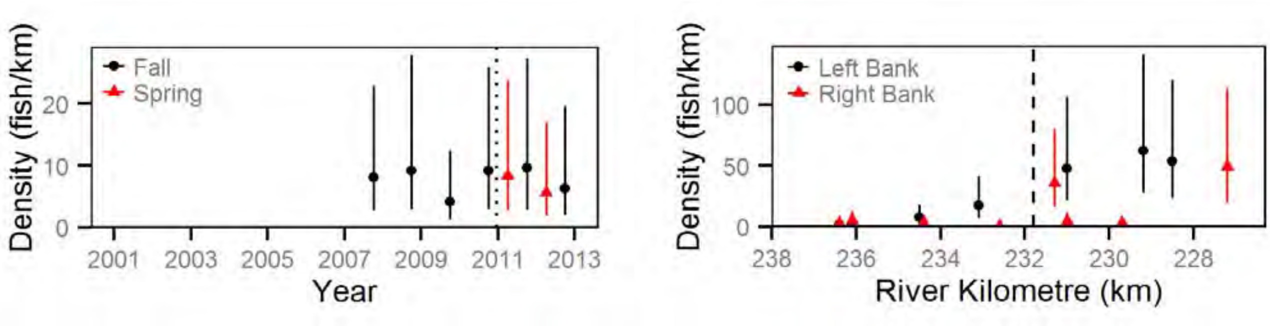

Figure 17: Absolute density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Rainbow Trout in the Middle Columbia River study area, 2007 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.6.6 Sucker Species

In 2001 and from 2010 to 2012, Sucker species that were captured were identified to the species level; Sucker species were not identified to the species level during other study years. During years when Sucker species was recorded (fall sample periods only), Largescale Sucker accounted for approximately 96% of the Sucker species catch; the remaining 4% were Longnose Sucker (*Catostomus catostomus*). During spring sample periods (2011 and 2012 combined), Largescale Sucker accounted for 48% of the Sucker species catch; the remaining 52% were Longnose Sucker (Attachment A). Density for all Sucker species combined (count based) was estimated from 2001 to 2012. Catch density was calculated for Largescale Sucker for 2010 to 2012 but there were not enough mark-recapture data to estimate absolute density for this species.

During the fall season, count density estimates for Sucker species increased from 2009 to 2012, and was greater in 2011 and 2012 when compared to all previous study years (Figure 18). Catch density of Largescale Sucker also showed an increasing trend from 2010 to 2012 (fall season; Figure 19). Sucker species densities were generally lowest immediately downstream of REV and highest along the right bank in the upstream portion of Reach 3 (i.e., between the narrows downstream of Big Eddy and the Tonkawatla Creek confluence; Figure 18). Spatial distribution of Largescale Sucker was similar to that of the all Sucker species combined. However, there was less of a difference in density between the left and right banks in estimates of catch density of Largescale Sucker (Figure 19) when compared to the count-based model of all Sucker species.

Season was a significant predictor of Sucker species count density (P<0.001) and of Largescale Sucker catch density (P<0.001), with higher values in the fall than in the spring. There was a significant relationship between Sucker species count density and flow regime (P=0.02), with greater densities after the flow regime change. Flow regime was not a significant predictor of Largescale Sucker catch density (P=0.4).

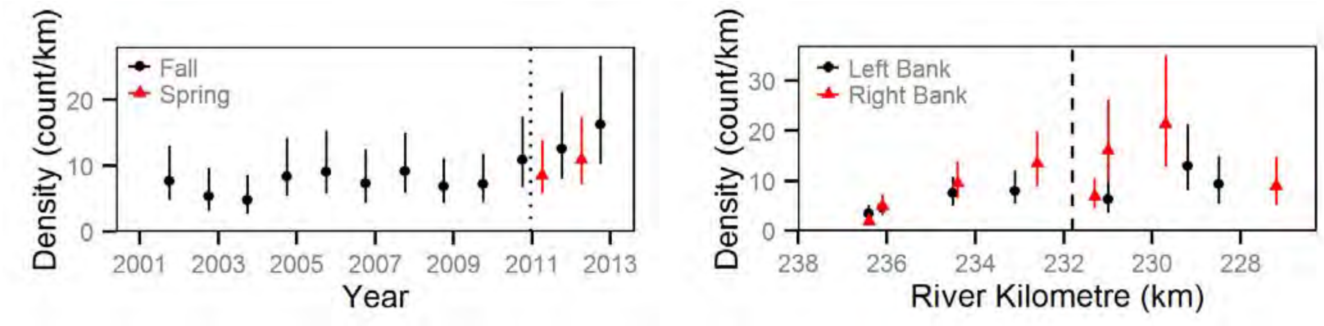

Figure 18: Count density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Sucker species in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

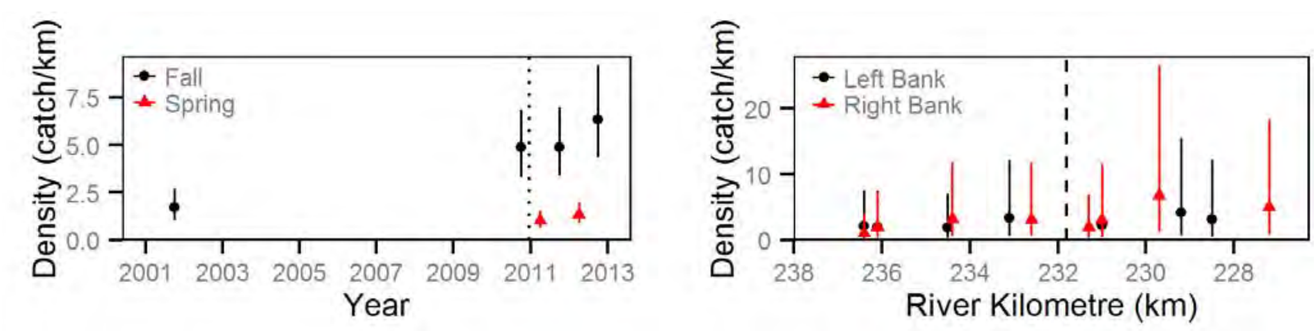

Figure 19: Catch density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Largescale Sucker in the Middle Columbia River study area, 2001, and 2010 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.6.7 Northern Pikeminnow

Northern Pikeminnow densities in the MCR remained relatively low between 2001 and 2006, increased substantially between 2007 and 2010 and then declined from 2010 to 2012 (Figure 20). Northern Pikeminnow density was greater in Reach 3 than in Reach 4 (Figure 20). Season was a significant predictor of Northern Pikeminnow density ($P < 0.001$), with fall densities approximately 10 times greater than spring densities. There was no relationship between Northern Pikeminnow density and flow regime (P=0.7).

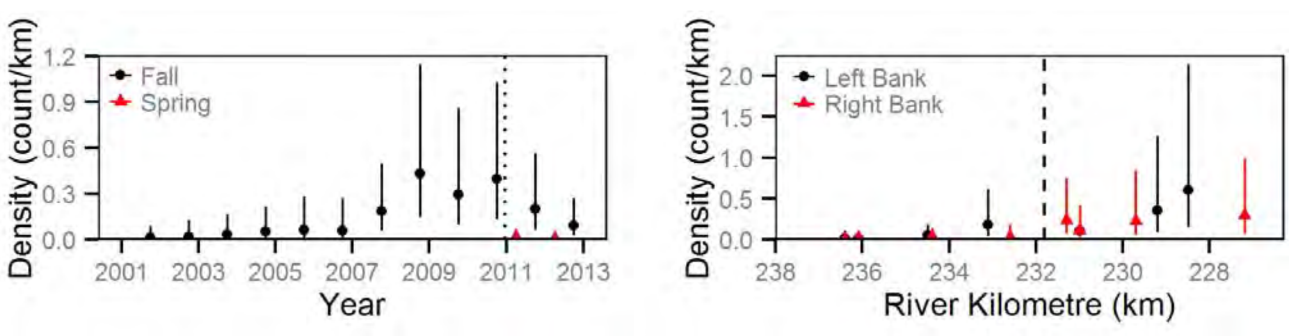

Figure 20: Count density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Northern Pikeminnow in the Middle Columbia River study area, from 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.6.8 Sculpin Species

Densities of Sculpin species in the MCR remained relatively low between 2001 and 2005, increased between 2005 and 2008, declined substantially between 2008 and 2009, and remained at fairly low densities from 2009 to 2012 (Figure 21). Site-level density estimates were variable and did not indicate any obvious patterns or trends (Figure 21).

There was no relationship between Sculpin species density and flow regime (P=0.3) or season (P=0.1).

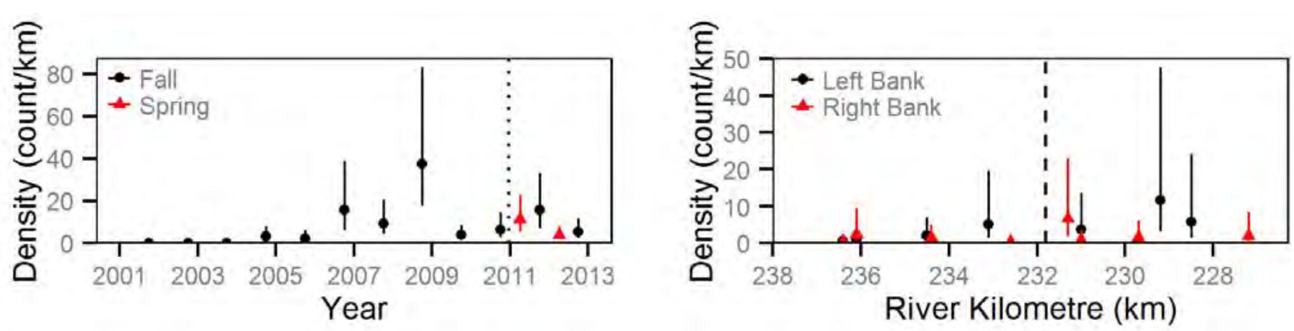

Figure 21: Count density estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for Sculpin species in the Middle Columbia River study area, 2001 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.6.9 Capture Efficiencies

Capture efficiency was calculated with a HBA using mark-recapture data. Median estimates of capture efficiency for Bull Trout were consistent over time, ranging from 3.0 to 4.5% across all sessions and years (Appendix G, Figure G10). Capture efficiency was lower for age-1 Mountain Whitefish (<1%) but stable across sampling sessions and years (Appendix G, Figure G11). For adult Mountain Whitefish (age-2 and older), capture efficiency was similar across years and sessions but greater in the spring (~2-3%) than in the fall (~3-5%) in both 2011 and 2012 (Appendix G, Figure G12). This may indicate that adult Mountain Whitefish were more likely to leave the study area after marking during the fall than they are during the spring. Capture efficiency of Rainbow Trout (2.5-4.6%) varied little among sessions, years, and seasons (Appendix G, Figure G13). Although there were differences among species and life stages (for Mountain Whitefish), there were no long term trends in capture efficiency over time or sessions. Inter-session variations in capture efficiency did not appear to co-vary substantially among species. This indicates that field crews maintained similar capture efficiency within and among sample sessions.

3.6.10 Site Fidelity

Site fidelity, defined as the probability of a fish recaptured within the same season being encountered at the same site as the previous capture, was primarily used to adjust the capture efficiencies in the absolute density models. However, site fidelity estimates also were used to assess movements within the study area in different seasons (Appendix G, Figures G14 to G18). Of the four species that had enough recapture data for assessment, Rainbow Trout exhibited the highest site fidelity in both the fall (75%) and spring (99%) sessions although the difference between seasons was not significant (P=0.05). The spring site fidelity estimate was based on relatively few data points (n = 6; Attachment A). Site fidelity of Bull Trout was low compared to other species, and not different between the fall (44%) and spring (33%; P=0.3). Largescale Sucker had a site fidelity of 58% in the fall and 61% in the spring (P=0.9). For Mountain Whitefish, age-1 fish had much lower site fidelity with no significant difference between fall (27%) and spring (33%) estimates (P=0.8), whereas age-2 and older Mountain Whitefish had much higher site fidelity, and significantly greater fidelity in the spring (78%) than in the fall (49%; P<0.001).

3.7 Growth Rate

Limited mark-recapture data prevented detailed growth-related analysis for all species with the exception of Bull Trout (Section 3.7.1) and Mountain Whitefish (Section 3.7.2).

3.7.1 Bull Trout

3.7.1.1 Length-At-Age

Changes in Bull Trout length-at-age could not be estimated using a Hierarchical Bayesian mixture analysis of length-frequency distributions due to indistinguishable age-classes in length-frequency histograms for this species (Appendix E, Figure E1).

3.7.1.2 Growth

Based on an HBA of annual growth of recaptured individuals, there was a substantial decline in Bull Trout growth rates between 2007 and 2008, followed by an increase from 2008 to 2012 (Figure 22). For a Bull Trout with a fork length of 500 mm, median annual growth increased from ~42 mm in 2008 to ~58 mm in 2012 (Figure 22). There was no significant relationship between Bull Trout growth and flow regime (*P*=0.3).

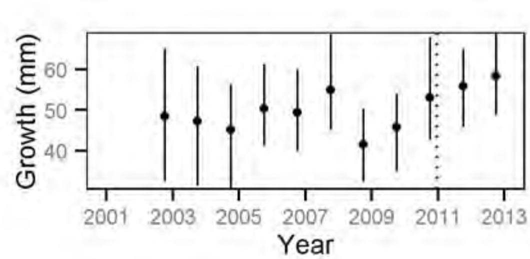

Figure 22: Annual growth estimates (with 95% credible intervals) by year for a 500 mm FL Bull Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

3.7.2 Mountain Whitefish

3.7.2.1 Length-At-Age

Hierarchical Bayesian mixture analysis of length-frequency data indicated greater length-at-age for age-0 and age-1 Mountain Whitefish from 2001 to 2006 and lower length-at-age from 2007 to 2012 (Figure 23). Length-at-age of age-0 Mountain Whitefish increased slightly in 2010, but declined in 2011 and 2012. Length-at-age of age-1 Mountain Whitefish declined after the flow regime change and was lower in 2011 and 2012 than all previous study years. Length-at-age was significantly smaller after the flow regime change for age-1 Mountain Whitefish (*P*=0.004) but not significantly different for age-0 (*P*=0.2).

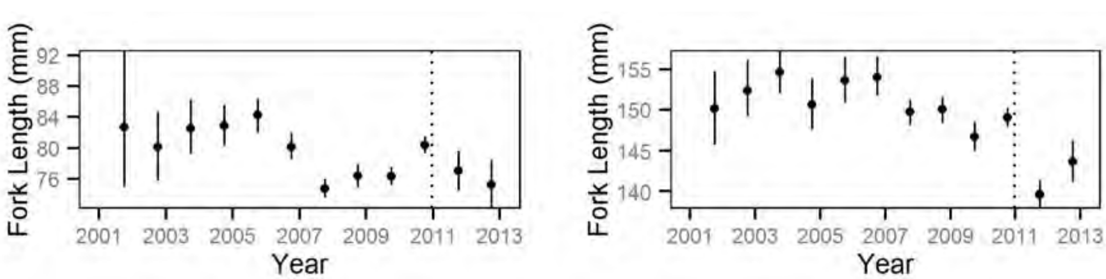

Figure 23: Length estimates (with 95% credible intervals) by year for age-0 (left panel) and age-1 (right panel) Mountain Whitefish in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

3.7.2.2 Annual Growth

Annual growth of recaptured Mountain Whitefish was similar from 2001 to 2012. Credible intervals overlapped for all estimates (Figure 24).There was no significant difference in growth before and after the flow regime change (*P*=0.8).

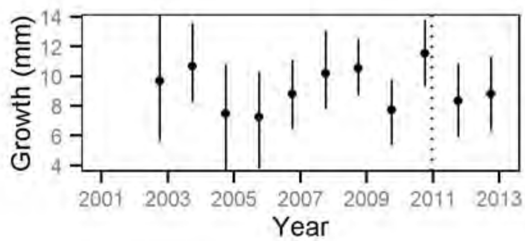

Figure 24: Annual growth estimates (with 95% credible intervals) by year for a 250 mm FL Mountain Whitefish in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

3.8 Body Condition

Variation in body condition is presented in terms of the percent change in body weight of a median length individual by species. Body condition estimates were not available for 2001 because fish were not weighed during that study year.

3.8.1 Bull Trout

The body condition of Bull Trout in the MCR has fluctuated since 2001. The percent change in body condition relative to a typical year decreased from 2004 to 2008, increased in 2009 and 2010, and decreased in 2011 and 2012 (Figure 25). Although condition decreased following the implementation of the flow regime change, flow regime was not a significant predictor of body condition (*P*=0.3). Body condition of Bull Trout did not differ between spring and fall seasons (*P*=0.5). Variation in condition between sample sites was negligible (Figure 25).

In previous years of the study, modelling results indicated that a Bull Trout marked with a T-bar anchor tag during a previous study year tended to be in significantly better condition than its unmarked equivalent, while a Bull Trout marked with a PIT tag was not (Ford and Thorley 2011a, 2012). In the analysis presented in this report, only previously untagged fish were included in models of body condition to avoid potential tagging effects; therefore, tag type was not included in the models.

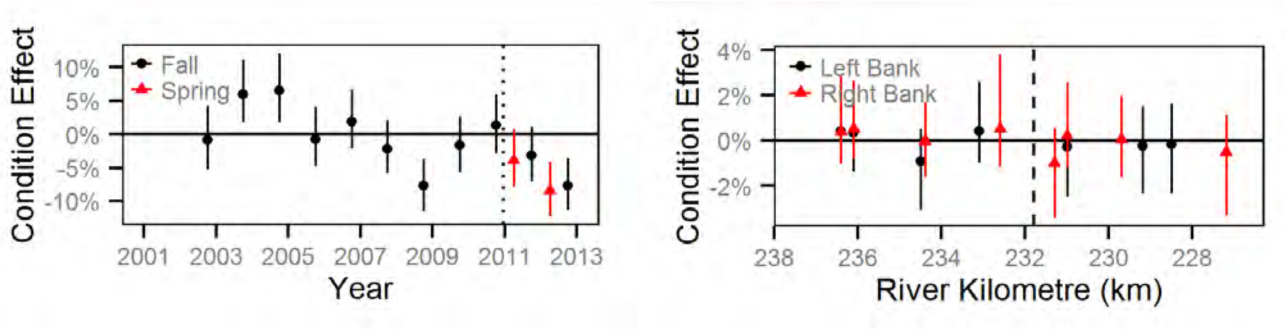

Figure 25: Body condition effect size estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for a 500 mm FL Bull Trout in the Middle Columbia River study area, 2002 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.8.2 Mountain Whitefish

Trends in body condition of Mountain Whitefish were similar to those for Bull Trout, with decreasing values in the late 2000s, increased body condition in 2010, and low body condition after the flow regime change (Figure 26). Body condition of Mountain Whitefish was greater before the flow regime change than after but the difference was marginally significant (P=0.048). Mountain Whitefish body condition was significantly greater in the fall than in the spring (P<0.001). For all study years combined, Mountain Whitefish body condition was lower in Reach 4 and higher in Reach 3 for all sample sites (Figure 26).

In previous years of the study, Mountain Whitefish marked with T-bar anchor tags had significantly lower body condition than unmarked fish, whereas there was no difference between PIT-tagged fish and unmarked fish (Ford and Thorley 2011a, 2012). As was the case for Bull Trout, analyses in this report only included previously untagged fish to avoid potential effects of tagging on body condition.

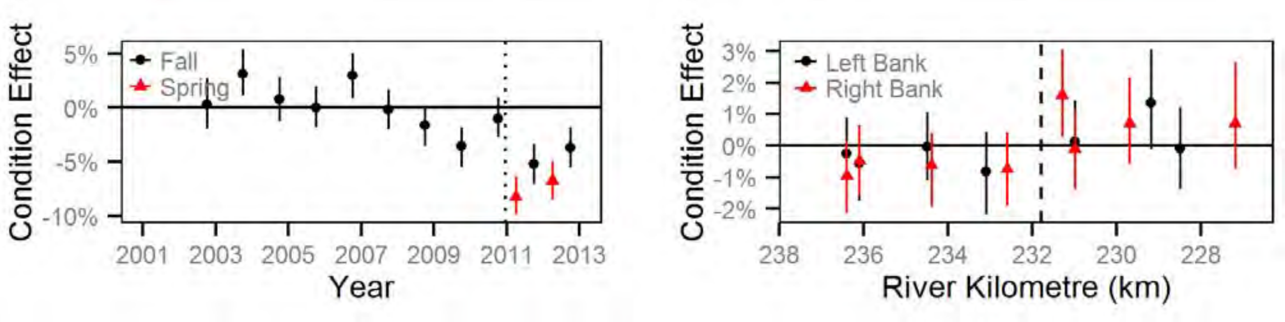

Figure 26: Body condition effect size estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for a 250 mm FL Mountain Whitefish in the Middle Columbia River study area, 2002 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.8.3 Rainbow Trout

Sparse life history data for Rainbow Trout in the study area resulted in relatively uncertain body condition estimates for this species. Estimates of body condition could not be calculated for Rainbow Trout prior to 2003 because weights were not recorded in 2001 and Rainbow Trout were not encountered in 2002. Body condition varied little among study years and credible intervals overlapped for all estimates (Figure 27). Body condition could not be estimated for Rainbow Trout at Site 232.6-R because this species has never been captured at that site. Body condition was higher at Site 227.2-R (Salmon Rocks) when compared to all other sites (Figure 27).

Body condition of Rainbow Trout was significantly greater in the fall than in the spring ($P<0.001$). There was no change in body condition associated with the flow regime change ($P=0.9$).

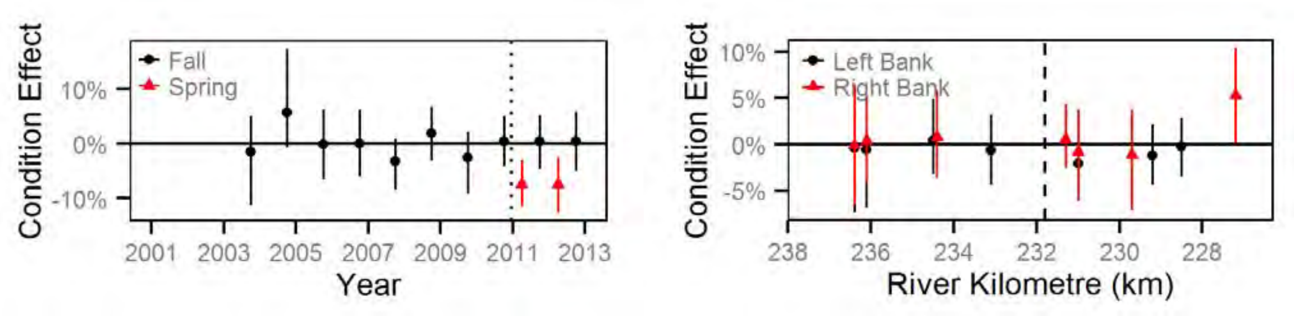

Figure 27: Body condition effect size estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for a 250 mm FL Rainbow Trout in the Middle Columbia River study area, 2003 to 2012. The dotted line (left panel) represents the implementation of the minimum flow release and REV5 operations. The dashed line (right panel) represents the divide between Reaches 3 and 4 at the Jordan River confluence.

3.8.4 Other Species

Length and weight data were recorded for all species encountered in 2010 to 2012. In addition to Bull Trout, Mountain Whitefish, and Rainbow Trout, body condition also was analyzed using HBA for Lake Whitefish, Largescale Sucker, Northern Pikeminnow, Prickly Sculpin, and Redside Shiner. Wide credible intervals precluded any meaningful interpretation of the results for these species. Estimates from the HBA are expected to become more precise during future study years as additional data are collected.

3.9 Changes in Spatial Distribution Over Time

The effect of the flow regime change on the spatial distribution of adult fish in the MCR was assessed using plots that compared the density estimates by site and year (Appendix G, Figures G19-G28). These plots show the variation in density related to site, year and flow regime, while other variables in the model were held at fixed levels. For all species examined, the spatial distribution of fish among sites was similar in most years, with no apparent differences before and after the flow regime change. In other words, sites that tended to have high densities relative to other sites before the flow regime change also had higher densities after the change. This pattern was true for comparisons of absolute density based on mark-recapture data and for count density estimates.

3.10 Environmental Variables

Cross-correlations of the year-to-year differences in abundance, density, condition, length-at-age, and environmental variables revealed 15 relationships that were significant at the $P<0.001$ level. For Mountain Whitefish, variance of discharge (July to August) was negatively correlated with absolute density of age-1 fish, and reservoir elevation (January to February) was positively correlated with growth. In addition, there were three correlations between fish population metrics for Mountain Whitefish (Table 7). Growth of Bull Trout was positively correlated with two measures of discharge variability (mean hourly difference, May to June, and variance, May to June). Absolute density of Rainbow Trout was correlated with mean discharge (November to December), mean hourly difference in discharge (May to June), and mean reservoir elevation (March to April). Burbot count density was correlated with two measures of discharge variability (mean hourly difference, May to June, and variance, November to December). Sculpin count density was correlated with mean hourly difference in discharge (May to June).

Water temperature data were only available from 2007 to 2012. With limited water temperature data recorded prior to 2007, data were insufficient data for the correlation analysis. Links between water temperature and fish population variables were explored graphically and are discussed in Section 4.0.

Table 7: Cross-correlations among fish abundance, condition, life-history and environmental variables from the Middle Columbia River, 2001-2012. Only correlations significant at the 0.001 level are shown.

Variable 1	Variable 2	Correlation Coefficient	P-value
Discharge (Variance, July - August)	Absolute Density (Age-1 Mountain Whitefish)	-0.96	0.0000002
Reservoir Elevation (Mean, January - February)	Growth (Mountain Whitefish)	0.93	0.0000030
Length-At-Age (Age-1 Mountain Whitefish)	Growth (Mountain Whitefish)	-0.91	0.0000125
Discharge (Mean Hourly Difference, May - June)	Growth (Bull Trout)	0.91	0.0000130
Absolute Density (Age-1 Mountain Whitefish)	Length-At-Age (Age-0 Mountain Whitefish)	0.89	0.0000498
Count Density (Burbot)	Count Density (Sculpin Species)	0.84	0.0003002
Count Density (Sculpin Species)	Growth (Bull Trout)	0.84	0.0003579
Discharge (Mean, November – December of previous year)	Absolute Density (Rainbow Trout)	0.84	0.0003683
Discharge (Mean Hourly Difference, May - June)	Absolute Density (Rainbow Trout)	0.83	0.0004406

Variable 1	Variable 2	Correlation Coefficient	P-value
Discharge (Variance, May - June)	Growth (Bull Trout)	0.82	0.0005273
Reservoir Elevation (Mean, March - April)	Absolute Density (Rainbow Trout)	0.82	0.0005985
Discharge (Variance, November - December of previous year)	Count Density (Burbot)	-0.81	0.0007369
Body Condition (Mountain Whitefish)	Length-At-Age (Age-1 Mountain Whitefish)	0.81	0.0008313
Discharge (Mean Hourly Difference, May - June)	Count Density (Sculpin Species)	0.81	0.0008991
Discharge (Mean Hourly Difference, May - June)	Count Density (Burbot)	0.80	0.0009123

4.0 DISCUSSION

The primary purpose of CLBMON-16 is to answer four key management questions:

- Is there a change in the abundance of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in growth rate of adult life stages of the most common fish species using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in body condition (measured as a function of relative weight to length) of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?
- Is there a change in spatial distribution of adult life stages of fish using the MCR that corresponds with the implementation of a year-round minimum flow?

Another objective of the program, although not specifically identified as a key management question, is to investigate and document changes in species richness or species diversity in the MCR in response to the minimum flow release.

As discussed previously, the increased generation capacity of REV5 has an equal or greater potential to result in changes to fish population metrics downstream from REV as does the implementation of a year-round minimum flow. Due to the inability to separate the effects of these two flow changes, the following discussions are restricted to the effects of the overall flow regime change.

4.1 Discharge, Temperature, and Revelstoke Dam Operations

Variation in discharge before and after the flow regime change was not analyzed in detail in this study. However, discharges were presented (Section 3.1 and Appendix C) to provide context when interpreting trends in fish populations in the MCR. The effects of the flow regime change on water levels and other habitat variables were assessed as part of BC Hydro's MCR Physical Habitat Monitoring Project (CLBMON-15a). A key finding of that study was a predicted 32% increase in permanently wetted riverbed area, based on modelling results, during times of low reservoir elevation and no backwatering effect from ALR (Golder in preparation). An increase in the permanently wetted riverbed area would be expected to increase the benthic productivity in the study area, which could result in benefits to the fish community (Perrin et al. 2004). In addition, the results suggested greater diel variation in water levels at some sites after the flow regime change (Golder in preparation). Greater diel variation is plausible because the range of possible discharges at REV changed from 0-1700 m^3/s to 142-2124 m^3/s with the flow regime change. There also were possible differences in diel temperature variations, with greater daily temperature ranges expected before the flow regime change than after, although modelled differences were small (<1°C) and may or may not be biologically significant (Golder in preparation). Not surprisingly, the change in flow regime at REV resulted in significant differences in physical habitat in the MCR including a greater permanently wetted river channel area, greater peak flows and higher flow variability. These changes have the potential to affect fish populations. Additional studies are required to determine which physical habitat variables and components of dam operations influence fish populations in the MCR (see below). Two years of data have been collected since the flow regime change, and both of these years were characterized by greater than average river discharge. Additional years of data are required to determine whether changes in flow variability and fish populations are related to the flow regime change or other environmental factors.

The implementation of the minimum flow release coincided with an additional unit (REV5) going online at REV. The increased capacity at REV due to REV5 resulted in both increased daily flow variability and higher peak daily discharge levels. During periods of high energy demand, REV operates at full or near full capacity to maximize power generation, which results in higher discharge levels in the MCR. In order to compensate for the additional water released through REV during periods of high energy demand, the dam operates at lower discharge levels during periods of low energy demand for longer durations (typically at night). This operational change makes it difficult to determine if changes identified in the fish community downstream of REV are the result of the minimum flow release or the result of higher daily peak discharge levels (or a combination of both).

One way to determine which input (i.e., the higher peak daily discharge or the minimum flow release) affects the fish community could involve a multi-year study with different input combinations. As an example:

- operate REV5 with the minimum flow release; and,
- operate REV5 without the minimum flow release.

Operating REV in this manner would require significant changes to the WUP. In addition, the duration of time required under each scenario would be different for each fish species of interest and each management question to be answered. For example, measuring a change in the body condition of Sucker species may require as little as one year under each scenario as food availability for these species would be directly related to primary and secondary productivity. Determining the body condition of Bull Trout would require several years of operation under each scenario as body condition for this species are partially dependent on prey fish abundance, and prey fish abundance would likely require several years to stabilize.

4.2 Species Richness and Diversity

Estimates of species richness increased from 2001 to 2008. The change in richness was related to increases in the probability of occupancy of several species, including Burbot, Lake Whitefish, Redside Shiner, and Sculpin species. Overall, species richness generally increased with distance downstream from the dam. Higher species richness downstream is likely a reflection of this portion of the study area serving as a transition zone between the flowing section of the Columbia River and ALR. If this transition zone provides diverse habitat types, including more riverine and lacustrine areas, then it could explain the higher richness compared to other reaches. Species richness was lower in Site 232.6-R (upstream of the Jordan River confluence) than in neighbouring sites. Habitat within this site is very homogenous, encompassing a large, flat, gravel/cobble fan upstream of the confluence. Shallower water depths, a lack of suitable cover, and the uniform nature of the substrate result in a low habitat diversity that would reduce the suitability of the area for certain species. For most of the study area, species richness was higher on the left bank than the right bank. The left bank has more armoured substrate (85%) than the right bank (57%; Appendix B, Table B2).

Species evenness increased from 2001 to 2008. The increase in evenness resulted from the less common species becoming relatively more common during this time period. Density estimates showed increasing trends for Burbot, Northern Pikeminnow, Rainbow Trout and Sculpin species, whereas densities of more common species, such as Bull Trout and Mountain Whitefish remained relatively stable. Both richness and evenness were lower in the spring than in the fall, which was related to lower probability of occupancy and/or density of Burbot, Northern Pikeminnow, Lake Whitefish, and Sucker species.

Species evenness was significantly higher in Site 233.1-L (along the left bank in Reach 4 along the Revelstoke Golf Course) than in neighbouring sites, in part due to lower Mountain Whitefish densities in this site relative to other sites. During the fall season, Mountain Whitefish generally prefer areas with shallow water depths and cobble/boulder substrate (Golder 2012). Site 233.1-L is characterized by steep banks, deep water, and large (i.e., rip-rap) substrate. Reach 3 represents a transition zone between lacustrine and riverine habitats, particularly during the fall study period when ALR water elevations levels are higher. The complex species assemblage (higher species richness and evenness) in that portion of the study area reflects the greater habitat diversity in the transition zone.

Increasing trends from 2001 to 2008 in richness, evenness, and the probability of occupancy for several less common species suggest a substantial change in the fish community during this time period. Overall, the results do not suggest a change in species richness or evenness related to the flow regime change, as these metrics fluctuated with no increasing or decreasing trend from 2009 to 2012 when the flow regime change occurred.

4.3 Management Question #1 - Abundance

4.3.1 Bull Trout

Bull Trout density generally increased from 2001 to 2007 and was relatively stable from 2007 to 2012, with slightly lower values in 2012. Two years of post-flow regime change monitoring data do not suggest a significant change in Bull Trout abundance related to the flow regime change. The period of increasing Bull Trout density from 2001 to 2006 was associated with generally lower river discharge and ALR water levels, whereas the period of higher and relatively stable abundance was associated with higher discharges and reservoir elevations. However, there were no significant correlations between Bull Trout abundance and discharge or reservoir elevation, indicating that there was not a consistent relationship between these variables.

Given the magnitude of changes observed from 2001 to 2007, these differences in density may not reflect actual changes in abundance in the overall population in ALR and may reflect differences in migration rates out of ALR and into the study area. Prior to the spring 2011 survey, it was assumed that Bull Trout were most abundant in the study area during the fall season due to feeding activity on spawning Kokanee. Bull Trout abundance during other portions of the year was assumed to be lower. This assumption was based on relatively low Bull Trout catch-rates during the 2001 survey (which was conducted several weeks earlier than other surveys), declining Bull Trout catch-rates over the duration of most study periods, and angler tag return data from ALR. However, density estimates in the spring of 2011 and 2012 were both very close to estimates during the fall periods in those years and may indicate that Bull Trout are more resident in the study area than previously thought. Site fidelity estimates for Bull Trout were not significantly different between spring and fall, which suggest similar rates of movement within the MCR during the two sampling seasons.

4.3.2 Burbot

Density estimates for Burbot were higher in 2008 and 2011 than in other study years. Based on catch-rates recorded during BC Hydro's Arrow Reservoir Burbot Life History and Habitat Use Study (CLBMON-31; LGL 2009), Burbot are relatively common in Upper Arrow Lake (i.e., Reaches 1 and 2) when compared to Reaches 3 and 4. During the 2008 and 2011 field seasons, ALR levels were higher than during any other study years (Appendix C, Figure C3), with the reservoir backing up into Reach 4 for most of the field season during both years. Higher water elevation levels during the 2008 and 2011 field seasons may help explain higher Burbot densities observed during those study years, although the relationship between changes in Burbot density and reservoir level was not significant. Burbot count density in October was negatively correlated with variance in discharge during November and December of the previous year. Burbot spawn in the winter, typically between January and April, and likely in February and March in ALR (Arndt and Baxter 2006); therefore, greater variability in discharge in November to December did not likely have a large influence on spawning that could explain the association with Burbot count density.

Burbot densities increased from 2001 to 2006, and fluctuated between 2007 and 2012 with no obvious trend. These results do not suggest a significant impact on Burbot density in the MCR due to the flow regime change.

4.3.3 Kokanee

Density of Kokanee was not estimated because the extremely variable counts of this species prevented the model from converging. Probability of occupancy at a typical site varied substantially among years (Appendix G, Figure G2). Kokanee migrate into the MCR during the fall season to spawn in adjoining tributaries, but this species generally rears and feeds in large lakes (e.g., ALR; Scott and Crossman 1973). Because the study area is primarily used as a migratory corridor during the fall, it is unlikely that abundance of this species in the MCR will be influenced by the flow regime change. Other dam-related factors, such as entrainment rates through REV, could potentially have a larger impact on the abundance of Kokanee in the MCR.

4.3.4 Mountain Whitefish

Densities of age-2 and older Mountain Whitefish and of all cohorts combined indicated stable abundance between 2001 and 2012. There were relatively higher densities of age-1 Mountain Whitefish in 2010 and 2011 compared to other study years, which was supported by larger numbers of age-0 fish in 2009 and 2010 (Appendix E, Figure E2). These two cohorts represent spawning that occurred during the winters of 2008/2009 and 2009/2010, time periods that were characterized by water temperatures and river discharges comparable to other study years, but higher than average water elevation during winter in ALR, especially in 2008/2009 (Appendix C, Figure C3).

Densities of Mountain Whitefish were greater in the spring compared to the subsequent fall in 2011 and 2012 for age-1 fish, age-2 and older fish (catch density only), and all age-classes combined. These seasonal differences in abundance suggest that many Mountain Whitefish, especially the age-1 class, likely migrate into the MCR from ALR or tributaries during the spring and leave the MCR in the fall.

Catch of age-0 Mountain Whitefish was substantially lower during the 2011 and 2012 surveys than in other study years (Appendix D, Figure E2). These fish represent cohorts that hatched since the winter of 2010/2011 when REV5 went online and the minimum flow release was implemented. Age-1 Mountain Whitefish in 2012, which represent the first cohort since the flow regime change, also had very low densities. Since the flow regime change, discharge from REV was more variable (Appendix C, Figure C1) and water level elevations in ALR were relatively high (Appendix C, Figure C4) compared to earlier study years. The absolute density of age-1 Mountain Whitefish was negatively correlated with discharge variance, which supports a potential link between greater discharge variability and lower abundance of juvenile life stages of Mountain Whitefish. This relationship could be explained by higher mortality, or movement of juvenile Mountain Whitefish out of the study area (e.g., downstream into ALR) when discharge variability in the MCR is high. A previous study in the MCR found that the activity of adult Mountain Whitefish, based on telemetry data, was not correlated with within-hour changes in discharge but was correlated with discharge magnitude (Taylor and Lewis 2011). The flow regime change could also potentially affect Mountain Whitefish populations through effects on spawning in the mainstem. Evidence of Mountain Whitefish spawning in the MCR is limited to reports by field crews of adult Mountain Whitefish in spawning condition (i.e., gravid or ripe individuals) during most study years (Attachment A), although spawning locations are unknown.

In 2011 and 2012, recapture rates of adult Mountain Whitefish (age-2 and older) were higher in the spring (~2-4%) than in the fall (~3-5%; Appendix G, Figure G12). Reasons for the large increase in capture efficiency in the spring, especially in 2011, are unknown but could be related to greater likelihood of adult Mountain Whitefish leaving the study area in the fall, as estimates of site fidelity indicated greater movement among sites in the fall than in the spring (Appendix G, Figure G18). This degree of seasonal difference in capture efficiency was not noted for any other species or life-stages, which indicates that the increase was not due to a sampling bias (e.g., equipment error, selective netting by the field crew, differences in water conductivity, etc.) but more likely related to seasonal changes in behaviour of adult Mountain Whitefish. Mountain Whitefish spawn between November and February in the Lower Columbia River (LCR) downstream of HLK (Golder 2012), so some adult fish may migrate out of the MCR during the fall and into spawning tributaries. However, capture efficiency did not decline in subsequent sessions of the fall season in most years, which would be expected if the number of Mountain Whitefish leaving the study area increased during the fall sampling season. Without mark-recapture data, seasonal differences in sampling efficiency would not have been detected and spring abundance would have been overestimated.

4.3.5 Rainbow Trout

Density estimates for Rainbow Trout gradually increased from 2001 to 2008. Densities of Rainbow Trout were low in 2009 but there was no clear directional trend between 2008 and 2012. Overall, densities estimates for this species were quite low, with wide credible intervals. There were no differences in Rainbow Trout density between spring and fall seasons. Overall, the results do not suggest a significant change in Rainbow Trout abundance related to the flow regime change, although low catches of this species resulted in high uncertainty in density estimates.

Absolute density of Rainbow Trout was positively correlated to the mean and hourly difference in river discharge, and with ALR water level. These relationships suggest Rainbow Trout abundance was relatively greater in years with higher and more variable water levels compared to years with low water levels. However, count density was not associated with discharge or reservoir levels, and uncertainty in absolute density estimates was high; therefore, these relationships should be interpreted with caution.

Rainbow Trout in the LCR typically spawn between early March and late June when water temperatures are between 4 and 14°C (Thorley and Baxter 2012). In the MCR, springs surveys in 2011 and 2012 were conducted in June when water temperatures were between 5 and 9°C. If Rainbow Trout in the MCR spawn under conditions similar to those in the LCR, the spring 2011 survey would have occurred during their expected spawning season. Water temperatures in the MCR are rarely higher than approximately 11°C (Appendix C, Figure C5). During the spring 2011 survey, three Rainbow Trout (4% of the total Rainbow Trout catch) were in spawning condition (all three were males; Attachment A). None of the Rainbow Trout caught during the spring 2012 survey were releasing gametes or in obvious spawning condition. Spawning redds were not observed by the field crew during either spring season. This suggests that the MCR is not a major spawning area for this species; therefore annual variations in Rainbow Trout densities are not likely related to the spawning success of this species in the MCR. The bulk of Rainbow Trout spawning probably occurs in tributaries because high ALR water elevations during the late spring and early summer would flood most potential spawning habitat downstream of the Illecillewaet River confluence. A Rainbow Trout spawning assessment would be required to determine the extent of mainstem spawning for this species.

4.3.6 Sucker Species

Sucker species density was stable from 2001 to 2008, but steadily increased from 2009 to 2012, more than doubling from 7.2 to 16.2 fish counted per kilometre during this period (Figure 18). This result is suspect. Because of the long-lived nature of these species (at least age-15; Scott and Crossman 1973) and the number of years it takes for these fish to reach sexual maturity (age-5; Nelson and Paetz 1992), it is unlikely that the population increased so dramatically since 2010. An alternate explanation for the increase is changes in sampling methods. Field crews did not attempt to capture Sucker species from 2002 to 2009. Density estimates for those years were based entirely on netter observations and Sucker species may have been consistently misidentified or under estimated. However, Sucker species generally react to electricity by rapidly swimming to the surface and rolling onto their backs with their lips distended. This behaviour makes their identification relatively easy, suggesting that netters did not consistently misidentify them. A more probable hypothesis is that in past survey years, the netters underestimated numbers observed. Sucker species tend to aggregate in large groups and when the electrofishing boat passes over these groups, large numbers of fish tend to rise to the surface at once, making enumeration more difficult and therefore, less accurate. Unfortunately, the change in sampling protocols in 2010 and the potential effect on density estimates limit inferences about the effect of the flow regime change on Sucker species.

Of the Sucker species captured in the spring sessions, 42% of those captured in 2011, and 27% of those captured in 2012 were identified as spawners, through the release of eggs or milt or the presence of tubercles (both species combined, Attachment A). These observations suggest that the MCR could be a major spawning area for these species. During surveys, Sucker species were routinely observed in suitable spawning habitats (shallow riffles over small gravel substrate) at Sites 232.6-R, 231.0-R, and 229.7-L. If Suckers spawn in these areas, there is the potential for eggs to become stranded during nightly flow reductions or for fry to become stranded prior to emergence (approximately four weeks after spawning; Scott and Crossman 1973) when BC Hydro drafts ALR (which can occur at any time after early July).

4.3.7 Northern Pikeminnow

Density of Northern Pikeminnow in the MCR increased from 2007 to 2010 but decreased in 2011 and 2012. The period of increasing density coincided with higher than average reservoir elevation in ALR from 2007 to 2010, but there was no significant correlation between count density and reservoir elevation. The decrease in the density of Northern Pikeminnow coincided with the implementation of the flow regime change but the HBA indicated no significant effect of the change.

Northern Pikeminnow density was approximately 10 times greater in the fall than in spring of 2011 and 2012, which suggests that this species uses habitat in the MCR in the fall but may migrate out of the study area sometime before the spring. Northern Pikeminnow spawn in the spring, typically in streams at sites with water velocity less than 0.4 m/s but occasionally in lakes (McPhail 2007). Little is known about spawning behaviour of Northern Pikeminnow in the MCR, so it is unclear if the very low densities observed in the spring are due to spawning migration out of the area or other factors.

4.3.8 Sculpin Species

The count density of Sculpin species increased from very low levels (<1 fish/km) in 2001 to 2003 to 37 fish/km in 2008. The increasing trend in density was supported by a similar trend in occupancy. The probability of occupancy of Sculpin species at a typical site increased from 3% in 2001 to >80% in 2006 to 2008. Density and occupancy remained at intermediate levels from 2009 to 2012, with similar values before and after the flow regime change. As sampling protocols were relatively consistent from 2001 to 2008, these results suggest a substantial change in Sculpin species abundance during this period. Reasons for the increase in Sculpin abundance are unknown, and did not seem to be related to most measures of discharge, reservoir elevation, or water temperature based on the correlation analysis (Section 3.10). Typically during boat electroshocking surveys, the electrical field is not strong enough to attract Sculpin species to the water surface. This means that most Sculpin species observed in the MCR are usually at depths greater than approximately 1.0 m. Observations or captures made at these depths are influenced by water surface visibility, water clarity, netter efficiency, and water velocity. A preliminary review of habitat data recorded at the time of sampling (Appendix B, Table B3; Attachment A) did not indicate poorer observational conditions during any particular study year.

Density and occupancy estimates for Sculpin species provide some indication of abundance over time in the MCR and do not suggest a significant impact of the flow regime change on Sculpin species. However, given their small-bodied nature and the associated inefficiency of the selected sampling method at capturing Sculpin species, it is unlikely that the program, in its current form, will generate reliable estimates to answer the management questions for these species. Sculpin species are routinely captured as part of BC Hydro's MCR Juvenile Fish Habitat Use Program (CLBMON-17; Triton 2009, 2010, 2011, 2012). If necessary, it may be more practical to answer specific management questions regarding these species under that program.

4.4 Management Question #2 - Growth Rate

Growth rates were examined using two separate HBAs. One HBA used a hierarchical Bayesian mixture model to estimate length-at-age based on length-frequency data. Mountain Whitefish was the only species in which adequate length-frequency data were available. Low annual growth rates, which cause individual age-cohorts to overlap in length-frequency histograms, and/or limited life history data, which hinder the interpretation of modes in length-frequency histograms, prevented the application of this HBA for all other species. The second HBA was based on individual growth rates of inter-year recaptured fish. Limited mark-recapture data excluded this analysis for all species except Mountain Whitefish and Bull Trout.

Information on annual growth rates for species other than Bull Trout and Mountain Whitefish may become available in future study years as more life history and mark-recapture data are collected. However, given the limited dataset that exists for species other than Mountain Whitefish and Bull Trout prior to the implementation of the flow regime change (i.e., prior to 2010), it is unlikely that the HBAs will be able to link any changes in annual growth of these species to changes in the flow regime.

4.4.1 Bull Trout

Although there was no significant relationship between Bull Trout growth and flow regime, there was a consistent increase in growth between 2008 and 2012 for this species. Correlation analysis indicated significant positive correlations between Bull Trout growth and two measures of discharge variability, which were: variance of discharge from May to June; and, mean hourly difference in discharge from May to June. If these relationships are not spurious and indicate real biological phenomena, one possible explanation is that greater variability in river discharge increases the availability or vulnerability of prey fish to Bull Trout, resulting in higher growth rates. Taylor and Lewis (2011) found that swimming muscle activity was not related to discharge variability from REV but was positively associated with discharge magnitude, and was greater at sites closer to the dam than further downstream. These relationships suggest that energy expenditure from swimming increases with discharge and greater proximity to the dam. However, the lack of a relationship between discharge magnitude and growth in the present study suggests that greater swimming activity did not necessarily result in reduced growth of Bull Trout in the MCR.

Reasons for the sharp drop in Bull Trout growth rate from 2007 to 2008 are unknown but could have been related to the unusually high ALR levels in 2008 (Appendix C, Figure C4). Because the increase in Bull Trout growth rates started several years before the flow regime change, the results do not suggest a significant impact of flow regime on Bull Trout growth.

4.4.2 Mountain Whitefish

Length-at-age of Mountain Whitefish declined after 2006 for age-0 and age-1 fish. Following the flow regime change in 2010, length-at-age of age-0 Mountain Whitefish decreased slightly. Length-at-age of age-1 Mountain Whitefish decreased substantially following the flow regime change to the lowest levels observed in the study. Length-at-age of age-2 and older fish was not compared in detail before and after the flow regime change because this group comprises several age classes; changes in length-at-age for this group could represent changing population age structure rather than changing length-at-age and/or growth. Overall, length-at-age of Mountain Whitefish followed similar trends for the age-0 and age-1 classes. This similarity was likely due to these age-classes inhabiting similar habitats and feeding on similar prey organisms. Growth rate, modelled as the annual increase in fork length using the von Bertalanffy equation, did not suggest the same trends as length-at-age and was comparable before and after the flow regime change.

After two years of monitoring following the flow regime change, it is unclear whether the observed decrease in length-at-age for age-1 Mountain Whitefish was caused in part by the flow regime change or simply represents unusual year-effects or natural random variation. Additional years of data are required to confirm a link between length-at-age and flow regime for this species.

Growth rate was significantly correlated with reservoir elevation during January and February, suggesting that during low reservoir levels, growth would be relatively lower than at high reservoir levels. Low water levels in ALR result in more riverine conditions in Reach 3 of the MCR. The correlation between reservoir levels and growth does not imply a causal mechanism and it is not clear why less reservoir influence in the MCR would lead to less growth for Mountain Whitefish. Growth rate was not significantly correlated with any of the measures of river discharge, and was not clearly associated with year-to-year variation in temperature based on a graphical assessment. In the Skeena River, another large river in British Columbia, food abundance was the main factor limiting growth and abundance for Mountain Whitefish (Godfrey 1995 as cited by Ford et al. 1995).

4.5 Management Question #3 - Body Condition

Body condition was analyzed using a HBA for Lake Whitefish, Largescale Sucker, Northern Pikeminnow, Prickly Sculpin, and Redside Shiner (in addition to Bull Trout, Mountain Whitefish, and Rainbow Trout; see below); however, limited data for these species resulted in wide credible intervals surrounding all estimates. Temporal or spatial trends in body condition were not observed for any of the above species. Relationships between body condition and flow regime were not evident for these species. Life history data were collected for these species from 2010 to 2012 only, as such, credible intervals surrounding body condition estimates were extremely wide. However, uncertainty surrounding these estimates will likely decrease during future study years as more data become available. Given the limited dataset that exists for most species prior to the flow regime change (i.e., 1 year of data), it is unlikely that the HBA will be able to link any observed changes in body condition for these species to flow regime changes.

4.5.1 Bull Trout

Bull Trout body condition started decreasing in the mid-2000s, increased slightly in 2009 and 2010, and decreased again in 2011 and 2012 following the flow regime change. A similar trend was observed over the same time period in the body condition of Mountain Whitefish. There were no significant correlations between Bull Trout condition and reservoir elevation or river discharge that could help explain the body condition trends observed. There was no obvious association between body condition and water temperature based on a graphical assessment, and too few temperature data points were available for the correlation analysis.

Overall, Bull Trout condition in the MCR could not be associated with any of the environmental variables examined.

For Bull Trout, there was very little variation in body condition between sample sites. This suggests that: 1) all sample sites were homogenous in terms of habitat quality; or, 2) individual fish did not remain associated with any particular site for a long enough time prior to capture for the habitat quality of that site to affect their body condition. Based on variability of habitat measurements taken during the field season (e.g., available cover, water velocities, water depths, etc.) the former scenario is unlikely to be true. The latter scenario is more likely to influence body condition since REV operations dewater large portions of the channel margin on a nightly basis, which forces fish to seek refuge in different areas. This diurnal movement, coupled with annual migratory patterns for this species, support a hypothesis that individual fish do not remain in a particular site long enough for that association to have a measurable impact on body condition.

In previous years of this study, gastric lavage and observations of Bull Trout feeding on Kokanee in the fall suggested that recently ingested Kokanee could have increased Bull Trout body weights by up to 20%, which could influence or bias body condition estimates for fish captured in the fall (Ford and Thorley 2012). The effect of recently ingested Kokanee was suggested as a factor that could have contributed to observed differences in body condition between tag types (i.e., PIT or T-bar) and a declining trend of body condition with day of the year during the fall (Ford and Thorley 2012). If true, body condition in the spring (when Kokanee are less abundant and potential effects of gut fullness on body condition are reduced) should be lower. However, analyses in this report indicate no differences between fall and spring estimates of Bull Trout body condition, which suggests that the effect of gut fullness from Kokanee, while dramatic in some cases, is unlikely to have severely affected overall estimates of Bull Trout condition in the fall.

Although Bull Trout body condition decreased to the lowest levels observed in the study following the flow regime change, the flow regime change was not a significant predictor in the HBA. As body condition varied substantially during the pre-minimum flow period, it is difficult to determine whether the low condition values observed in 2011 to 2012 were related to the flow regime change or natural variability caused by environmental factors (e.g., high discharge). The similar decline in length-at-age and body condition of Mountain Whitefish after the flow regime change supports the idea that Bull Trout body condition was indeed lower in 2011 and 2012. However, additional years of data after the flow regime change are required to determine whether the change in body condition was related to flow.

4.5.2 Mountain Whitefish

The trend in the body condition of Mountain Whitefish was very similar to the trend in length-at-age, with a large decline beginning in 2006, a slight increase in 2010, and further decline to low levels in 2011 and 2012 following the flow regime change. The trends in body condition of Mountain Whitefish and Bull Trout also were similar. Whether declines in body condition were in response to the flow regime change is not known. The body condition of Mountain Whitefish was substantially lower after the flow regime change when compared to pre-flow regime change estimates. However, the decline appeared to have started in 2006, several years before the flow regime change. The finding that the flow regime change began during a period when body condition was already changing due to some other unknown factor(s) makes it more difficult to assess the effects of the flow regime change on this parameter. Additional years of data are required to determine if the decline is due to annual variation or reflects a relationship between Mountain Whitefish body condition and flow regime.

Years with generally higher water temperatures (e.g., 2010 and 2012) were associated with increases in body condition but there was not a consistent relationship between condition and water temperature, and too few temperature data points for a correlation analysis. The factors affecting body condition of Mountain Whitefish are likely complex and the analyses presented here provide limited support for links between environmental variables and body condition. The positive correlations between body condition and length-at-age (age-1), and absolute density (age-1) and length-at-age (age-0) suggest that in years when environmental conditions were favorable, abundance, length-at-age, and body condition were all greater for Mountain Whitefish. These results suggest that density-dependent processes, whereby higher abundances result in lower body size or condition due to intra-specific competition, were not limiting Mountain Whitefish populations in the MCR.

Overall, the body condition of Mountain Whitefish was higher in Reach 3 than in Reach 4. This result may be due to additional nutrients flowing into the MCR from the Jordan River (i.e., the divide line between the two reaches) resulting in higher productivity downstream of the confluence. As recommended by Schleppe et al. (2011; CLBMON-15b), monitoring the benthos upstream and downstream of the confluence would provide valuable insight into this result. Mountain Whitefish body condition was highest within Site 231.3-R (Big Eddy). This site is located immediately downstream of the Jordan River confluence. Due to the topography of the area, most of the water flowing out of the Jordan River circulates through the Big Eddy hydraulic before flowing downstream. Significantly greater body conditions for Mountain Whitefish in the fall compared to the spring likely reflects greater food availability during summer when compared to winter.

4.5.3 Rainbow Trout

Limited life history data for Rainbow Trout resulted in large uncertainty surrounding body condition estimates. Long-term patterns or trends were not evident in annual estimates. Body condition was similar before and after the implementation of minimum flows, which suggested no effect of the flow regime change on Rainbow Trout condition, based on the limited data set. As was observed for Mountain Whitefish, body condition of Rainbow Trout was much lower in the spring than in the fall, likely because of less food availability in winter than in summer.

Body condition was substantially higher at Site 227.2-R (i.e., Salmon Rocks) than at sites immediately upstream (no sites were located downstream of Salmon Rocks). Site 227.2-R is located at the downstream end of Reach 3 and is close to both the Illecillewaet River and ALR Reservoir. Rainbow Trout in these locations may have higher body conditions than Rainbow Trout in the MCR and the higher body condition estimates in Site 227.2-R are due to the sites closer proximity to these areas. Boat electroshocking surveys were conducted in Reach 2 in 2008 and 2009. During those surveys, 42 Rainbow Trout were measured for length and weight (Attachment A). Although based on relatively few data points, a preliminary review of these data did not indicate higher body conditions in Reach 2 when compared to Rainbow Trout recorded in Reach 3. Boat electroshocking surveys have never been conducted in the Illecillewaet River under the current program. However, a study of juvenile fish habitat use in the MCR (CLBMON-17) found that juvenile Rainbow Trout caught in tributaries had greater body condition than those caught in the mainstem MCR (Triton 2012). Overall, the body condition of Rainbow Trout tended to vary more by site than it did for Bull Trout and Mountain Whitefish.

4.6 Management Question #4 – Spatial Distribution

The effect of the flow regime change on the spatial distribution of adult fish in the MCR was assessed by comparing densities among sites during each year (Appendix G, Figures G19-G29). There were very few apparent differences in the spatial distribution of fish species in the MCR before and after implementation of the flow regime change. The spatial distribution and any observed changes over time are discussed for each species in the following section. Taken together, the results did not suggest an effect of minimum flows on the spatial distribution of adult fish in the MCR.

4.6.1 Bull Trout

Bull Trout densities in Reach 4 were highest near the Moses Creek Spawning Channel (RKm 236.4) and tended to decrease with increased downstream distance from REV. Similarly, in Reach 3, Bull Trout densities were highest near the Jordan River confluence (RKm 231.6) and tended to decrease with distance downstream from the confluence. Both Moses Creek and the Jordan River are known spawning areas for Kokanee. The pattern of decreasing Bull Trout densities with increased distance downstream of both tributaries suggests that Bull Trout are aggregating to feed on pre-spawning Kokanee entering these systems or on spent Kokanee exiting these systems. However, densities of Bull Trout also were high at these locations during the spring, which suggests that availability of Kokanee spawners as prey is not the only factor leading to high Bull Trout densities near the tributaries. There was no evidence of any large changes in the spatial distribution of Bull Trout following the flow regime change.

4.6.2 Burbot

For Burbot, credible intervals overlapped for all site-level density estimates. Similar to results reported in previous years (e.g. Ford and Thorley 2012), density was slightly higher at Site 231.0-L, which is along the left bank between the Revelstoke Golf Course and the Rock Groyne. This site contains rip-rap substrate, steep banks, and high water velocities. Higher catch-rates of Burbot were recorded in similar habitats downstream of HLK as part of BC Hydro's LCR Fish Population Indexing Program (CLBMON-45; Ford and Thorley 2011b). The low and variable numbers of Burbot observed and caught made it difficult to assess any changes in spatial distribution over time but, in general, Burbot distribution was similar before and after the flow regime change.

4.6.3 Kokanee

Spatial distribution was assessed using catch data (Appendix D, Figure D1-D2) because densities were not estimated using HBA due to extremely variable data that prevented models from converging. Kokanee catches were higher at sites that included confluences of major tributaries or were immediately downstream of tributaries (i.e., Moses Creek, Scales Creek, Jordan River).

Kokanee are in the study area primarily during the fall season for spawning purposes; for that reason, densities are higher near these tributaries (either spawning at the creek mouths or migrating into the creeks to spawn). Based on field observations, densities generally decreased with distance downstream from the confluences of tributaries. One exception was Site 229.7-L, on the left bank near the Trans-Canada highway bridge, where Kokanee were often observed. Kokanee may use this habitat near the bridge for holding en-route to tributaries or for spawning.

4.6.4 Mountain Whitefish

One of the key management questions for this study relates to the spatial distribution of adult life stages of fish using the MCR. Mountain Whitefish was the only species with adequate data to robustly analyse age groups. Age-2 and older Mountain Whitefish were most common from Site 232.6-R (upstream of the Jordan River confluence) to Big Eddy Bridge (Site 227.2-R). Habitat in this portion of the study area is dominated by shallow water depths, high water velocities, and small substrate (i.e., gravel and cobble) and may serve as a holding area for this species prior to spawning. Mountain Whitefish spawning has not been documented in the MCR; however, field crews have noted both gravid and ripe Mountain Whitefish during surveys. Mountain Whitefish densities were noticeably lower on the opposite bank (i.e., between the Revelstoke Golf Course and the Rock Groyne). Habitat in this area is typified by high water velocities, high water depths, and rip-rap or large substrate banks. Site 227.2-R (i.e., Salmon Rocks) has similar habitat characteristics and also had low age-2 and older Mountain Whitefish densities. Habitat preferences inferred from these observations generally agree with studies from other areas in western Canada, as Mountain Whitefish are typically found in areas with moderate to high flows, large gravels or cobbles, and shallow depths (Ford et al. 1995, McPhail 2007, Golder 2012).

Age-1 Mountain Whitefish were most common in the upstream portion of Reach 4 (i.e., opposite the Moses Creek Spawning Channel) and in the upstream portion of Reach 3 (i.e., between Big Eddy and Big Eddy Bridge). Spatial distribution of age-1 and age-2 and older Mountain Whitefish was quite similar, which suggested similar habitat preferences for these age groups. Ford et al. (1995) reported that diets of age-1 and age-2 Mountain Whitefish were similar but differed from age-3, 4 and 5 fish, which could help explain similar habitat preferences between age-1 and age-2 and older fish in this study.

The spatial distribution of adult (age-2 and older) Mountain Whitefish was similar before and after the flow regime change. One difference was lower density of age-1 Mountain Whitefish, relative to other sites, at Sites 236.4-R and 236.4-L (the two sites closest the REV) in years following the flow regime change (Appendix H, Figure H23). In addition, density of adult Mountain Whitefish increased at Site 233.1-L near the Revelstoke Golf Course, which could have been related to the habitat enhancements at that site in 2009 (see Section 3.6.4). Whether the flow regime change also contributed to density changes at these sites is unknown and overall the results do not suggest a significant change in spatial distribution related to the flow regime change.

4.6.5 Rainbow Trout

Between 2001 and 2012, Rainbow Trout densities were highest in Big Eddy, adjacent to the rip-rapped left bank of Reach 3, and at Salmon Rocks (Site 227.2-R). Rainbow Trout densities were low throughout Reach 4 and along the right bank of Reach 3, with the exception of Big Eddy and Salmon Rocks.

In the fall of 2009, BC Hydro stabilized the bank of the Columbia River by adding large boulders and rip-rap to an approximately 2.5 km section of the bank along the Revelstoke Golf Course (Site 233.1-L; Appendix A, Figure A2). Prior to bank stabilization, a total of 23 Rainbow Trout were recorded in eight study seasons (this portion of the river was not sampled in 2009 due to construction of the bank stabilization works). During the 2010 and 2011 (fall only) surveys, 20 and 28 Rainbow Trout, respectively, were recorded in this portion of the river. Rainbow Trout were not caught or observed at Site 233.1-L in the fall of 2012. Although based on only three years of data, preliminary results indicate that the bank stabilization work conducted by BC Hydro in 2009 adjacent to Site 233.1-L has made the area more suitable for Rainbow Trout. Greater abundance of Rainbow Trout at this site since habitat modifications also is supported by the plot showing spatial distribution and density over time (Appendix G, Figure G25). Overall, 81% of the Rainbow Trout captured in Site 233.1-L since bank stabilization were classified as immature; 19% were classified as adult (Attachment A). The reason for lower Rainbow Trout catch and observations at Site 233.1-L in 2012 is not known, but the much higher than normal river discharge during sampling in October 2012 could have influenced catchability or suitability of the habitat for this species.

Overall, results suggest that the flow regime change likely did not have a significant impact on Rainbow Trout distribution in the MCR.

4.6.6 Sucker Species

For all Sucker species combined, density generally increased with increased distance downstream of the dam. Sucker species generally prefer lower water velocity area (except during their spawning season). In general, water velocities in the MCR are lower in Reach 3 than in Reach 4. Reach 3 also contains more backwater habitat areas (e.g., upstream of the Tonkawatla Creek confluence, behind the islands upstream of the Centennial Park Boat Launch, upstream of the Illecillewaet River confluence, and immediately downstream of the Rock Groyne; Appendix A, Figure A2) that are suitable for rearing and feeding.

Sucker species density was lower during the spring survey than in the fall. However, most of the Sucker species recorded during the spring season were in spawning condition (i.e., with tubercles or spawning colours). Sucker species in spawning condition were most commonly recorded in Site 229.7-R (between Big Eddy Bridge and the Tonkawatla Creek confluence).

Density of Sucker species at Site 227.2-R (Salmon Rocks) was greater relative to other sites after the implementation of minimum flows than before. As Site 227.2-R is the furthest site downstream, the effects the flow regime change would be expected to be smaller relative to other sites due to the moderating effects of the reservoir. Therefore, increased usage of habitat in Site 227.2-R by Sucker species in 2011 and 2012 was likely related to factors other than minimum flows, such as higher than normal discharge and reservoir levels in these years. No other clear changes in the spatial distribution of Sucker species were observed, which suggests that the flow regime change likely did not have a significant impact on Sucker distribution in the MCR.

4.6.7 Northern Pikeminnow

Overall, Northern Pikeminnow densities were low compared to other species, but slightly higher in Reach 3 than in Reach 4. Credible intervals overlapped for all estimates, but densities for this species were generally higher in sites that contained backwater habitat areas or had lower water velocities, such as Site 228.5-L (upstream of the Illecillewaet River confluence), Site 231.3-L (Big Eddy), Site 227.2-R (Salmon Rocks), and Site 229.2-L (between the Rock Groyne and the Centennial Park Boat Launch). This distribution reflects this species preference for low velocity habitats (Scott and Crossman 1973).

Northern Pikeminnow were more abundant in the MCR during the fall season than during the spring season. Given the large size of the Northern Pikeminnow present during the fall season, it is possible that these fish were in the study area to feed on spawning Kokanee. Although the density of Northern Pikeminnow varied during the study period, there were no apparent changes in their spatial distribution due to the flow regime change.

4.6.8 Sculpin Species

Overall, Sculpin species densities were highest in Big Eddy and along the rip-rap on the left bank of Reach 3. Of the Sculpin species captured in the fall since 2010, 98% were Prickly Sculpin (*n* = 113) and 2% were Slimy Sculpin (*Cottus bairdii*) (*n* = 2). During spring sampling, 88% were Prickly Sculpin (*n* = 72) and 12% were Slimy Sculpin (*n* = 10). Of all Sculpin caught since 2010, 75% of the Slimy Sculpin were caught in Reach 3. Slimy Sculpin could be more common in Reach 3 than in Reach 4, or, alternatively, slower water velocity or other habitat differences may make capturing Sculpin more efficient in Reach 3 than in Reach 4. Spatial distribution of Sculpin species based on density estimates did not suggest any changes related to the flow regime change.

4.7 Summary

Information regarding the abundance, spatial distribution, body condition, growth, and diversity of fish species in the MCR was collected for 10 years prior to the flow regime change and has been collected for 2 years since the flow regime change. These data were analyzed using hierarchical Bayesian methods as a robust and defensible way to assess trends over time and space, and the effects of the flow regime change on fish populations. There was an increase in species richness and evenness between 2001 and 2008 which was attributed to significant increases in the abundance of several less common species. The density and/or probability of occupancy of Burbot, Lake Whitefish, Northern Pikeminnow, Rainbow Trout and Sculpin species all increased, while densities of more common species, such as Bull Trout and Mountain Whitefish remained relatively stable during this time period. Although the results suggest a substantial change in the fish community between 2001 and 2008, reasons for the change are unknown, and increasing fish densities were not strongly correlated with environmental variables including discharge, reservoir elevation, or water temperature.

With only two years of data following the flow regime change, it is not possible to draw strong conclusions about its effect on fish populations. In general, the abundance of most species was stable or within the range of previously observed fluctuations. However, there was some evidence to suggest that conditions for growth or abundance of juvenile fish in the MCR may have declined in the two years following the flow regime change. The two cohorts of juvenile Mountain Whitefish that were rearing in the MCR following the flow regime change (i.e., age-0 in 2011 and age-1 in 2012, and age-0 in 2012) were noticeably less abundant compared to previous years, based on density estimates and length-frequency distributions. In addition, length-at-age of age-0 and age-1 Mountain Whitefish, and body condition of Mountain Whitefish and Bull Trout all declined to low levels in the two years following the flow regime change. The similar trends in all these variables suggest that growth was likely lower in 2011 and 2012 but the cause of the decline remains unclear. The negative correlation between absolute density of age-1 Mountain Whitefish and discharge variance suggests that increased variability in discharge following the flow regime change could have contributed to the decline in juvenile life stages. While Bull Trout condition decreased, the annual growth in fork length of Bull Trout increased following the flow regime change and was significantly correlated with two of the measures of river discharge variability. Additional years of data collection are required to assess the influence of environmental variables, and whether the change in operations at REV contributed to any of the observed differences in fish populations.

Large data gaps still exist for all fish species that were not intensively monitored from 2001 to 2009 (i.e., all species except Bull Trout, Mountain Whitefish, and Rainbow Trout); however, long-term patterns and trends for some or most of these species are expected to become clearer with each successive sample year. Low catch-rates for Brook Trout, Cutthroat Trout, Peamouth, Pygmy Whitefish, Yellow Perch and White Sturgeon will hamper monitoring changes for these species. In addition, the sample methods used limit the data collected, and therefore conclusions that can be made for Kokanee, Redside Shiner, and Sculpin species.

5.0 RECOMMENDATIONS

In consideration of the results of this study and the overall objectives of CLBMON-16, fish population indexing surveys should continue in future years, with the modifications recommended below.

- The feasibility of operating REV5 for extended time periods without maintaining the minimum flow release should be examined. This would provide insight into the effect on the downstream fish community of both the minimum flow release and the higher peak daily discharges associated with REV5.
- Future analyses should consider exploring relationships between fish population metrics from this program and variables from other programs of the RFMP including physical habitat variables, primary and secondary productivity, and juvenile fish metrics.
- An additional electrofishing pass should be conducted at each site during which fish would be enumerated but not captured. This enumeration pass would allow the collection of fine-scale spatial distribution data (by geo-referencing the location of fish within the site using a hand-held GPS) and more accurate count data (observers would focus on counting instead of capturing). This approach would provide valuable information on the fine-scale abundance, diversity, and distribution of fish. In addition, if several years of enumeration are conducted in parallel with mark-recapture, it may eventually prove possible to calibrate the efficiency of the method and reduce the number of mark-recapture passes needed during each sample season.
- A Mountain Whitefish spawning assessment should be conducted to confirm and/or identify local spawning activity and assist in identifying the source of age-0 Mountain Whitefish found in the study area. This information would confirm whether flow regime changes or other dam operations may influence spawning success of Mountain Whitefish, which would be expected to influence abundance of this species in the MCR.
- Aerial surveys should be conducted during the Rainbow Trout spawning season to determine the extent of mainstem spawning for this species. This would provide insight into whether Rainbow Trout are spawning in the MCR or migrating into tributaries to spawn, which is important when assessing whether minimum flows or other dam operations influence spawning and early life history survival of Rainbow Trout.
- The feasibility of monitoring the benthos upstream and downstream of the Tonkawatla Creek confluence should be explored. These data may help explain the high body condition values recorded for Rainbow Trout near Salmon Rocks.

6.0 LITERATURE CITED

Arndt, S. and J. Baxter. 2006. Status of Burbot (*Lota lota*) in Arrow Lakes Reservoir. Report for the Columbia Basin Fish and Wildlife Compensation Program, March 2006. Nelson, BC. v + 30pp.

BC Hydro. 1999. Revelstoke dam and generating station water use plan. Prepared by BC Hydro Power Supply, Vancouver, BC. Report no. MEP341. 37 p. + 4 app.

BC Hydro. 2005. Consultative Committee report: Columbia River Water Use Plan, Volumes 1 and 2. Report prepared for the Columbia River Water Use Plan Consultative Committee by BC Hydro, Burnaby BC.

BC Hydro. 2007. Columbia River Projects, Water Use Plan. 41 p. + 1 appendix.

BC Hydro. 2010. Columbia River Project Water Use Plan, Monitoring Program Terms of Reference, REVELSTOKE FLOW MANAGEMENT PLAN, CLBMON-16 Middle Columbia River Fish Population Surveys Revisions. Reference Number: RFP-386. 12 May 2010. 13 p.

Boulinier, T., J.D. Nichols, J.R. Sauer, J.E. Hines, and K.H. Pollock. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79: 1018-1028.

Bradford, M.J., J. Korman and P.S. Higgins. 2005. Using confidence intervals to estimate the response of salmon populations (*Oncorhynchus* spp.) to experimental habitat alterations. Canadian Journal of Fisheries and Aquatic Sciences 62: 2716-2726.

Environment Canada. 2013. National Climate Data and Information Archive. Available: http://climate.weatheroffice.gc.ca/climateData/canada_e.html. (May 2013).

Fabens, A.J. 1965. Properties and fitting of the von Bertalanffy growth curve. Growth 29: 265-289.

Ford, D. and J.L. Thorley. 2011a. CLBMON-16 Middle Columbia River Fish Population Indexing Surveys – 2010 Investigations. Report prepared by BC Hydro Generation, Water Licence Requirements, Revelstoke, BC. Golder Report No. 10-1492-0079F: 54 p. + 5 app.

Ford, D. and J.L. Thorley. 2011b. CLBMON-45 Lower Columbia River Fish Population Indexing Surveys – 2010 Investigations. Report prepared by BC Hydro Generation, Water Licence Requirements, Castlegar, BC. Golder Report No. 10-1492-0102F: 54 p. + 5 app.

Ford, D. and J.L. Thorley. 2012. CLBMON-16 Middle Columbia River Fish Population Indexing Surveys – 2011 Investigations. Report prepared by BC Hydro Generation, Water Licence Requirements, Revelstoke, BC. Golder Report No. 10-1492-0079F: 55 p. + 5 app.

Ford, B.S., P.S. Higgins, A.F. Lewis, K.L. Cooper, T.A. Watson, C.M. Gee, G.L. Ennis, and R.L. Sweeting. 1995. Literature reviews of the life history, habitat requirements and mitigation/compensation strategies for thirteen sport fish species in the Peace, Liard, and Columbia River drainages of British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2321: xxiv + 342 p.

Gelfand, A.E., A.M. Schmidt, S. Wu, J.A Silander, A. Latimer, A.G. Rebelo. 2005. Modelling species diversity through species level hierarchical modelling. Journal of the Royal Statistical Society - Series C - Applied Statistics 54: 1-20.

Godfrey, H. 1955. On the ecology of the Skeena River whitefishes *Coregonus* and *Prosopium*. Journal of the Fisheries Research Board of Canada 12: 488-527.

Golder Associates Ltd. 2002. Middle Columbia River Fish Indexing Program. 2001 Phase 1 investigations. Report prepared for BC Hydro, Burnaby, B.C. Golder Report No. 012-8006F: 41p + 4 app.

Golder Associates Ltd. 2003. Large River Fish Indexing Program – Middle Columbia River 2002 Phase 2 Investigations. Report prepared for B.C. Hydro Power Supply Environmental Services, Burnaby, B.C. Golder Report No. 022-8024F: 39p + 4 app.

Golder Associates Ltd. 2004a. Large River Fish Indexing Program – Middle Columbia River 2003 Phase 3 Investigations. Report prepared for B.C. Hydro Power Supply Environmental Services, Burnaby, B.C. Golder Report No. 03-1480-022F: 53p + 4 app.

Golder Associates Ltd. 2004b. Large River Fish Indexing Program – Lower Columbia River 2003 Phase 3 Investigations. Report prepared for B.C. Hydro, Burnaby, B.C. Golder Report No. 03-1480-021F: 54p + 6 app.

Golder Associates Ltd. 2005a. Large River Fish Indexing Program – Middle Columbia River 2004 Phase 4 Investigations. Report prepared for B.C. Hydro Power Supply Environmental Services, Burnaby, B.C. Golder Report No. 04-1480-048F: 66p + 5 app.

Golder Associates Ltd. 2005b. Large River Fish Indexing Program – Lower Columbia River 2004 Phase 4 Investigations. Report prepared for B.C. Hydro, Burnaby, B.C. Golder Report No. 04-1480-047F: 57p + 6 app.

Golder Associates Ltd. 2006. Large River Fish Indexing Program – Middle Columbia River 2005 Phase 5 Investigations. Report prepared for B.C. Hydro Power Supply Environmental Services, Burnaby, B.C. Golder Report No. 05-1480-037F: 51p + 6 app.

Golder Associates Ltd. 2007. Large River Fish Indexing Program – Middle Columbia River 2006 Phase 6 Investigations. Report prepared for B.C. Hydro Power Supply Environmental Services, Burnaby, B.C. Golder Report No. 06-1480-032F: 52p + 6 app.

Golder Associates Ltd. 2008. Large River Fish Indexing Program – Middle Columbia River 2007 Phase 7 Investigations. Report prepared for B.C. Hydro Power Supply Environmental Services, Burnaby, B.C. Golder Report No. 07-1480-068F: 60p + 6 app.

Golder Associates Ltd. 2009. Large River Fish Indexing Program – Middle Columbia River 2008 Phase 8 Investigations. Report prepared for B.C. Hydro Power Supply Environmental Services, Burnaby, B.C. Golder Report No. 08-1480-047F: 49p + 6 app.

Golder Associates Ltd. 2010. Large River Fish Indexing Program – Middle Columbia River 2009 Phase 9 Investigations. Report prepared for B.C. Hydro Power Supply Environmental Services, Burnaby, B.C. Golder Report No. 09-1480-050F: 64p + 4 app.

Golder Associates Ltd. 2012. Lower Columbia River whitefish life history and egg mat monitoring program: Year 4 data report. Report prepared for BC Hydro, Castlegar, BC. Golder Report No. 11-1492-0111F: 48p + 3 app.

Golder Associates Ltd. In preparation. CLBMON-15a Mid-Columbia River Physical Habitat Monitoring Synthesis Report (Years 1-6). Report prepared for BC Hydro, Revelstoke, BC. Golder Report No. 12-1492-0084. 41 p. + 6 app.

Gotelli N.J. and R.K. Colwell. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4: 379-391.

He, J.X., J.R. Bence, J.E. Johnson, D.F. Clapp and M.P. Ebener. 2008. Modeling Variation in Mass-Length Relations and Condition Indices of Lake Trout and Chinook Salmon in Lake Huron: a Hierarchical Bayesian Approach. Transactions of the American Fisheries Society 137: 801-817.

Kery, M. and J.A. Royle. 2008. Hierarchical Bayes estimation of species richness and occupancy in spatially replicated surveys. Journal of Applied Ecology 45: 589-598.

Kery, M. and M. Schaub. 2011. Bayesian population analysis using WinBUGS – a hierarchical perspective. Academic Press, Burlington.

Krebs, C.J. 1999. Ecological Methodology. Addison Wesley, Longman, Menlo Park, California.

LGL Limited. 2009. Arrow Lakes Reservoir Burbot Life History and Habitat Use Study. Year 1. Report prepared for BC Hydro, Revelstoke, BC. 35 p. + 1 app.

Mackay, W.C., G.R. Ash and H.J. Norris. 1990. Fish ageing methods for Alberta. R.L. & L. Environmental Services Ltd. in association with Alberta and Wildlife Division and University of Alberta, Edmonton. 133p.

Macdonald, P.D.M and T. J. Pitcher. 1979. Age-groups from size-frequency data: A versatile and efficient method of analyzing distribution mixtures. Journal of the Fisheries Research Board of Canada 36:987-1001.

McPhail, J.D. 2007. The Freshwater Fishes of British Columbia. University of Alberta Press, Edmonton, AB. pp. 620.

Nelson, J.S. and M.J. Paetz. 1992. The fishes of Alberta. 2nd Edition. The University of Alberta Press. Edmonton Alberta.

Perrin, C.J., J. Korman, and D. Schmidt. 2004. A monitoring protocol for benthic invertebrates and periphyton in the middle and lower Columbia River. Report prepared by Limnotek Research and Development Inc., Econometric Research Ltd. and Golder Associates Ltd. for BC Hydro. 59p.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131-144.

Plummer, M. 2003. JAGS: A Program for Analysis of Bayesian Graphical Models Using Gibbs Sampling, Proceedings of the 3rd International Workshop on Distributed Statistical Computing (DSC 2003), March 20–22, Vienna, Austria. ISSN 1609-395X

Province of British Columbia. 2013. Ministry of Forests, Lands, and Natural Resource Operations. River Forecast Centre. Available: http://bcrfc.env.gov.bc.ca/bulletins/watersupply/archive.htm. (May 2013).

R.L. & L. Environmental Services Ltd. 1994. Fish stock and habitat assessments of the Columbia River below Revelstoke Canyon Dam. Report prepared for BC Hydro, Environmental Resources. R.L. & L. Report No. 340F: 99 p. + app.

R.L. & L. Environmental Services Ltd. 1995. Fish habitat utilization and productive capacity of the Columbia River below Revelstoke Canyon Dam. Draft report prepared for BC Hydro, Environmental Affairs. R.L. & L. Rep. No. 419D: 96 p. + 3 app.

Schleppe, J., H. Larratt, and M.A. Olson-Russello. 2011. CLBMON-15b Middle Columbia River Ecological Productivity Monitoring, Annual Report 2010. Ecoscape Environmental Consultants Ltd. & Larratt Aquatic Consulting Ltd. Ecoscape File No. 10-599 Kelowna, BC.

Scott, W.B. and E.J. Crossman 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184:1-966.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. The University of Illinois Press, Urbana. 177pp.

Taylor, M. and B. Lewis. 2011. CLBMON-18 Middle Columbia River Adult Fish Habitat Use Program. Study Period: Year 3 – 2010. Golder Associates (Castlegar, BC) and Carleton University (Ottawa, ON). Report prepared for BC Hydro, Revelstoke Flow Management Plan, Golder Project No. 10-1492-0082. 81p. + 2 app.

Thorley, J.L. and J.T.A. Baxter. 2012. WLR Monitoring Study No. CLBMON-46 (Year 4) Lower Columbia River Rainbow Trout Spawning Assessment. Columbia River Water Use Plan. BC Hydro, Castlegar. Mountain Water Research and Poisson Consulting Ltd.

Triton Environmental Consultants Ltd. 2009. Middle Columbia River Juvenile Fish Habitat Use (Year 1) CLBMON-17. Report prepared for B.C. Hydro Columbia River Project Water Use Plan, Revelstoke, B.C. Triton Project No. 3943: 45p + 6 app.

Triton Environmental Consultants Ltd. 2010. Middle Columbia River Juvenile Fish Habitat Use (Year 2) CLBMON-17. Report prepared for B.C. Hydro Columbia River Project Water Use Plan, Revelstoke, B.C. Triton Project No. 3943: 48p + 6 app.

Triton Environmental Consultants Ltd. 2011. Middle Columbia River Juvenile Fish Habitat Use (Year 3) CLBMON-17. Report prepared for B.C. Hydro Columbia River Project Water Use Plan, Revelstoke, B.C. Triton Project No. 3943: 51p + 6 app.

Triton Environmental Consultants Ltd. 2012. Middle Columbia River Juvenile Fish Habitat Use (Year 4) CLBMON-17. Report prepared for B.C. Hydro Columbia River Project Water Use Plan, Revelstoke, B.C. Triton Project No. 4471: 59p + 6 app.

von Bertalanffy, L. 1938. A quantitative theory of organic growth (inquiries on growth laws ii). Human Biology 10:181-213.

7.0 CLOSURE

We trust that this report meets your current requirements. If you have any further questions, please do not hesitate to contact the undersigned.

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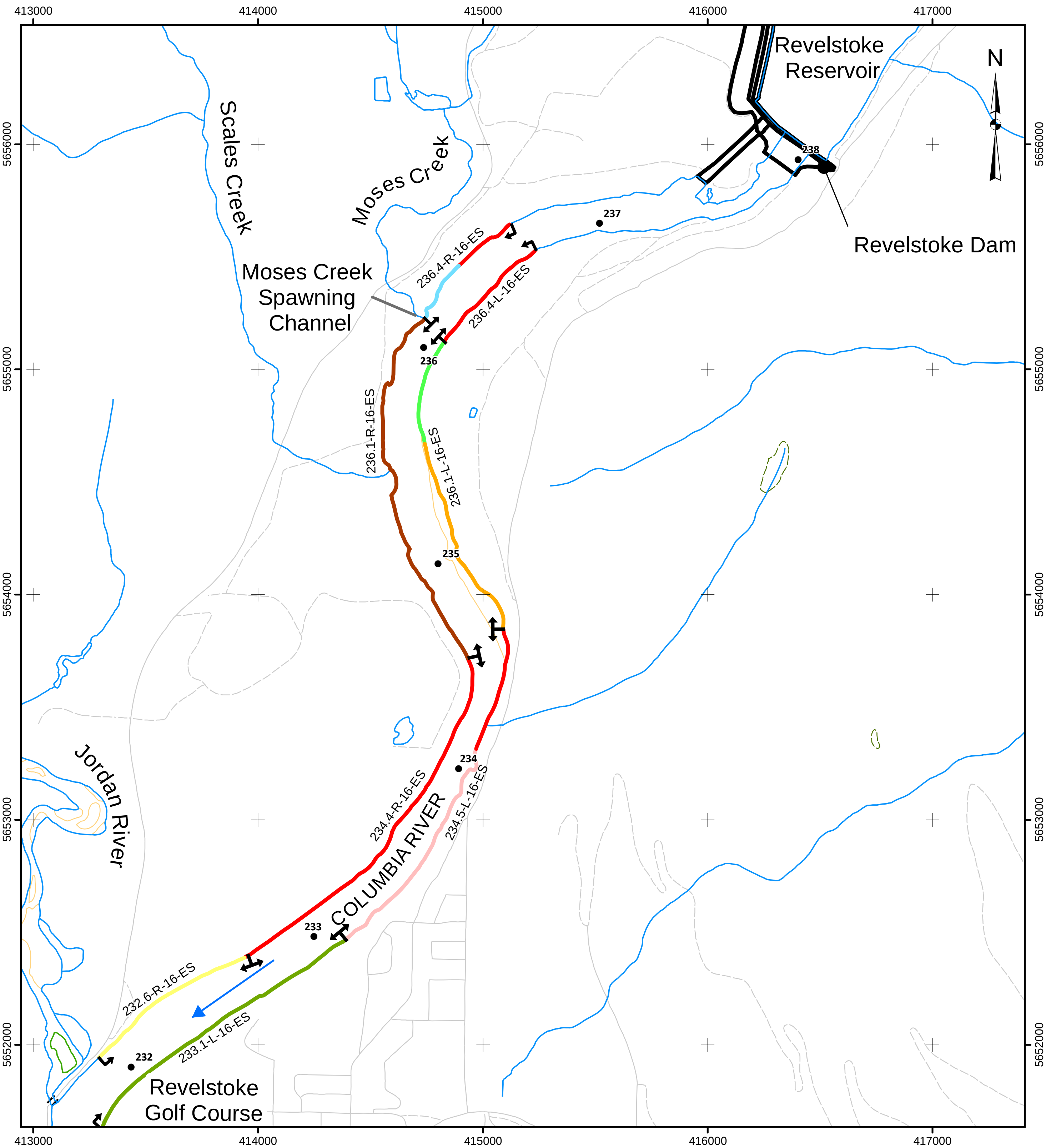
APPENDIX A

Maps and UTM Coordinates

Table A1 Locations and distances from Revelstoke Dam of boat electroshocking sites in the Middle Columbia River, 2012.

Site Designation[a]	Location (km)[b]	Bank[c]	UTM Coordinates		
			Zone	Easting	Northing
Reach 4					
236.4-R-16-ES U/S	236.4	Right	11U	415126	5655641
236.4-R-16-ES D/S	236.1	Right	11U	414721	5655227
236.4-L-16-ES U/S	236.4	Left	11U	415228	5655538
236.4-L-16-ES D/S	236.1	Left	11U	414821	5655127
236.1-L-16-ES U/S	236.1	Left	11U	414821	5655127
236.1-L-16-ES D/S	234.5	Left	11U	415048	5653833
236.1-R-16-ES U/S	236.1	Right	11U	414721	5655227
236.1-R-16-ES D/S	234.4	Right	11U	414936	5653705
234.4-R-16-ES U/S	234.4	Right	11U	414936	5653705
234.4-R-16-ES D/S	232.6	Right	11U	413944	5652387
234.5-L-16-ES U/S	234.5	Left	11U	415048	5653833
234.5-L-16-ES D/S	233.1	Left	11U	414048	5652251
233.1-L-16-ES U/S	233.1	Left	11U	414380	5652467
233.1-L-16-ES D/S	231.6	Left	11U	413294	5651640
232.6-R-16-ES U/S	232.6	Right	11U	413944	5652387
232.6-R-16-ES D/S	231.9	Right	11U	413292	5651941
Reach 3					
231.3-R-16-ES U/S	231.3	Right	11U	413030	5651196
231.3-R-16-ES D/S	231.2	Right	11U	413333	5651079
231.0-L-16-ES U/S	231.0	Left	11U	413408	5651353
231.0-L-16-ES D/S	229.3	Left	11U	415023	5650860
231.0-R-16-ES U/S	231.0	Right	11U	413418	5651133
231.0-R-16-ES D/S	229.7	Right	11U	414486	5651009
229.7-R-16-ES U/S	229.7	Right	11U	414486	5651009
229.7-R-16-ES D/S	227.3	Right	11U	414436	5648973
229.2-L-16-ES U/S	229.2	Left	11U	415089	5650679
229.2-L-16-ES D/S	228.5	Left	11U	415608	5650080
228.5-L-16-ES U/S	228.5	Left	11U	415608	5650080
228.5-L-16-ES D/S	227.4	Left	11U	414942	5649059
227.2-R-16-ES U/S	227.2	Right	11U	414474	5648871
227.2-R-16-ES D/S	226.9	Right	11U	414804	5648490

[a] U/S = Upstream limit of site; D/S = Downstream limit of site.
[b] River kilometres measured upstream from the Canada-U.S. border.
[c] Bank location as viewed facing downstream.



LEGEND

●	RIVER KILOMETRES FROM U.S. BORDER
	DAM BASE
	ISLAND
	WETLAND
	SAND OR GRAVEL BAR
	WATERCOURSE
	ROUGH ROAD
	PAVED ROAD
	AIR FACILITY
	ROAD BRIDGE

DIRECTION OF FLOW

BANK HABITAT TYPE

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

500 250 0 500

SCALE 1:24,000 METRES

REFERENCE

TRIM MAPS PROVIDED BY BC HYDRO
PROJECTION: UTM ZONE 11 N DATUM: NAD 83

PROJECT
MIDDLE COLUMBIA RIVER FISH POPULATION INDEXING SURVEY

TITLE
BANK HABITAT TYPE AND SAMPLE LOCATIONS
REACH 4

Golder Associates
Castlegar, British Columbia

PROJECT No. 10-1492-0079			SCALE AS SHOWN	REV. 0
DESIGN	DF	14 Feb. 2012	FIGURE A1	
GIS	AL	14 Feb. 2012		
CHECK	DF	22 Apr. 2013		
REVIEW	LH	22 Apr. 2013		

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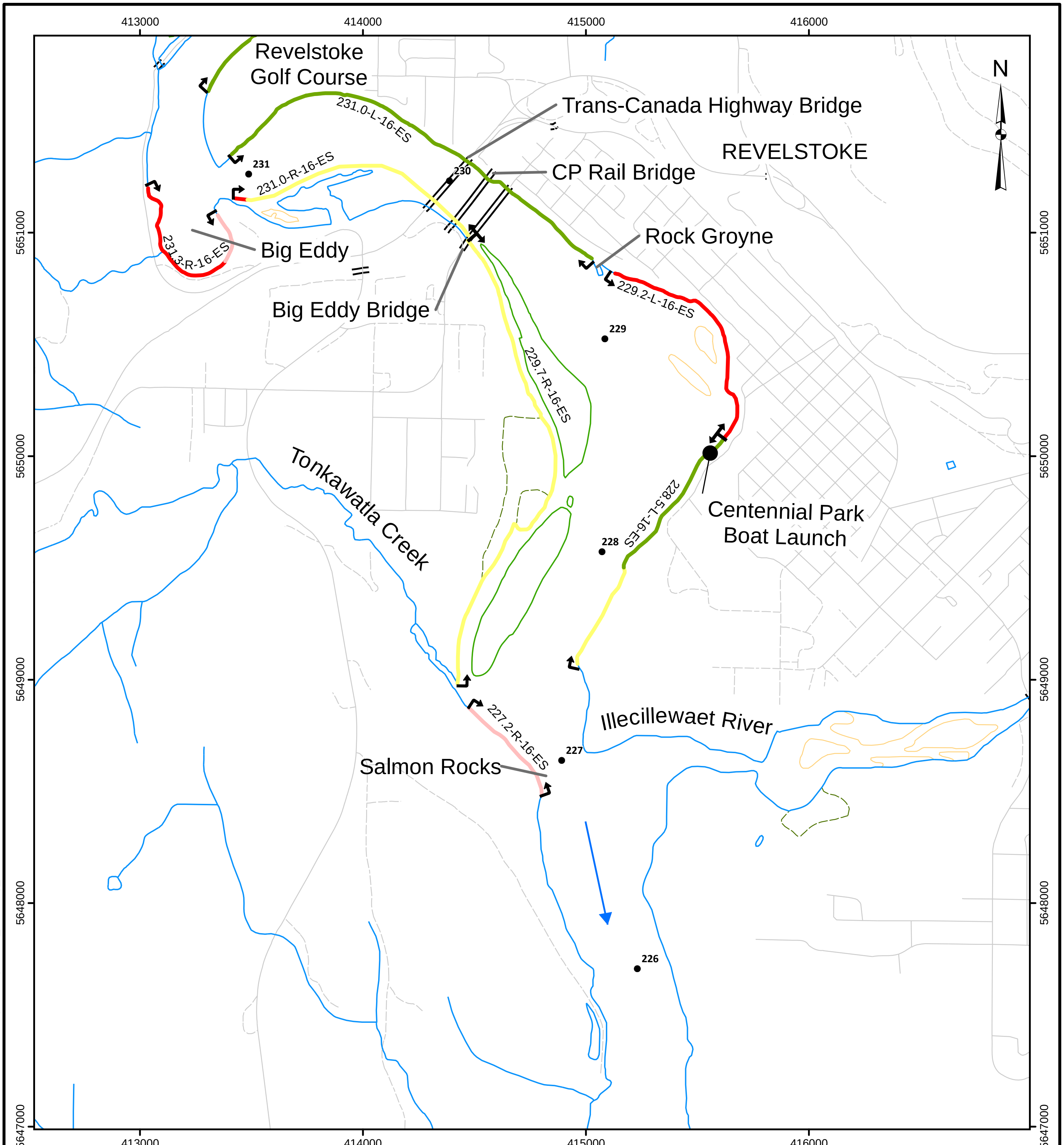

LEGEND

- RIVER KILOMETRES FROM U.S. BORDER
- DAM BASE
- ISLAND
- WETLAND
- SAND OR GRAVEL BAR
- WATERCOURSE
- ROUGH ROAD
- PAVED ROAD
- AIR FACILITY
- ROAD BRIDGE
- DIRECTION OF FLOW

BANK HABITAT TYPE

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

REFERENCE

TRIM MAPS PROVIDED BY BC HYDRO
PROJECTION: UTM ZONE 11 N DATUM: NAD 83

500 250 0 500
SCALE 1:24,000 METRES

PROJECT
MIDDLE COLUMBIA RIVER FISH POPULATION INDEXING SURVEY

TITLE
BANK HABITAT TYPE AND SAMPLE LOCATIONS
REACH 3

Golder Associates
Castlegar, British Columbia

PROJECT No. 10-1492-0079			SCALE AS SHOWN	REV. 0
DESIGN	DF	14 Feb. 2012	FIGURE A2	
GIS	AL	14 Feb. 2012		
CHECK	DF	22 Apr. 2013		
REVIEW	LH	22 Apr. 2013		

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APPENDIX B

Habitat Summary Information

Table B1 Descriptions of categories used in the Middle 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 Lengths of bank habitat types within boat electroshocking sites in the Middle Columbia River, 2012.

Reach	Site[a]	Length (m) of Bank Habitat Type[b]								Total Length (m)
		A1	A3	A4	A5	A6	A1+A2	D1	D2	
4	236.4-R-16-ES	296		298						**594**
	236.4-L-16-ES	581								**581**
	236.1-L-16-ES		482						928	**1410**
	236.1-R-16-ES						1733			**1733**
	234.4-R-16-ES	1736								**1736**
	234.5-L-16-ES	559			1095					**1654**
	233.1-L-16-ES					1408				**1408**
	232.6-R-16-ES							796		**796**
Reach 4 Total		**3172**	**482**	**298**	**1095**	**1408**	**1733**	**796**	**928**	**9911**
3	231.3-R-16-ES	665			231					**896**
	231.0-L-16-ES					1964				**1964**
	231.0-R-16-ES	55						1138		**1193**
	229.7-R-16-ES							2270		**2270**
	229.2-L-16-ES	1101								**1101**
	228.5-L-16-ES					742		489		**1231**
	227.2-R-16-ES				519					**519**
Reach 3 Total		**1820**	**0**	**0**	**751**	**2706**	**0**	**3897**	**0**	**9173**
Grand Total		**4992**	**482**	**298**	**1845**	**4114**	**1733**	**4693**	**928**	**19 085**

[a] See Appendix A, Figures A1 and A2 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, 28 May to 22 June 2012.

Reach	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	Terrestrial Vegetation	Shallow Water	Deep Water	Other Cover
4	236.4-L-16-ES	1	14	6	140	Overcast	High	High	High	100	0	0	0	0	0	0
4	236.4-L-16-ES	2	12.5	6.3	140	Overcast	Medium	Low	High	50	0	0	0	20	30	0
4	236.4-L-16-ES	3	14	5	120	Partly cloudy	High			0	0	0	0	0	0	0
4	236.4-L-16-ES	4	10	5.8	120	Clear	High	High	High	80	0	0	0	20	0	0
4	236.4-R-16-ES	1	18	6	140	Overcast	High	High	High	80	0	10	0	10	0	0
4	236.4-R-16-ES	2	12.5	6.7	140	Overcast	Medium	Medium	High	30	0	20	0	20	30	0
4	236.4-R-16-ES	3	15	5	120	Partly cloudy	High	High	High	50	0	10	0	20	20	0
4	236.4-R-16-ES	4	12	5.8	120	Partly cloudy	High	High	Medium	50	0	20	0	10	20	0
4	236.1-L-16-ES	1	10	6	140	Overcast	High	Medium	High	100	0	0	0	0	0	0
4	236.1-L-16-ES	2	12	6.3	140	Overcast	Medium	Low	High	20	5	0	0	25	50	0
4	236.1-L-16-ES	3	10	5.4	120	Partly cloudy	High	High	High	0	0	0	0	20	20	60
4	236.1-L-16-ES	4	9	5.8	120	Clear	High	High	High	60	5	10	0	5	20	0
4	236.1-R-16-ES	1	12	6	140	Overcast	High	High	High	80	0	5	0	10	5	0
4	236.1-R-16-ES	2	12	6.3	140	Overcast	Medium	Low	High	50	5	2	0	20	23	0
4	236.1-R-16-ES	3	12	5.4	120	Partly cloudy	High	High	Medium	20	0	20	0	0	40	20
4	236.1-R-16-ES	4	10	6.3	120	Clear	High	Medium	Medium	30	0	10	0	30	30	0
4	234.4-R-16-ES	1	12	5.6	130	Partly cloudy	High	High	High	80	20	0	0	0	0	0
4	234.4-R-16-ES	2	9	5.5	120	Overcast	High	Medium	High	30	20	0	0	10	40	0
4	234.4-R-16-ES	3	10	5.4	130	Overcast	High	Medium	High	10	10	0	0	40	0	40
4	234.4-R-16-ES	4	13	5.6	120	Clear	High	High	High	0	5	0	0	20	45	30
4	234.5-L-16-ES	1	11	5.6	130	Partly cloudy	High	High	High	90	0	5	0	0	5	0
4	234.5-L-16-ES	2	9	5.8	120	Overcast	High	Medium	High	20	5	5	0	20	50	0
4	234.5-L-16-ES	3	12	5.4	130	Overcast	High	High	High	0	0	20	0	0	80	0
4	234.5-L-16-ES	4	14	5.8	120	Clear	High	High	High	0	2	3	0	0	75	20
4	232.6-R-16-ES	1	12	5.6	130	Partly cloudy	High	High	High	100	0	0	0	0	0	0
4	232.6-R-16-ES	2	9	5.5	120	Overcast	High	Medium	High	30	15	0	0	35	20	0
4	232.6-R-16-ES	3	10	5.4	130	Overcast	High	Medium	High	20	0	0	0	80	0	0
4	232.6-R-16-ES	4	12	5.6	120	Clear	High	Medium	High	20	2	0	0	78	0	0
4	233.1-L-16-ES	1	9	5.6	130	Mostly cloudy	High	High	High	70	10	10	0	5	5	0
4	233.1-L-16-ES	2	12	6.8	140	Overcast	High	Low	High	40	10	0	0	25	25	0

continued…

[a] See Appendix A, Figures A1 and A2 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.

Reach	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	Terrestrial Vegetation	Shallow Water	Deep Water	Other Cover
4	233.1-L-16-ES	3	13	5.4	130	Overcast	Medium	High	Medium	30	5	0	0	0	25	40
4	233.1-L-16-ES	4	13	5	120	Partly cloudy	High	High	High	30	40	10	0	0	20	0
3	231.3-R-16-ES	1	10	5.6	140	Clear	High	Low	High	75	10	5	0	0	10	0
3	231.3-R-16-ES	2	12	6.8	140	Overcast	Low	Low	Low	20	40	5	0	25	10	0
3	231.3-R-16-ES	3	12	5	110	Overcast	Medium	Low	Low	0	20	0	0	0	60	20
3	231.3-R-16-ES	4	12	5	110	Partly cloudy	Medium	Medium	Low	20	50	10	0	10	10	0
3	231.0-L-16-ES	1	9	5.6	130	Overcast	High	High	High	85	0	5	0	0	10	0
3	231.0-L-16-ES	2	8	5.8	130	Overcast	High	Low	High	30	15	10	0	10	35	0
3	231.0-L-16-ES	3	10	5	100	Overcast	Medium	High	Low	20	5	0	0	0	20	55
3	231.0-L-16-ES	4	10	5.4	110	Overcast	High	Medium	Medium	60	1	4	0	0	25	10
3	231.0-R-16-ES	1	9	5.6	140	Clear	High	High	High	80	5	15	0	0	0	0
3	231.0-R-16-ES	2	12	6.8	90	Overcast	Medium	Low	Low	20	5	5	0	70	0	0
3	231.0-R-16-ES	3	10	5	100	Overcast	Medium	High	Medium	20	5	0	0	35	20	20
3	231.0-R-16-ES	4	10	5	100	Partly cloudy	High	Medium	Medium	10	10	0	0	80	0	0
3	229.7-R-16-ES	1	14	5.4	140	Clear	High	Low	High	30	30	5	5	10	20	0
3	229.7-R-16-ES	2	12	5.8	120	Overcast	High	Low	High	20	10	0	0	30	40	0
3	229.7-R-16-ES	3	10	5.4	120	Partly cloudy	High	Medium	Medium	20	20	0	5	45	0	10
3	229.7-R-16-ES	4	16	6.3	110	Clear	High	Low	Medium	20	10	0	30	20	20	0
3	229.2-L-16-ES	1	9	5.7	130	Mostly cloudy	High	Low	High	80	5	0	0	0	15	0
3	229.2-L-16-ES	2	11	5.8	120	Overcast	Medium	Low	Medium	10	20	0	0	30	40	0
3	229.2-L-16-ES	3	9	5.4	120	Partly cloudy	High	Low	Medium	45	5	0	0	30	20	0
3	229.2-L-16-ES	4	12	5.8	120	Clear	High	Low	High	10	5	0	20	20	45	0
3	228.5-L-16-ES	1	12	5.7	140	Overcast	Medium	High	High	80	5	5	0	5	5	0
3	228.5-L-16-ES	2	11	5.8	120	Overcast	Medium	Low	High	30	10	0	0	25	35	0
3	228.5-L-16-ES	3	9	5.4	110	Partly cloudy	High	High	Medium	20	10	10	0	20	40	0
3	228.5-L-16-ES	4	15	7.9	110	Clear	High	Low	High	20	10	0	20	20	0	30
3	227.2-R-16-ES	1	10	5.4	140	Clear	High	Low	High	50	0	0	0	0	50	0
3	227.2-R-16-ES	2	11	5.8	120	Overcast	High	Low	Low	5	2	0	0	0	93	0
3	227.2-R-16-ES	3	10	5.8	60	Partly cloudy	High	Medium	Low	0	1	0	0	0	50	49
3	227.2-R-16-ES	4	16	7.9	70	Clear	High	Low	Low	0	10	0	10	0	0	80

[a] See Appendix A, Figures A1 and A2 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 habitat variables recorded at boat electroshocking sites in the Middle Columbia River, 2 to 25 October 2012.

Reach	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	Terrestrial Vegetation	Shallow Water	Deep Water	Other Cover
4	236.4-L-16-ES	1	8	11.1	140	Clear	High	High	High	100	0	0	0	0	0	0
4	236.4-L-16-ES	2	14	10.4	140	Clear	High	High	High	100	0	0	0	0	0	0
4	236.4-L-16-ES	3	14	9.5	140	Overcast	High	High	High	60	0	0	0	40	0	0
4	236.4-L-16-ES	4	2	9	150	Overcast	Low	High	High	20	0	0	0	80	0	0
4	236.4-R-16-ES	1	12	10.2	150	Mostly cloudy	High	High	High	90	0	5	0	5	0	0
4	236.4-R-16-ES	2	15	10.2	140	Clear	High	High	High	90	0	5	0	0	5	0
4	236.4-R-16-ES	3	15	9.5	140	Overcast	High	High	High	80	0	10	0	0	10	0
4	236.4-R-16-ES	4	4	9	150	Overcast	Medium	High	High	80	0	10	0	0	10	0
4	236.1-L-16-ES	1	12	10.2	150	Mostly cloudy	High	High	High	100	0	0	0	0	0	0
4	236.1-L-16-ES	2	14	10.3	140	Clear	High	High	High	100	0	0	0	0	0	0
4	236.1-L-16-ES	3	12	9.5	140	Overcast	Low	High	High	100	0	0	0	0	0	0
4	236.1-L-16-ES	4	2	9	150	Overcast	Low	High	High	100	0	0	0	0	0	0
4	236.1-R-16-ES	1	8	11.1	140	Clear	High	High	High	80	0	5	3	7	5	0
4	236.1-R-16-ES	2	14	10.4	140	Clear	High	High	High	80	0	10	0	5	5	0
4	236.1-R-16-ES	3	13	9.5	140	Overcast	Low	Medium	High	75	0	5	0	10	10	0
4	236.1-R-16-ES	4	3	9	150	Overcast	Low	High	High	80	0	5	5	5	5	0
4	234.4-R-16-ES	1	10	10.1	150	Partly cloudy	High	High	High	80	5	0	0	5	10	0
4	234.4-R-16-ES	2	13	10.3	140	Clear	High	High	High	95	2	3	0	0	0	0
4	234.4-R-16-ES	3	10	10.5	140	Clear	High	Medium	High	90	10	0	0	0	0	0
4	234.4-R-16-ES	4	3	9	150	Overcast	Medium	High	High	40	20	0	40	0	0	0
4	234.5-L-16-ES	1	8	11.1	140	Clear	High	High	High	65	0	5	0	0	30	0
4	234.5-L-16-ES	2	12	10.4	140	Clear	High	High	High	20	0	20	40	0	20	0
4	234.5-L-16-ES	3	14	10.5	140	Partly cloudy	High	Medium	High	70	0	5	0	15	10	0
4	234.5-L-16-ES	4	5	9	150	Overcast	High	High	High	40	0	5	20	5	30	0
4	232.6-R-16-ES	1	7	11.1	140	Clear	High	High	High	99	1	0	0	0	0	0
4	232.6-R-16-ES	2	9	10.4	140	Clear	High	High	High	100	0	0	0	0	0	0
4	232.6-R-16-ES	3	10	10.5	140	Partly cloudy	High	Medium	High	100	0	0	0	0	0	0
4	232.6-R-16-ES	4	3	9	150	Overcast	Medium	High	High	100	0	0	0	0	0	0
4	233.1-L-16-ES	1	8	10	150	Clear	High	High	High	100	0	0	0	0	0	0
4	233.1-L-16-ES	2	12	10.4	140	Clear	High	High	High	90	0	10	0	0	0	0

continued…

[a] See Appendix A, Figures A1 and A2 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 Concluded.

Reach	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	Terrestrial Vegetation	Shallow Water	Deep Water	Other Cover
4	233.1-L-16-ES	3	10	10.5	140	Overcast	High	High	High	90	0	5	0	5	0	0
4	233.1-L-16-ES	4	0	9	150	Overcast	High	High	High	90	0	10	0	0	0	0
3	231.3-R-16-ES	1	8	9.9	150	Clear	High	Low	High	75	10	0	0	5	10	0
3	231.3-R-16-ES	2	9	10.3	140	Clear	High	High	High	70	5	10	0	5	10	0
3	231.3-R-16-ES	3	14	9	140	Clear	High	High	High	60	5	5	5	10	15	0
3	231.3-R-16-ES	4	5	9	150	Overcast	High	Low	High	60	5	5	10	5	15	0
3	231.0-L-16-ES	1	6	11.1	140	Clear	High	High	High	75	5	10	0	0	10	0
3	231.0-L-16-ES	2	14	10.1	140	Overcast	High	High	High	60	5	15	0	0	20	0
3	231.0-L-16-ES	3	13	9	140	Clear	High	High	High	80	0	5	5	0	10	0
3	231.0-L-16-ES	4	2	9	150	Overcast	High	High	High	80	0	5	5	0	10	0
3	231.0-R-16-ES	1	14	10.7	140	Clear	High	High	High	90	2	3	0	5	0	0
3	231.0-R-16-ES	2	15	10	140	Overcast	High	High	High	100	0	0	0	0	0	0
3	231.0-R-16-ES	3	9	8.5	150	Overcast	Low	High	High	90	5	0	0	0	5	0
3	231.0-R-16-ES	4	3	9	150	Overcast	High	High	High	100	0	0	0	0	0	0
3	229.7-R-16-ES	1	9	10.7	140	Clear	High	Medium	High	70	10	5	0	10	5	0
3	229.7-R-16-ES	2	14	10.3	140	Clear	High	Low	High	50	5	5	0	40	0	0
3	229.7-R-16-ES	3	4	8.5	140	Overcast	Low	Medium	Medium	70	10	0	0	10	10	0
3	229.7-R-16-ES	4	6	8	150	Clear	High	Medium	High	70	10	0	0	10	10	0
3	229.2-L-16-ES	1	6	11	140	Clear	High	Medium	High	80	5	5	0	5	5	0
3	229.2-L-16-ES	2	14	10.1	140	Overcast	High	Low	High	90	5	0	0	0	5	0
3	229.2-L-16-ES	3	10	9	140	Clear	High	Low	High	65	5	0	10	10	10	0
3	229.2-L-16-ES	4	3	9	150	Overcast	High	Low	High	75	5	0	10	0	10	0
3	228.5-L-16-ES	1	8	10.9	140	Clear	High	Low	High	100	0	0	0	0	0	0
3	228.5-L-16-ES	2	9	10.3	140	Clear	High	High	High	80	0	5	5	5	5	0
3	228.5-L-16-ES	3	8	9	140	Clear	High	High	High	70	0	0	10	10	5	5
3	228.5-L-16-ES	4	2	8	150	Clear	Low	High	High	100	0	0	0	0	0	0
3	227.2-R-16-ES	1	6	10.8	140	Clear	High	High	High	10	5	20	0	0	65	0
3	227.2-R-16-ES	2	10	10.3	140	Clear	High	High	High	40	0	10	0	0	50	0
3	227.2-R-16-ES	3	4	9.5	150	Overcast	Low	High	Medium	50	0	0	0	0	50	0
3	227.2-R-16-ES	4	4	8	150	Clear	High	High	High	30	0	10	0	0	60	0

[a] See Appendix A, Figures A1 and A2 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 B5 Summary of species counts adjacent to bank habitat types in the Middle Columbia River during the spring season, 28 May to 22 June 2012.

Reach	Site[a]	Species	Size Class	Bank Habitat Type[b]									Total
				A1	A3	A4	A5	A6	A1+A2	D1	D2	D1+D2	
4	236.4-R-16-ES	Bull Trout	Adult	28		7							35
	236.4-R-16-ES	Bull Trout	Immature	1		1							2
	236.4-R-16-ES	Cutthroat Trout	Adult	1									1
	236.4-R-16-ES	Largescale Sucker	Adult			1							1
	236.4-R-16-ES	Mountain Whitefish	Adult	91		58							149
	236.4-R-16-ES	Mountain Whitefish	Immature	71		32							103
	236.4-R-16-ES	Rainbow Trout	Adult	1									1
	236.4-R-16-ES	Sucker spp.	Adult	2									2
	Site 236.4-R-16-ES Total			**195**	**0**	**99**	**0**	**0**	**0**	**0**	**0**	**0**	**294**
	236.4-L-16-ES	Bull Trout	Adult	65									65
	236.4-L-16-ES	Bull Trout	Immature	1									1
	236.4-L-16-ES	Largescale Sucker	Adult	3									3
	236.4-L-16-ES	Longnose Sucker	Adult	2									2
	236.4-L-16-ES	Mountain Whitefish	Adult	52									52
	236.4-L-16-ES	Mountain Whitefish	Immature	29									29
	236.4-L-16-ES	Sucker spp.	Adult	4									4
	Site 236.4-L-16-ES Total			**156**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**156**
	236.1-R-16-ES	Bull Trout	Adult						180				180
	236.1-R-16-ES	Bull Trout	Immature						2				2
	236.1-R-16-ES	Burbot	Adult						3				3
	236.1-R-16-ES	Kokanee	Adult						1				1
	236.1-R-16-ES	Largescale Sucker	Adult						6				6
	236.1-R-16-ES	Longnose Sucker	Adult						3				3
	236.1-R-16-ES	Mountain Whitefish	Adult						376				376
	236.1-R-16-ES	Mountain Whitefish	Immature						294				294
	236.1-R-16-ES	Prickly Sculpin	All						1				1
	236.1-R-16-ES	Rainbow Trout	Adult						3				3
	236.1-R-16-ES	Rainbow Trout	Immature						2				2
	236.1-R-16-ES	Sculpin spp.	Adult						2				2
	236.1-R-16-ES	Sculpin spp.	All						13				13
	236.1-R-16-ES	Sucker spp.	Adult						5				5
	236.1-R-16-ES	Sucker spp.	Immature						1				1
	Site 236.1-R-16-ES Total			**0**	**0**	**0**	**0**	**0**	**892**	**0**	**0**	**0**	**892**
	236.1-L-16-ES	Bull Trout	Adult		20						72		92
	236.1-L-16-ES	Bull Trout	Immature		1								1
	236.1-L-16-ES	Burbot	Adult								1		1
	236.1-L-16-ES	Kokanee	Adult								1		1
	236.1-L-16-ES	Largescale Sucker	Adult								3		3
	236.1-L-16-ES	Mountain Whitefish	Adult		18						150		168
	236.1-L-16-ES	Mountain Whitefish	Immature		17						73		90
	236.1-L-16-ES	Rainbow Trout	Adult		3								3
	236.1-L-16-ES	Sucker spp.	Adult		1						13		14
	Site 236.1-L-16-ES Total			**0**	**60**	**0**	**0**	**0**	**0**	**0**	**313**	**0**	**373**

[a] See Appendix A, Figures A1 and A2 for sample site locations.

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

Continued…

Table B5 Continued.

Reach	Site[a]	Species	Size Class	Bank Habitat Type[b]									Total
				A1	A3	A4	A5	A6	A1+A2	D1	D2	D1+D2	
4	234.5-L-16-ES	Bull Trout	Adult	7			11						18
	234.5-L-16-ES	Kokanee	Immature	1									1
	234.5-L-16-ES	Largescale Sucker	Adult				2						2
	234.5-L-16-ES	Mountain Whitefish	Adult	53			236						289
	234.5-L-16-ES	Mountain Whitefish	Immature	17			74						91
	234.5-L-16-ES	Rainbow Trout	Adult				3						3
	234.5-L-16-ES	Sculpin spp.	All	1			6						7
	234.5-L-16-ES	Sucker spp.	Adult	1			7						8
	Site 234.5-L-16-ES Total			**80**	**0**	**0**	**339**	**0**	**0**	**0**	**0**	**0**	**419**
	234.4-R-16-ES	Bull Trout	Adult	23									23
	234.4-R-16-ES	Bull Trout	Immature	2									2
	234.4-R-16-ES	Kokanee	Adult	3									3
	234.4-R-16-ES	Lake Whitefish	Adult	1									1
	234.4-R-16-ES	Largescale Sucker	Adult	9									9
	234.4-R-16-ES	Longnose Sucker	Adult	10									10
	234.4-R-16-ES	Mountain Whitefish	Adult	223									223
	234.4-R-16-ES	Mountain Whitefish	Immature	155									155
	234.4-R-16-ES	Prickly Sculpin	All	2									2
	234.4-R-16-ES	Rainbow Trout	Adult	1									1
	234.4-R-16-ES	Sculpin spp.	All	61									60
	234.4-R-16-ES	Slimy Sculpin	All	1									1
	234.4-R-16-ES	Sucker spp.	Adult	58									58
	Site 234.4-R-16-ES Total			**549**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**548**
	233.1-L-16-ES	Bull Trout	Adult					18					18
	233.1-L-16-ES	Bull Trout	Immature					3					3
	233.1-L-16-ES	Largescale Sucker	Adult					6					6
	233.1-L-16-ES	Longnose Sucker	Adult					5					5
	233.1-L-16-ES	Mountain Whitefish	Adult					168					168
	233.1-L-16-ES	Mountain Whitefish	Immature					116					116
	233.1-L-16-ES	Peamouth	Adult					1					1
	233.1-L-16-ES	Prickly Sculpin	All					7					7
	233.1-L-16-ES	Rainbow Trout	Immature					3					3
	233.1-L-16-ES	Redside Shiner	All					1					1
	233.1-L-16-ES	Sculpin spp.	All					72					72
	233.1-L-16-ES	Slimy Sculpin	All					2					2
	233.1-L-16-ES	Sucker spp.	Adult					16					16
	Site 233.1-L-16-ES Total			**0**	**0**	**0**	**0**	**418**	**0**	**0**	**0**	**0**	**418**
	232.6-R-16-ES	Bull Trout	Adult							12			12
	232.6-R-16-ES	Largescale Sucker	Adult							8			8
	232.6-R-16-ES	Longnose Sucker	Adult							22			22
	232.6-R-16-ES	Mountain Whitefish	Adult							194			194
	232.6-R-16-ES	Mountain Whitefish	Immature							110			110
	232.6-R-16-ES	Sculpin spp.	All							1			1
	232.6-R-16-ES	Sucker spp.	Adult							96			96
	Site 232.6-R-16-ES Total			**0**	**0**	**0**	**0**	**0**	**0**	**443**	**0**	**0**	**443**
Reach 4 Total				**980**	**60**	**99**	**339**	**418**	**892**	**443**	**313**	**0**	**3543**

[a] See Appendix A, Figures A1 and A2 for sample site locations.

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

Continued…

Table B5 Continued.

Reach	Site[a]	Species	Size Class	Bank Habitat Type[b] A1	A3	A4	A5	A6	A1+A2	D1	D2	D1+D2	Total
3	231.3-R-16-ES	Bull Trout	Adult	21			1						22
	231.3-R-16-ES	Bull Trout	Immature	3									3
	231.3-R-16-ES	Largescale Sucker	Adult	2									2
	231.3-R-16-ES	Longnose Sucker	Adult	1									1
	231.3-R-16-ES	Mountain Whitefish	Adult	277			6						283
	231.3-R-16-ES	Mountain Whitefish	Immature	198			1						199
	231.3-R-16-ES	Mountain Whitefish	YOY	3									3
	231.3-R-16-ES	Prickly Sculpin	All	1									1
	231.3-R-16-ES	Rainbow Trout	Adult	7									7
	231.3-R-16-ES	Rainbow Trout	Immature	3									3
	231.3-R-16-ES	Redside Shiner	All	5									5
	231.3-R-16-ES	Sculpin spp.	All	77									77
	231.3-R-16-ES	Sucker spp.	Adult	6									6
	Site 231.3-R-16-ES Total			**604**	**0**	**0**	**8**	**0**	**0**	**0**	**0**	**0**	**612**
	231.0-R-16-ES	Bull Trout	Adult	9						58			67
	231.0-R-16-ES	Bull Trout	Immature	2						1			3
	231.0-R-16-ES	Burbot	Adult							1			1
	231.0-R-16-ES	Largescale Sucker	Adult							10			10
	231.0-R-16-ES	Longnose Sucker	Adult							21			21
	231.0-R-16-ES	Mountain Whitefish	Adult	24						586			610
	231.0-R-16-ES	Mountain Whitefish	Immature	2						267			269
	231.0-R-16-ES	Prickly Sculpin	All							1			1
	231.0-R-16-ES	Rainbow Trout	Adult							1			1
	231.0-R-16-ES	Sculpin spp.	All							1			1
	231.0-R-16-ES	Sucker spp.	Adult	5						204			209
	Site 231.0-R-16-ES Total			**42**	**0**	**0**	**0**	**0**	**0**	**1151**	**0**	**0**	**1193**
	231.0-L-16-ES	Bull Trout	Adult					17					17
	231.0-L-16-ES	Bull Trout	Immature					1					1
	231.0-L-16-ES	Kokanee	Adult					3					3
	231.0-L-16-ES	Largescale Sucker	Adult					5					5
	231.0-L-16-ES	Longnose Sucker	Adult					11					11
	231.0-L-16-ES	Mountain Whitefish	Adult					450					450
	231.0-L-16-ES	Mountain Whitefish	Immature					142					142
	231.0-L-16-ES	Rainbow Trout	Adult					2					2
	231.0-L-16-ES	Rainbow Trout	Immature					5					5
	231.0-L-16-ES	Sculpin spp.	All					4					4
	231.0-L-16-ES	Sucker spp.	Adult					95					95
	Site 231.0-L-16-ES Total			**0**	**0**	**0**	**0**	**735**	**0**	**0**	**0**	**0**	**735**
	229.7-R-16-ES	Brook Trout	Immature							1			1
	229.7-R-16-ES	Bull Trout	Adult							47			47
	229.7-R-16-ES	Bull Trout	Immature							6			6
	229.7-R-16-ES	Burbot	Adult							1			1
	229.7-R-16-ES	Kokanee	Adult							2			2
	229.7-R-16-ES	Largescale Sucker	Adult							35			35
	229.7-R-16-ES	Longnose Sucker	Adult							54			54
	229.7-R-16-ES	Mountain Whitefish	Adult							561			561
	229.7-R-16-ES	Mountain Whitefish	Immature							335			335
	229.7-R-16-ES	Peamouth	Adult							2			2
	229.7-R-16-ES	Rainbow Trout	Adult							3			3
	229.7-R-16-ES	Sculpin spp.	All							52			52
	229.7-R-16-ES	Sucker spp.	Adult							234			234
	Site 229.7-R-16-ES Total			**0**	**0**	**0**	**0**	**0**	**0**	**1333**	**0**	**0**	**1333**

[a] See Appendix A, Figures A1 and A2 for sample site locations.

Continued…

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

Table B5 Concluded.

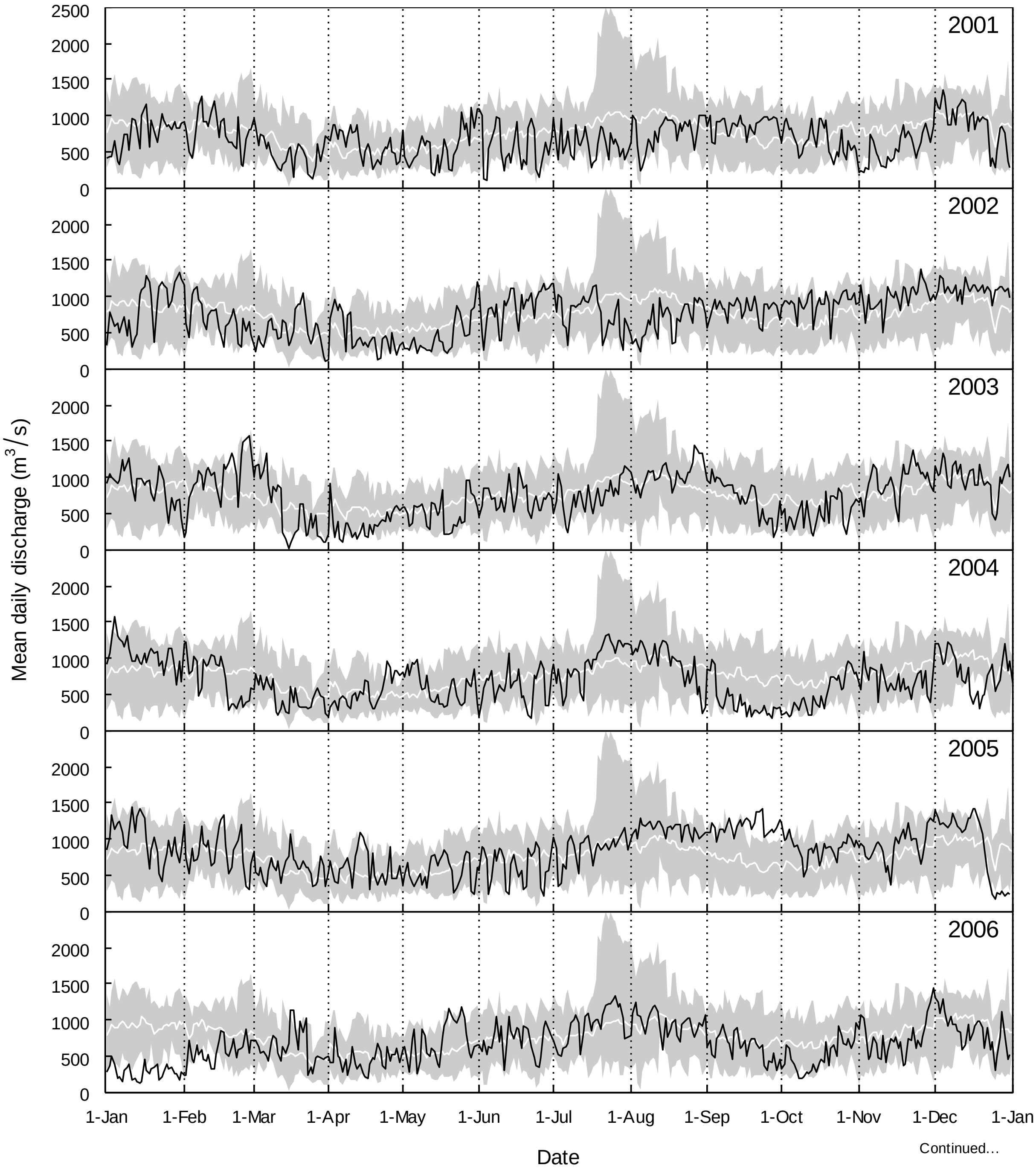
Reach	Site[a]	Species	Size Class	Bank Habitat Type[b] A1	A3	A4	A5	A6	A1+A2	D1	D2	D1+D2	Total
3	229.2-L-16-ES	Bull Trout	Adult	9									9
	229.2-L-16-ES	Bull Trout	Immature	3									3
	229.2-L-16-ES	Kokanee	Adult	2									2
	229.2-L-16-ES	Largescale Sucker	Adult	13									13
	229.2-L-16-ES	Longnose Sucker	Adult	1									1
	229.2-L-16-ES	Mountain Whitefish	Adult	234									234
	229.2-L-16-ES	Mountain Whitefish	Immature	80									80
	229.2-L-16-ES	Prickly Sculpin	All	4									4
	229.2-L-16-ES	Rainbow Trout	Adult	5									5
	229.2-L-16-ES	Rainbow Trout	Immature	5									5
	229.2-L-16-ES	Sculpin spp.	All	67									67
	229.2-L-16-ES	Slimy sculpin	All	1									1
	229.2-L-16-ES	Sucker spp.	Adult	34									34
	229.2-L-16-ES	Sucker spp.	Immature	2									2
	Site 229.2-L-16-ES Total			**460**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**460**
	228.5-L-16-ES	Bull Trout	Adult					7		5		2	14
	228.5-L-16-ES	Bull Trout	Immature							1			1
	228.5-L-16-ES	Largescale Sucker	Adult					2		4			6
	228.5-L-16-ES	Longnose Sucker	Adult							4			4
	228.5-L-16-ES	Mountain Whitefish	Adult					32		74		20	126
	228.5-L-16-ES	Mountain Whitefish	Immature					9		98		14	121
	228.5-L-16-ES	Rainbow Trout	Immature					7					7
	228.5-L-16-ES	Sculpin spp.	All					16		39		4	58
	228.5-L-16-ES	Sucker spp.	Adult					7		16		3	26
	Site 228.5-L-16-ES Total			**0**	**0**	**0**	**0**	**80**	**0**	**241**	**0**	**43**	**363**
	227.2-R-16-ES	Bull Trout	Adult				4						4
	227.2-R-16-ES	Kokanee	Immature				1						1
	227.2-R-16-ES	Largescale Sucker	Adult				19						19
	227.2-R-16-ES	Longnose Sucker	Adult				1						1
	227.2-R-16-ES	Mountain Whitefish	Adult				26						26
	227.2-R-16-ES	Mountain Whitefish	Immature				7						7
	227.2-R-16-ES	Prickly Sculpin	All				2						2
	227.2-R-16-ES	Rainbow Trout	Immature				3						3
	227.2-R-16-ES	Redside Shiner	All				4						4
	227.2-R-16-ES	Sculpin spp.	All				8						8
	227.2-R-16-ES	Sucker spp.	Adult				56						56
	Site 227.2-R-16-ES Total			**0**	**0**	**0**	**131**	**0**	**0**	**0**	**0**	**0**	**131**
Reach 3 Total				**1106**	**0**	**0**	**139**	**815**	**0**	**2725**	**0**	**43**	**4827**
Grand Total				**2086**	**60**	**99**	**478**	**1233**	**892**	**3168**	**313**	**43**	**8370**

[a] See Appendix A, Figures A1 and A2 for sample site locations.

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

APPENDIX C

Discharge, Temperature, and Water Elevation Data



Continued…

Figure C1 Mean daily discharge (m^3/s) for the Columbia River at Revelstoke Dam, 2001 to 2012. The shaded area represents minimum and maximum mean daily discharge values recorded at Revelstoke Dam during other study years (between 2001 and 2012). The white line represents average mean daily discharge values over the same time period.

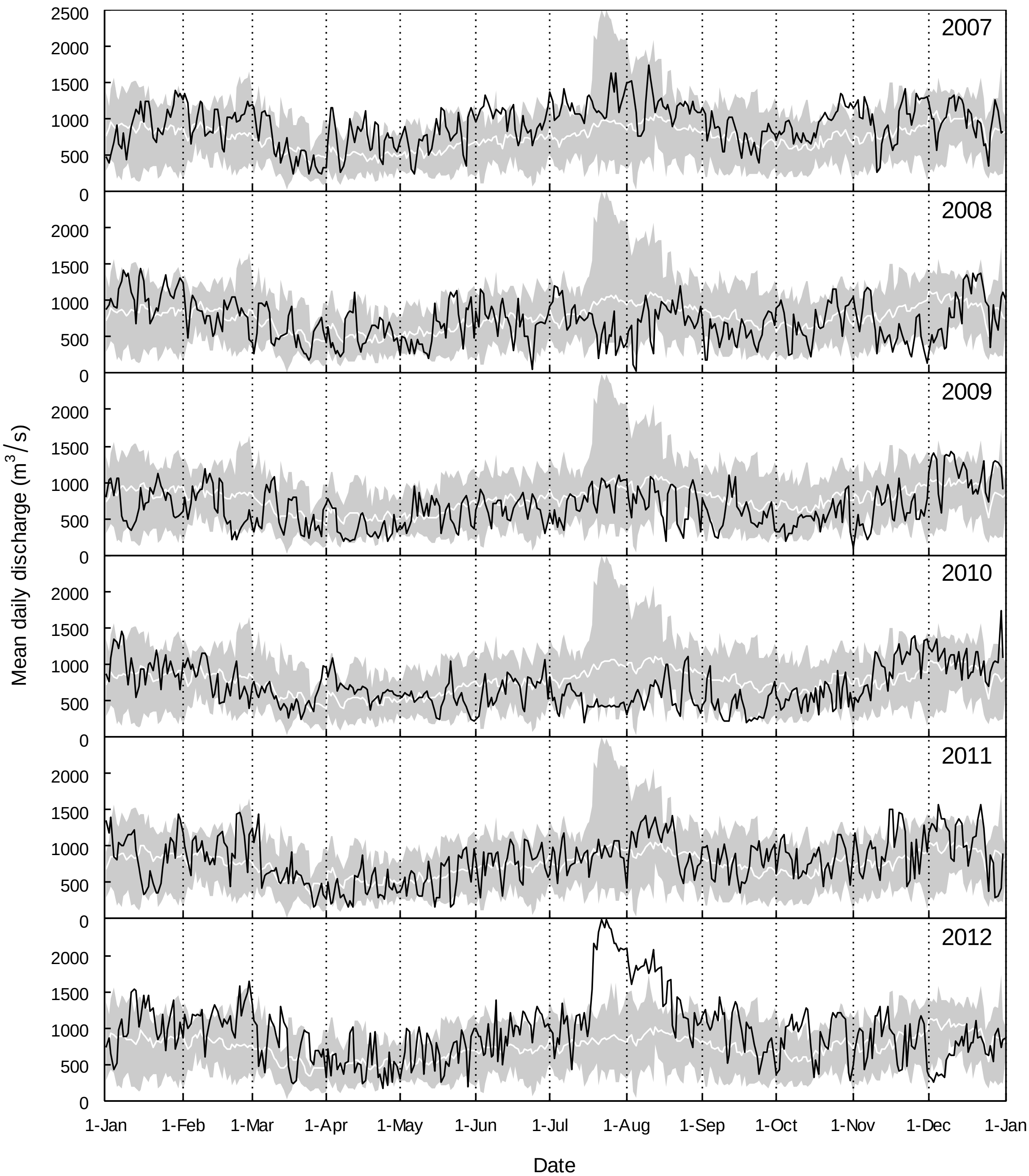


Figure C1 Concluded.

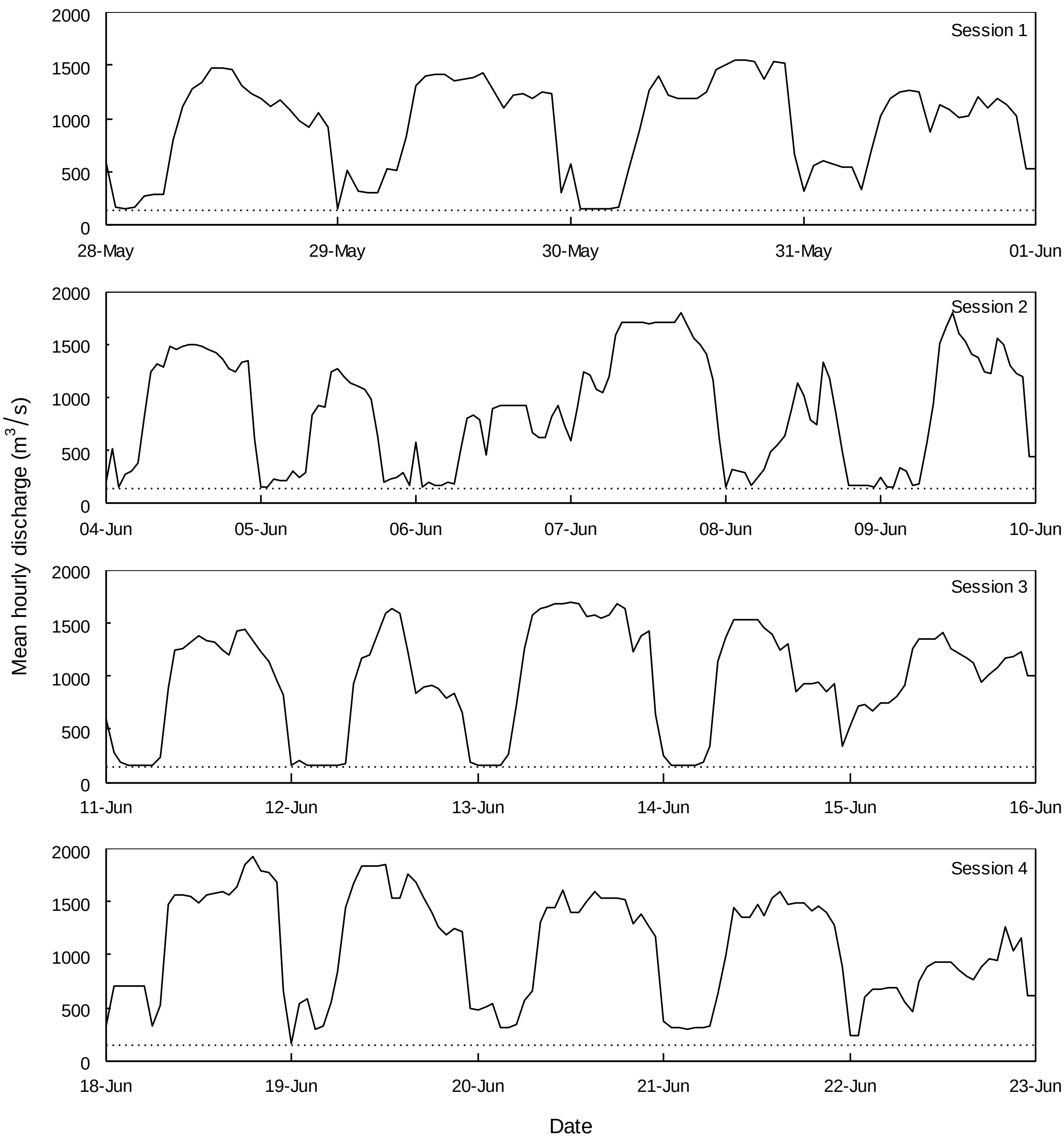


Figure C2 Mean hourly discharge (m³/s) for the Columbia River at Revelstoke Dam by sample session, May 28 to June 22, 2012. The dotted line denotes the 142 m³/s minimum flow release.

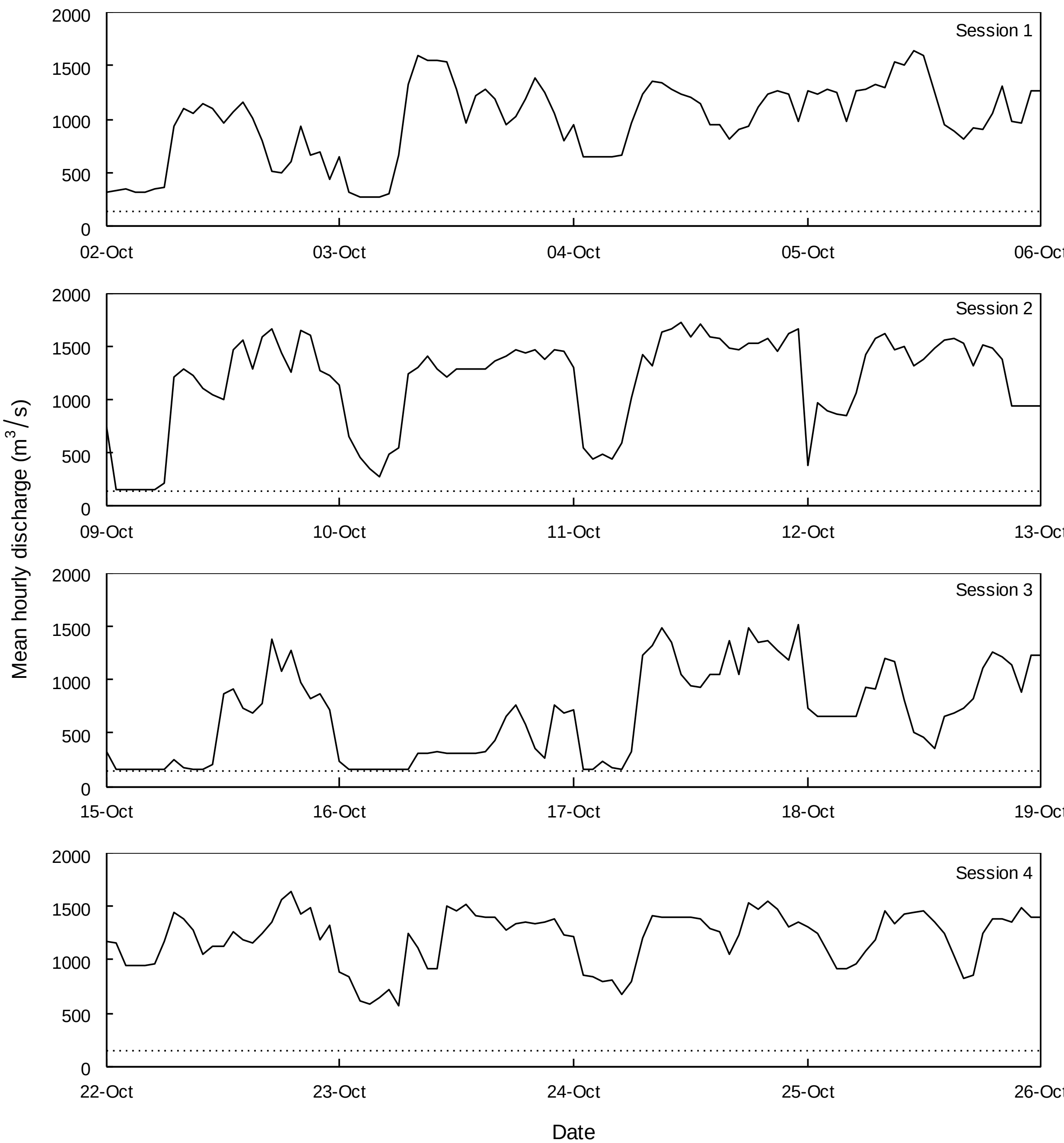
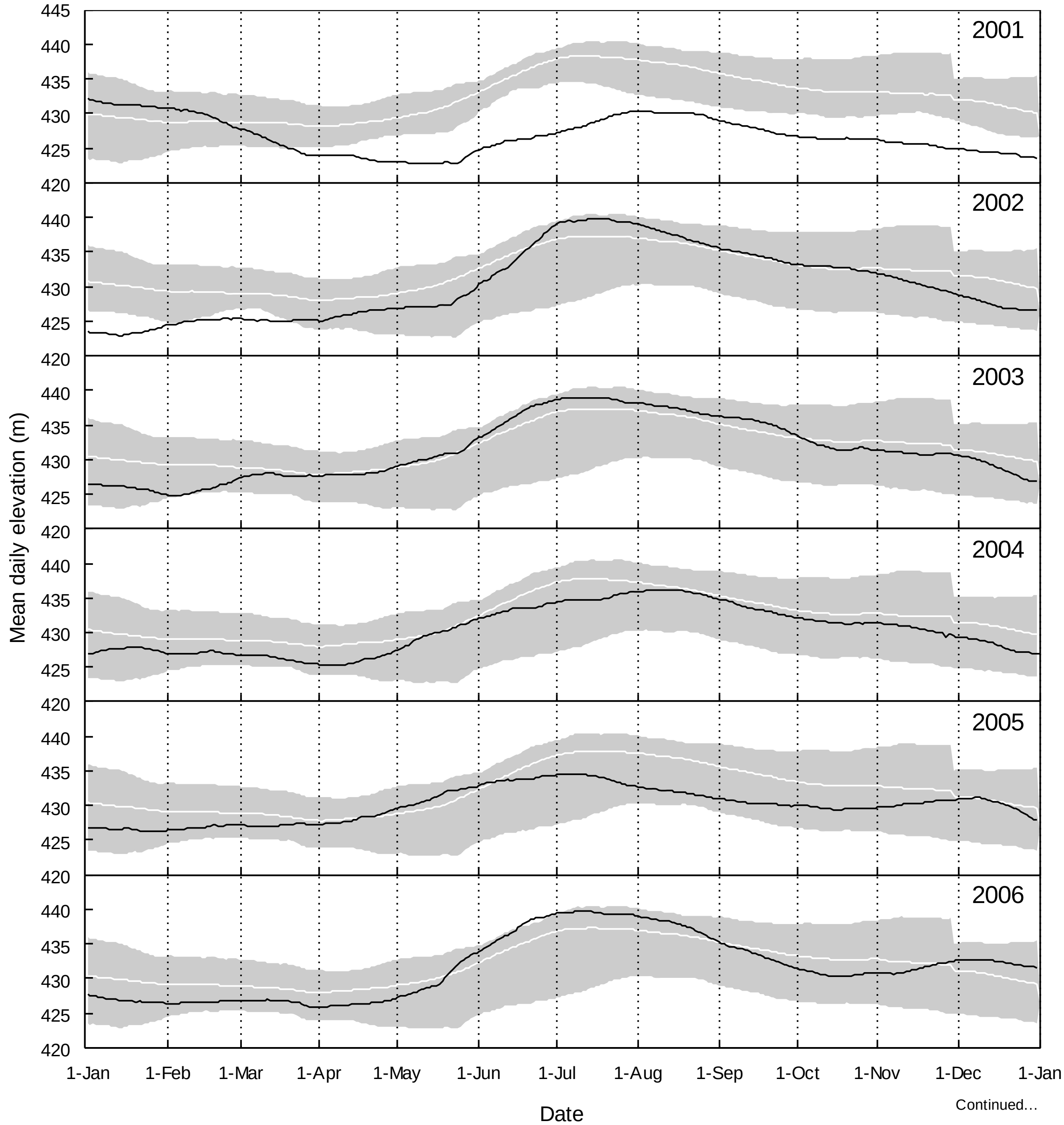


Figure C3 Mean hourly discharge (m^3/s) for the Columbia River at Revelstoke Dam by sample session, October 2 to 25, 2012. The dotted line denotes the 142 m^3/s minimum flow release.



Continued…

Figure C4 Mean daily water level elevation (in metres above sea level) for the Columbia River at Nakusp, 2001 to 2012. The shaded area represents minimum and maximum mean daily water elevations recorded at Nakusp during other study years (between 2001 and 2012). The white line represents average mean daily water elevation over the same time period.

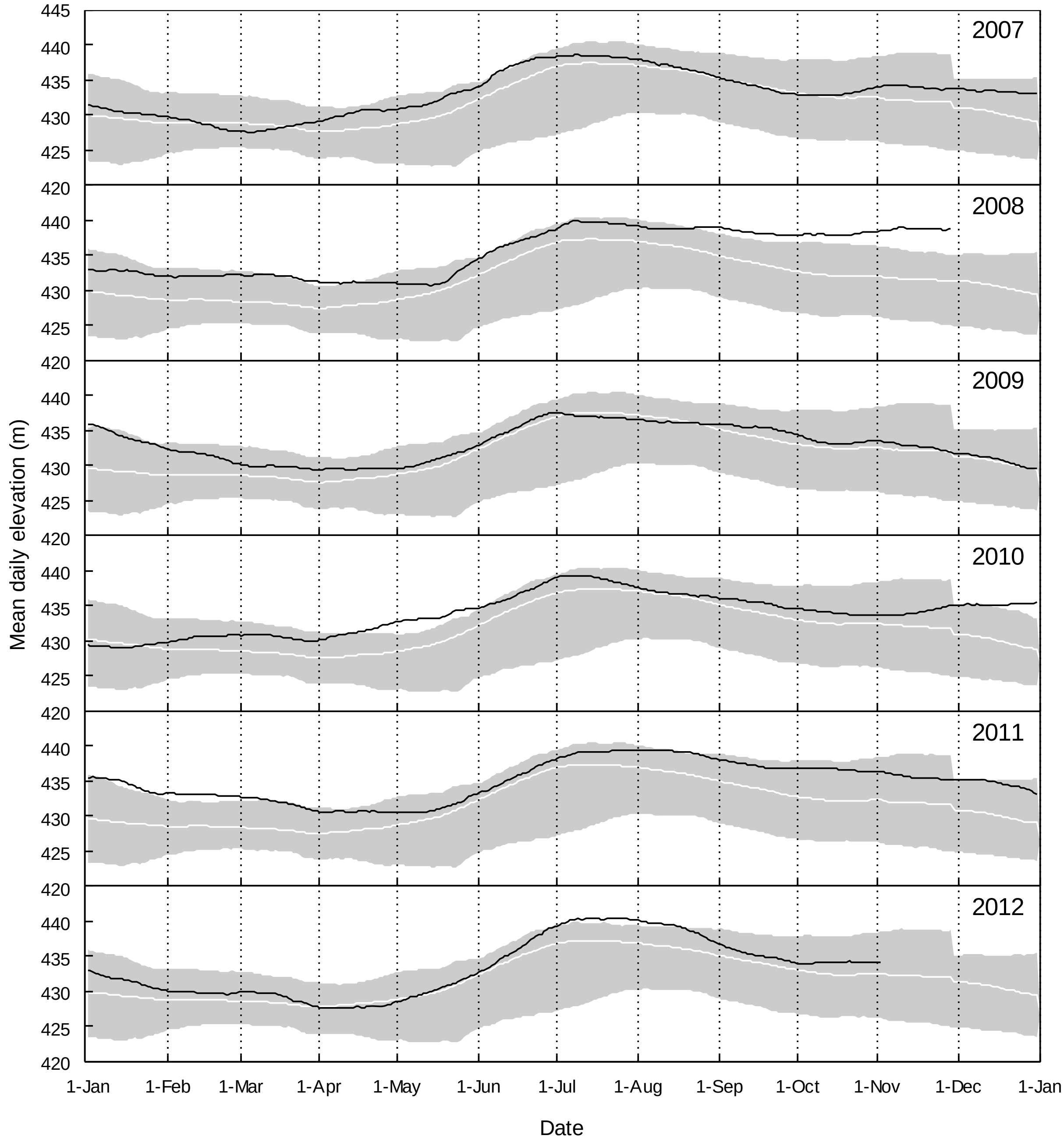


Figure C4 Concluded.

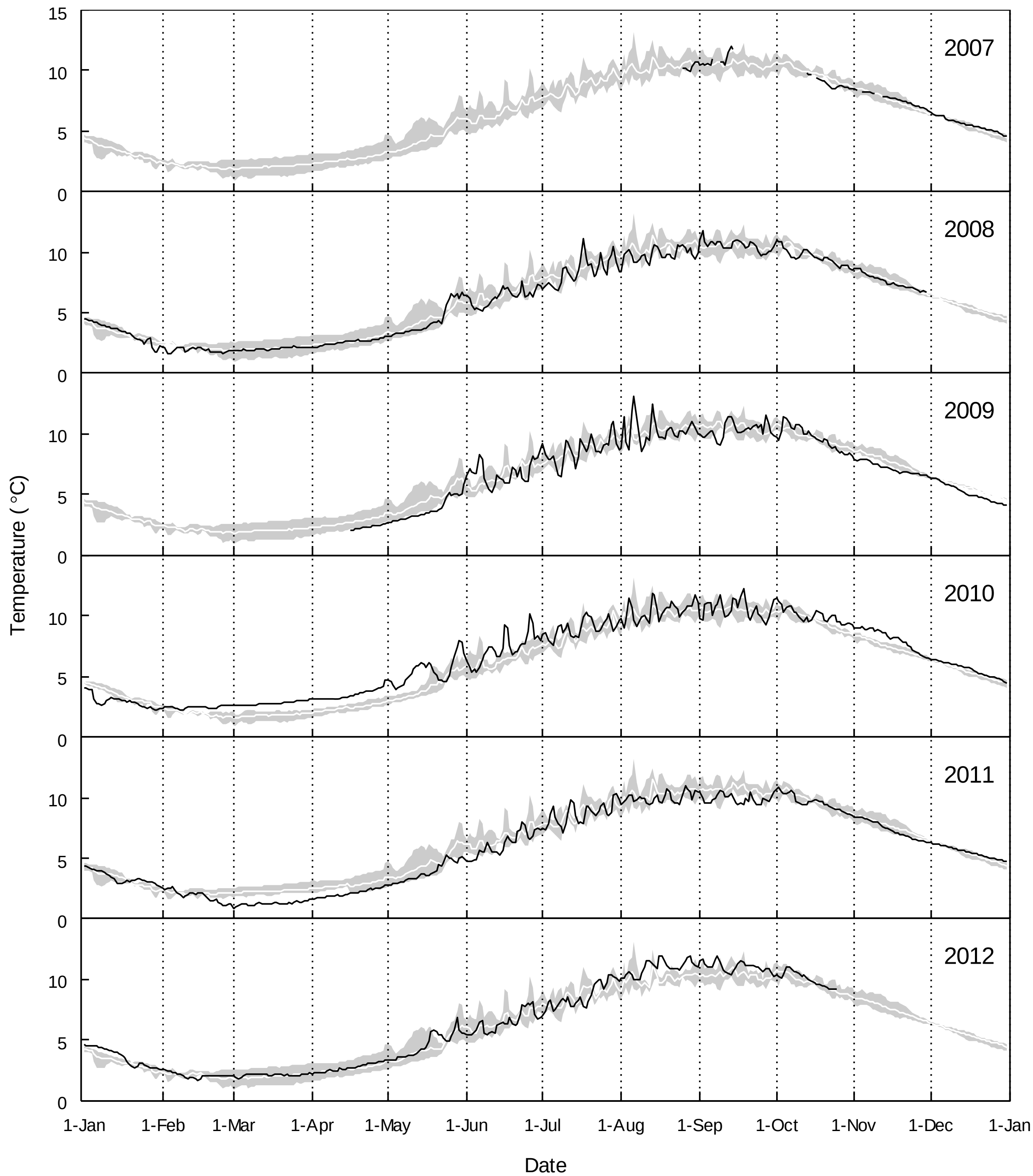


Figure C5 Mean daily water temperature (°C) for the Columbia River at Revelstoke Dam, 2007 to 2012. The shaded area represents minimum and maximum mean daily water temperatures recorded at Revelstoke Dam during other study years (between 2007 and 2012). The white line represents average mean daily water temperature over the same time period. Temperature data are from Station 2 of the Middle Columbia River Physical Habitat Monitoring Program (CLBMON-15a).

APPENDIX D

Catch and Effort Data Summaries

Table D1 Number of fish caught and observed during boat electroshocking surveys conducted during the fall season and their frequency of occurrence in sampled sections of the Middle Columbia River, 2001 to 2012.

Species	2001[a]		2002[a]		2003[a]		2004[a]		2005[a]		2006[a]		2007[a]		2008[a]		2009[a]		2010[a]		2011[a]		2012[a]	
	n **[b]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b,d]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b]**	**%[c]**	***n*** **[b]**	**%[c]**
Sportfish																								
Brook Trout					1	<1							1	<1					1	<1	3	<1		
Bull Trout	311	3	300	6	416	12	301	9	440	7	358	4	882	3	780	7	516	2	532	2	659	4	498	9
Burbot			7	<1	1	<1	5	<1	14	<1	14	<1	32	<1	61	<1	8	<1	22	<1	61	<1	27	<1
Cutthroat Trout													1	<1					1	<1				
Kokanee	5326	45	41	<1	263	8	87	3	1861	30	5874	62	20 602	70	1890	17	17 140	81	18 304	68	8173	53	86	1
Lake Whitefish	5	<1	34	<1	53	2	44	1	275	4	60	<1	12	<1	42	<1	7	<1	983	4	230	1	92	2
Mountain Whitefish	6228	52	4234	92	2706	79	2721	86	3509	57	3133	33	7861	27	8219	72	3461	16	6720	25	6014	39	5059	87
Pygmy Whitefish			1	<1																				
Rainbow Trout	5	<1			5	<1	14	<1	11	<1	15	<1	157	<1	305	3	42	<1	111	<1	217	1	70	1
White Sturgeon	1	<1																						
Yellow Perch							8	<1	2	<1	3	<1	9	<1	134	1	1	<1	104	<1	2	<1	2	<1
Sportfish Subtotal	**11 876**	**100**	**4617**	**100**	**3445**	**100**	**3180**	**100**	**6112**	**100**	**9457**	**100**	**29 557**	**100**	**11 431**	**100**	**21 175**	**100**	**26 778**	**100**	**15 359**	**100**	**5834**	**100**
Non-sportfish																								
Northern Pikeminnow					1	<1	2	<1	3	<1	2	<1	35	1	78	1	53	5	52	2	39	1	17	<1
Peamouth											1	<1	1	<1			1	<1			1	<1		
Redside Shiner			11	6	1	<1	239	32	246	29	97	8	553	18	2050	26	146	14	976	33	237	8	286	9
Sculpin spp.[e]	1	<1	7	4	4	2	186	25	179	21	849	67	1387	45	4801	62	464	43	772	26	1807	59	1010	32
Sucker spp.[e]	419	100	162	90	206	97	331	44	426	50	318	25	1088	36	845	11	407	38	1168	39	974	32	1835	58
Non-sportfish Subtotal	**420**	**100**	**180**	**100**	**212**	**100**	**758**	**100**	**854**	**100**	**1267**	**100**	**3064**	**100**	**7774**	**100**	**1071**	**100**	**2968**	**100**	**3058**	**100**	**3148**	**100**
All species	**12 296**		**4797**		**3657**		**3938**		**6966**		**10 724**		**32 621**		**19 205**		**22 246**		**29 746**		**18 417**		**8982**	

[a] From 2001 to 2006, the study area included all of Reach 4 and the Big Eddy section of Reach; from 2007 to 2010 the study area included all of Reaches 4 and 3.

[b] Includes fish observed and identified to species.

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

[d] Excludes fish recorded during the last session; data were not comparable due to lost observational datasheets

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

Table D2 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) during the spring season in the Middle Columbia River, 28 May to 21 June 2012.

Reach	Section	Session	Site	Date	Time Sampled (s)	Length Sampled (km)	Number Caught (CPUE=no. fish/km/hr)																	
							Brook Trout		Bull Trout		Burbot		Cutthroat Trout		Kokanee		Lake Whitefish		Mountain Whitefish		Rainbow Trout		All Species	
							No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*
4	Upper																							
		1	232.6-R	30-May-12	586	0.80	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	8	*61.43*	0	*0.00*	**8**	***61.43***
			233.1-L	31-May-12	919	1.41	0	*0.00*	10	*27.78*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	87	*241.71*	3	*8.33*	**100**	***277.82***
			234.4-R	30-May-12	768	1.74	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	1	*2.69*	0	*0.00*	20	*53.88*	0	*0.00*	**21**	***56.57***
			234.5-L	30-May-12	1110	1.65	0	*0.00*	10	*19.66*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	251	*493.37*	0	*0.00*	**261**	***513.02***
			236.1-L	29-May-12	907	1.41	0	*0.00*	26	*73.19*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	89	*250.53*	1	*2.81*	**116**	***326.54***
			236.1-R	29-May-12	724	1.73	0	*0.00*	18	*51.74*	1	*2.87*	0	*0.00*	0	*0.00*	0	*0.00*	119	*342.03*	3	*8.62*	**141**	***405.26***
			236.4-L	28-May-12	416	0.58	0	*0.00*	7	*104.44*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	29	*432.69*	0	*0.00*	**36**	***537.14***
			236.4-R	28-May-12	365	0.59	0	*0.00*	1	*16.72*	0	*0.00*	1	*16.72*	0	*0.00*	0	*0.00*	84	*1404.23*	1	*16.72*	**87**	***1454.38***
		Session Summary			**724**	**9.9**	**0**	***0.00***	**72**	***36.11***	**1**	***0.50***	**1**	***0.50***	**1**	***0.50***	**0**	***0.00***	**687**	***344.53***	**8**	***4.01***	**770**	***386.15***
		2	232.6-R	07-Jun-12	408	0.80	0	*0.00*	1	*11.03*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	14	*154.41*	0	*0.00*	**15**	***165.44***
			233.1-L	05-Jun-12	901	1.36	0	*0.00*	8	*23.50*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	90	*264.41*	0	*0.00*	**98**	***287.92***
			234.4-R	07-Jun-12	894	1.74	0	*0.00*	8	*18.51*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	48	*111.09*	0	*0.00*	**56**	***129.60***
			234.5-L	08-Jun-12	994	1.65	0	*0.00*	1	*2.19*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	65	*142.67*	3	*6.58*	**69**	***151.45***
			236.1-L	05-Jun-12	973	1.41	0	*0.00*	13	*34.11*	1	*2.62*	0	*0.00*	0	*0.00*	0	*0.00*	51	*133.83*	2	*5.25*	**67**	***175.81***
			236.1-R	05-Jun-12	1322	1.73	0	*0.00*	16	*25.19*	1	*1.57*	0	*0.00*	0	*0.00*	0	*0.00*	206	*324.26*	1	*1.57*	**224**	***352.59***
			236.4-L	04-Jun-12	362	0.58	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	20	*342.92*	0	*0.00*	**20**	***342.92***
			236.4-R	04-Jun-12	317	0.59	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	45	*866.17*	0	*0.00*	**45**	***866.17***
		Session Summary			**771**	**9.9**	**0**	***0.00***	**47**	***22.25***	**2**	***0.95***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**539**	***255.12***	**6**	***2.84***	**594**	***281.16***
		3	232.6-R	14-Jun-12	709	0.80	0	*0.00*	5	*31.73*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	237	*1504.23*	0	*0.00*	**242**	***1535.97***
			233.1-L	12-Jun-12	865	1.41	0	*0.00*	2	*5.90*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	68	*200.71*	0	*0.00*	**70**	***206.62***
			234.4-R	13-Jun-12	1386	1.74	0	*0.00*	6	*8.96*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	188	*280.64*	0	*0.00*	**194**	***289.60***
			234.5-L	13-Jun-12	822	1.65	0	*0.00*	3	*7.96*	0	*0.00*	0	*0.00*	1	*2.65*	0	*0.00*	27	*71.67*	0	*0.00*	**31**	***82.28***
			236.1-L	12-Jun-12	1110	1.41	0	*0.00*	5	*11.50*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	32	*73.61*	0	*0.00*	**37**	***85.11***
			236.1-R	12-Jun-12	1331	1.73	0	*0.00*	20	*31.27*	1	*1.56*	0	*0.00*	0	*0.00*	0	*0.00*	192	*300.18*	1	*1.56*	**214**	***334.57***
			236.4-L	11-Jun-12	397	0.58	0	*0.00*	10	*156.35*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	7	*109.44*	0	*0.00*	**17**	***265.79***
			236.4-R	11-Jun-12	281	0.59	0	*0.00*	1	*21.71*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	25	*542.86*	0	*0.00*	**26**	***564.57***
		Session Summary			**863**	**9.9**	**0**	***0.00***	**52**	***21.90***	**1**	***0.42***	**0**	***0.00***	**1**	***0.42***	**0**	***0.00***	**776**	***326.79***	**1**	***0.42***	**831**	***349.95***
		4	232.6-R	21-Jun-12	640	0.80	0	*0.00*	6	*42.19*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	45	*316.41*	0	*0.00*	**51**	***358.59***
			233.1-L	19-Jun-12	864	1.41	0	*0.00*	1	*2.96*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	39	*115.25*	0	*0.00*	**40**	***118.20***
			234.4-R	20-Jun-12	1174	1.74	0	*0.00*	11	*19.39*	0	*0.00*	0	*0.00*	2	*3.52*	1	*1.76*	122	*215.00*	1	*1.76*	**137**	***241.44***
			234.5-L	20-Jun-12	892	1.65	0	*0.00*	4	*9.78*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	37	*90.50*	0	*0.00*	**41**	***100.29***
			236.1-L	19-Jun-12	951	1.41	0	*0.00*	49	*131.55*	0	*0.00*	0	*0.00*	1	*2.68*	0	*0.00*	86	*230.89*	0	*0.00*	**136**	***365.13***
			236.1-R	19-Jun-12	1205	1.73	0	*0.00*	128	*221.04*	0	*0.00*	0	*0.00*	1	*1.73*	0	*0.00*	153	*264.22*	0	*0.00*	**282**	***486.99***
			236.4-L	18-Jun-12	412	0.58	0	*0.00*	49	*738.20*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	25	*376.63*	0	*0.00*	**74**	***1114.83***
			236.4-R	18-Jun-12	353	0.59	0	*0.00*	35	*604.98*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	98	*1693.96*	0	*0.00*	**133**	***2298.94***
		Session Summary			**811**	**9.9**	**0**	***0.00***	**283**	***126.70***	**0**	***0.00***	**0**	***0.00***	**4**	***1.79***	**1**	***0.45***	**605**	***270.87***	**1**	***0.45***	**894**	***400.26***
	Upper Section Total All Samples				**25358**	**39.59**	**0**		**454**		**4**		**1**		**6**		**1**		**2607**		**16**		**3089**	
	Upper Section Average All Samples				**792**	**1.24**	**0**	***0.00***	**14**	***52.10***	**0**	***0.46***	**0**	***0.11***	**0**	***0.69***	**0**	***0.11***	**81**	***299.15***	**1**	***1.84***	**97**	***454.78***
	Upper Section Standard Error of Mean						**0.00**	***0.00***	**4.32**	***29.13***	**0.06**	***0.13***	**0.03**	***0.52***	**0.08**	***0.18***	**0.03**	***0.06***	**12.18**	***73.45***	**0.17**	***0.65***	**13.97**	***88.03***

Table D2 Continued.

Reach	Section	Session	Site	Date	Time Sampled (s)	Length Sampled (km)	Number Caught (CPUE=no. fish/km/hr)																	
							Brook Trout		Bull Trout		Burbot		Cutthroat Trout		Kokanee		Lake Whitefish		Mountain Whitefish		Rainbow Trout		All Species	
							No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
3	Eddy																							
		1	231.3-R	30-May-12	890	0.90	0	*0.00*	2	*8.99*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	255	*1146.07*	0	*0.00*	**257**	***1155.06***
		Session Summary			**890**	**0.9**	**0**	***0.00***	**2**	***8.99***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**255**	***1146.07***	**0**	***0.00***	**257**	***1155.06***
		2	231.3-R	06-Jun-12	823	0.90	0	*0.00*	3	*14.58*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	77	*374.24*	0	*0.00*	**80**	***388.82***
		Session Summary			**823**	**0.9**	**0**	***0.00***	**3**	***14.58***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**77**	***374.24***	**0**	***0.00***	**80**	***388.82***
		3	231.3-R	12-Jun-12	855	0.90	0	*0.00*	3	*14.04*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	83	*388.30*	2	*9.36*	**88**	***411.70***
		Session Summary			**855**	**0.9**	**0**	***0.00***	**3**	***14.04***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**83**	***388.30***	**2**	***9.36***	**88**	***411.70***
		4	231.3-R	19-Jun-12	993	0.90	0	*0.00*	17	*68.48*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	70	*281.97*	8	*32.23*	**95**	***382.68***
		Session Summary			**993**	**0.9**	**0**	***0.00***	**17**	***68.48***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**70**	***281.97***	**8**	***32.23***	**95**	***382.68***
	Eddy Section Total All Samples				**3561**	**3.60**	**0**		**25**		**0**		**0**		**0**		**0**		**485**		**10**		**520**	
	Eddy Section Average All Samples				**890**	**0.90**	**0**	***0.00***	**6**	***28.08***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**121**	***544.79***	**3**	***11.23***	**130**	***584.56***
	Eddy Section Standard Error of Mean						**0.00**	***0.00***	**3.59**	***14.04***	**0.00**	***0.00***	**0.00**	***0.00***	**0.00**	***0.00***	**0.00**	***0.00***	**44.66**	***200.86***	**1.89**	***7.60***	**42.44**	***190.27***
3	Middle																							
		1	227.2-R	30-May-12	536	0.52	0	*0.00*	2	*25.83*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	8	*103.33*	0	*0.00*	**10**	***129.16***
			228.5-L	31-May-12	816	1.23	0	*0.00*	8	*28.69*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	72	*258.25*	2	*7.17*	**82**	***294.12***
			229.2-L	31-May-12	901	1.10	0	*0.00*	4	*14.53*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	80	*290.59*	4	*14.53*	**88**	***319.64***
			229.7-R	29-May-12	908	2.27	1	*1.75*	11	*19.21*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	148	*258.50*	0	*0.00*	**160**	***279.45***
			231.0-L	31-May-12	1099	1.96	0	*0.00*	3	*5.01*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	288	*481.33*	1	*1.67*	**292**	***488.01***
			231.0-R	30-May-12	950	0.94	0	*0.00*	9	*36.28*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	434	*1749.61*	0	*0.00*	**443**	***1785.89***
		Session Summary			**868**	**8.0**	**1**	***0.52***	**37**	***19.13***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**1030**	***532.45***	**7**	***3.62***	**1075**	***555.71***
		2	227.2-R	09-Jun-12	496	0.52	0	*0.00*	1	*13.96*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	11	*153.54*	0	*0.00*	**12**	***167.49***
			228.5-L	09-Jun-12	995	1.18	0	*0.00*	2	*6.13*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	45	*137.98*	0	*0.00*	**47**	***144.11***
			229.2-L	09-Jun-12	1116	1.10	0	*0.00*	5	*14.66*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	57	*167.16*	0	*0.00*	**62**	***181.82***
			229.7-R	08-Jun-12	1895	2.17	0	*0.00*	16	*14.01*	1	*0.88*	0	*0.00*	0	*0.00*	0	*0.00*	139	*121.69*	0	*0.00*	**156**	***136.57***
			231.0-L	08-Jun-12	1206	1.96	0	*0.00*	4	*6.09*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	84	*127.93*	0	*0.00*	**88**	***134.02***
			231.0-R	06-Jun-12	830	1.14	0	*0.00*	18	*68.48*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	140	*532.66*	1	*3.80*	**159**	***604.95***
		Session Summary			**1090**	**8.1**	**0**	***0.00***	**46**	***18.83***	**1**	***0.41***	**0**	***0.00***	**0**	***0.00***	**0**	***0.00***	**476**	***194.87***	**1**	***0.41***	**524**	***214.52***
		3	227.2-R	15-Jun-12	503	0.52	0	*0.00*	1	*13.76*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	4	*55.05*	3	*41.29*	**8**	***110.11***
			228.5-L	15-Jun-12	1248	1.23	0	*0.00*	3	*7.04*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	81	*189.96*	0	*0.00*	**84**	***197.00***
			229.2-L	15-Jun-12	1191	1.10	0	*0.00*	2	*5.50*	0	*0.00*	0	*0.00*	1	*2.75*	0	*0.00*	123	*337.99*	3	*8.24*	**129**	***354.48***
			229.7-R	14-Jun-12	1909	2.17	0	*0.00*	10	*8.69*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	255	*221.60*	2	*1.74*	**267**	***232.03***
			231.0-L	13-Jun-12	1340	1.96	0	*0.00*	5	*6.85*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	109	*149.41*	2	*2.74*	**116**	***159.00***
			231.0-R	13-Jun-12	903	1.14	0	*0.00*	15	*52.46*	1	*3.50*	0	*0.00*	0	*0.00*	0	*0.00*	180	*629.48*	0	*0.00*	**196**	***685.43***
		Session Summary			**1182**	**8.1**	**0**	***0.00***	**36**	***13.50***	**1**	***0.37***	**0**	***0.00***	**1**	***0.37***	**0**	***0.00***	**752**	***281.98***	**10**	***3.75***	**800**	***299.98***
		4	227.2-R	22-Jun-12	609	0.52	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	1	*11.37*	0	*0.00*	10	*113.68*	0	*0.00*	**11**	***125.05***
			228.5-L	22-Jun-12	1456	1.23	0	*0.00*	2	*4.02*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	49	*98.50*	5	*10.05*	**56**	***112.57***
			229.2-L	21-Jun-12	1318	1.10	0	*0.00*	1	*2.48*	0	*0.00*	0	*0.00*	1	*2.48*	0	*0.00*	54	*134.09*	3	*7.45*	**59**	***146.50***
			229.7-R	21-Jun-12	1987	2.27	0	*0.00*	16	*12.77*	0	*0.00*	0	*0.00*	2	*1.60*	0	*0.00*	354	*282.54*	1	*0.80*	**373**	***297.71***
			231.0-L	20-Jun-12	1672	1.96	0	*0.00*	6	*6.59*	0	*0.00*	0	*0.00*	3	*3.30*	0	*0.00*	111	*121.94*	4	*4.39*	**124**	***136.22***
			231.0-R	20-Jun-12	1117	1.14	0	*0.00*	28	*79.16*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	125	*353.39*	0	*0.00*	**153**	***432.55***
		Session Summary			**1360**	**8.2**	**0**	***0.00***	**53**	***17.07***	**0**	***0.00***	**0**	***0.00***	**7**	***2.25***	**0**	***0.00***	**703**	***226.41***	**13**	***4.19***	**776**	***249.92***
	Middle Section Total All Samples				**27001**	**32.43**	**1**		**172**		**2**		**0**		**8**		**0**		**2961**		**31**		**3175**	
	Middle Section Average All Samples				**1125**	**1.35**	**0**	***0.10***	**7**	***16.97***	**0**	***0.20***	**0**	***0.00***	**0**	***0.79***	**0**	***0.00***	**123**	***292.16***	**1**	***3.06***	**132**	***318.91***
	Middle Section Standard Error of Mean						**0.04**	***0.07***	**1.43**	***4.24***	**0.06**	***0.15***	**0.00**	***0.00***	**0.16**	***0.50***	**0.00**	***0.00***	**22.55**	***70.01***	**0.33**	***1.80***	**23.19**	***71.53***
All Sections Total All Samples					**55920**	**75.62**	**1**	***0.00***	**651**	***0.55***	**6**	***0.01***	**1**	***0.00***	**14**	***0.01***	**1**	***0.00***	**6053**	***5.15***	**57**	***0.05***	**6784**	***5.78***
All Sections Average All Samples							**0**	***0.05***	**11**	***33.25***	**0**	***0.31***	**0**	***0.05***	**0**	***0.72***	**0**	***0.05***	**101**	***309.19***	**1**	***2.91***	**113**	***346.53***
All Sections Standard Error of Mean							**0.02**	***0.03***	**2.41**	***15.96***	**0.04**	***0.09***	**0.02**	***0.28***	**0.08**	***0.22***	**0.02**	***0.03***	**11.61**	***49.83***	**0.21**	***0.95***	**12.24**	***56.58***

Table D3 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) during the spring season in the Middle Columbia River, 28 May to 21 June 2012.

Reach	Section	Session	Site	Date	Time Sampled (seconds)	Length Sampled (km)	Number Caught (CPUE=no. fish/km/h)									
							Peamouth		Redside Shiner		Sculpin spp.		Sucker spp.		All Species	
							No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*
4	Upper															
		1	232.6-R	30-May-12	586	0.80	0	*0.00*	0	*0.00*	0	*0.00*	6	*46.08*	6	*46.08*
			233.1-L	31-May-12	919	1.41	0	*0.00*	0	*0.00*	0	*0.00*	8	*22.23*	8	*22.23*
			234.4-R	30-May-12	768	1.74	0	*0.00*	0	*0.00*	0	*0.00*	4	*10.78*	4	*10.78*
			234.5-L	30-May-12	1110	1.65	0	*0.00*	0	*0.00*	6	*11.79*	5	*9.83*	11	*21.62*
			236.1-L	29-May-12	907	1.41	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
			236.1-R	29-May-12	724	1.73	0	*0.00*	0	*0.00*	2	*5.75*	4	*11.50*	6	*17.25*
			236.4-L	28-May-12	416	0.58	0	*0.00*	0	*0.00*	0	*0.00*	4	*59.68*	4	*59.68*
			236.4-R	28-May-12	365	0.59	0	*0.00*	0	*0.00*	0	*0.00*	1	*16.72*	1	*16.72*
		Session 1 Summary			**724**	**9.91**	**0**	***0.00***	**0**	***0.00***	**8**	***4.01***	**32**	***16.05***	**40**	***20.06***
		2	232.6-R	07-Jun-12	408	0.80	0	*0.00*	0	*0.00*	0	*0.00*	13	*143.38*	13	*143.38*
			233.1-L	05-Jun-12	901	1.36	0	*0.00*	0	*0.00*	63	*185.09*	11	*32.32*	74	*217.41*
			234.4-R	07-Jun-12	894	1.74	0	*0.00*	0	*0.00*	0	*0.00*	8	*18.51*	8	*18.51*
			234.5-L	08-Jun-12	994	1.65	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
			236.1-L	05-Jun-12	973	1.41	0	*0.00*	0	*0.00*	0	*0.00*	3	*7.87*	3	*7.87*
			236.1-R	05-Jun-12	1322	1.73	0	*0.00*	0	*0.00*	12	*18.89*	2	*3.15*	14	*22.04*
			236.4-L	04-Jun-12	362	0.58	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
			236.4-R	04-Jun-12	317	0.59	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
		Session 2 Summary			**771**	**9.86**	**0**	***0.00***	**0**	***0.00***	**75**	***35.50***	**37**	***17.51***	**112**	***53.01***
		3	232.6-R	14-Jun-12	709	0.80	0	*0.00*	0	*0.00*	1	*6.35*	71	*450.63*	72	*456.98*
			233.1-L	12-Jun-12	865	1.41	1	*2.95*	1	*2.95*	0	*0.00*	3	*8.85*	5	*14.76*
			234.4-R	13-Jun-12	1386	1.74	0	*0.00*	0	*0.00*	41	*61.20*	51	*76.13*	92	*137.33*
			234.5-L	13-Jun-12	822	1.65	0	*0.00*	0	*0.00*	0	*0.00*	4	*10.62*	4	*10.62*
			236.1-L	12-Jun-12	1110	1.41	0	*0.00*	0	*0.00*	0	*0.00*	1	*2.30*	1	*2.30*
			236.1-R	12-Jun-12	1331	1.73	0	*0.00*	0	*0.00*	1	*1.56*	4	*6.25*	5	*7.82*
			236.4-L	11-Jun-12	397	0.58	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
			236.4-R	11-Jun-12	281	0.59	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
		Session 3 Summary			**863**	**9.91**	**1**	***0.42***	**1**	***0.42***	**43**	***18.11***	**134**	***56.43***	**179**	***75.38***
		4	232.6-R	21-Jun-12	640	0.80	0	*0.00*	0	*0.00*	0	*0.00*	36	*253.12*	36	*253.12*
			233.1-L	19-Jun-12	864	1.41	0	*0.00*	0	*0.00*	18	*53.19*	5	*14.78*	23	*67.97*
			234.4-R	20-Jun-12	1174	1.74	0	*0.00*	0	*0.00*	22	*38.77*	14	*24.67*	36	*63.44*
			234.5-L	20-Jun-12	892	1.65	0	*0.00*	0	*0.00*	1	*2.45*	1	*2.45*	2	*4.89*
			236.1-L	19-Jun-12	951	1.41	0	*0.00*	0	*0.00*	0	*0.00*	13	*34.90*	13	*34.90*
			236.1-R	19-Jun-12	1205	1.73	0	*0.00*	0	*0.00*	1	*1.73*	5	*8.63*	6	*10.36*
			236.4-L	18-Jun-12	412	0.58	0	*0.00*	0	*0.00*	0	*0.00*	5	*75.33*	5	*75.33*
			236.4-R	18-Jun-12	353	0.59	0	*0.00*	0	*0.00*	0	*0.00*	2	*34.57*	2	*34.57*
		Session 4 Summary			**811**	**9.91**	**0**	***0.00***	**0**	***0.00***	**42**	***18.80***	**81**	***36.27***	**123**	***55.07***
	Upper Section Total All Samples				**25358**	**39.59**	**1**		**1**		**168**		**284**		**454**	
	Upper Section Average All Samples				**792**	**1.24**	**0**	***0.11***	**0**	***0.11***	**5**	***19.28***	**9**	***32.59***	**14**	***52.10***
	Upper Section Standard Error of Mean						**0.03**	***0.09***	**0.03**	***0.09***	**2.41**	***6.21***	**2.74**	***15.91***	**4.12**	***16.99***
3	Eddy															
		1	231.3-R	30-May-12	890	0.90	0	*0.00*	0	*0.00*	2	*8.99*	0	*0.00*	2	*8.99*
		Session 1 Summary			**890**	**0.90**	**0**	***0.00***	**0**	***0.00***	**2**	***8.99***	**0**	***0.00***	**2**	***8.99***
		2	231.3-R	06-Jun-12	823	0.90	0	*0.00*	0	*0.00*	1	*4.86*	1	*4.86*	2	*9.72*
		Session 2 Summary			**823**	**0.90**	**0**	***0.00***	**0**	***0.00***	**1**	***4.86***	**1**	***4.86***	**2**	***9.72***
		3	231.3-R	12-Jun-12	855	0.90	0	*0.00*	5	*23.39*	30	*140.35*	0	*0.00*	35	*163.74*
		Session 3 Summary			**855**	**0.90**	**0**	***0.00***	**5**	***23.39***	**30**	***140.35***	**0**	***0.00***	**35**	***163.74***
		4	231.3-R	19-Jun-12	993	0.90	0	*0.00*	0	*0.00*	45	*181.27*	8	*32.23*	53	*213.49*
		Session 4 Summary			**993**	**0.90**	**0**	***0.00***	**0**	***0.00***	**45**	***181.27***	**8**	***32.23***	**53**	***213.49***
	Eddy Section Total All Samples				**3561**	**3.60**	**0**		**5**		**78**		**9**		**92**	
	Eddy Section Average All Samples				**890**	**0.90**	**0**	***0.00***	**1**	***5.62***	**20**	***87.62***	**2**	***10.11***	**23**	***103.34***
	Eddy Section Standard Error of Mean						**0.00**	***0.00***	**1.25**	***5.85***	**10.84**	***45.21***	**1.93**	***7.74***	**12.67**	***52.74***
3	Middle															
		1	227.2-R	30-May-12	536	0.52	0	*0.00*	0	*0.00*	0	*0.00*	27	*348.74*	27	*348.74*
			228.5-L	31-May-12	816	1.23	0	*0.00*	0	*0.00*	5	*17.93*	6	*21.52*	11	*39.45*
			229.2-L	31-May-12	901	1.10	0	*0.00*	0	*0.00*	6	*21.79*	8	*29.06*	14	*50.85*
			229.7-R	29-May-12	908	2.27	0	*0.00*	0	*0.00*	22	*38.42*	18	*31.44*	40	*69.86*
			231.0-L	31-May-12	1099	1.96	0	*0.00*	0	*0.00*	3	*5.01*	19	*31.75*	22	*36.77*
			231.0-R	30-May-12	950	0.94	0	*0.00*	0	*0.00*	2	*8.06*	15	*60.47*	17	*68.53*
		Session 1 Summary			**868**	**8.02**	**0**	***0.00***	**0**	***0.00***	**38**	***19.64***	**93**	***48.08***	**131**	***67.72***
		2	227.2-R	09-Jun-12	496	0.52	0	*0.00*	3	*41.87*	5	*69.79*	40	*558.31*	48	*669.98*
			228.5-L	09-Jun-12	995	1.18	0	*0.00*	0	*0.00*	6	*18.40*	10	*30.66*	16	*49.06*
			229.2-L	09-Jun-12	1116	1.10	0	*0.00*	0	*0.00*	0	*0.00*	17	*49.85*	17	*49.85*
			229.7-R	08-Jun-12	1895	2.17	0	*0.00*	0	*0.00*	6	*5.25*	85	*74.41*	91	*79.67*
			231.0-L	08-Jun-12	1206	1.96	0	*0.00*	0	*0.00*	0	*0.00*	36	*54.83*	36	*54.83*
			231.0-R	06-Jun-12	830	1.14	0	*0.00*	0	*0.00*	0	*0.00*	19	*72.29*	19	*72.29*
		Session 2 Summary			**1090**	**8.07**	**0**	***0.00***	**3**	***1.23***	**17**	***6.96***	**207**	***84.74***	**227**	***92.93***
		3	227.2-R	15-Jun-12	503	0.52	0	*0.00*	0	*0.00*	3	*41.29*	2	*27.53*	5	*68.82*
			228.5-L	15-Jun-12	1248	1.23	0	*0.00*	0	*0.00*	1	*2.35*	13	*30.49*	14	*32.83*
			229.2-L	15-Jun-12	1191	1.10	0	*0.00*	0	*0.00*	8	*21.98*	6	*16.49*	14	*38.47*
			229.7-R	14-Jun-12	1909	2.17	0	*0.00*	0	*0.00*	3	*2.61*	122	*106.02*	125	*108.63*
			231.0-L	13-Jun-12	1340	1.96	0	*0.00*	0	*0.00*	0	*0.00*	46	*63.05*	46	*63.05*
			231.0-R	13-Jun-12	903	1.14	0	*0.00*	0	*0.00*	0	*0.00*	33	*115.40*	33	*115.40*
		Session 3 Summary			**1182**	**8.12**	**0**	***0.00***	**0**	***0.00***	**15**	***5.62***	**222**	***83.25***	**237**	***88.87***
		4	227.2-R	22-Jun-12	609	0.52	0	*0.00*	1	*11.37*	2	*22.74*	7	*79.58*	10	*113.68*
			228.5-L	22-Jun-12	1456	1.23	0	*0.00*	0	*0.00*	47	*94.48*	7	*14.07*	54	*108.55*
			229.2-L	21-Jun-12	1318	1.10	0	*0.00*	0	*0.00*	58	*144.02*	19	*47.18*	77	*191.20*
			229.7-R	21-Jun-12	1987	2.27	2	*1.60*	0	*0.00*	21	*16.76*	98	*78.22*	121	*96.57*
			231.0-L	20-Jun-12	1672	1.96	0	*0.00*	0	*0.00*	1	*1.10*	10	*10.99*	11	*12.08*
			231.0-R	20-Jun-12	1117	1.14	0	*0.00*	0	*0.00*	0	*0.00*	173	*489.09*	173	*489.09*
		Session 4 Summary			**1360**	**8.22**	**2**	***0.64***	**1**	***0.32***	**129**	***41.55***	**314**	***101.13***	**446**	***143.64***
	Middle Section Total All Samples				**27001**	**32.43**	**2**		**4**		**199**		**836**		**1041**	
	Middle Section Average All Samples				**1125**	**1.35**	**0**	***0.20***	**0**	***0.39***	**8**	***19.64***	**35**	***82.49***	**43**	***102.72***
	Middle Section Standard Error of Mean						**0.08**	***0.07***	**0.13**	***1.79***	**3.04**	***7.18***	**8.71**	***29.91***	**8.92**	***32.11***
All Sections Total All Samples					**55920**	**75.62**	**3**		**10**		**445**		**1129**		**1587**	
All Sections Average All Samples					**932**	**1.26**	**0**	***0.15***	**0**	***0.51***	**7**	***22.73***	**19**	***57.67***	**26**	***81.06***
All Sections Standard Error of Mean							**0.04**	***0.06***	**0.10**	***0.81***	**1.92**	***5.56***	**4.11**	***15.08***	**4.59**	***16.45***

Table D4 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) during the fall seasonin the Middle Columbia River, 2 to 25 October 2012.

Reach	Section	Session	Site	Date	Time Sampled (s)	Length Sampled (km)	Number Caught (CPUE=no. fish/km/hr) Bull Trout		Burbot		Kokanee		Lake Whitefish		Mountain Whitefish		Rainbow Trout		Yellow Perch		All Species	
							No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*
4	Upper																					
		1	2.6-R-16-E	04-Oct-12	409	0.80	2	*22.00*	0	*0.00*	0	*0.00*	0	*0.00*	43	*473.11*	0	*0.00*	0	*0.00*	**45**	***495.11***
			3.1-L-16-E	02-Oct-12	900	1.41	29	*82.27*	1	*2.84*	0	*0.00*	0	*0.00*	47	*133.33*	0	*0.00*	0	*0.00*	**77**	***218.44***
			4.4-R-16-E	02-Oct-12	885	1.74	18	*42.08*	0	*0.00*	0	*0.00*	0	*0.00*	147	*343.66*	0	*0.00*	0	*0.00*	**165**	***385.74***
			4.5-L-16-E	04-Oct-12	1040	1.65	14	*29.37*	0	*0.00*	1	*2.10*	0	*0.00*	216	*453.15*	1	*2.10*	0	*0.00*	**232**	***486.71***
			6.1-L-16-E	02-Oct-12	226	0.48	4	*132.19*	0	*0.00*	0	*0.00*	0	*0.00*	32	*1057.54*	0	*0.00*	0	*0.00*	**36**	***1189.73***
			6.1-R-16-E	04-Oct-12	1296	1.73	17	*27.30*	0	*0.00*	2	*3.21*	0	*0.00*	209	*335.58*	2	*3.21*	0	*0.00*	**230**	***369.30***
			6.4-L-16-E	04-Oct-12	336	0.58	3	*55.42*	0	*0.00*	0	*0.00*	0	*0.00*	18	*332.51*	0	*0.00*	0	*0.00*	**21**	***387.93***
			6.4-R-16-E	02-Oct-12	340	0.59	3	*53.84*	0	*0.00*	0	*0.00*	0	*0.00*	46	*825.52*	0	*0.00*	0	*0.00*	**49**	***879.36***
		Session Summary			**679**	**9.0**	**90**	***53.13***	**1**	***0.59***	**3**	***1.77***	**0**	***0.00***	**758**	***447.43***	**3**	***1.77***	**0**	***0.00***	**855**	***504.69***
		2	2.6-R-16-E	11-Oct-12	410	0.80	4	*43.90*	0	*0.00*	0	*0.00*	0	*0.00*	82	*900.00*	0	*0.00*	0	*0.00*	**86**	***943.90***
			3.1-L-16-E	10-Oct-12	758	1.41	9	*30.31*	7	*23.58*	3	*10.10*	1	*3.37*	104	*350.31*	0	*0.00*	0	*0.00*	**124**	***417.67***
			4.4-R-16-E	10-Oct-12	853	1.74	14	*33.96*	0	*0.00*	2	*4.85*	0	*0.00*	175	*424.47*	0	*0.00*	0	*0.00*	**191**	***463.27***
			4.5-L-16-E	11-Oct-12	883	1.65	3	*7.41*	2	*4.94*	0	*0.00*	0	*0.00*	146	*360.75*	1	*2.47*	0	*0.00*	**152**	***375.58***
			6.1-L-16-E	10-Oct-12	221	0.48	2	*67.59*	0	*0.00*	1	*33.80*	0	*0.00*	8	*270.37*	0	*0.00*	0	*0.00*	**11**	***371.75***
			6.1-R-16-E	11-Oct-12	1257	1.73	16	*26.49*	1	*1.66*	3	*4.97*	0	*0.00*	227	*375.79*	3	*4.97*	0	*0.00*	**250**	***413.87***
			6.4-L-16-E	11-Oct-12	342	0.58	6	*108.89*	0	*0.00*	0	*0.00*	0	*0.00*	64	*1161.52*	1	*18.15*	0	*0.00*	**71**	***1288.57***
			6.4-R-16-E	10-Oct-12	350	0.59	4	*69.73*	0	*0.00*	0	*0.00*	0	*0.00*	35	*610.17*	1	*17.43*	0	*0.00*	**40**	***697.34***
		Session Summary			**634**	**9.0**	**58**	***36.65***	**10**	***6.32***	**9**	***5.69***	**1**	***0.63***	**841**	***531.45***	**6**	***3.79***	**0**	***0.00***	**925**	***584.54***
		3	2.6-R-16-E	16-Oct-12	396	0.75	2	*24.37*	0	*0.00*	0	*0.00*	0	*0.00*	43	*524.01*	0	*0.00*	0	*0.00*	**45**	***548.38***
			3.1-L-16-E	16-Oct-12	695	1.41	5	*18.37*	0	*0.00*	2	*7.35*	0	*0.00*	45	*165.31*	0	*0.00*	0	*0.00*	**52**	***191.03***
			4.4-R-16-E	16-Oct-12	981	1.74	4	*8.44*	1	*2.11*	0	*0.00*	0	*0.00*	204	*430.24*	0	*0.00*	0	*0.00*	**209**	***440.79***
			4.5-L-16-E	16-Oct-12	669	1.65	6	*19.57*	0	*0.00*	1	*3.26*	0	*0.00*	76	*247.86*	2	*6.52*	0	*0.00*	**85**	***277.21***
			6.1-L-16-E	15-Oct-12	183	0.48	2	*81.97*	0	*0.00*	0	*0.00*	0	*0.00*	10	*409.84*	0	*0.00*	0	*0.00*	**12**	***491.80***
			6.1-R-16-E	15-Oct-12	1273	1.73	11	*17.98*	0	*0.00*	2	*3.27*	0	*0.00*	174	*284.43*	2	*3.27*	0	*0.00*	**189**	***308.95***
			6.4-L-16-E	15-Oct-12	342	0.58	6	*108.89*	1	*18.15*	0	*0.00*	0	*0.00*	36	*653.36*	0	*0.00*	0	*0.00*	**43**	***780.40***
			6.4-R-16-E	15-Oct-12	344	0.59	3	*53.21*	0	*0.00*	0	*0.00*	0	*0.00*	9	*159.64*	1	*17.74*	0	*0.00*	**13**	***230.59***
		Session Summary			**610**	**8.9**	**39**	***25.77***	**2**	***1.32***	**5**	***3.30***	**0**	***0.00***	**597**	***394.48***	**5**	***3.30***	**0**	***0.00***	**648**	***428.18***
		4	2.6-R-16-E	23-Oct-12	414	0.80	3	*32.61*	0	*0.00*	0	*0.00*	5	*54.35*	47	*510.87*	0	*0.00*	0	*0.00*	**55**	***597.83***
			3.1-L-16-E	24-Oct-12	708	1.41	3	*10.82*	2	*7.21*	0	*0.00*	9	*32.46*	86	*310.13*	0	*0.00*	0	*0.00*	**100**	***360.62***
			4.4-R-16-E	23-Oct-12	821	1.74	15	*37.80*	0	*0.00*	1	*2.52*	10	*25.20*	146	*367.93*	1	*2.52*	0	*0.00*	**173**	***435.97***
			4.5-L-16-E	24-Oct-12	993	1.65	4	*8.79*	0	*0.00*	0	*0.00*	17	*37.35*	107	*235.10*	1	*2.20*	0	*0.00*	**129**	***283.44***
			6.1-L-16-E	23-Oct-12	232	0.48	1	*32.33*	0	*0.00*	0	*0.00*	2	*64.66*	0	*0.00*	0	*0.00*	0	*0.00*	**3**	***96.98***
			6.1-R-16-E	23-Oct-12	1314	1.73	9	*14.25*	0	*0.00*	0	*0.00*	6	*9.50*	145	*229.63*	4	*6.33*	0	*0.00*	**164**	***259.72***
			6.4-L-16-E	23-Oct-12	313	0.58	1	*19.83*	0	*0.00*	0	*0.00*	2	*39.66*	64	*1269.14*	0	*0.00*	0	*0.00*	**67**	***1328.63***
			6.4-R-16-E	23-Oct-12	273	0.59	5	*111.75*	0	*0.00*	0	*0.00*	0	*0.00*	9	*201.15*	0	*0.00*	0	*0.00*	**14**	***312.91***
		Session Summary			**634**	**9.0**	**41**	***25.95***	**2**	***1.27***	**1**	***0.63***	**51**	***32.27***	**604**	***382.22***	**6**	***3.80***	**0**	***0.00***	**705**	***446.14***
	Upper Section Total All Samples				**20457**	**35.87**	**228**		**15**		**18**		**52**		**2800**		**20**		**0**		**3133**	
	Upper Section Average All Samples				**639**	**1.12**	**7**	***35.79***	**0**	***2.35***	**1**	***2.83***	**2**	***8.16***	**88**	***439.58***	**1**	***3.14***	**0**	***0.00***	**98**	***510.30***
	Upper Section Standard Error of Mean						**1.14**	***6.01***	**0.23**	***0.93***	**0.17**	***1.10***	**0.68**	***3.12***	**12.36**	***52.96***	**0.18**	***0.93***	**0.00**	***0.00***	**13.31**	***55.03***

Table D4 Continued.

Reach	Section	Session	Site	Date	Time Sampled (s)	Length Sampled (km)	Number Caught (CPUE=no. fish/km/hr)															
							Bull Trout		Burbot		Kokanee		Lake Whitefish		Mountain Whitefish		Rainbow Trout		Yellow Perch		All Species	
							No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*
3	Eddy																					
		1	31.3-R-16-E	03-Oct-12	839	0.90	23	*109.65*	0	*0.00*	13	*61.98*	1	*4.77*	97	*462.46*	6	*28.61*	1	*4.77*	**141**	***672.23***
		Session Summary			**839**	**0.9**	**23**	***109.65***	**0**	***0.00***	**13**	***61.98***	**1**	***4.77***	**97**	***462.46***	**6**	***28.61***	**1**	***4.77***	**141**	***672.23***
		2	31.3-R-16-E	12-Oct-12	841	0.90	13	*61.83*	0	*0.00*	2	*9.51*	0	*0.00*	219	*1041.62*	3	*14.27*	0	*0.00*	**237**	***1127.23***
		Session Summary			**841**	**0.9**	**13**	***61.83***	**0**	***0.00***	**2**	***9.51***	**0**	***0.00***	**219**	***1041.62***	**3**	***14.27***	**0**	***0.00***	**237**	***1127.23***
		3	31.3-R-16-E	17-Oct-12	820	0.90	8	*39.02*	0	*0.00*	2	*9.76*	1	*4.88*	62	*302.44*	0	*0.00*	0	*0.00*	**73**	***356.10***
		Session Summary			**820**	**0.9**	**8**	***39.02***	**0**	***0.00***	**2**	***9.76***	**1**	***4.88***	**62**	***302.44***	**0**	***0.00***	**0**	***0.00***	**73**	***356.10***
		4	31.3-R-16-E	25-Oct-12	856	0.90	8	*37.38*	0	*0.00*	1	*4.67*	2	*9.35*	128	*598.13*	3	*14.02*	0	*0.00*	**142**	***663.55***
		Session Summary			**856**	**0.9**	**8**	***37.38***	**0**	***0.00***	**1**	***4.67***	**2**	***9.35***	**128**	***598.13***	**3**	***14.02***	**0**	***0.00***	**142**	***663.55***
	Eddy Section Total All Samples				**3356**	**3.60**	**52**		**0**		**18**		**4**		**506**		**12**		**1**		**593**	
	Eddy Section Average All Samples				**839**	**0.90**	**13**	***61.98***	**0**	***0.00***	**5**	***21.45***	**1**	***4.77***	**127**	***603.10***	**3**	***14.30***	**0**	***1.19***	**148**	***704.78***
	Eddy Section Standard Error of Mean						**3.54**	***16.84***	**0.00**	***0.00***	**2.84**	***13.55***	**0.41**	***1.91***	**33.65**	***158.77***	**1.22**	***5.84***	**0.25**	***1.19***	**33.70**	***158.85***
3	Middle																					
		1	27.2-R-16-E	03-Oct-12	431	0.52	13	*208.82*	0	*0.00*	3	*48.19*	1	*16.06*	15	*240.94*	0	*0.00*	0	*0.00*	**32**	***514.01***
			28.5-L-16-E	03-Oct-12	888	1.23	28	*92.29*	4	*13.18*	0	*0.00*	0	*0.00*	82	*270.27*	1	*3.30*	0	*0.00*	**115**	***379.04***
			29.2-L-16-E	04-Oct-12	906	1.10	4	*14.45*	0	*0.00*	2	*7.22*	0	*0.00*	41	*148.10*	1	*3.61*	0	*0.00*	**48**	***173.39***
			29.7-R-16-E	03-Oct-12	1636	2.27	57	*55.25*	0	*0.00*	27	*26.17*	0	*0.00*	146	*141.53*	0	*0.00*	0	*0.00*	**230**	***222.96***
			31.0-L-16-E	05-Oct-12	1011	1.96	13	*23.62*	2	*3.63*	3	*5.45*	0	*0.00*	118	*214.38*	1	*1.82*	0	*0.00*	**137**	***248.89***
			31.0-R-16-E	03-Oct-12	658	1.14	3	*14.40*	0	*0.00*	6	*28.80*	0	*0.00*	62	*297.55*	0	*0.00*	0	*0.00*	**71**	***340.75***
		Session Summary			**922**	**8.2**	**118**	***56.07***	**6**	***2.85***	**41**	***19.48***	**1**	***0.48***	**464**	***220.48***	**3**	***1.43***	**0**	***0.00***	**633**	***300.79***
		2	27.2-R-16-E	09-Oct-12	363	0.52	6	*114.43*	1	*19.07*	1	*19.07*	0	*0.00*	9	*171.65*	1	*19.07*	0	*0.00*	**18**	***343.29***
			28.5-L-16-E	09-Oct-12	838	1.23	10	*34.93*	0	*0.00*	0	*0.00*	0	*0.00*	121	*422.61*	0	*0.00*	0	*0.00*	**131**	***457.54***
			29.2-L-16-E	12-Oct-12	940	1.10	3	*10.44*	0	*0.00*	1	*3.48*	0	*0.00*	72	*250.68*	3	*10.44*	0	*0.00*	**79**	***275.05***
			29.7-R-16-E	09-Oct-12	823	1.77	10	*24.71*	0	*0.00*	1	*2.47*	0	*0.00*	84	*207.59*	0	*0.00*	0	*0.00*	**95**	***234.78***
			31.0-L-16-E	12-Oct-12	915	1.96	6	*12.04*	0	*0.00*	0	*0.00*	0	*0.00*	207	*415.52*	3	*6.02*	0	*0.00*	**216**	***433.59***
			31.0-R-16-E	12-Oct-12	573	1.12	4	*22.48*	0	*0.00*	2	*11.24*	0	*0.00*	75	*421.47*	0	*0.00*	0	*0.00*	**81**	***455.19***
		Session Summary			**742**	**7.7**	**39**	***24.58***	**1**	***0.63***	**5**	***3.15***	**0**	***0.00***	**568**	***357.99***	**7**	***4.41***	**0**	***0.00***	**620**	***390.76***
		3	27.2-R-16-E	18-Oct-12	355	0.52	3	*58.50*	0	*0.00*	0	*0.00*	0	*0.00*	4	*78.01*	2	*39.00*	0	*0.00*	**9**	***175.51***
			28.5-L-16-E	17-Oct-12	821	1.23	10	*35.65*	1	*3.56*	0	*0.00*	0	*0.00*	102	*363.63*	8	*28.52*	0	*0.00*	**121**	***431.36***
			29.2-L-16-E	17-Oct-12	964	1.10	0	*0.00*	1	*3.39*	1	*3.39*	1	*3.39*	71	*241.04*	4	*13.58*	0	*0.00*	**78**	***264.81***
			29.7-R-16-E	18-Oct-12	1019	1.57	5	*11.25*	0	*0.00*	0	*0.00*	0	*0.00*	73	*164.27*	1	*2.25*	0	*0.00*	**79**	***177.77***
			31.0-L-16-E	17-Oct-12	1060	1.96	3	*5.20*	2	*3.47*	2	*3.47*	1	*1.73*	91	*157.68*	5	*8.66*	1	*1.73*	**105**	***181.94***
			31.0-R-16-E	18-Oct-12	576	1.14	5	*27.41*	0	*0.00*	0	*0.00*	1	*5.48*	79	*433.11*	1	*5.48*	0	*0.00*	**86**	***471.49***
		Session Summary			**799**	**7.5**	**26**	***15.57***	**4**	***2.40***	**3**	***1.80***	**3**	***1.80***	**420**	***251.59***	**21**	***12.58***	**1**	***0.60***	**478**	***286.34***
		4	27.2-R-16-E	22-Oct-12	394	0.52	2	*35.14*	0	*0.00*	0	*0.00*	7	*123.00*	20	*351.43*	3	*52.71*	0	*0.00*	**32**	***562.28***
			28.5-L-16-E	22-Oct-12	737	1.23	3	*11.91*	0	*0.00*	0	*0.00*	12	*47.66*	30	*119.14*	1	*3.97*	0	*0.00*	**46**	***182.68***
			29.2-L-16-E	25-Oct-12	1089	1.10	1	*3.01*	0	*0.00*	0	*0.00*	0	*0.00*	43	*129.23*	2	*6.01*	0	*0.00*	**46**	***138.24***
			29.7-R-16-E	22-Oct-12	1364	2.27	17	*19.77*	0	*0.00*	1	*1.16*	13	*15.11*	64	*74.41*	0	*0.00*	0	*0.00*	**95**	***110.46***
			31.0-L-16-E	24-Oct-12	944	1.96	4	*7.78*	1	*1.95*	0	*0.00*	0	*0.00*	106	*206.24*	1	*1.95*	0	*0.00*	**112**	***217.92***
			31.0-R-16-E	25-Oct-12	605	1.14	8	*41.76*	0	*0.00*	0	*0.00*	0	*0.00*	38	*198.35*	0	*0.00*	0	*0.00*	**46**	***240.10***
		Session Summary			**856**	**8.2**	**35**	***17.92***	**1**	***0.51***	**1**	***0.51***	**32**	***16.38***	**301**	***154.09***	**7**	***3.58***	**0**	***0.00***	**377**	***193.00***
	Middle Section Total All Samples				**19910**	**31.66**	**218**		**12**		**50**		**36**		**1753**		**38**		**1**		**2108**	
	Middle Section Average All Samples				**830**	**1.32**	**9**	***29.88***	**1**	***1.64***	**2**	***6.85***	**2**	***4.93***	**73**	***240.29***	**2**	***5.21***	**0**	***0.14***	**88**	***301.38***
	Middle Section Standard Error of Mean						**2.43**	***9.36***	**0.20**	***0.95***	**1.12**	***2.48***	**0.75**	***5.39***	**9.55**	***22.79***	**0.40**	***2.77***	**0.04**	***0.07***	**11.14**	***26.89***
All Sections Total All Samples					**43723**	**71.13**	**498**	***0.58***	**27**	***0.03***	**86**	***0.10***	**92**	***0.11***	**5059**	***5.86***	**70**	***0.08***	**2**	***0.00***	**5834**	***6.75***
All Sections Average All Samples							**8**	***34.59***	**0**	***1.88***	**1**	***5.97***	**2**	***6.39***	**84**	***351.37***	**1**	***4.86***	**0**	***0.14***	**97**	***405.20***
All Sections Standard Error of Mean							**1.17**	***5.04***	**0.15**	***0.62***	**0.50**	***1.52***	**0.47**	***2.70***	**7.99**	***34.47***	**0.22**	***1.33***	**0.02**	***0.08***	**8.74**	***36.07***

Table D5 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) during the fall season in the Middle Columbia River, 2 to 25 October 2012.

Reach	Section	Session	Site	Date	Time Sampled (seconds)	Length Sampled (km)	Number Caught (CPUE=no. fish/km/h)									
							Northern Pikeminnow		Redside Shiner		Sculpin spp.		Sucker spp.		All Species	
							No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*	No.	*CPUE*
4	Upper															
		1	232.6-R	04-Oct-12	409	0.80	0	*0.00*	0	*0.00*	0	*0.00*	15	*165.04*	15	*165.04*
			233.1-L	02-Oct-12	900	1.41	0	*0.00*	0	*0.00*	31	*87.94*	187	*530.50*	218	*618.44*
			234.4-R	02-Oct-12	885	1.74	0	*0.00*	0	*0.00*	1	*2.34*	61	*142.61*	62	*144.94*
			234.5-L	04-Oct-12	1040	1.65	0	*0.00*	0	*0.00*	4	*8.39*	51	*106.99*	55	*115.38*
			236.1-L	02-Oct-12	226	0.48	0	*0.00*	0	*0.00*	2	*66.10*	0	*0.00*	2	*66.10*
			236.1-R	04-Oct-12	1296	1.73	1	*1.61*	0	*0.00*	40	*64.23*	21	*33.72*	62	*99.55*
			236.4-L	04-Oct-12	336	0.58	0	*0.00*	0	*0.00*	1	*18.47*	5	*92.36*	6	*110.84*
			236.4-R	02-Oct-12	340	0.59	0	*0.00*	0	*0.00*	0	*0.00*	5	*89.73*	5	*89.73*
		Session 1 Summary			**679**	**8.98**	**1**	***0.59***	**0**	***0.00***	**79**	***46.63***	**345**	***203.65***	**425**	***250.87***
		2	232.6-R	11-Oct-12	410	0.80	0	*0.00*	0	*0.00*	0	*0.00*	22	*241.46*	22	*241.46*
			233.1-L	10-Oct-12	758	1.41	0	*0.00*	0	*0.00*	54	*181.89*	89	*299.78*	143	*481.67*
			234.4-R	10-Oct-12	853	1.74	0	*0.00*	0	*0.00*	0	*0.00*	38	*92.17*	38	*92.17*
			234.5-L	11-Oct-12	883	1.65	0	*0.00*	0	*0.00*	0	*0.00*	23	*56.83*	23	*56.83*
			236.1-L	10-Oct-12	221	0.48	0	*0.00*	0	*0.00*	4	*135.18*	1	*33.80*	5	*168.98*
			236.1-R	11-Oct-12	1257	1.73	0	*0.00*	0	*0.00*	29	*48.01*	30	*49.66*	59	*97.67*
			236.4-L	11-Oct-12	342	0.58	0	*0.00*	0	*0.00*	1	*18.15*	11	*199.64*	12	*217.79*
			236.4-R	10-Oct-12	350	0.59	0	*0.00*	0	*0.00*	2	*34.87*	0	*0.00*	2	*34.87*
		Session 2 Summary			**634**	**8.98**	**0**	***0.00***	**0**	***0.00***	**90**	***56.87***	**214**	***135.23***	**304**	***192.11***
		3	232.6-R	16-Oct-12	396	0.75	0	*0.00*	0	*0.00*	1	*12.19*	22	*268.10*	23	*280.28*
			233.1-L	16-Oct-12	695	1.41	0	*0.00*	0	*0.00*	7	*25.72*	138	*506.96*	145	*532.68*
			234.4-R	16-Oct-12	981	1.74	0	*0.00*	0	*0.00*	3	*6.33*	74	*156.07*	77	*162.40*
			234.5-L	16-Oct-12	669	1.65	0	*0.00*	0	*0.00*	3	*9.78*	15	*48.92*	18	*58.70*
			236.1-L	15-Oct-12	183	0.48	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
			236.1-R	15-Oct-12	1273	1.73	0	*0.00*	1	*1.63*	3	*4.90*	16	*26.15*	20	*32.69*
			236.4-L	15-Oct-12	342	0.58	0	*0.00*	0	*0.00*	4	*72.60*	3	*54.45*	7	*127.04*
			236.4-R	15-Oct-12	344	0.59	0	*0.00*	0	*0.00*	0	*0.00*	5	*88.69*	5	*88.69*
		Session 3 Summary			**610**	**8.93**	**0**	***0.00***	**1**	***0.66***	**21**	***13.88***	**273**	***180.39***	**295**	***194.93***
		4	232.6-R	23-Oct-12	414	0.80	0	*0.00*	0	*0.00*	0	*0.00*	8	*86.96*	8	*86.96*
			233.1-L	24-Oct-12	708	1.41	0	*0.00*	0	*0.00*	16	*57.70*	27	*97.37*	43	*155.07*
			234.4-R	23-Oct-12	821	1.74	0	*0.00*	0	*0.00*	0	*0.00*	25	*63.00*	25	*63.00*
			234.5-L	24-Oct-12	993	1.65	0	*0.00*	0	*0.00*	2	*4.39*	14	*30.76*	16	*35.16*
			236.1-L	23-Oct-12	232	0.48	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
			236.1-R	23-Oct-12	1314	1.73	0	*0.00*	1	*1.58*	4	*6.33*	5	*7.92*	10	*15.84*
			236.4-L	23-Oct-12	313	0.58	0	*0.00*	0	*0.00*	0	*0.00*	3	*59.49*	3	*59.49*
			236.4-R	23-Oct-12	273	0.59	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
		Session 4 Summary			**634**	**8.98**	**0**	***0.00***	**1**	***0.63***	**22**	***13.92***	**82**	***51.89***	**105**	***66.45***
	Upper Section Total All Samples				**20457**	**35.87**	**1**		**2**		**212**		**914**		**1129**	
	Upper Section Average All Samples				**639**	**1.12**	**0**	***0.16***	**0**	***0.31***	**7**	***33.28***	**29**	***143.49***	**35**	***177.24***
	Upper Section Standard Error of Mean						**0.03**	***0.05***	**0.04**	***0.07***	**2.32**	***7.65***	**7.41**	***23.39***	**8.78**	***26.42***
3	Eddy															
		1	231.3-R	03-Oct-12	839	0.90	1	*4.77*	6	*28.61*	39	*185.94*	24	*114.42*	70	*333.73*
		Session 1 Summary			**839**	**0.90**	**1**	***4.77***	**6**	***28.61***	**39**	***185.94***	**24**	***114.42***	**70**	***333.73***
		2	231.3-R	12-Oct-12	841	0.90	0	*0.00*	1	*4.76*	3	*14.27*	30	*142.69*	34	*161.71*
		Session 2 Summary			**841**	**0.90**	**0**	***0.00***	**1**	***4.76***	**3**	***14.27***	**30**	***142.69***	**34**	***161.71***
		3	231.3-R	17-Oct-12	820	0.90	0	*0.00*	0	*0.00*	1	*4.88*	4	*19.51*	5	*24.39*
		Session 3 Summary			**820**	**0.90**	**0**	***0.00***	**0**	***0.00***	**1**	***4.88***	**4**	***19.51***	**5**	***24.39***
		4	231.3-R	25-Oct-12	856	0.90	0	*0.00*	50	*233.64*	16	*74.77*	2	*9.35*	68	*317.76*
		Session 4 Summary			**856**	**0.90**	**0**	***0.00***	**50**	***233.64***	**16**	***74.77***	**2**	***9.35***	**68**	***317.76***
	Eddy Section Total All Samples				**3356**	**3.60**	**1**		**57**		**59**		**60**		**177**	
	Eddy Section Average All Samples				**839**	**0.90**	**0**	***1.19***	**14**	***67.94***	**15**	***70.32***	**15**	***71.51***	**44**	***210.97***
	Eddy Section Standard Error of Mean						**0.25**	***1.19***	**11.99**	***55.98***	**8.74**	***41.64***	**7.05**	***33.51***	**15.47**	***72.86***
3	Middle															
		1	227.2-R	03-Oct-12	431	0.52	0	*0.00*	0	*0.00*	40	*642.51*	8	*128.50*	48	*771.02*
			228.5-L	03-Oct-12	888	1.23	2	*6.59*	2	*6.59*	52	*171.39*	74	*243.90*	130	*428.48*
			229.2-L	04-Oct-12	906	1.10	0	*0.00*	9	*32.51*	18	*65.02*	98	*354.00*	125	*451.54*
			229.7-R	03-Oct-12	1636	2.27	2	*1.94*	0	*0.00*	34	*32.96*	150	*145.41*	186	*180.30*
			231.0-L	05-Oct-12	1011	1.96	1	*1.82*	0	*0.00*	54	*98.10*	50	*90.84*	105	*190.76*
			231.0-R	03-Oct-12	658	1.14	0	*0.00*	0	*0.00*	0	*0.00*	18	*86.39*	18	*86.39*
		Session 1 Summary			**922**	**8.22**	**5**	***2.38***	**11**	***5.23***	**198**	***94.09***	**398**	***189.12***	**612**	***290.81***
		2	227.2-R	09-Oct-12	363	0.52	0	*0.00*	0	*0.00*	1	*19.07*	10	*190.72*	11	*209.79*
			228.5-L	09-Oct-12	838	1.23	1	*3.49*	11	*38.42*	9	*31.43*	37	*129.23*	58	*202.57*
			229.2-L	12-Oct-12	940	1.10	3	*10.44*	4	*13.93*	308	*1072.34*	45	*156.67*	360	*1253.38*
			229.7-R	09-Oct-12	823	1.77	2	*4.94*	0	*0.00*	2	*4.94*	49	*121.09*	53	*130.98*
			231.0-L	12-Oct-12	915	1.96	0	*0.00*	0	*0.00*	0	*0.00*	40	*80.29*	40	*80.29*
			231.0-R	12-Oct-12	573	1.12	0	*0.00*	0	*0.00*	0	*0.00*	2	*11.24*	2	*11.24*
		Session 2 Summary			**742**	**7.70**	**6**	***3.78***	**15**	***9.45***	**320**	***201.68***	**183**	***115.34***	**524**	***330.26***
		3	227.2-R	18-Oct-12	355	0.52	0	*0.00*	0	*0.00*	0	*0.00*	1	*19.50*	1	*19.50*
			228.5-L	17-Oct-12	821	1.23	1	*3.56*	26	*92.69*	25	*89.12*	37	*131.90*	89	*317.28*
			229.2-L	17-Oct-12	964	1.10	1	*3.39*	157	*533.01*	106	*359.86*	24	*81.48*	288	*977.74*
			229.7-R	18-Oct-12	1019	1.57	0	*0.00*	3	*6.75*	0	*0.00*	34	*76.51*	37	*83.26*
			231.0-L	17-Oct-12	1060	1.96	1	*1.73*	2	*3.47*	15	*25.99*	27	*46.78*	45	*77.97*
			231.0-R	18-Oct-12	576	1.14	0	*0.00*	0	*0.00*	0	*0.00*	18	*98.68*	18	*98.68*
		Session 3 Summary			**799**	**7.52**	**3**	***1.80***	**188**	***112.62***	**146**	***87.46***	**141**	***84.46***	**478**	***286.34***
		4	227.2-R	22-Oct-12	394	0.52	0	*0.00*	1	*17.57*	0	*0.00*	3	*52.71*	4	*70.29*
			228.5-L	22-Oct-12	737	1.23	0	*0.00*	0	*0.00*	1	*3.97*	5	*19.86*	6	*23.83*
			229.2-L	25-Oct-12	1089	1.10	1	*3.01*	12	*36.06*	68	*204.36*	30	*90.16*	111	*333.58*
			229.7-R	22-Oct-12	1364	2.27	0	*0.00*	0	*0.00*	0	*0.00*	68	*79.06*	68	*79.06*
			231.0-L	24-Oct-12	944	1.96	0	*0.00*	0	*0.00*	6	*11.67*	21	*40.86*	27	*52.53*
			231.0-R	25-Oct-12	605	1.14	0	*0.00*	0	*0.00*	0	*0.00*	12	*62.64*	12	*62.64*
		Session 4 Summary			**856**	**8.22**	**1**	***0.51***	**13**	***6.66***	**75**	***38.39***	**139**	***71.16***	**228**	***116.72***
	Middle Section Total All Samples				**19910**	**31.66**	**15**		**227**		**739**		**861**		**1842**	
	Middle Section Average All Samples				**830**	**1.32**	**1**	***2.06***	**9**	***31.12***	**31**	***101.30***	**36**	***118.02***	**77**	***252.49***
	Middle Section Standard Error of Mean						**0.18**	***0.54***	**6.53**	***22.19***	**13.30**	***51.32***	**7.04**	***15.57***	**18.52**	***65.24***
All Sections Total All Samples					**43723**	**71.13**	**17**		**286**		**1010**		**1835**		**3148**	
All Sections Average All Samples					**729**	**1.19**	**0**	***1.18***	**5**	***19.86***	**17**	***70.15***	**31**	***127.45***	**52**	***218.64***
All Sections Standard Error of Mean							**0.08**	***0.25***	**2.76**	***9.72***	**5.62**	***21.57***	**4.88**	***14.03***	**9.09**	***30.51***

Table D6 Summary of fish captured and recaptured in sampled sections of the Middle Columbia River during the spring season, 28 May to 22 June 2012.

Species	Size-class	Session	Number of Fish Captured	Number of Fish Marked	Number of Fish Recaptured (within year)	Number of Fish Recaptured (between years)
Brook Trout	All	1	1	1	-	0
		2	0	0	0	0
		3	0	0	0	0
		4	0	0	0	0
Brook Trout Total			**1**	**1**	**0**	**0**
Bull Trout	All	1	58	41	-	17
		2	37	30	0	7
		3	36	22	6	8
		4	81	64	4	12
Bull Trout Total			**212**	**157**	**10**	**44**
Burbot	All	1	0	0	-	0
		2	0	0	0	0
		3	2	2	0	0
		4	0	0	0	0
Burbot Total			**2**	**2**	**0**	**0**
Cutthroat Trout	All	1	1	1	-	0
		2	0	0	0	0
		3	0	0	0	0
		4	0	0	0	0
Cutthroat Trout Total			**1**	**1**	**0**	**0**
Lake Whitefish	All	1	0	0	-	0
		2	0	0	0	0
		3	0	0	0	0
		4	1	1	0	0
Lake Whitefish Total			**1**	**1**	**0**	**0**
Mountain Whitefish	All	1	456	346	-	91
		2	331	232	15	78
		3	454	326	33	78
		4	334	227	32	53
Mountain Whitefish Total			**1575**	**1131**	**80**	**300**
Rainbow Trout	All	1	11	8	-	2
		2	1	1	0	0
		3	9	5	1	2
		4	9	8	0	1
Rainbow Trout Total			**30**	**22**	**1**	**5**
Peamouth	All	1	0	0	-	0
		2	0	0	0	0
		3	1	1	0	0
		4	2	2	0	0
Peamouth Total			**3**	**3**	**0**	**0**
Sucker species	All	1	48	46	-	2
		2	59	58	0	1
		3	80	75	2	2
		4	76	71	2	1
Sucker species Total			**263**	**250**	**4**	**6**

Table D7 Summary of fish captured and recaptured in sampled sections of the Middle Columbia River during the fall season, 2 to 25 October 2012.

Species	Size-class	Session	Number of Fish Captured	Number of Fish Marked	Number of Fish Recaptured (within year)	Number of Fish Recaptured (between years)
Bull Trout	All	1	85	59	-	25
		2	62	46	3	13
		3	34	26	2	6
		4	26	16	4	6
Bull Trout Total			**207**	**147**	**9**	**50**
Burbot	All	1	0	0	-	0
		2	1	1	0	0
		3	2	2	0	0
		4	0	0	0	0
Burbot Total			**3**	**3**	**0**	**0**
Lake Whitefish	All	1	1	1	-	0
		2	1	1	0	0
		3	3	3	0	0
		4	29	29	0	0
Lake Whitefish Total			**34**	**34**	**0**	**0**
Mountain Whitefish	All	1	293	220	-	53
		2	343	271	11	55
		3	255	187	9	53
		4	240	177	14	39
Mountain Whitefish Total			**1131**	**855**	**34**	**200**
Rainbow Trout	All	1	8	5	-	1
		2	11	8	0	3
		3	17	13	1	3
		4	12	10	2	0
Rainbow Trout Total			**48**	**36**	**3**	**7**
Yellow Perch	All	1	1	1	-	0
		2	0	0	0	0
		3	1	1	0	0
		4	0	0	0	0
Yellow Perch Total			**2**	**2**	**0**	**0**
Northern Pikeminnow	All	1	6	5	-	1
		2	5	5	0	0
		3	3	3	0	0
		4	1	1	0	0
Northern Pikeminnow Total			**15**	**14**	**0**	**1**
Sucker species	All	1	234	210	-	22
		2	138	120	6	11
		3	137	123	6	8
		4	64	54	4	6
Sucker species Total			**573**	**507**	**16**	**47**

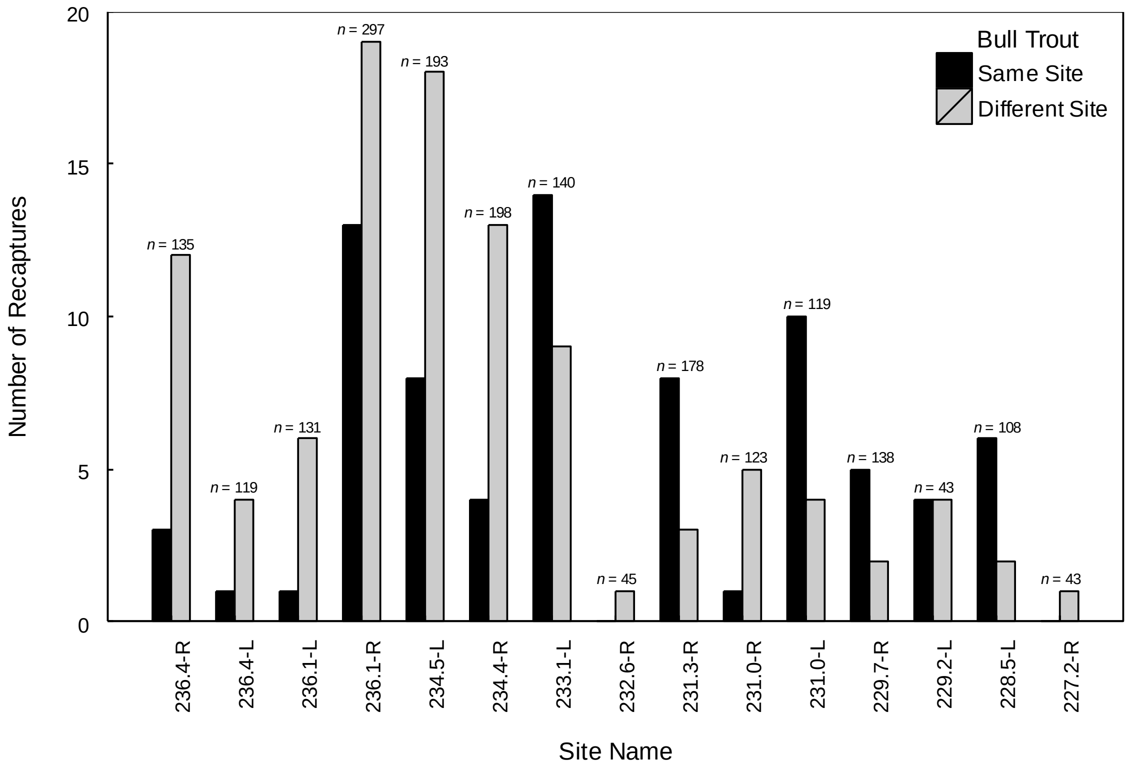


Figure D1 Summary of intra-year site movement by Bull Trout in the Middle Columbia River relative to the site of initial release, 2001 to 2012. The "*n*" value located above each site represents the number of fish marked at that site (all years combined) but excludes fish marked during the last session each year.

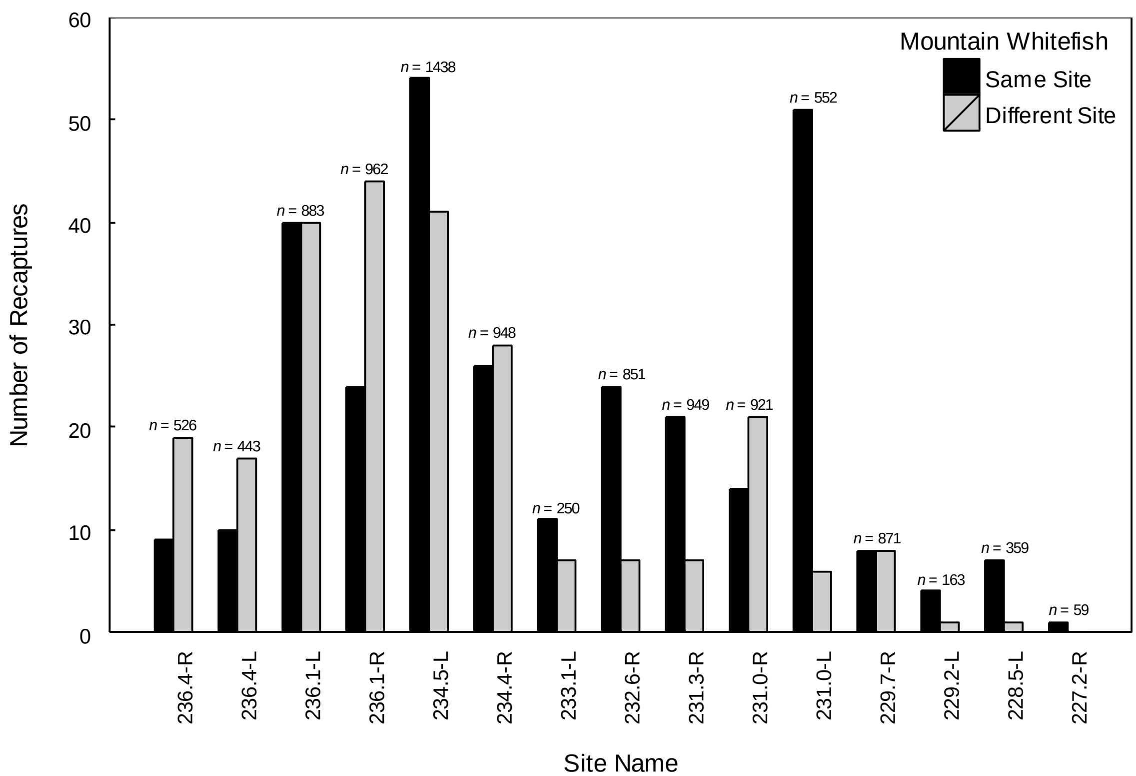


Figure D2 Summary of intra-year site movement by Mountain Whitefish in the Middle Columbia River relative to the site of initial release, 2001 to 2012. The "*n*" value located above each site represents the number of fish marked at that site (all years combined) but excludes fish marked during the last session each year.

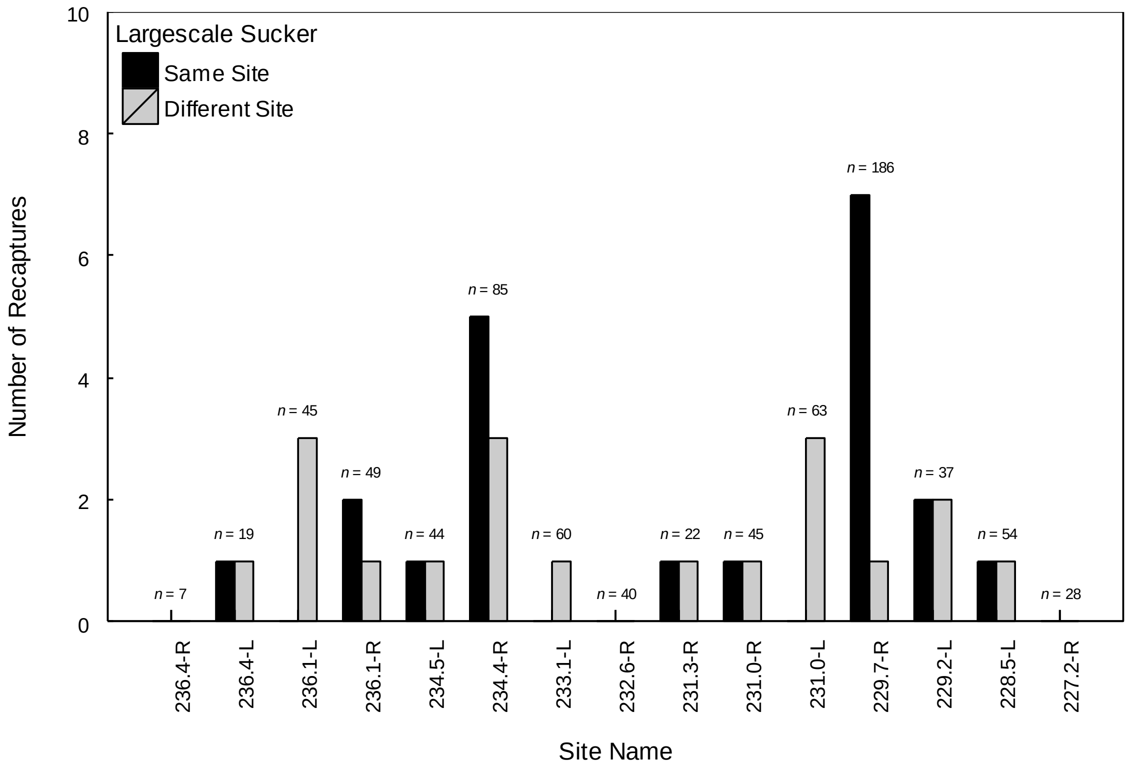


Figure D3 Summary of intra-year site movement by Largescale Sucker in the Middle Columbia River relative to the site of initial release, 2001 to 2012. The "*n*" value located above each site represents the number of fish marked at that site (all years combined) but excludes fish marked during the last session each year.

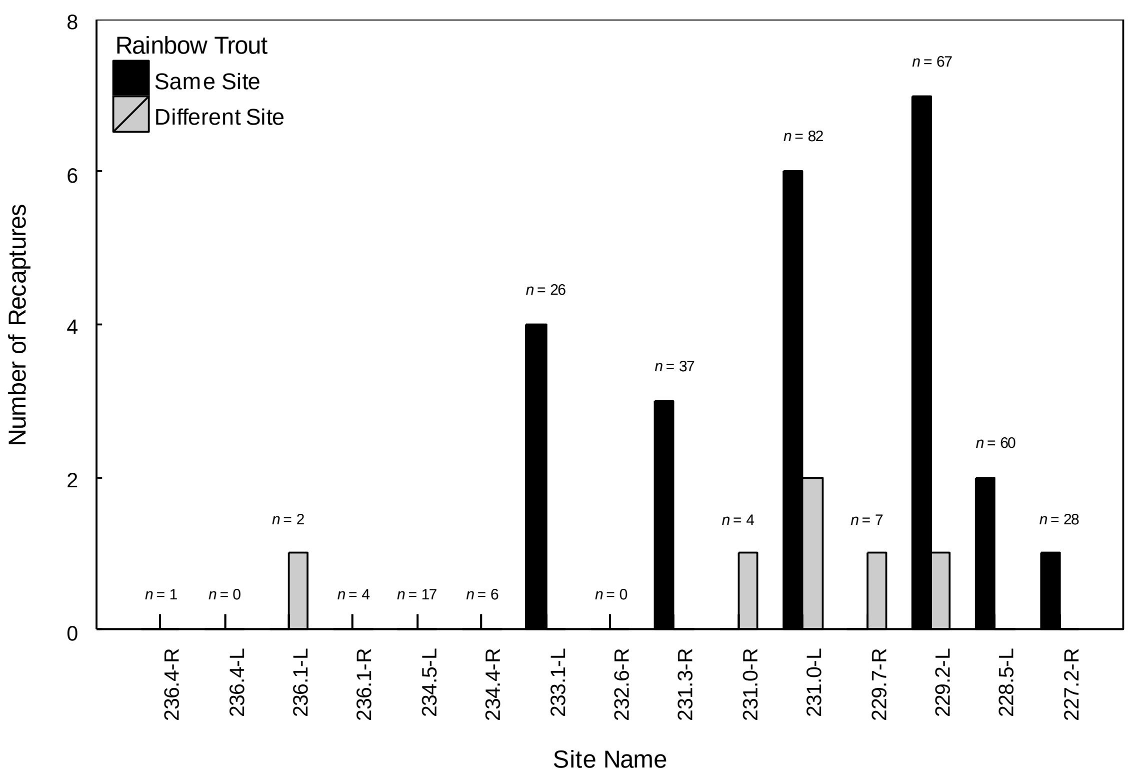


Figure D4 Summary of intra-year site movement by Rainbow Trout in the Middle Columbia River relative to the site of initial release, 2001 to 2012. The "*n*" value located above each site represents the number of fish marked at that site (all years combined) but excludes fish marked during the last session each year.

APPENDIX E

Life History Data

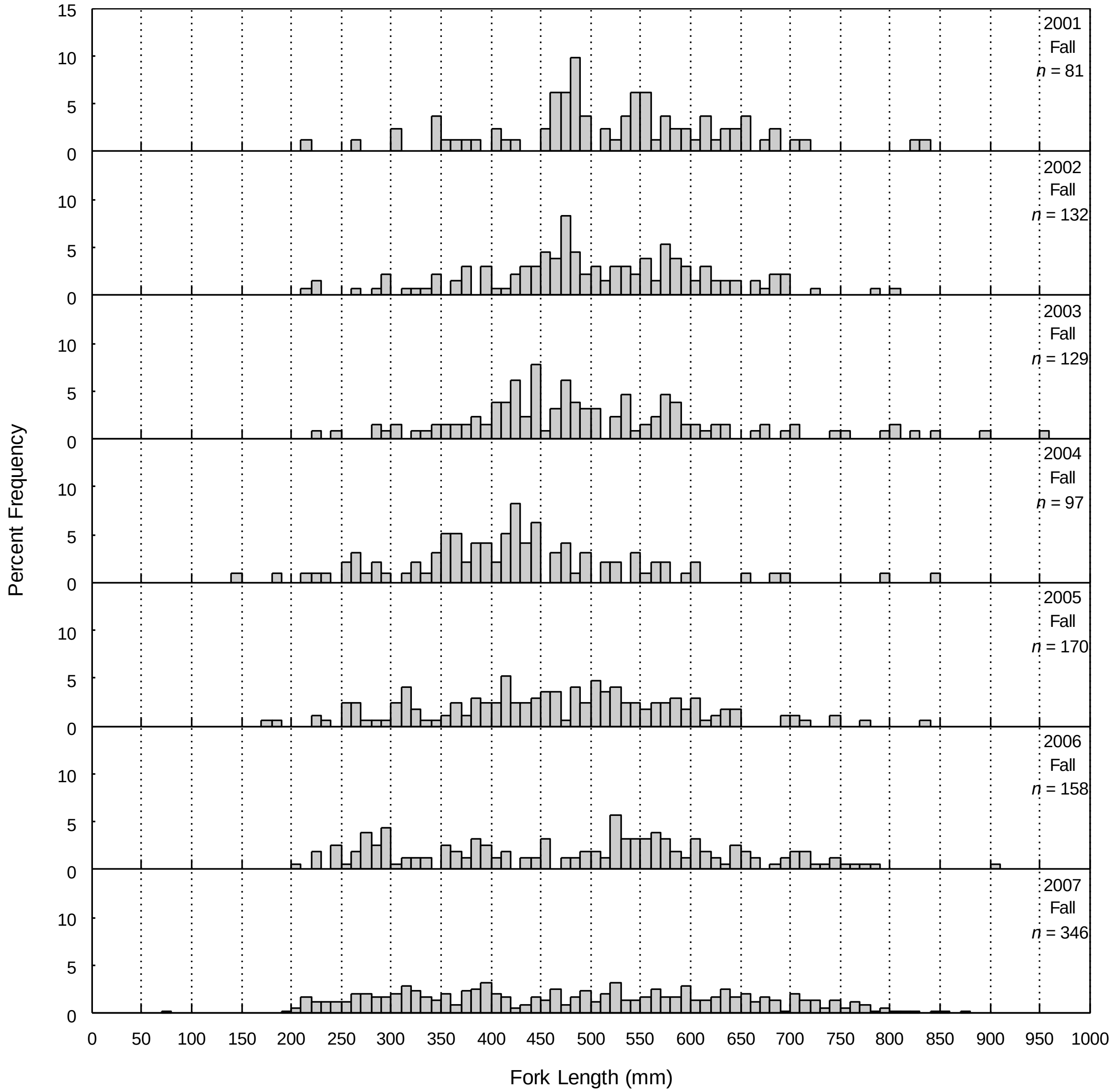


Figure E1 Length-frequency distributions for Bull Trout captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2001 to 2012. Bull Trout that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth. Boat electroshocking surveys were not conducted downstream of Big Eddy for all years prior to 2007.

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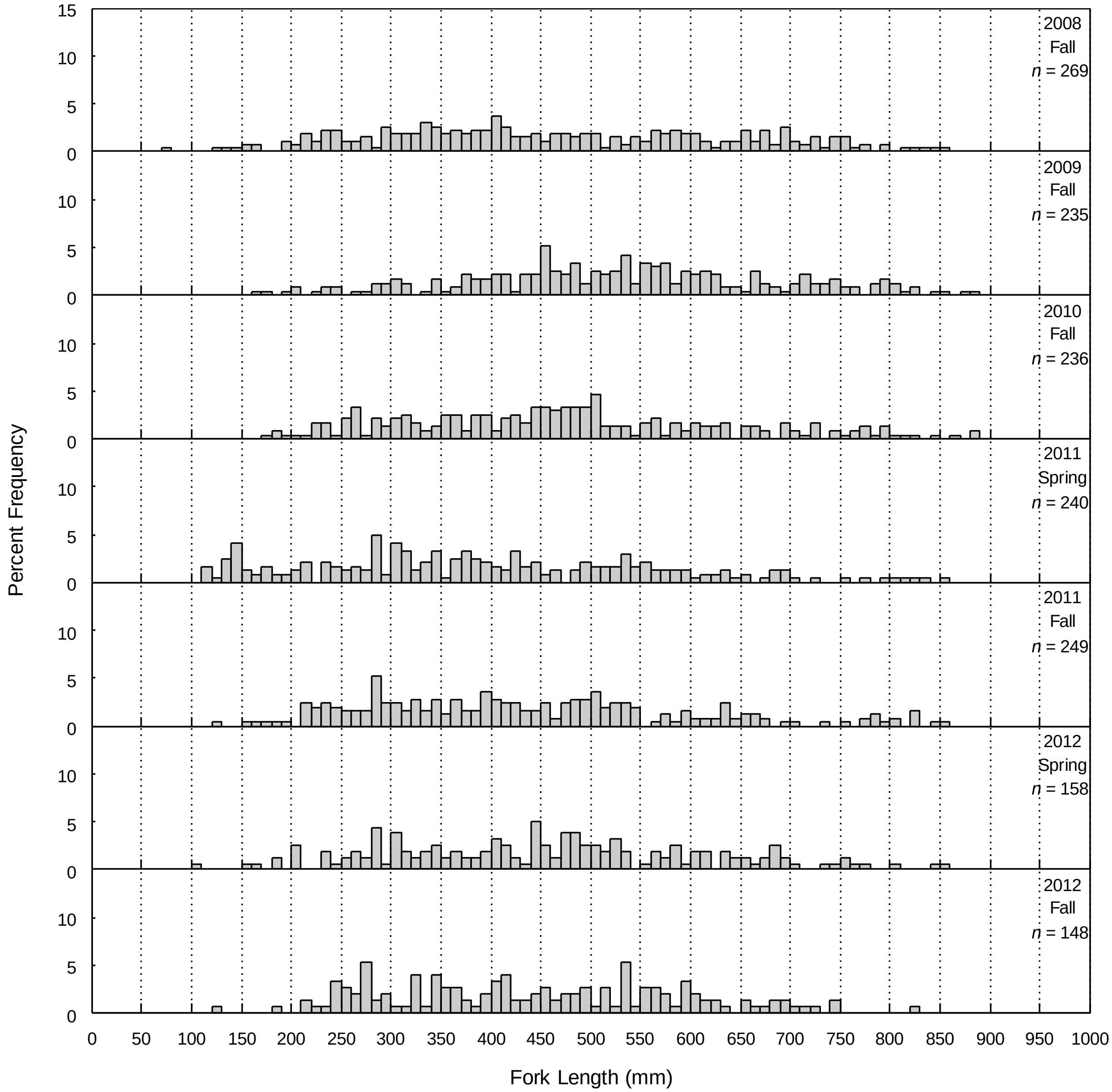

Figure E1 Concluded.

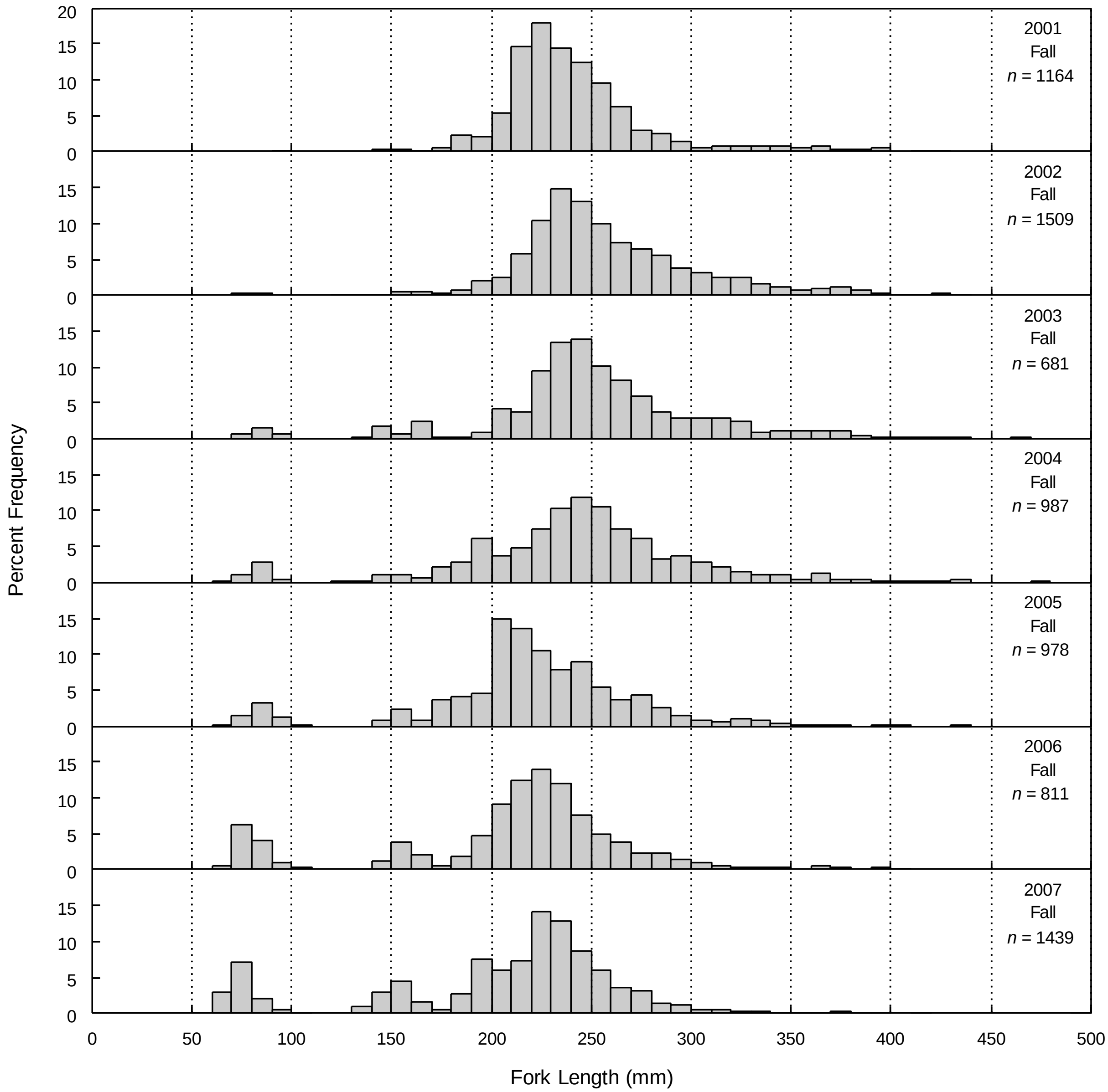

Figure E2 Length-frequency distributions for Mountain Whitefish captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2001 to 2012. Mountain Whitefish that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth. Boat electroshocking surveys were not conducted downstream of Big Eddy for all years prior to 2007.

Continued…

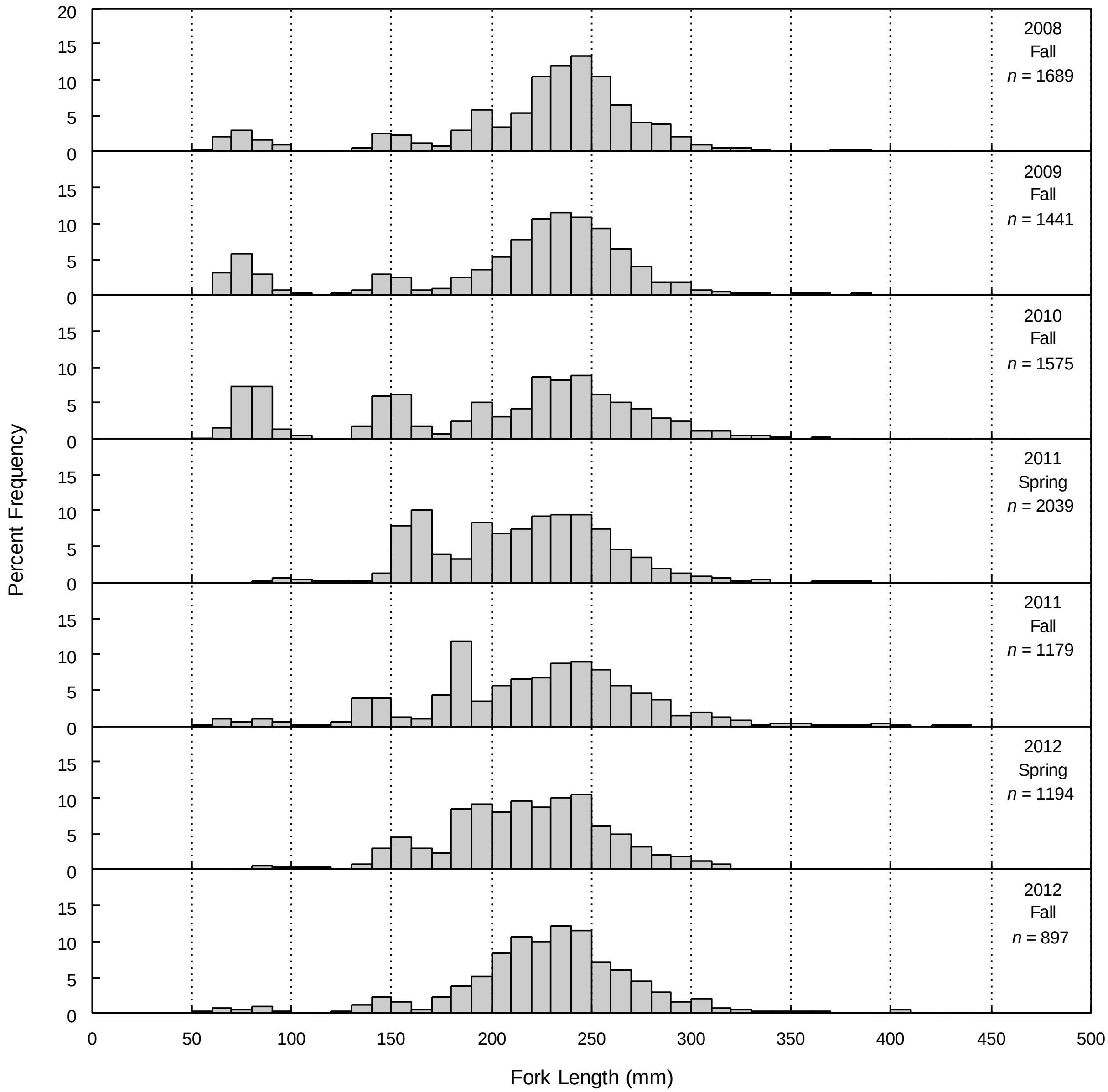

Figure E2 Concluded.

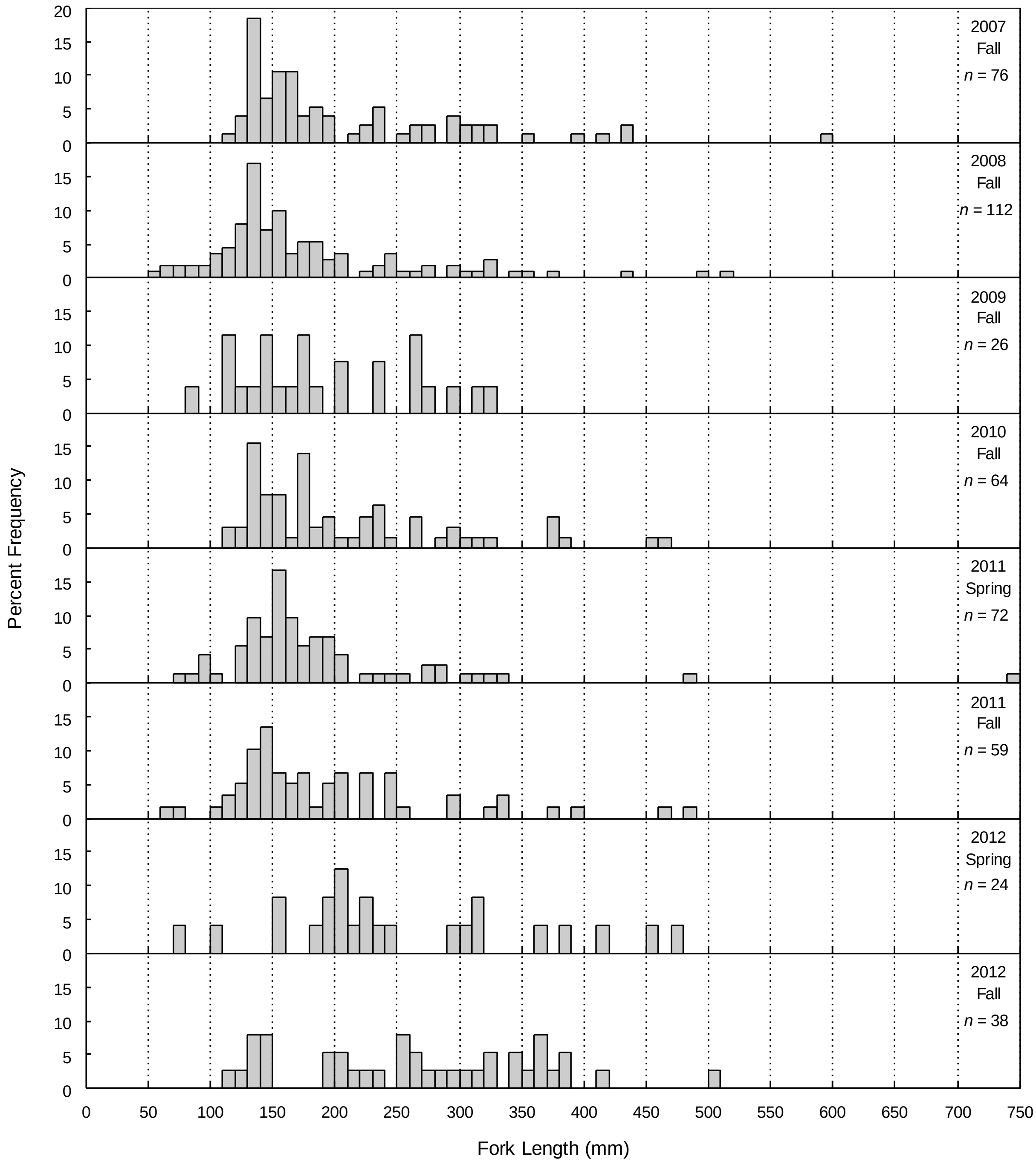

Figure E3 Length-frequency distributions for Rainbow Trout captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2007 to 2012. Rainbow Trout that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth. Boat electroshocking surveys were not conducted downstream of Big Eddy for all years prior to 2007.

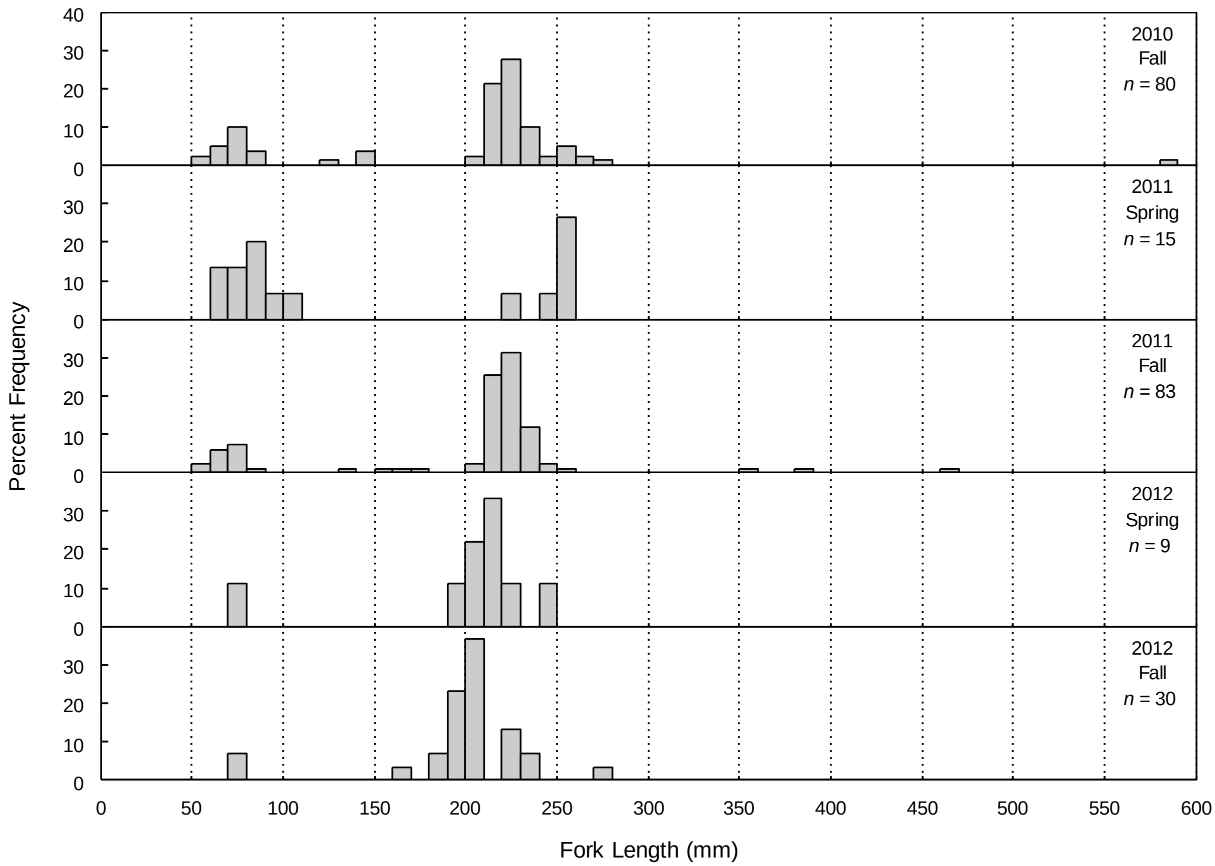

Figure E4 Length-frequency distributions for Kokanee captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012.

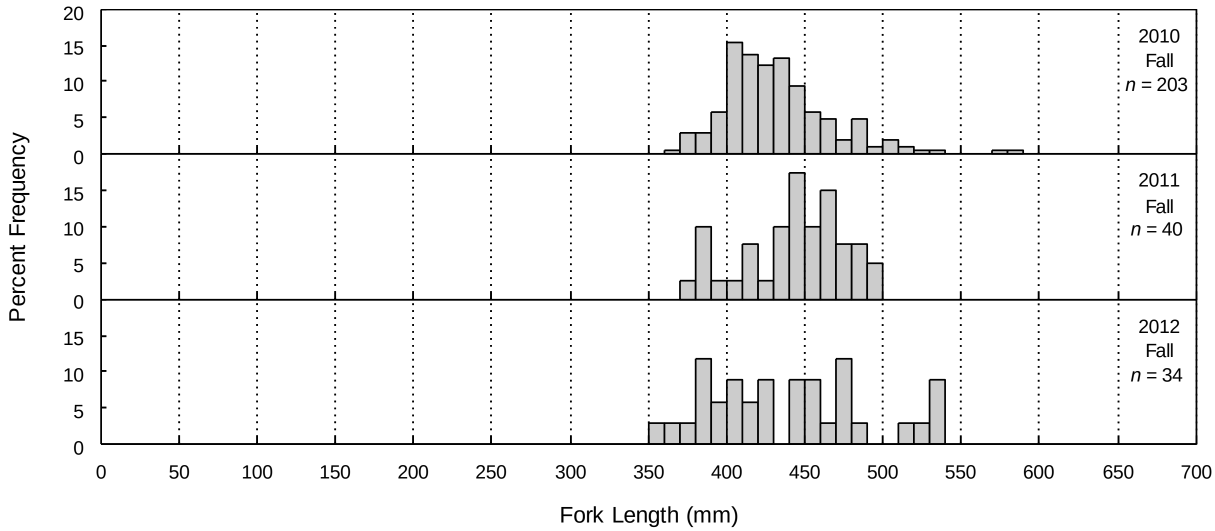

Figure E5 Length-frequency distributions for Lake Whitefish captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012. Lake Whitefish that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth.

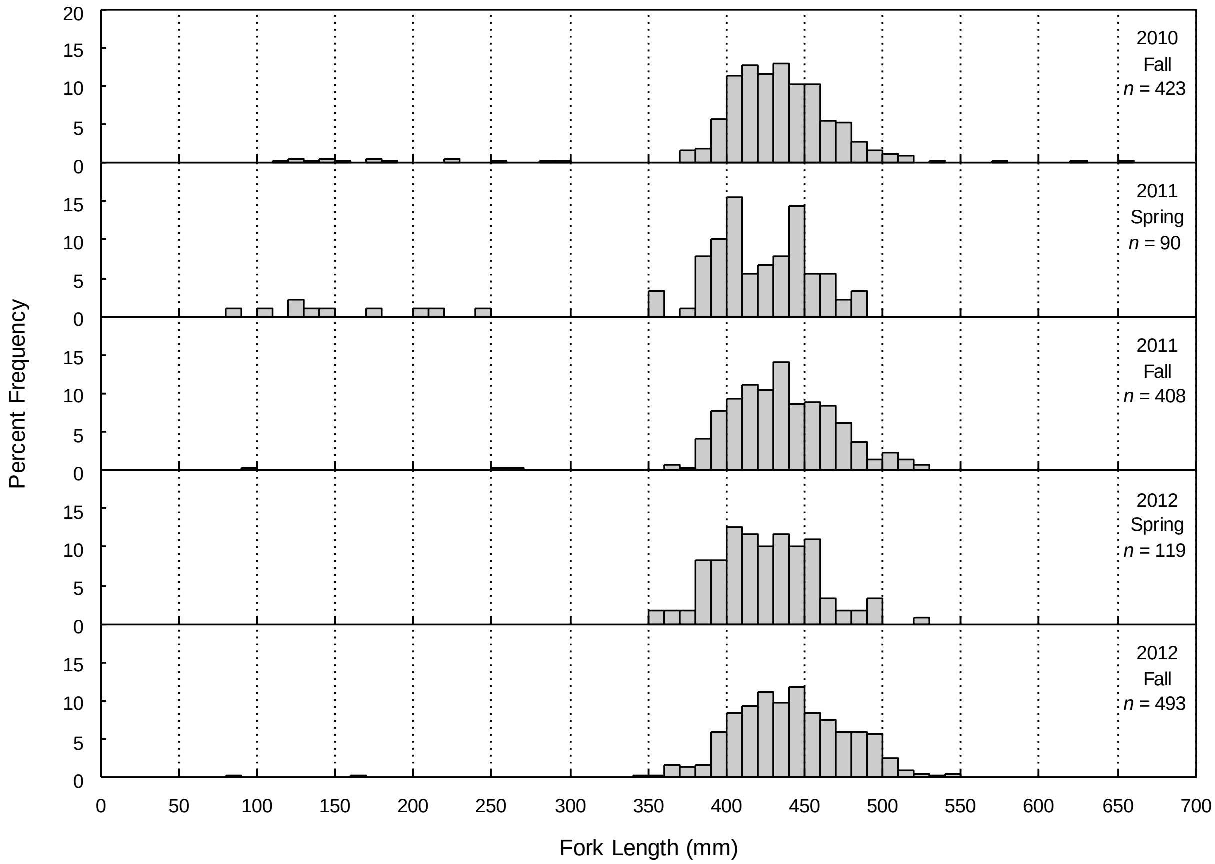

Figure E6 Length-frequency distributions for Largescale Sucker captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012. Largescale Sucker that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth.

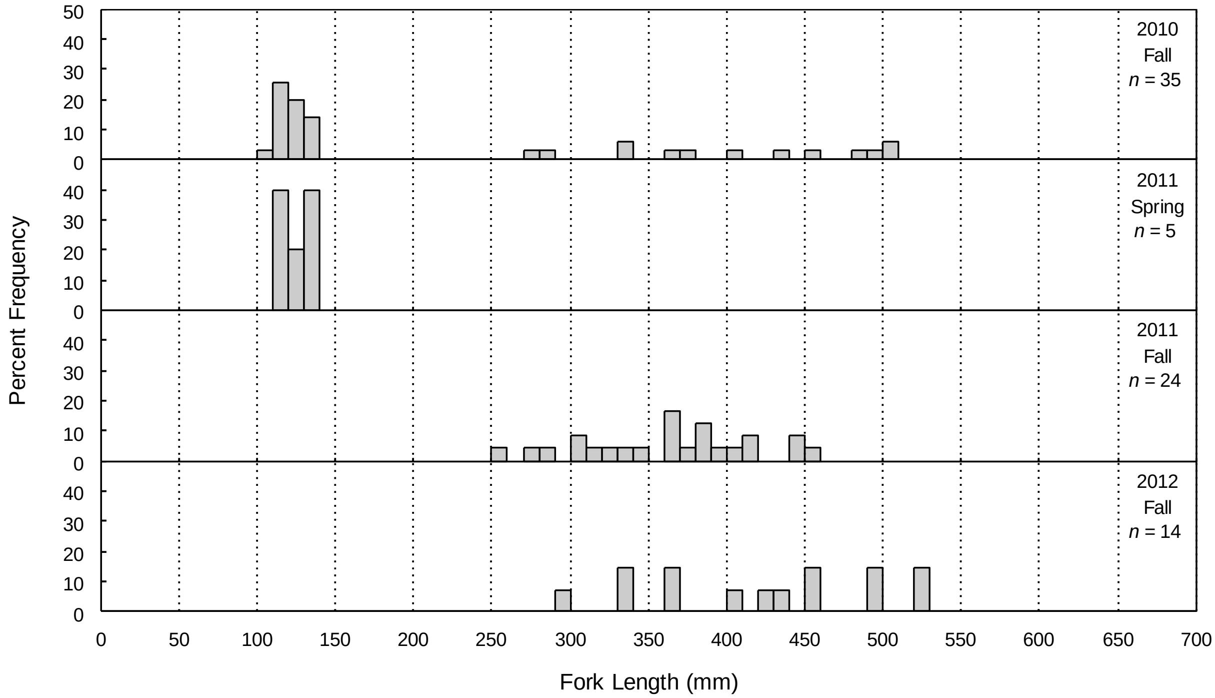

Figure E7 Length-frequency distributions for Northern Pikeminnow captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012. Northern Pikeminnow that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth.

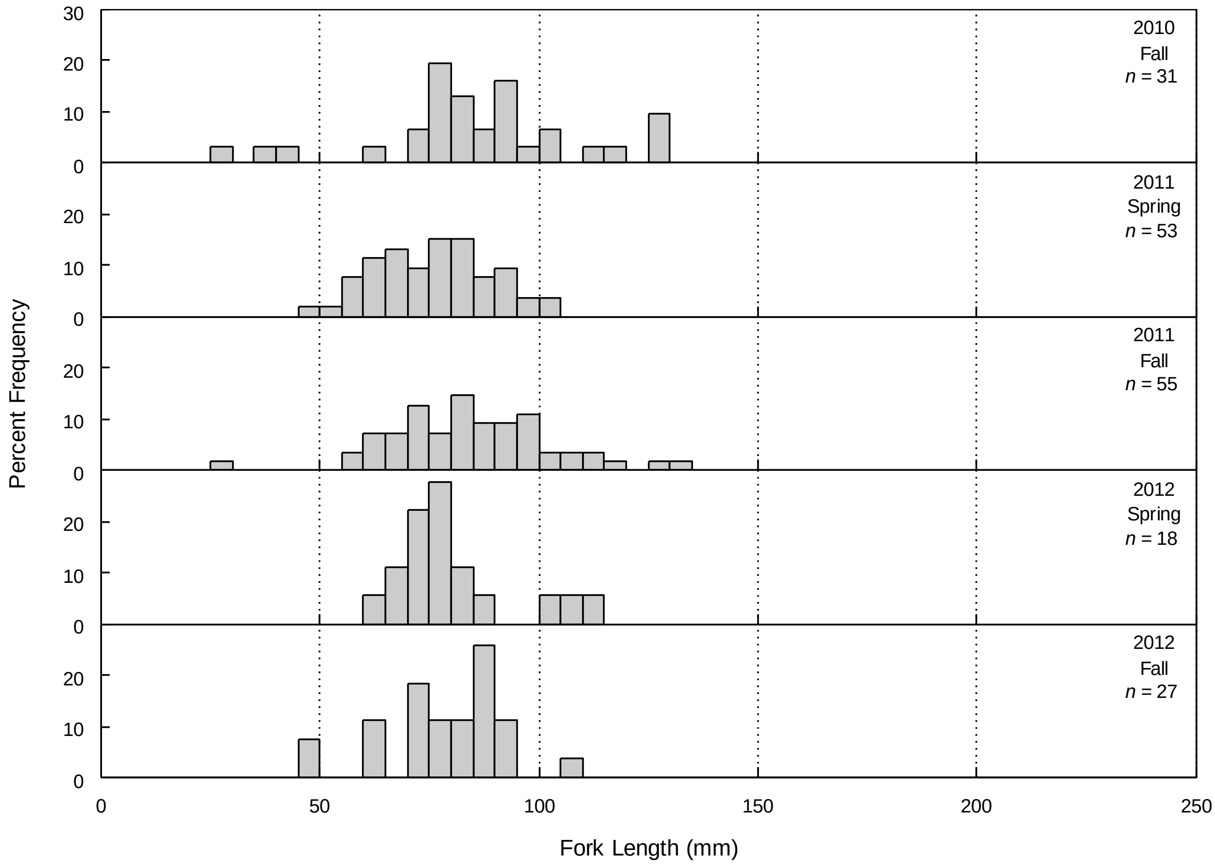

Figure E8 Length-frequency distributions for Prickly Sculpin captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012.

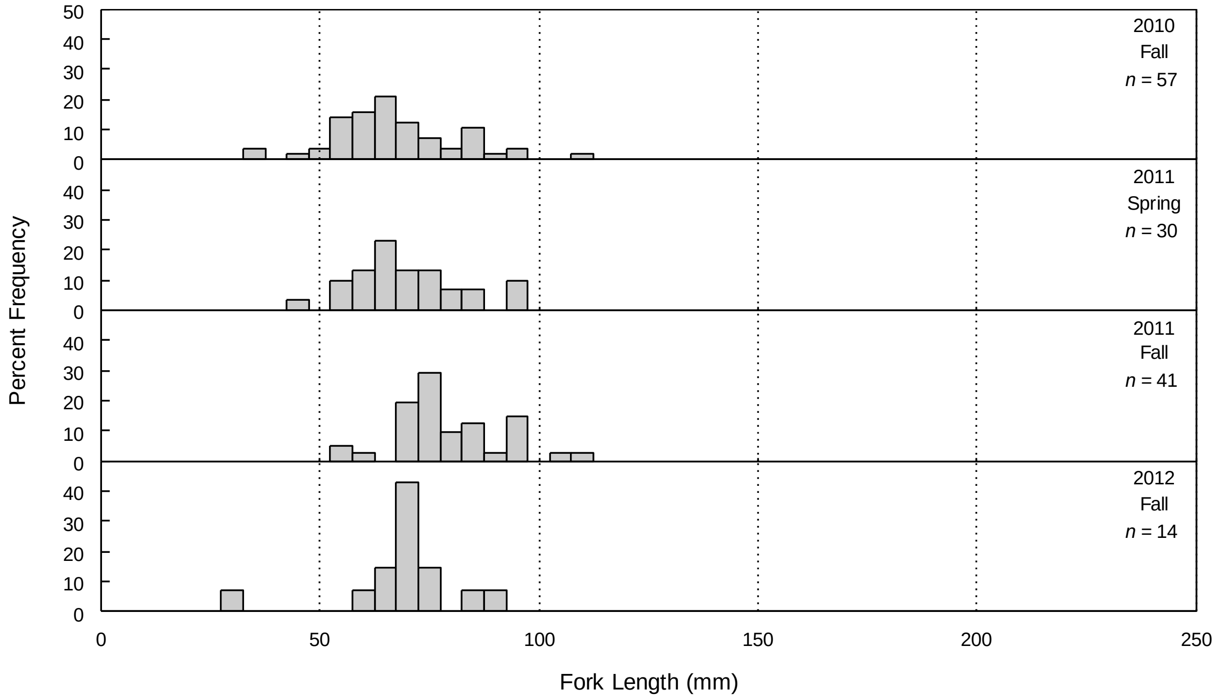

Figure E9	Length-frequency distributions for Redside Shiner captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012.

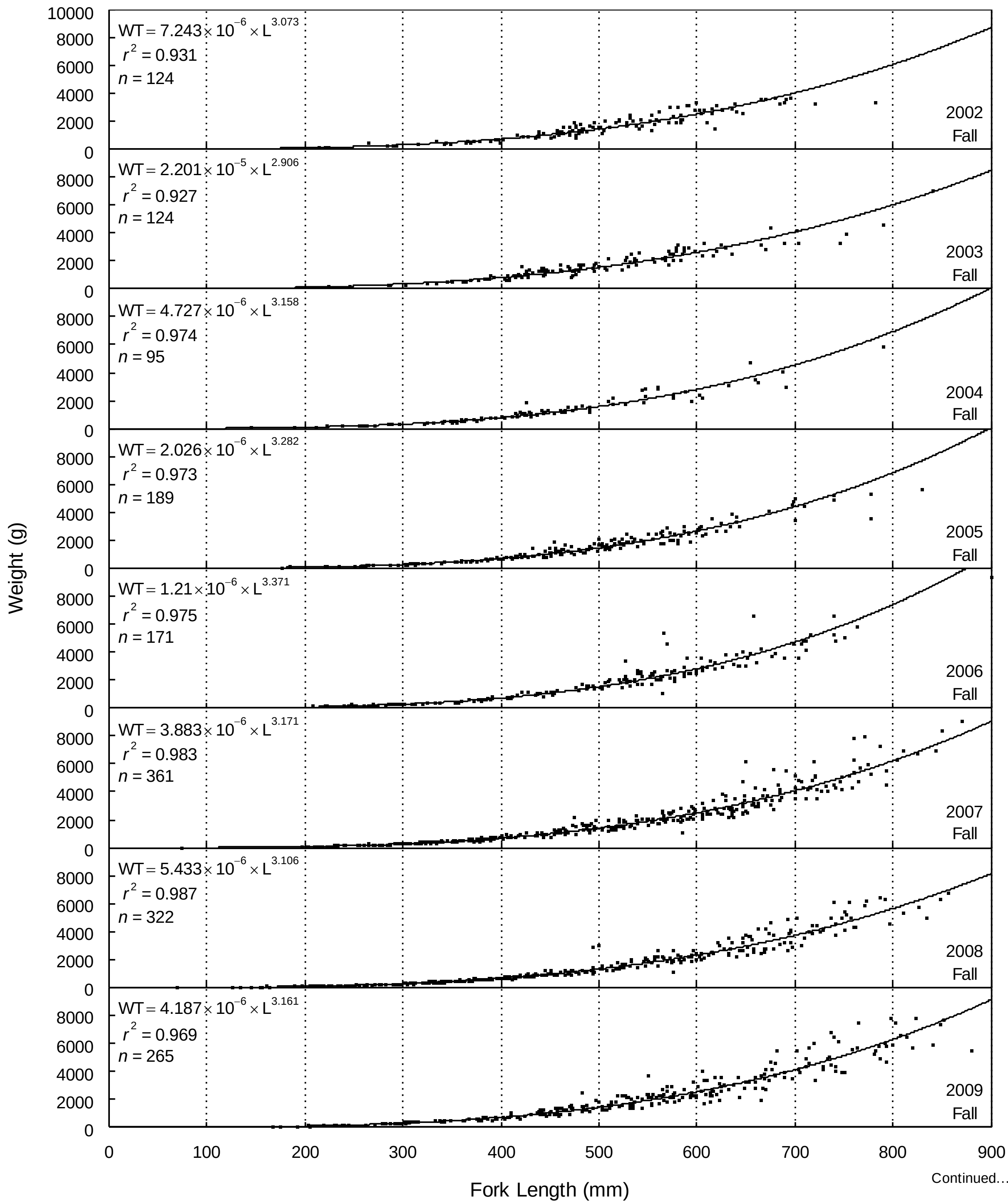

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Figure E10 Length-weight regression for Bull Trout captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2001 to 2012. Bull Trout that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth. Boat electroshocking surveys were not conducted downstream of Big Eddy for all years prior to 2007.

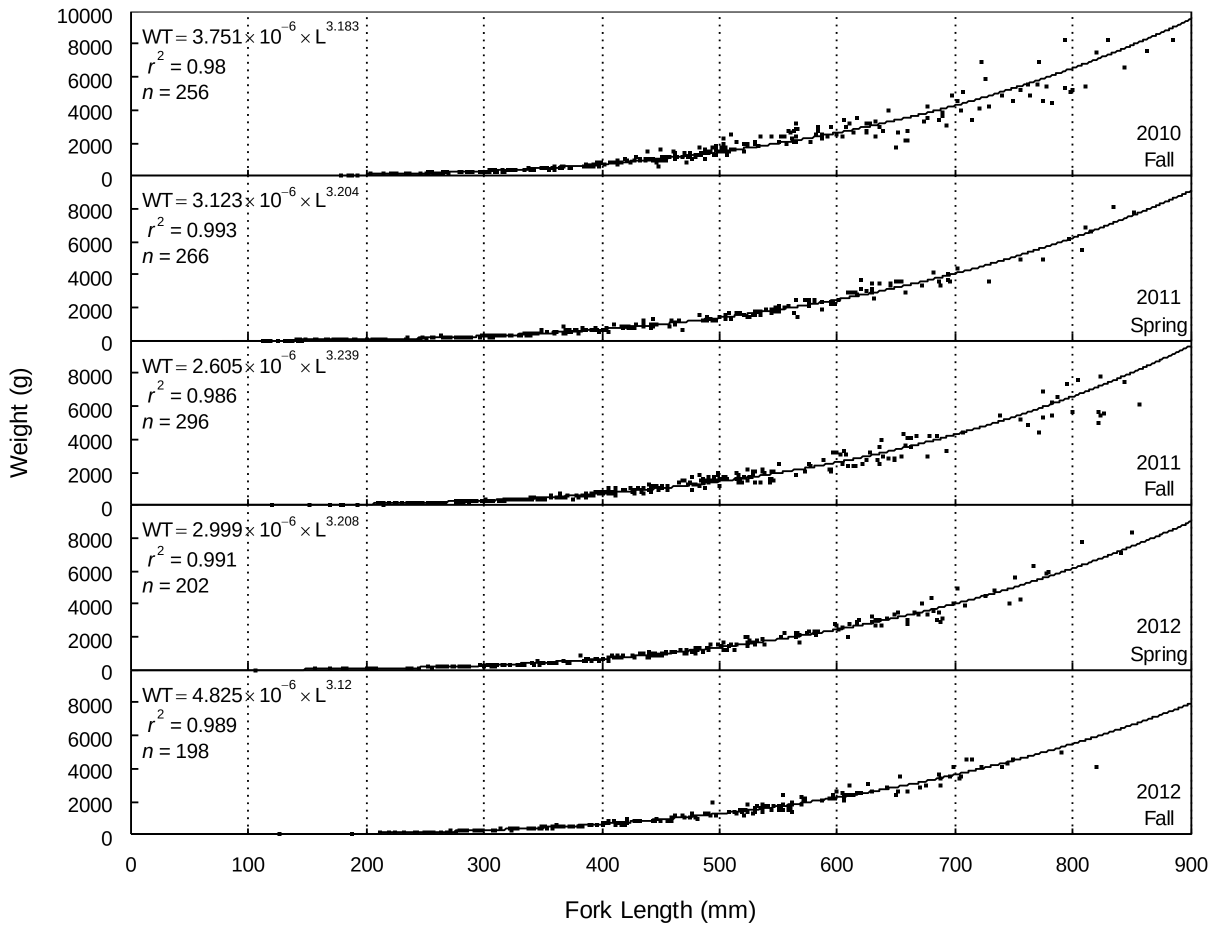
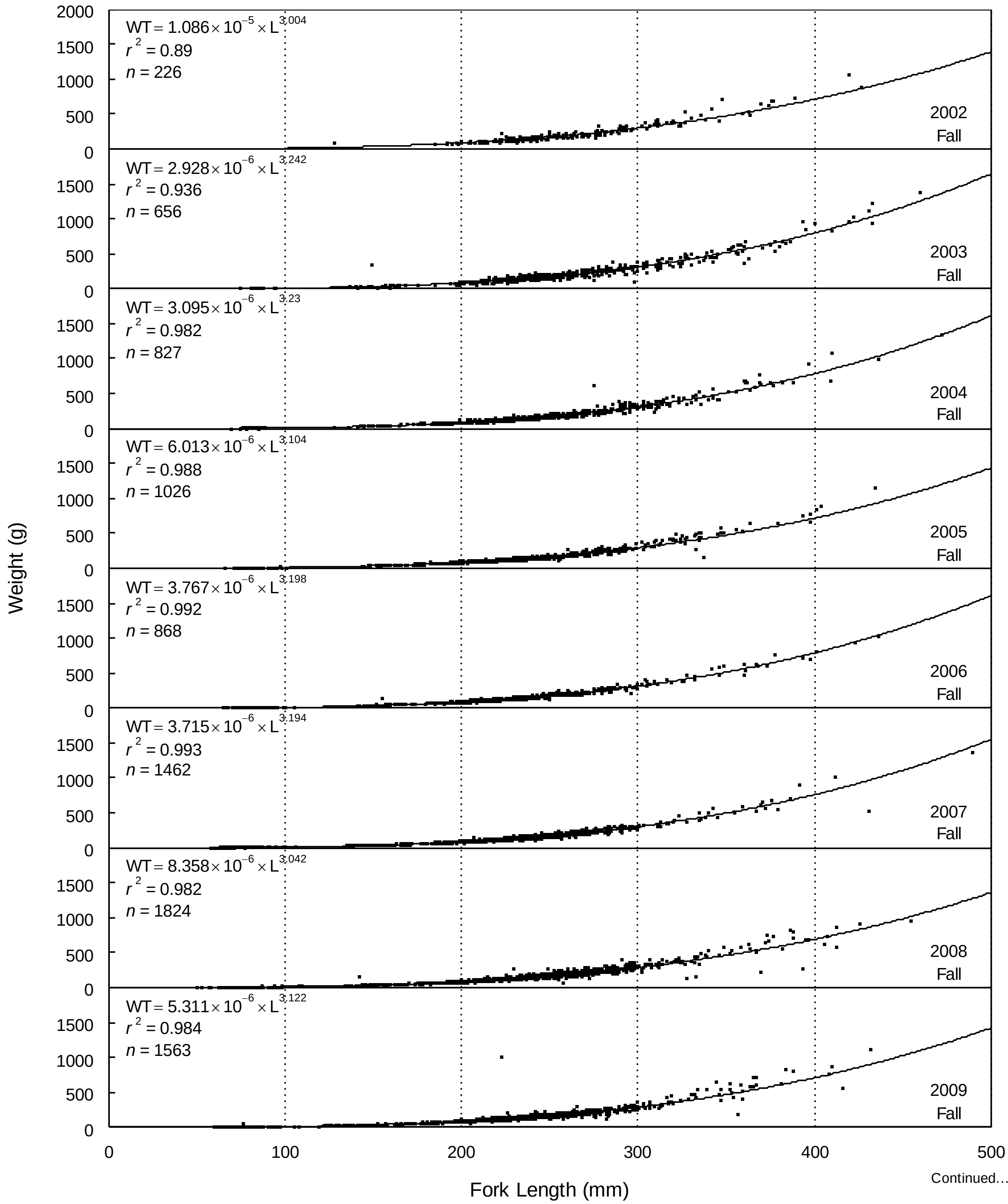


Figure E10 Concluded.



Continued…

Figure E11 Length-weight regression for Mountain Whitefish captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2001 to 2012. Mountain Whitefish that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth. Boat electroshocking surveys were not conducted downstream of Big Eddy for all years prior to 2007.

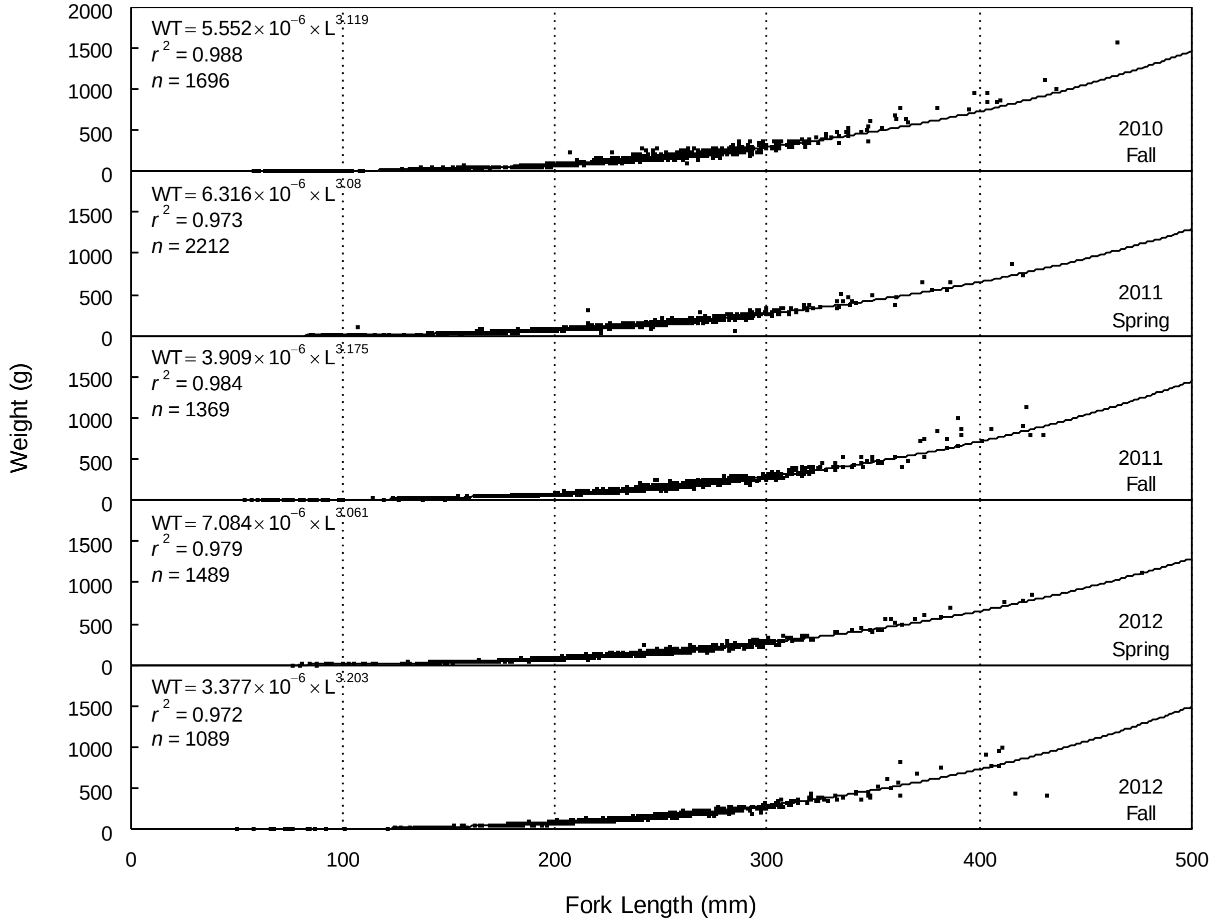


Figure E11 Concluded.

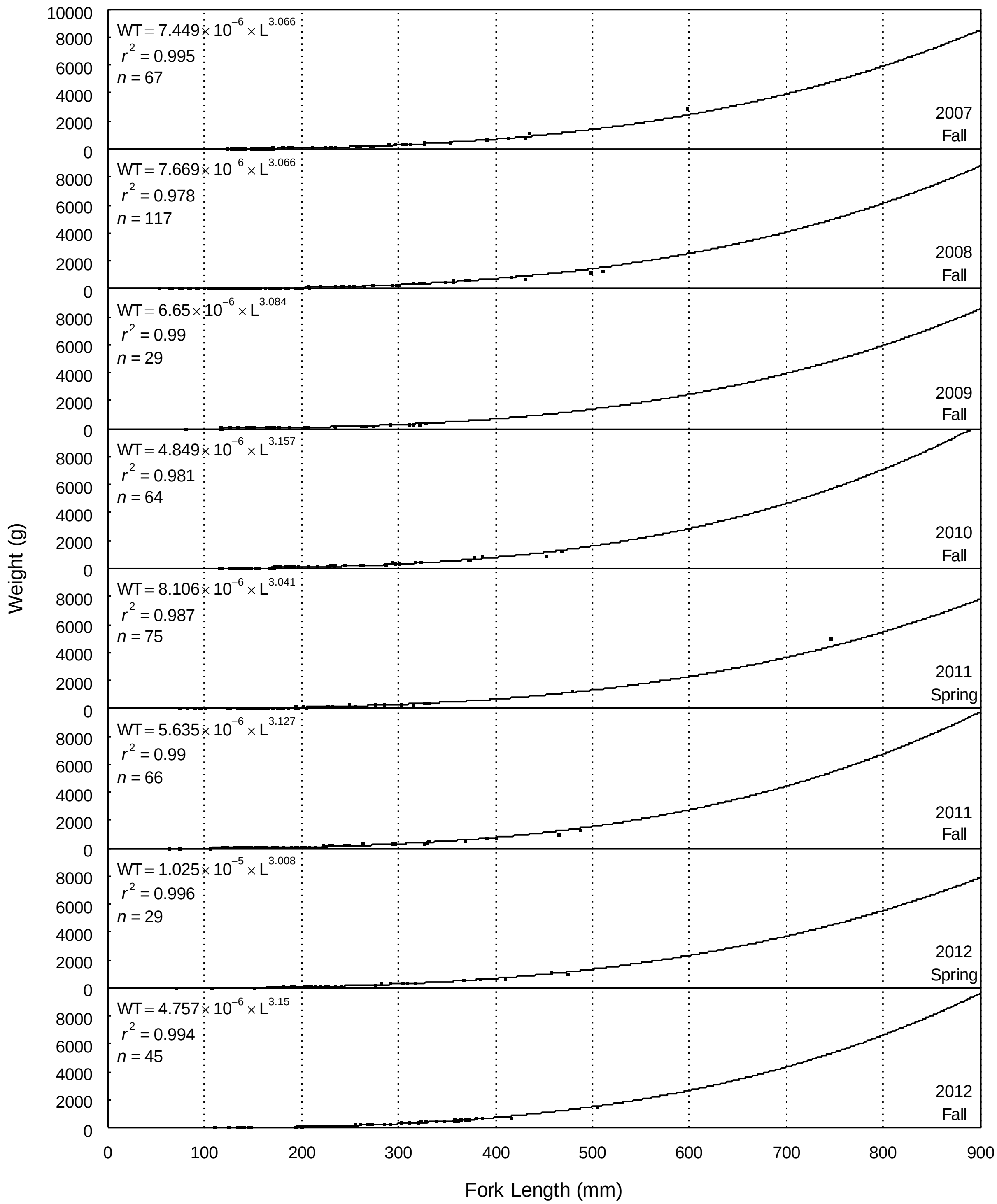


Figure E12 Length-weight regression for Rainbow Trout captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2007 to 2012. Rainbow Trout that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth. Boat electroshocking surveys were not conducted downstream of Big Eddy for all years prior to 2007.

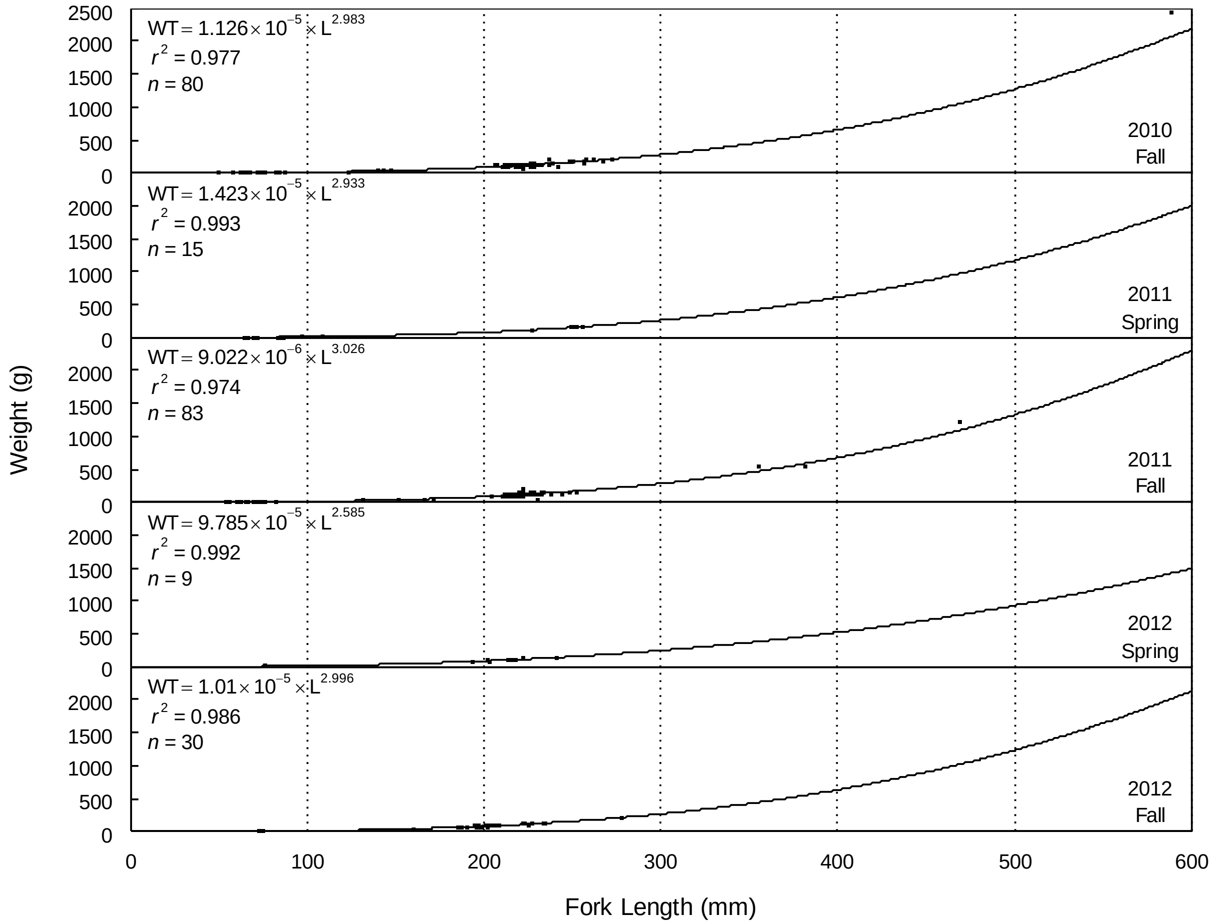


Figure E13 Length-weight regression for Kokanee captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012.

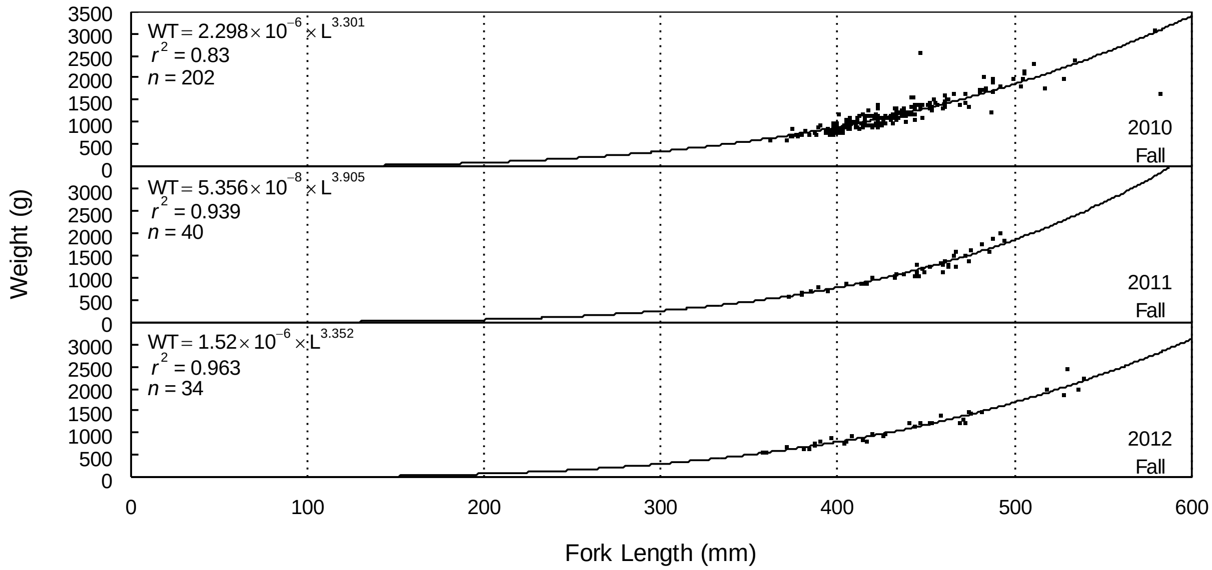


Figure E14 Length-weight regression for Lake Whitefish captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012. Lake Whitefish that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth.

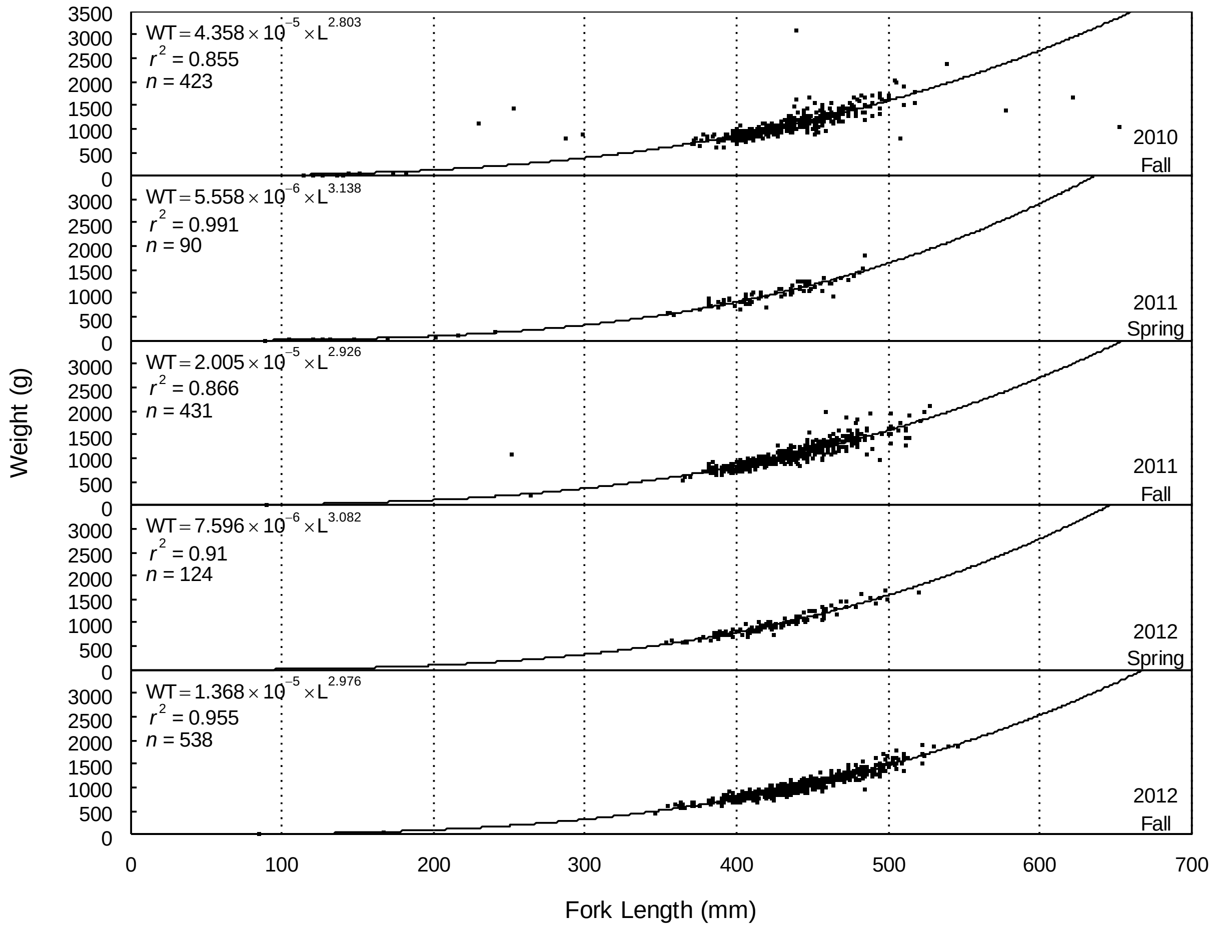


Figure E15 Length-weight regression for Largescale Sucker captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012. Largescale Sucker that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth.

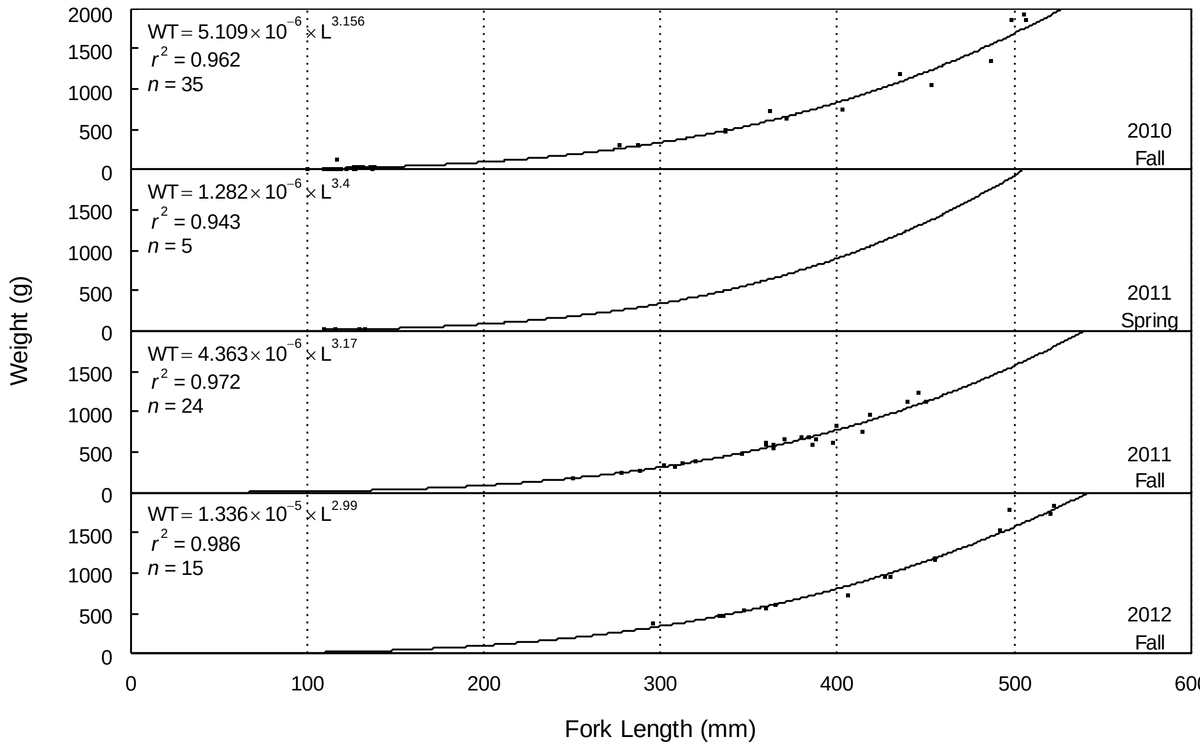


Figure E16 Length-weight regression for Northern Pikeminnow captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012. Northern Pikeminnow that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth.

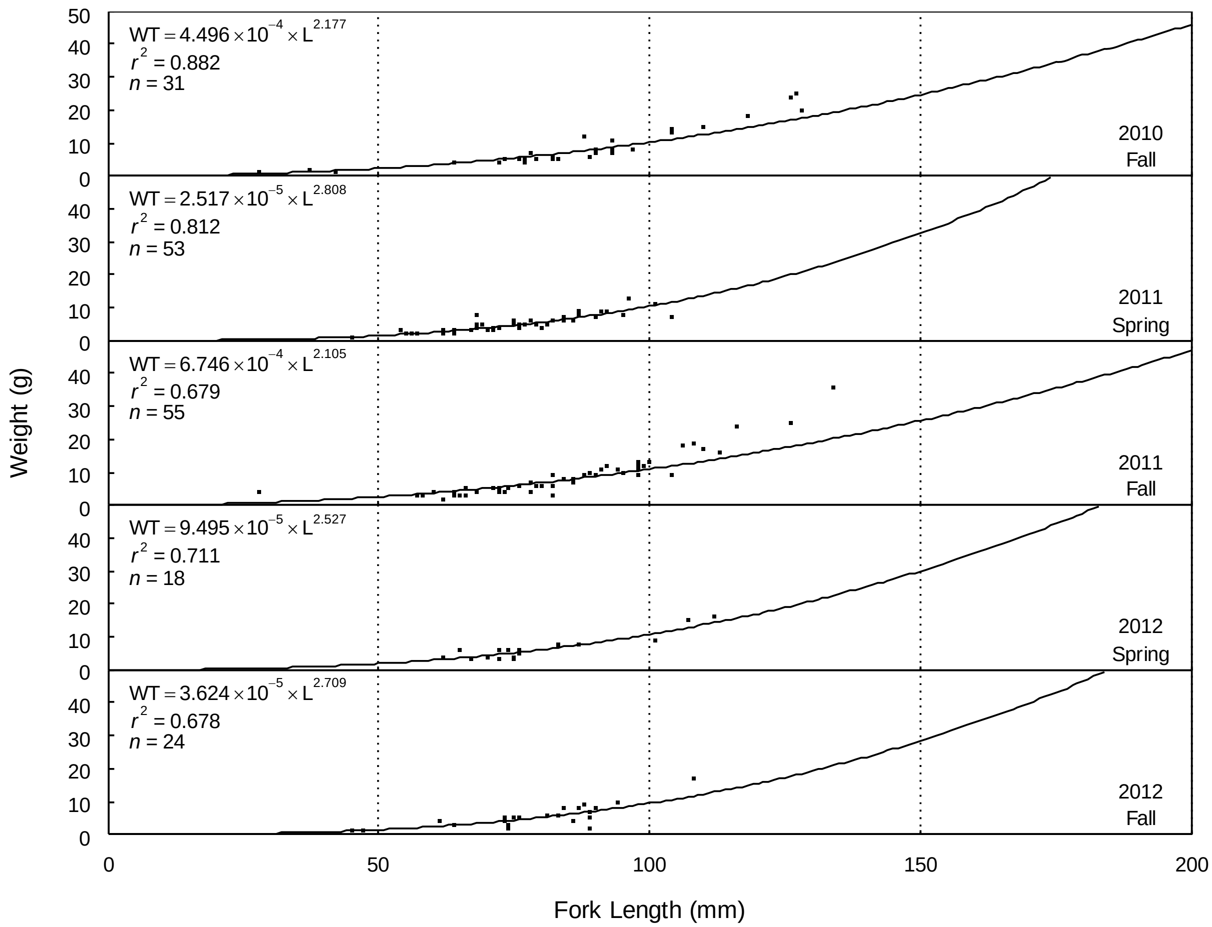


Figure E17 Length-weight regression for Prickly Sculpin captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012.

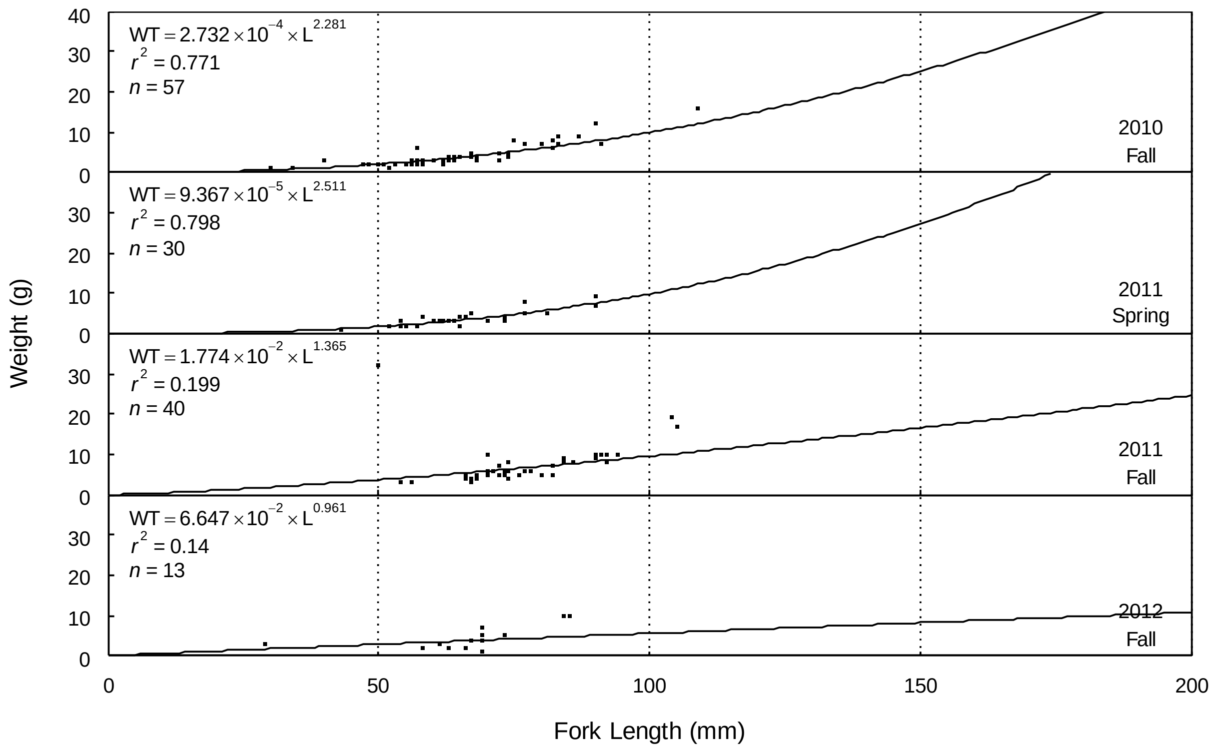


Figure E18 Length-weight regression for Redside Shiner captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010 to 2012.

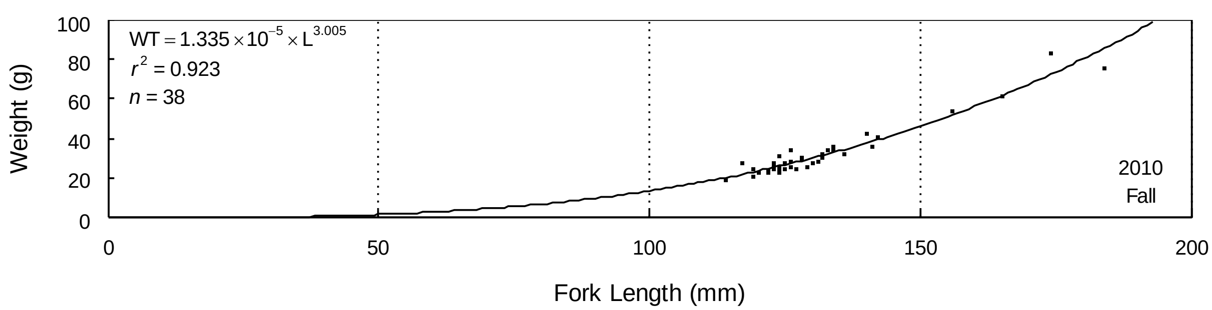


Figure E19 Length-weight regression for Yellow Perch captured by boat electroshocking in Reaches 3 and 4 of the Middle Columbia River, 2010. Yellow Perch that were initially marked during an earlier year of the program were excluded from the analysis due to potential tagging effects on growth.

APPENDIX F

Hierarchical Bayesian Analyses - Methods

Hierarchical Bayesian Analysis

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Poisson Consulting Ltd.

28 March 2013

1 General Approach

Hierarchical Bayesian models were fitted to the fish indexing data for the Middle Columbia River using the software packages R 2.15.3[8] and JAGS 3.3.0[7] which interfaced with each other via jaggernaut 0.1.4[9]. For additional information on hierarchical Bayesian modelling in the BUGS language, of which JAGS uses a dialect, the reader is referred to Kery and Schuab (2011)[5, p.41-44].

Unless specified, the models assumed vague (low information) prior distributions [5, p.36]. The posterior distributions were estimated from a minimum of 1,000 Markov Chain Monte Carlo (MCMC) samples thinned from the second halves of three chains[5, p.38-40]. Model convergence was confirmed by ensuring that Rhat[5, p.40] was less than 1.1 for each of the parameters in the model[5, p.61]. Posterior distributions were summarised in terms of a point *estimate* (median), *lower* and *upper* 95% credibility limits (2.5th and 97.5th percentiles), percent relative *error* (half the 95% credibility interval as a percent of the point estimate) and *significance* (Bayesian equivalent of two-sided frequentist p-value)[5, p.37,42].

The results were displayed graphically by plotting the modeled relationship between the particular variable(s) and the response (with 95% credibility intervals) 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 (expected values of the underlying hyperdistributions) [5, p.77-82]. Where informative the influence of particular variables was expressed in terms of the effect size (i.e., percent change in the response variable) with 95% credibility intervals[1]. Plots were produced using the ggplot2 R package [11].

2 JAGS Distributions, Functions and Operators

JAGS distributions, functions and operators are defined in the following three tables. For additional information on the JAGS dialect of the BUGS language see the JAGS User Manual[7].

JAGS Distribution	Description
dbern(p)	Bernoulli distribution
dbin(p, n)	Binomial distribution
dcat(pi)	Categorical distribution
ddirch(alpha)	Dirichlet distribution
dgamma(shape, rate)	Gamma distribution
dlnorm(mu, sd^-2)	Log-normal distribution
dnorm(mu, sd^-2)	Normal distribution
dpois(lambda)	Poisson distribution
dunif(a, b)	Uniform distribution

JAGS Function	Description
log(x)	Log of x
logit(x)	Log odds of x
max(x,y)	Maximum of x and y
min(x,y)	Minimum of x and y
round(x)	Round to integer away from zero
sum(a)	Sum of elements of a
T(x,y)	Truncate distribution so that values lie between x and y

JAGS Operator	Description
<-	Deterministic relationship
~	Stochastic relationship
1:n	Vector of integers from 1 to n
a[1:n]	Subset of first n values in a
for (i in 1:n) {...}	Repeat ... for 1 to n times incrementing i each time
x^y	Power where x is raised to the power of y

3 JAGS Models

The following sections provide the key assumptions, variable and parameter definitions and JAGS model code for the analyses. By convention variables are named using CamelCase and the number of levels of a discrete variable (factor) `ObservedFactor` is referenced by `nObservedFactor`. The following variables occur in multiple models.

Variable	Description
Period[i]	Period (flow regime) of ith survey(s)
ProportionSampled[i]	Proportion of site surveyed on ith survey(s)
Season[i]	Season of ith survey(s)
Site[i]	Site of ith survey(s)
SiteLength[i]	Length of site on ith survey(s)
Year[i]	Year of ith survey(s)

3.1 Occupancy and Species Richness

Occupancy which is the probability that a particular species was present at a site was estimated from the temporal replication of detection data[4, p.238-242][5, p.414-418], i.e., each site was surveyed multiple times within a season. A species was considered to have been detected if one or more individuals of the species were caught or counted. Its important to note that the model estimates the probability that the species was present at a given (or typical) site in a given (or typical) year as opposed to the probability that the species was present in the entire study area. The estimated occupancies for multiple species were summed to give the expected species richnesses.

Key assumptions of the occupancy model include:

- Occupancy (probability of presence) varies with flow regime (period) and season.
- Occupancy varies randomly with site, year, and the interaction between site and year.

- Efficiency (probability of detection) varies with the length of bank sampled.
- Sites are closed, i.e., the species is present or absent at a site for all the sessions in a particular season of a year.
- Observed presence is described by a bernoulli distribution.

3.1.1 Occupancy Model - Variables and Parameters

Variable/Parameter	Description
bEffConst	Efficiency constant
bOccIntercept	Log-odds occupancy intercept
bOccSite[st]	Effect of stth site on log-odds occupancy
bOccSiteYear[st, yr]	Effect of stth site in yrth year on log-odds occupancy
bOccYear[yr]	Effect of yrth year on log-odds occupancy
bPeriod[pd]	Effect of pdth period (flow regime) on log-odds occupancy
bSeason[sn]	Effect of snth season on log-odds occupancy
eEfficiency[i]	Expected efficiency on ith survey
eOccupancy[i]	Expected occupancy on ith survey
Observed[i]	Was the species observed on ith survey
sOccSite	SD of effect of site on log-odds occupancy
sOccSiteYear	SD of effect of site within year on log-odds occupancy
sOccYear	SD of effect of year on log-odds occupancy

3.1.2 Occupancy Model - JAGS Code

```
model {

  sOccYear ~ dunif(0, 5)
  sOccSite ~ dunif(0, 5)
  sOccSiteYear ~ dunif(0, 5)

  bOccIntercept ~ dnorm(0, 5^-2)
  bEffConst ~ dunif(0, 10)

  bSeason[1]<-0
  for(i in 2:nSeason) {
    bSeason[i]~dnorm(0, 5^-2)
  }

  bPeriod[1]<-0
  for(i in 2:nPeriod) {
    bPeriod[i]~dnorm(0, 5^-2)
  }

  for (yr in 1:nYear) {
    bOccYear[yr] ~ dnorm(0, sOccYear^-2)
  }

  for (st in 1:nSite) {
    bOccSite[st] ~ dnorm(0, sOccSite^-2)
```

```
    for (yr in 1:nYear) {
      bOccSiteYear[st, yr] ~ dnorm(0, sOccSiteYear^-2)
    }
  }

  for (i in 1:nrow) {
    logit(eOccupancy[i]) <- bOccIntercept
      + bPeriod[Period[i]] + bSeason[Season[i]]
      + bOccSite[Site[i]] + bOccYear[Year[i]] + bOccSiteYear[Site[i],Year[i]]
    eEfficiency[i] <- 1 - exp(-bEffConst * SiteLength[i] * ProportionSampled[i])
    Observed[i] ~ dbern(eOccupancy[i] * eEfficiency[i])
  }
}
```

3.2 Count and Species Diversity

The count data were analysed using an overdispersed Poisson model[4, p.168-170,180][5, p.55-56]. Unlike Kery[4] and Kery and Schaub[5], which used a log-normal distribution to account for the extra-Poisson variation, the current model used a gamma distribution with identical shape and scale parameters because it has a mean of 1 and therefore no overall effect on the expected count. The model does not distinguish between the abundance and observer efficiency, i.e., it estimates the count which is the product of the two. As such it is necessary to assume that changes in observer efficiency are negligible in order to interpret the estimates as relative abundance. The shannon index $-\sum p_i \log(p_i)$ was calculated from the estimated counts for multiple species to give the expected species diversity.

Key assumptions of the count model include:

- Count density (count/km) varies with flow regime (period) and season.
- Count density (count/km) varies randomly with site, year, and the interaction between site and year.
- Expected counts are the product of the count density (count/km) and the length of bank sampled.
- Sites are closed, i.e., the expected count at a site is constant for all the sessions in a particular season of a year.
- Observed counts are described by a Poisson-gamma distribution.

3.2.1 Count Model - Variables and Parameters

Variable/Parameter	Description
bDensityIntercept	Log density intercept
bDensitySite[st]	Effect of stth site on log density
bDensitySiteYear[st, yr]	Effect of stth site in yrth year on log density
bDensityYear[yr]	Effect of yrth year on log density
bPeriod[pd]	Effect of pdth period (flow regime) on log density
bSeason[sn]	Effect of snth season on log density
Count[i]	Count on ith survey
eCount[i]	Expected count if the entire site was surveyed on ith survey
eDensity[i]	Expected density on ith survey
eU[i]	Extra-poisson variation in count on ith survey
r	Overdispersion parameter
sDensitySite	SD of effect of site on log density
sDensitySiteYear	SD of effect of site within year on log density
sDensityYear	SD of effect of year on log density

3.2.2 Count Model - JAGS Code

```
model {

  r ~ dgamma(0.1, 0.1)
  sDensityYear ~ dunif(0, 2)
  sDensitySite ~ dunif(0, 5)
  sDensitySiteYear ~ dunif(0, 2)

  bDensityIntercept ~ dnorm(0, 5^-2)

  bSeason[1]<-0
  for(i in 2:nSeason) {
    bSeason[i]~dnorm(0, 5^-2)
  }

  bPeriod[1]<-0
  for(i in 2:nPeriod) {
    bPeriod[i]~dnorm(0, 5^-2)
  }

  for (yr in 1:nYear) {
    bDensityYear[yr] ~ dnorm(0, sDensityYear^-2)
  }

  for (st in 1:nSite) {
    bDensitySite[st] ~ dnorm(0, sDensitySite^-2)
    for (yr in 1:nYear) {
      bDensitySiteYear[st, yr] ~ dnorm(0, sDensitySiteYear^-2)
    }
  }

  for (i in 1:nrow) {
```

```
  log(eDensity[i]) <- bDensityIntercept + bPeriod[Period[i]] + bSeason[Season[i]]
    + bDensitySite[Site[i]] + bDensityYear[Year[i]] + bDensitySiteYear[Site[i],Year[i]]

    eCount[i] <- eDensity[i] * SiteLength[i]
    eU[i] ~ dgamma(r,r)

    Count[i] ~ dpois(eCount[i] * ProportionSampled[i] * eU[i])
  }
}
```

3.3 Catch

The catch data were analysed using the same overdispersed Poisson model as the count data to provide estimates of relative abundance.

3.4 Site Fidelity

The extent to which sites are closed, i.e., fish remain at the same site between sessions, was evaluated from a binomial "t-test" [4, p.211-213]. The "t-test" estimated the probability that intra-annual recaptures were caught at the same site as previously encountered (site fidelity) for the fall and spring seasons.

Key assumptions of the site fidelity model include:

- Log-odds site fidelity varies with season.
- Observed site fidelity is described by a bernoulli distribution.

3.4.1 Site Fidelity Model - Variables and Parameters

Variable/Parameter	Description
bIntercept	Log-odds probability same site recapture intercept
bSeason[sn]	Effect of snth season on log-odds probability of same site recapture
eRemained[i]	Expected probability of same site for ith recapture
Remained[i]	Was ith recapture recorded at same site as previously encountered

3.4.2 Site Fidelity Model - JAGS Code

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

  bSeason[1]<-0
  for(i in 2:nSeason) {
    bSeason[i]~dnorm(0, 5^-2)
  }

  for (i in 1:nrow) {
    logit(eRemained[i]) <- bIntercept + bSeason[Season[i]]
    Remained[i] ~ dbern(eRemained[i])
  }
}
```

3.5 Abundance

The catch data were also analysed using a capture-recapture-based binomial mixture model[4, p.253-257][5, p.134-136,384-388] to provide estimates of capture efficiency and absolute abundance. The expected abundance density was converted into an expected abundance using an offset[4, p.188-189] on site length. The site fidelity (probability that a recapture was encountered at the same site) was used to adjust the capture efficiency for marked fish by season.

Key assumptions of the abundance model include:

- Abundance density (fish/km) varies with flow regime (period) and season.
- Abundance density (fish/km) varies randomly with site, year and the interaction between site and year.
- Efficiency (probability of capture) varies randomly by session within year and season.
- The proportion of marked fish remaining at a site by season is described by the median estimates from the site fidelity model.
- Marked and unmarked fish have the same probability of capture.
- There is no tag loss, mortality or misidentification of fish.
- Other than the straying of marked fish, sites are closed, i.e., emigration of unmarked fish is accounted for by immigration of unmarked fish.
- The abundance at a site is described by a Poisson distribution.
- The number of marked and unmarked fish caught at a site is described by a binomial distribution.

3.5.1 Abundance Model - Variables and Parameters

Variable/Parameter	Description
bDenIntercept	Log density intercept
bDenSite[st]	Effect of stth site on log density
bDenSiteYear[st, yr]	Effect of stth site in yrth year on log density
bDenYear[yr]	Effect of yrth year on log density
bEffIntercept	Log-odds efficiency intercept
bEffYearSeasonSession[yr,sn,ss]	Effect of ssth session in snth season of yrth year on log-odds efficiency
bPeriod[pd]	Effect of pdth period (flow regime) on log density
bSeason[sn]	Effect of snth season on log density
eAbundance[i]	Expected abundance on ith surveys
eEfficiency[i,ss]	Expected efficiency on ssth session of ith surveys
eMarkedN[i, ss]	Abundance of marked fish on ssth session of ith surveys
eUnmarkedN[i, ss]	Expected abundance of unmarked fish on ssth session of ith surveys
Fish[i]	Minimum abundance on ith surveys
Marked[i,ss]	Number of marked fish caught in ssth session of ith surveys
Remained[ss]	Site fidelity for marked fish in ssth session of ith surveys
sDenSite	SD of effect of site on log density
sDenSiteYear	SD of effect of site within year on log density
sDenYear	SD of effect of year on log density
sEffYearSeasonSession	SD of effect of session within season and year on log density
Tagged[i,ss]	Number of unmarked fish tagged in ssth session of ith surveys
Unmarked[i,ss]	Number of unmarked fish caught in ssth session of ith surveys

3.5.2 Abundance Model - JAGS Code

```
model {

  sDenYear ~ dunif(0, 2)
  sDenSite ~ dunif(0, 5)
  sDenSiteYear ~ dunif(0, 2)
  sEffYearSeasonSession ~ dunif(0, 2)

  bDenIntercept ~ dnorm(0, 5^-2)
  bEffIntercept ~ dnorm(0, 5^-2)

  bSeason[1]<-0
  for(i in 2:nSeason) {
    bSeason[i]~dnorm(0, 5^-2)
  }

  bPeriod[1]<-0
  for(i in 2:nPeriod) {
    bPeriod[i]~dnorm(0, 5^-2)
  }

  for (yr in 1:nYear) {
    bDenYear[yr] ~ dnorm(0, sDenYear^-2)
    for (sn in 1:nSeason) {
      for (ss in 1:nSession) {
```

```
        bEffYearSeasonSession[yr,sn,ss] ~ dnorm(0, sEffYearSeasonSession^-2)
      }
    }
  }

  for (st in 1:nSite) {
    bDenSite[st] ~ dnorm(0, sDenSite^-2)
    for (yr in 1:nYear) {
      bDenSiteYear[st, yr] ~ dnorm(0, sDenSiteYear^-2)
    }
  }

  for (i in 1:nVisit) {
    log(eAbundance[i]) <- bDenIntercept + bPeriod[Period[i]] + bSeason[Season[i]]
        + bDenYear[Year[i]] + bDenSite[Site[i]] + bDenSiteYear[Site[i], Year[i]]
        + log(SiteLength[i])

    eN[i] ~ dpois(eAbundance[i])
    eUnmarkedN[i,1] <- eN[i]
    eMarkedN[i,1] <- 0

    for (ss in 1:nSession) {
      logit(eEfficiency[i,ss]) <- bEffIntercept
          + bEffYearSeasonSession[Year[i],Season[i],ss]

      eSamplingEff[i,ss] <- eEfficiency[i,ss] * ProportionSampled[i,ss]

      eMarkedEff[i,ss] <- eSamplingEff[i,ss]
        * step(eMarkedN[i,ss]-1) * Remained[i, ss]

      Unmarked[i,ss] ~ dbin(eSamplingEff[i,ss],eUnmarkedN[i,ss])
      Marked[i,ss] ~ dbin(eMarkedEff[i,ss], max(eMarkedN[i,ss],1))

      eMarkedN[i,ss+1] <- eMarkedN[i,ss] + Tagged[i,ss]
      eUnmarkedN[i,ss+1] <- eUnmarkedN[i,ss] - Tagged[i,ss]
    }
  }
}
```

3.6 Capture Efficiency

In order to estimate the capture efficiency independent of abundance a recapture-based binomial model[4, p.253-257][5, p.134-136,384-388] was fitted to just the marked fish. The model was equivalent to the abundance model without the estimation of the numbers of unmarked fish.

Key assumptions of the efficiency model include:

- Efficiency (probability of capture) varies randomly by session within year and season.
- The proportion of marked fish remaining at a site by season is described by the median estimates from the site fidelity model.
- There is no tag loss, mortality or misidentification of fish.

- The number of marked fish caught at a site is described by a binomial distribution.

3.6.1 Capture Efficiency Model - Variables and Parameters

The variables and parameters in the efficiency model are the same as those in the abundance model.

3.6.2 Capture Efficiency Model - JAGS Code

```
model {

  sEffYearSeasonSession ~ dunif(0, 2)

  bEffIntercept ~ dnorm(0, 5^-2)

  for (yr in 1:nYear) {
    for (sn in 1:nSeason) {
      for (ss in 1:nSession) {
        bEffYearSeasonSession[yr,sn,ss] ~ dnorm(0, sEffYearSeasonSession^-2)
      }
    }
  }

  for (i in 1:nVisit) {
    eMarkedN[i,1] <- 0

  for (ss in 1:nSession) {
      logit(eEfficiency[i,ss]) <- bEffIntercept
          + bEffYearSeasonSession[Year[i],Season[i],ss]

      eSamplingEff[i,ss] <- eEfficiency[i,ss] * ProportionSampled[i,ss]

      eMarkedEff[i,ss] <- eSamplingEff[i,ss]
        * step(eMarkedN[i,ss]-1) * Remained[i, ss]

      Marked[i,ss] ~ dbin(eMarkedEff[i,ss], max(eMarkedN[i,ss],1))

      eMarkedN[i,ss+1] <- eMarkedN[i,ss] + Tagged[i,ss]

    }
  }
}
```

3.7 Growth

Annual growth was estimated from the inter-annual recaptures using the Fabens method[2] for estimating the von Bertalanffy growth curve[10].

Key assumptions of the growth model include:

- Mean maximum length (L_∞) varies with flow regime (period).
- Mean maximum length (L_∞) varies randomly with year.
- Observed growth (change in length) is normally distributed.

3.7.1 Growth Model - Variables and Parameters

Variable/Parameter	Description
bYear[yr]	Effect of yrth year on mean maximum length
eGrowth[i]	Expected growth of the ith fish
Growth[i]	Change in length (growth) of the ith fish from the previous year
k	Von Bertalanffy growth rate coefficient
LengthAtRelease[i]	Length of the ith fish when released the previous year
Linf	Mean maximum length (length-at-infinity)
sGrowth	SD of residual variation in growth
sYear	SD of effect of year on mean maximum length
Year[i]	Year the ith fish was released

3.7.2 Growth Model - JAGS Code

```
model {
  sGrowth ~ dunif(0, 100)
  sYear ~ dunif (0, 100)

  k ~ dunif (0, 1)
  Linf ~ dunif(100, 1000)

  bPeriod[1]<-0
  for(i in 2:nPeriod) {
    bPeriod[i]~dunif(-100,100)
  }

  for (yr in 1:nYear) {
    bYear[yr] ~ dnorm(0, sYear^-2)
  }

  for (i in 1:nrow) {
    eGrowth[i]<-(Linf + bYear[Year[i]] + bPeriod[Period[i]] - LengthAtRelease[i])
                  * (1-exp(-k))
    Growth[i] ~ dnorm(eGrowth[i], sGrowth^-2)
  }
}
```

3.8 Length-at-Age

Length-at-age was estimated from the yearly fall length-frequency distributions using a finite mixture distribution model [6].

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

- Length-at-age varies with flow regime (period).
- Length-at-age varies randomly with year.
- Length-at-age is normally-distributed.

3.8.1 Length-at-Age Model - Variables and Parameters

Variable/Parameter	Description
Age[i]	Age of ith fish
bAgeYear[ag,yr]	Effect of yrth year on length of agth age fish
bIncrement[ag]	Length difference between agth and ag-1th age fish
bIntercept[ag]	Length of agth age fish intercept
eLength[i]	Expected length of ith fish
Length[i]	Length of ith fish
pAge[ag]	Proportion of fish belonging to agth age
sAgeYear[ag]	SD of effect of year on length of agth age fish
sLengthAge[ag]	SD of length of agth age fish
Year[i]	Year ith fish was observed

3.8.2 Length-at-Age Model - JAGS Code

```
model {
  for(ag in 1:nAge)  {
    dAge[ag] <- 1

    sLengthAge[ag] ~ dunif(0, 100)
    sAgeYear[ag] ~ dunif(0, 50)

    bIncrement[ag] ~ dunif(50, 250)

    bAgePeriod[ag,1] <- 0
    for (pd in 2:nPeriod) {
      bAgePeriod[ag,pd] ~ dnorm(0, 25^-2)
    }

    for(yr in 1:nYear) {
      bAgeYear[ag,yr] ~ dnorm(0, sAgeYear[ag]^-2)
    }
  }

  bIntercept[1]<-bIncrement[1]
  for(ag in 2:nAge) {
    bIntercept[ag] <- bIntercept[ag-1] + bIncrement[ag]
  }

  pAge[1:nAge] ~ ddirch(dAge[])

  for (i in 1:nrow) {
    Age[i] ~ dcat(pAge[])
    eLength[i] <- bIntercept[Age[i]] + bAgeYear[Age[i],Year[i]]
        + bAgePeriod[Age[i],Period[i]]
    Length[i] ~ dnorm(eLength[i], sLengthAge[Age[i]]^-2)
  }
}
```

3.9 Condition

Condition was estimated via an analysis of weight-length relations [3].

Key assumptions of the condition model include:

- Weight varies with length, flow regime (period) and season.
- Weight varies randomly with site, year and the interaction between site and year.
- Weight is log-normally distributed.

3.9.1 Condition Model - Variables and Parameters

Variable/Parameter	Description
bIntercept	Log weight intercept
bLength	Effect of log length on log weight
bSite[st]	Effect of stth site on log weight
bYear[yr]	Effect of yrth year on log weight
bYearSite[yr,st]	Effect of stth site in yrth year on log weight
eLogWeight[i]	Expected log weight of ith fish
LogLength[i]	Log length of ith fish
sSite	SD of effect of site on log weight
sWeight	SD of residual variation in log weight
sYear	SD of effect of year on log weight
sYearSite	SD of effect of site within year on log weight
Weight[i]	Weight of ith fish

3.9.2 Condition Model - JAGS Code

```
model {
  sWeight ~ dunif(0, 5)
  sSite ~ dunif(0, 5)
  sYear ~ dunif(0, 5)
  sSiteYear ~ dunif(0, 5)

  bIntercept ~ dnorm(5, 5^-2)
  bLength ~ dnorm(0, 5^-2)

  bSeason[1]<-0
  for(i in 2:nSeason) {
    bSeason[i]~dnorm(0, 5^-2)
  }

  bPeriod[1]<-0
  for(i in 2:nPeriod) {
    bPeriod[i]~dnorm(0, 5^-2)
  }


  for(yr in 1:nYear) {
    bYear[yr] ~ dnorm(0, sYear^-2)
```

```
  }

  for(st in 1:nSite) {
    bSite[st] ~ dnorm(0, sSite^-2)
    for(yr in 1:nYear) {
      bSiteYear[st, yr] ~ dnorm(0, sSiteYear^-2)
    }
  }

  for(i in 1:nrow) {
    eLogWeight[i] <- bIntercept + bLength * LogLength[i]
        + bPeriod[Period[i]] + bSeason[Season[i]]
        + bYear[Year[i]] + bSite[Site[i]] + bSiteYear[Site[i],Year[i]]
    Weight[i] ~ dlnorm(eLogWeight[i], sWeight^-2)
  }
}
```

References

[1] Michael J Bradford, Josh Korman, and Paul S Higgins. Using confidence intervals to estimate the response of salmon populations (oncorhynchus spp.) to experimental habitat alterations. *Canadian Journal of Fisheries and Aquatic Sciences*, 62(12):2716–2726, 2005.

[2] A J Fabens. Properties and fitting of the von bertalanffy growth curve. *Growth*, 29(3):265–289, September 1965. PMID: 5865688.

[3] Ji X. He, James R. Bence, James E. Johnson, David F. Clapp, and Mark P. Ebener. Modeling variation in mass-length relations and condition indices of lake trout and chinook salmon in lake huron: A hierarchical bayesian approach. *Transactions of the American Fisheries Society*, 137(3):801–817, May 2008.

[4] Marc Kéry. *Introduction to WinBUGS for Ecologists: A Bayesian approach to regression, ANOVA, mixed models and related analyses*. Elsevier, Amsterdam; Boston, 2010.

[5] Marc Kéry and Michael Schaub. *Bayesian population analysis using WinBUGS : a hierarchical perspective*. Academic Press, Boston, 2011.

[6] P. D. M. Macdonald and T. J. Pitcher. Age-groups from size-frequency data: A versatile and efficient method of analyzing distribution mixtures. *Journal of the Fisheries Research Board of Canada*, 36(8):987–1001, August 1979.

[7] M. Plummer. JAGS version 3.3.0 user manual, October 2012.

[8] R Core Team. R: A language and environment for statistical computing, 2013.

[9] J. L. Thorley. jaggernaut: An r package to facilitate bayesian analyses using JAGS (just another gibbs sampler), 2013.

[10] L. von Bertalanffy. A quantitative theory of organic growth (inquiries on growth laws ii). *Human Biology*, 10:181–213, 1938.

[11] Hadley Wickham. *ggplot2 elegant graphics for data analysis*. Springer, Dordrecht; New York, 2009.

APPENDIX G

Hierarchical Bayesian Analyses - Results

Hierarchical Bayesian Analysis - Results

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1 General Approach

The following appendix summarises the posterior distributions for the fixed[1, p.75] parameters in each model. As described in the accompanying Methods Appendix the posterior distributions are summarised in terms of a point *estimate* (median), *lower* and *upper* 95% credibility limits (2.5th and 97.5th percentiles), percent relative *error* (half the 95% credibility interval as a percent of the point estimate) and *significance* (Bayesian equivalent of two-sided frequentist p-value)[1, p.37,42].

2 Occupancy

2.1 Burbot

Parameter	estimate	lower	upper	error	significance
bEffConst	0.448	0.276	1.31	116	0
bOccIntercept	-0.95	-2.81	2.51	280	0.482
bPeriod[2]	2.41	-1.44	8.63	209	0.217
bSeason[2]	-1.66	-7.93	0.0693	240	0.0626
sOccSite	1.36	0.427	3.88	127	0
sOccSiteYear	1.42	0.131	4.43	152	0
sOccYear	2.51	0.955	4.84	77	0

2.2 Kokanee

Parameter	estimate	lower	upper	error	significance
bEffConst	6.76	4.08	9.79	42	0
bOccIntercept	2	0.55	3.61	77	0.0208
bPeriod[2]	-1.17	-4.4	2.29	287	0.437
bSeason[2]	-2.57	-3.24	-1.88	26	0
sOccSite	0.596	0.295	1.03	62	0
sOccSiteYear	0.173	0.00248	0.564	162	0
sOccYear	2.03	1.17	4.07	71	0

2.3 Lake Whitefish

Parameter	estimate	lower	upper	error	significance
bEffConst	4.66	1.67	9.69	86	0
bOccIntercept	-1.18	-2.16	-0.229	82	0.0154
bPeriod[2]	0.539	-1.49	2.65	384	0.597
bSeason[2]	-3.66	-5.43	-2.35	42	0
sOccSite	0.524	0.197	1.03	80	0
sOccSiteYear	0.215	0.0181	0.658	149	0
sOccYear	1.32	0.832	2.4	59	0

2.4 Northern Pikeminnow

Parameter	estimate	lower	upper	error	significance
bEffConst	1.19	0.567	8.45	330	0
bOccIntercept	-1.91	-3.73	0.466	110	0.0792
bPeriod[2]	0.236	-2.96	3.47	1.36e+03	0.864
bSeason[2]	-2.52	-5.11	-1.28	76	0
sOccSite	1.97	1.14	4.28	80	0
sOccSiteYear	0.667	0.0128	2.29	171	0
sOccYear	1.81	0.861	4.18	92	0

2.5 Rainbow Trout

Parameter	estimate	lower	upper	error	significance
bEffConst	2.65	1.58	9.35	147	0
bOccIntercept	-1.17	-3.05	0.951	171	0.261
bPeriod[2]	1.2	-0.826	3.61	185	0.205
bSeason[2]	0.0316	-0.786	0.962	2.76e+03	0.933
sOccSite	2.94	1.71	4.77	52	0
sOccSiteYear	0.869	0.407	1.4	57	0
sOccYear	1.22	0.555	2.67	87	0

2.6 Redside Shiner

Parameter	estimate	lower	upper	error	significance
bEffConst	6.1	2.36	9.78	61	0
bOccIntercept	-2.32	-4.22	-0.734	75	0
bPeriod[2]	0.378	-1.94	3.23	683	0.667
bSeason[2]	-0.895	-1.72	-0.0768	92	0.0282
sOccSite	2.25	1.46	3.89	54	0
sOccSiteYear	0.287	0.0204	0.807	137	0
sOccYear	1.38	0.719	2.81	76	0

2.7 Sculpin

Parameter	estimate	lower	upper	error	significance
bEffConst	5.67	2.61	9.71	63	0
bOccIntercept	-0.0898	-1.68	1.54	1.79e+03	0.881
bPeriod[2]	1.32	-1.59	4.37	225	0.385
bSeason[2]	-0.449	-1.1	0.171	141	0.145
sOccSite	1.36	0.867	2.22	50	0
sOccSiteYear	0.244	0.0214	0.67	133	0
sOccYear	2.11	1.36	3.73	56	0

2.8 Yellow Perch

Parameter	estimate	lower	upper	error	significance
bEffConst	5.78	1.61	9.79	71	0
bOccIntercept	-3.65	-5.92	-1.7	58	0
bPeriod[2]	-1.19	-4.76	2.73	315	0.485
bSeason[2]	-1.64	-4.44	0.393	147	0.136
sOccSite	2.18	1.33	3.79	56	0
sOccSiteYear	0.389	0.00149	1.12	143	0
sOccYear	2.12	1.15	4.11	70	0

3 Count

3.1 Burbot

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	-2.1	-3.07	-1.26	43	0
bPeriod[2]	1.02	-0.777	3.12	191	0.253
bSeason[2]	-0.894	-1.48	-0.362	62	0
r	0.699	0.447	1.2	54	0
sDensitySite	0.766	0.422	1.38	62	0
sDensitySiteYear	0.47	0.0755	0.835	81	0
sDensityYear	1.09	0.559	1.9	62	0

3.2 Bull Trout

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	2.01	1.76	2.27	13	0
bPeriod[2]	-0.00569	-0.308	0.353	5.81e+03	0.972
bSeason[2]	0.0865	-0.0981	0.257	205	0.357
r	3.06	2.63	3.54	15	0
sDensitySite	0.397	0.263	0.657	50	0
sDensitySiteYear	0.271	0.194	0.357	30	0
sDensityYear	0.145	0.0238	0.326	104	0

3.3 Mountain Whitefish

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	4.18	3.81	4.56	9	0
bPeriod[2]	0.0502	-0.32	0.461	778	0.79
bSeason[2]	0.257	0.0968	0.407	60	0
r	2.9	2.58	3.21	11	0
sDensitySite	0.562	0.38	0.933	49	0
sDensitySiteYear	0.354	0.279	0.436	22	0
sDensityYear	0.2	0.0794	0.407	82	0

3.4 Northern Pikeminnow

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	-2.46	-3.81	-1.31	51	0
bPeriod[2]	0.461	-1.74	2.65	476	0.659
bSeason[2]	-2.37	-3.53	-1.42	44	0
r	0.556	0.384	0.835	40	0
sDensitySite	1.44	0.887	2.45	54	0
sDensitySiteYear	0.635	0.186	1.06	69	0
sDensityYear	1.38	0.775	1.96	43	0

3.5 Rainbow Trout

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	-1.39	-2.86	-0.205	96	0.018
bPeriod[2]	1.02	-0.574	2.67	159	0.198
bSeason[2]	-0.131	-0.469	0.215	262	0.505
r	1.38	1.02	1.83	29	0
sDensitySite	1.96	1.32	3.17	47	0
sDensitySiteYear	0.65	0.458	0.892	33	0
sDensityYear	1.02	0.521	1.79	63	0

3.6 Sculpin

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	0.679	-0.502	2.03	187	0.33
bPeriod[2]	1.47	-1.46	4.46	201	0.338
bSeason[2]	-0.333	-0.734	0.0918	124	0.117
r	0.459	0.393	0.523	14	0
sDensitySite	1.14	0.767	1.74	43	0
sDensitySiteYear	0.592	0.373	0.823	38	0
sDensityYear	1.84	1.41	1.99	16	0

3.7 Suckers

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	2.01	1.57	2.47	22	0
bPeriod[2]	0.637	0.0889	1.31	96	0.022
bSeason[2]	-0.395	-0.627	-0.168	58	0
r	1.51	1.32	1.71	13	0
sDensitySite	0.68	0.449	1.07	46	0
sDensitySiteYear	0.408	0.294	0.54	30	0
sDensityYear	0.307	0.137	0.599	75	0

4 Catch

4.1 Bull Trout

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	1.11	0.765	1.45	31	0
bPeriod[2]	0.0773	-0.583	0.746	859	0.8
bSeason[2]	-0.0752	-0.252	0.0846	224	0.369
r	5.83	4.43	7.81	29	0
sDensitySite	0.39	0.261	0.642	49	0
sDensitySiteYear	0.286	0.198	0.378	32	0
sDensityYear	0.368	0.216	0.65	59	0

4.2 Mountain Whitefish - Juvenile

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	0.173	-0.814	1.1	555	0.663
bPeriod[2]	-0.164	-1.52	1.44	904	0.796
bSeason[2]	0.963	0.733	1.18	23	0
r	3.14	2.24	4.73	40	0
sDensitySite	0.862	0.547	1.48	54	0
sDensitySiteYear	0.536	0.386	0.733	32	0
sDensityYear	0.713	0.317	1.62	92	0

4.3 Mountain Whitefish - Adult

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	2.7	2.35	3	12	0
bPeriod[2]	-0.0469	-0.388	0.25	679	0.729
bSeason[2]	0.393	0.258	0.54	36	0
r	4.05	3.49	4.69	15	0
sDensitySite	0.572	0.393	0.901	44	0
sDensitySiteYear	0.343	0.271	0.422	22	0
sDensityYear	0.165	0.0328	0.348	96	0

4.4 Rainbow Trout

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	-1.3	-2.48	-0.196	88	0.032
bPeriod[2]	0.134	-1.15	1.41	954	0.776
bSeason[2]	-0.143	-0.485	0.185	235	0.407
r	3.55	2.04	7.17	72	0
sDensitySite	1.79	1.17	2.98	51	0
sDensitySiteYear	0.444	0.184	0.712	60	0
sDensityYear	0.524	0.157	1.51	129	0

4.5 Largescale Sucker

Parameter	estimate	lower	upper	error	significance
bDensityIntercept	1.04	-0.649	2.25	139	0.175
bPeriod[2]	0.708	-0.847	3.45	304	0.355
bSeason[2]	-1.55	-1.81	-1.33	15	0
r	2.81	2.07	4.01	34	0
sDensitySite	0.532	0.322	0.871	52	0
sDensitySiteYear	0.183	0.00849	0.381	102	0
sDensityYear	0.802	0.301	1.85	96	0

5 Site Fidelity

5.1 Bull Trout

Parameter	estimate	lower	upper	error	significance
bIntercept	-0.233	-0.55	0.097	139	0.164
bSeason[2]	-0.474	-1.43	0.441	198	0.287

5.2 Mountain Whitefish - Juvenile

Parameter	estimate	lower	upper	error	significance
bIntercept	-0.971	-3.02	0.594	186	0.213
bSeason[2]	0.266	-2.33	2.81	965	0.799

5.3 Mountain Whitefish - Adult

Parameter	estimate	lower	upper	error	significance
bIntercept	-0.0241	-0.202	0.176	783	0.819
bSeason[2]	1.3	0.916	1.7	30	0

5.4 Rainbow Trout

Parameter	estimate	lower	upper	error	significance
bIntercept	1.09	0.33	2.12	82	0.008
bSeason[2]	3.92	0.00808	11.2	143	0.0494

5.5 Largescale Sucker

Parameter	estimate	lower	upper	error	significance
bIntercept	0.306	-0.24	0.853	179	0.259
bSeason[2]	0.12	-1.86	2.55	1.83e+03	0.916

6 Abundance

6.1 Bull Trout

Parameter	estimate	lower	upper	error	significance
bDenIntercept	4.39	3.97	4.78	9	0
bEffIntercept	-3.24	-3.47	-3.01	7	0
bPeriod[2]	0.0627	-0.494	0.685	940	0.842
bSeason[2]	-0.058	-0.308	0.181	422	0.621
sDenSite	0.402	0.26	0.646	48	0
sDenSiteYear	0.349	0.28	0.425	21	0
sDenYear	0.338	0.168	0.635	69	0
sEffYearSeasonSession	0.245	0.184	0.329	29	0

6.2 Mountain Whitefish - Juvenile

Parameter	estimate	lower	upper	error	significance
bDenIntercept	5.4	4.2	7.42	30	0
bEffIntercept	-5.18	-6.11	-4.33	17	0
bPeriod[2]	-0.141	-1.73	1.11	1.00e+03	0.789
bSeason[2]	1	0.688	1.33	32	0
sDenSite	0.876	0.568	1.41	48	0
sDenSiteYear	0.607	0.468	0.796	27	0
sDenYear	0.709	0.288	1.83	108	0
sEffYearSeasonSession	0.285	0.188	0.418	40	0

6.3 Mountain Whitefish - Adult

Parameter	estimate	lower	upper	error	significance
bDenIntercept	6.47	6.04	6.78	6	0
bEffIntercept	-3.69	-3.83	-3.55	4	0
bPeriod[2]	-0.0759	-0.485	0.238	476	0.631
bSeason[2]	-0.113	-0.368	0.128	219	0.369
sDenSite	0.574	0.392	0.937	47	0
sDenSiteYear	0.417	0.364	0.48	14	0
sDenYear	0.132	0.0102	0.33	121	0
sEffYearSeasonSession	0.351	0.286	0.452	24	0

6.4 Rainbow Trout

Parameter	estimate	lower	upper	error	significance
bDenIntercept	2.01	0.806	3.18	59	0
bEffIntercept	-3.29	-3.75	-2.93	12	0
bPeriod[2]	0.0346	-1.03	1.19	3.2e+03	0.924
bSeason[2]	-0.128	-0.472	0.208	266	0.495
sDenSite	1.78	1.16	2.85	48	0
sDenSiteYear	0.474	0.274	0.709	46	0
sDenYear	0.49	0.0985	1.47	140	0
sEffYearSeasonSession	0.18	0.023	0.384	100	0

7 Capture Efficiency

7.1 Bull Trout

Parameter	estimate	lower	upper	error	significance
bEffIntercept	-3.31	-3.61	-3.06	8	0
sEffYearSeasonSession	0.351	0.0198	0.746	103	0

7.2 Mountain Whitefish - Juvenile

Parameter	estimate	lower	upper	error	significance
bEffIntercept	-5.58	-7.37	-4.52	26	0
sEffYearSeasonSession	0.884	0.0868	1.92	104	0

7.3 Mountain Whitefish - Adult

Parameter	estimate	lower	upper	error	significance
bEffIntercept	-3.66	-3.85	-3.49	5	0
sEffYearSeasonSession	0.412	0.257	0.603	42	0

7.4 Rainbow Trout

Parameter	estimate	lower	upper	error	significance
bEffIntercept	-3.46	-4.12	-2.97	17	0
sEffYearSeasonSession	0.483	0.0611	1.19	117	0

7.5 Largescale Sucker

Parameter	estimate	lower	upper	error	significance
bEffIntercept	-4	-4.66	-3.57	14	0
sEffYearSeasonSession	0.551	0.0906	1.35	114	0

8 Growth

8.1 Bull Trout

Parameter	estimate	lower	upper	error	significance
bPeriod[2]	57.6	-44.7	97.5	123	0.277
k	0.126	0.105	0.165	24	0
Linf	913	796	994	11	0
sGrowth	27.2	24.3	30.7	12	0
sYear	58.9	3.55	96.9	79	0

8.2 Mountain Whitefish

Parameter	estimate	lower	upper	error	significance
bPeriod[2]	-5.46	-53.1	41.3	865	0.767
k	0.106	0.081	0.137	26	0
Linf	341	316	382	10	0
sGrowth	9.05	8.45	9.66	7	0
sYear	20.9	6.55	48.7	101	0

9 Length-at-Age

9.1 Mountain Whitefish

Parameter	estimate	lower	upper	error	significance
bAgePeriod[1,2]	-3.8	-10.5	2.96	177	0.22
bAgePeriod[2,2]	-9.35	-14.7	-4.06	57	0.004
bAgePeriod[3,2]	-5.69	-17.8	6.01	209	0.375
bIncrement[1]	80.1	77.4	82.9	3	0
bIncrement[2]	71	67.4	74.5	5	0
bIncrement[3]	83.8	78.3	88.8	6	0
bIntercept[1]	80.1	77.4	82.9	3	0
bIntercept[2]	151	149	154	1	0
bIntercept[3]	235	230	240	2	0
pAge[1]	0.0819	0.0774	0.0868	6	0
pAge[2]	0.0667	0.0619	0.0715	7	0
pAge[3]	0.852	0.845	0.858	1	0
sAgeYear[1]	3.87	2.31	7.1	62	0
sAgeYear[2]	3.1	1.76	5.77	65	0
sAgeYear[3]	7.07	4.63	12.3	54	0
sLengthAge[1]	8.72	8.34	9.11	4	0
sLengthAge[2]	7.84	7.42	8.3	6	0
sLengthAge[3]	27.9	27.6	28.4	1	0

10 Condition

10.1 Bull Trout

Parameter	estimate	lower	upper	error	significance
bIntercept	6.85	6.81	6.89	1	0
bLength	1.17	1.16	1.17	1	0
bPeriod[2]	-0.0495	-0.133	0.041	176	0.255
bSeason[2]	-0.00813	-0.0278	0.0132	252	0.466
sSite	0.0106	0.00158	0.0241	106	0
sSiteYear	0.0207	0.00838	0.0307	54	0
sWeight	0.142	0.139	0.147	3	0
sYear	0.0496	0.0301	0.0935	64	0

10.2 Mountain Whitefish

Parameter	estimate	lower	upper	error	significance
bIntercept	4.79	4.78	4.81	0	0
bLength	0.628	0.626	0.63	0	0
bPeriod[2]	-0.041	-0.0721	-0.00138	86	0.0484
bSeason[2]	-0.0324	-0.038	-0.0266	18	0
sSite	0.0103	0.00507	0.0183	64	0
sSiteYear	0.0158	0.0126	0.0199	23	0
sWeight	0.0954	0.0943	0.0966	1	0
sYear	0.0237	0.0143	0.044	63	0

10.3 Rainbow Trout

Parameter	estimate	lower	upper	error	significance
bIntercept	4.4	4.36	4.45	1	0
bLength	1.03	1.02	1.04	1	0
bPeriod[2]	0.00372	-0.0793	0.0849	2.21e+03	0.914
bSeason[2]	-0.0806	-0.117	-0.0458	44	0
sSite	0.029	0.00607	0.0579	89	0
sSiteYear	0.0155	0.00198	0.0399	122	0
sWeight	0.114	0.107	0.124	7	0
sYear	0.0395	0.00751	0.101	118	0

References

[1] Marc Kéry and Michael Schaub. *Bayesian population analysis using WinBUGS : a hierarchical perspective*. Academic Press, Boston, 2011.

APPENDIX H

Hierarchical Bayesian Analyses - Additional Figures

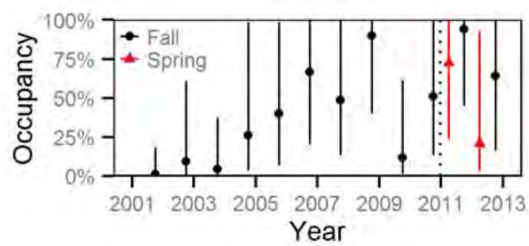

Figure H1. Occupancy estimates (with 95% credible intervals) by year and season for Burbot in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

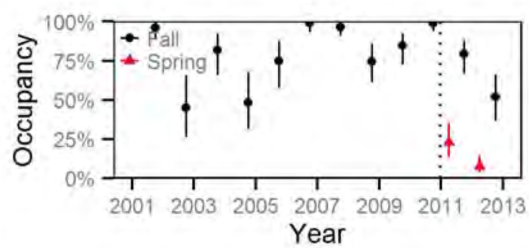

Figure H2. Occupancy estimates (with 95% credible intervals) by year and season for Kokanee in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

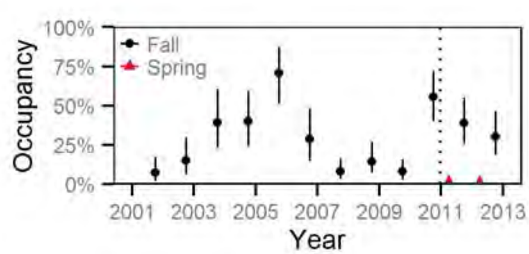

Figure H3. Occupancy estimates (with 95% credible intervals) by year and season for Lake Whitefish in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

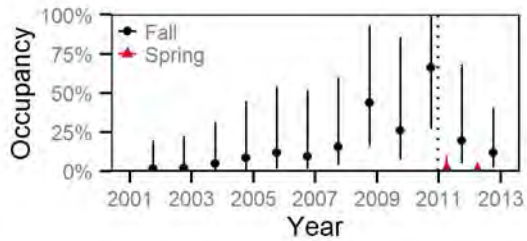

Figure H4: Occupancy estimates (with 95% credible intervals) by year and season for Northern Pikeminnow in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

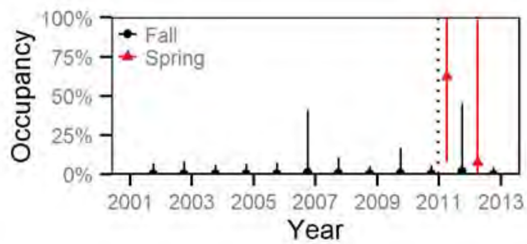

Figure H5. Occupancy estimates (with 95% credible intervals) by year and season for Peamouth in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

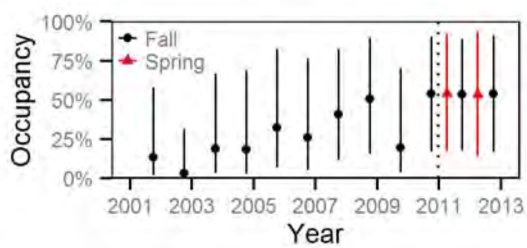

Figure H6. Occupancy estimates (with 95% credible intervals) by year and season for Rainbow Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

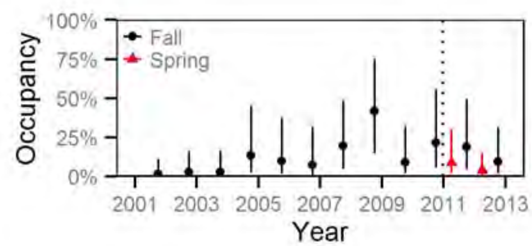

Figure H7. Occupancy estimates (with 95% credible intervals) by year and season for Redside Shiner in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

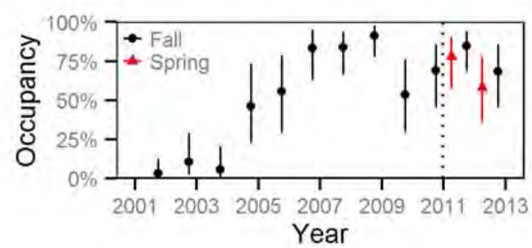

Figure H8. Occupancy estimates (with 95% credible intervals) by year and season for Sculpin species in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

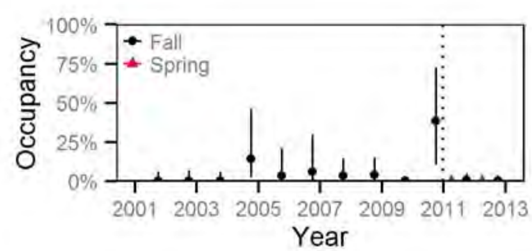

Figure H9. Occupancy estimates (with 95% credible intervals) by year and season for Yellow Perch in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

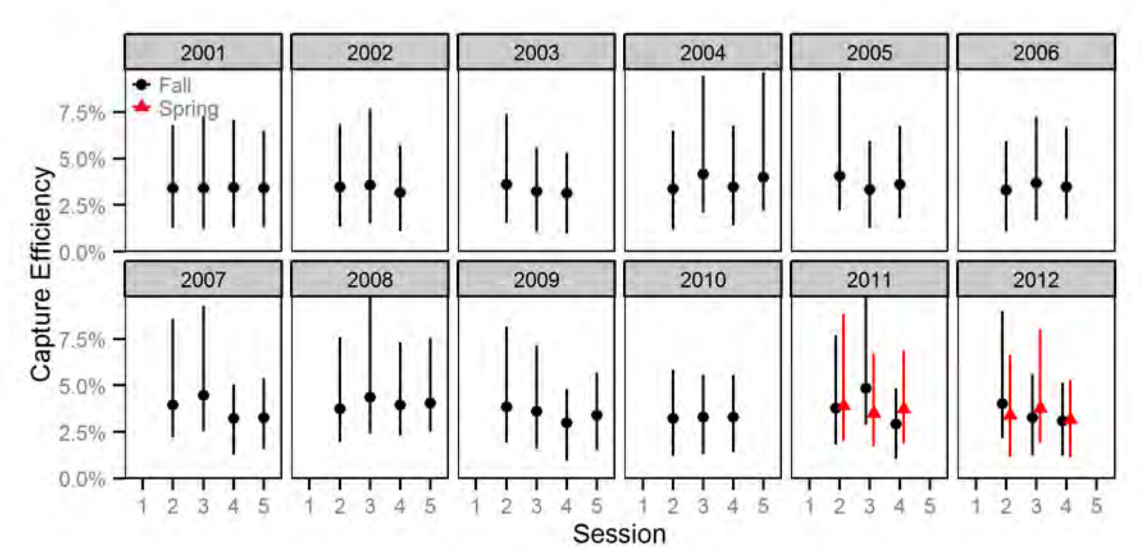

Figure H10. Capture efficiency estimates (with 95% credible intervals) by year, season, and session for Bull Trout in the Middle Columbia River study area, 2001 to 2012. Efficiency was calculated in the hierarchical Bayesian model estimating absolute abundance using mark-recapture data.

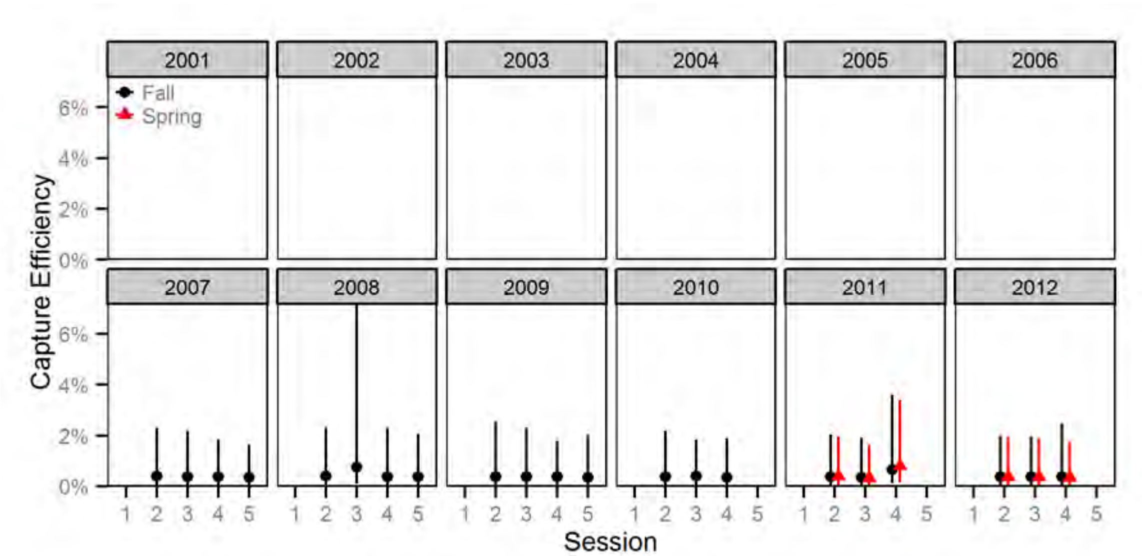

Figure H11. Capture efficiency estimates (with 95% credible intervals) by year, season, and session for age-1 Mountain Whitefish in the Middle Columbia River study area, 2001 to 2012. Efficiency was calculated in the hierarchical Bayesian model estimating absolute abundance using mark-recapture data.

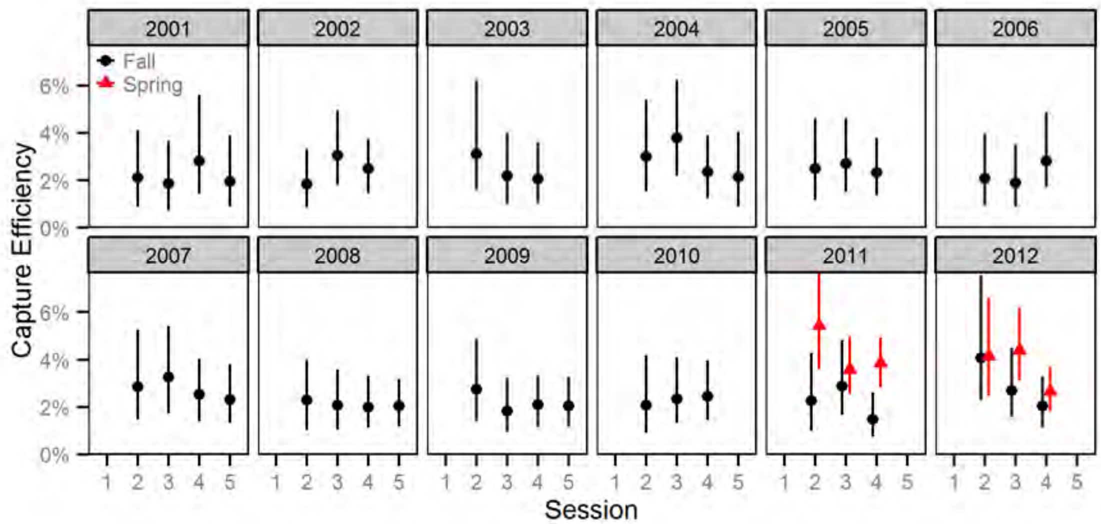

Figure H12. Capture efficiency estimates (with 95% credible intervals) by year, season, and session for age-2 and older Mountain Whitefish in the Middle Columbia River study area, 2001 to 2012. Efficiency was calculated in the hierarchical Bayesian model estimating absolute abundance using mark-recapture data.

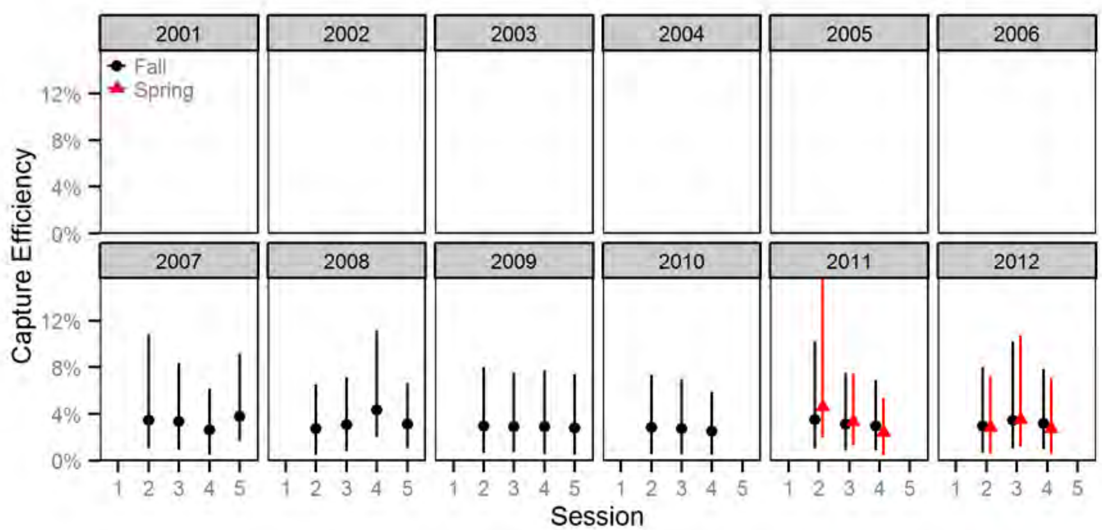

Figure H13. Capture efficiency estimates (with 95% credible intervals) by year, season, and session for Rainbow Trout in the Middle Columbia River study area, 2007 to 2012. Efficiency was calculated in the hierarchical Bayesian model estimating absolute abundance using mark-recapture data.

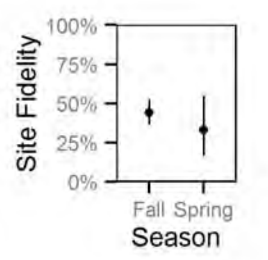

Figure H14. Site fidelity estimates (with 95% credible intervals) by season for intra-year recaptured Bull Trout in the Middle Columbia River study area, 2001-2012.

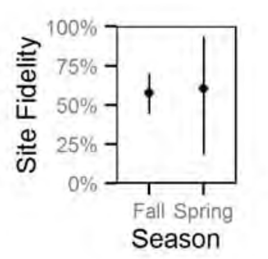

Figure H15. Site fidelity estimates (with 95% credible intervals) by season for intra-year recaptured Largescale Sucker in the Middle Columbia River study area, 2001-2012.

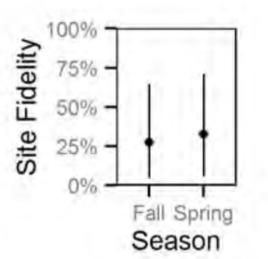

Figure H16. Site fidelity estimates (with 95% credible intervals) by season for intra-year recaptured age-1 Mountain Whitefish in the Middle Columbia River study area, 2001-2012.

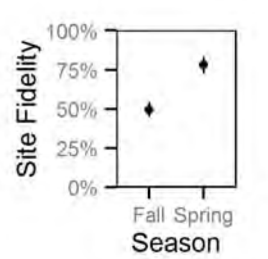

Figure H17. Site fidelity estimates (with 95% credible intervals) by season for intra-year recaptured age-2 and older Mountain Whitefish in the Middle Columbia River study area, 2001-2012.

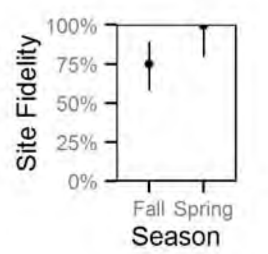

Figure H18. Site fidelity estimates (with 95% credible intervals) by season for intra-year recaptured Rainbow Trout in the Middle Columbia River study area, 2007-2012.

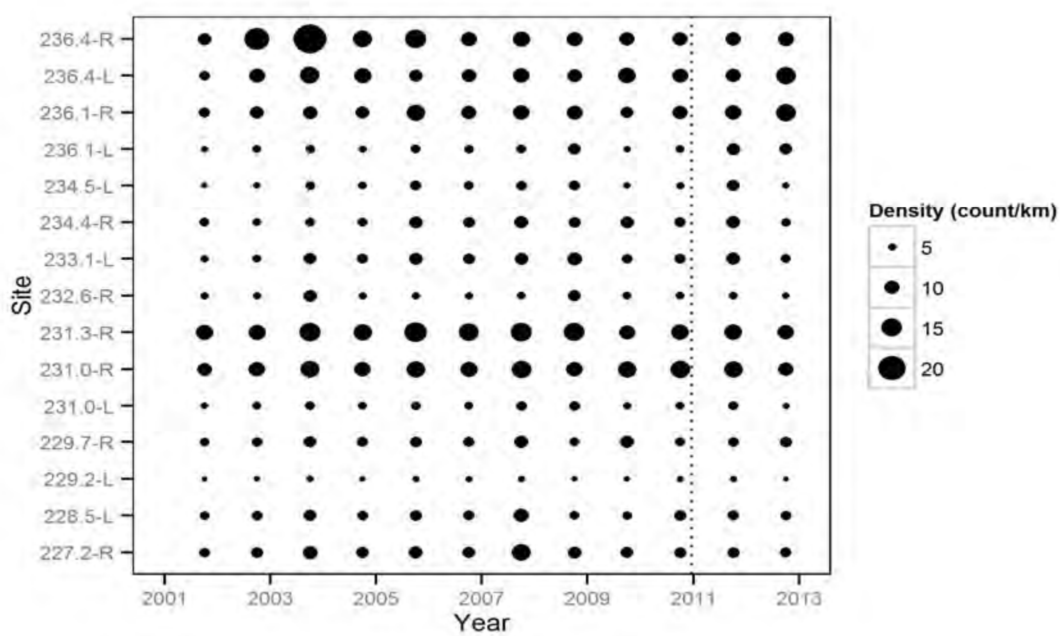

Figure H19. Count density estimates by site and year for Bull Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

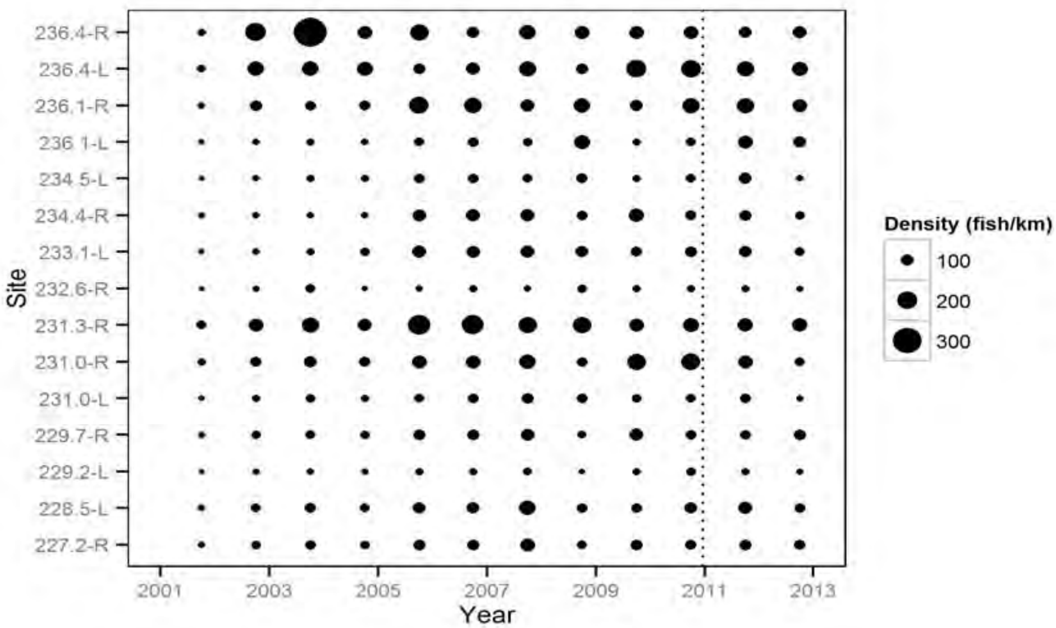

Figure H20. Absolute density estimates by site and year for Bull Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

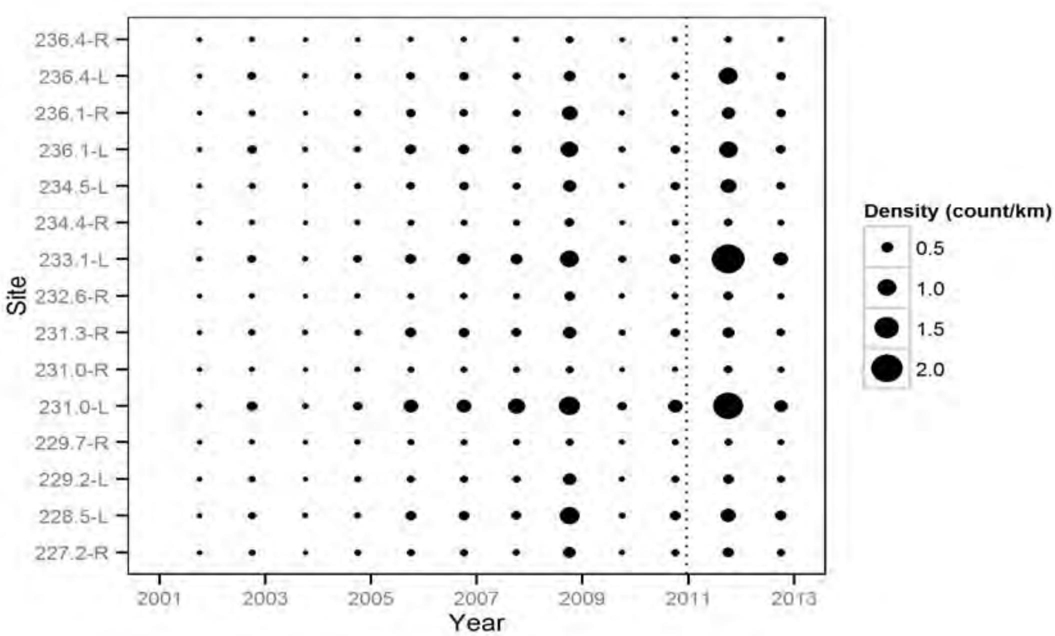

Figure H21. Count density estimates by site and year for Burbot in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

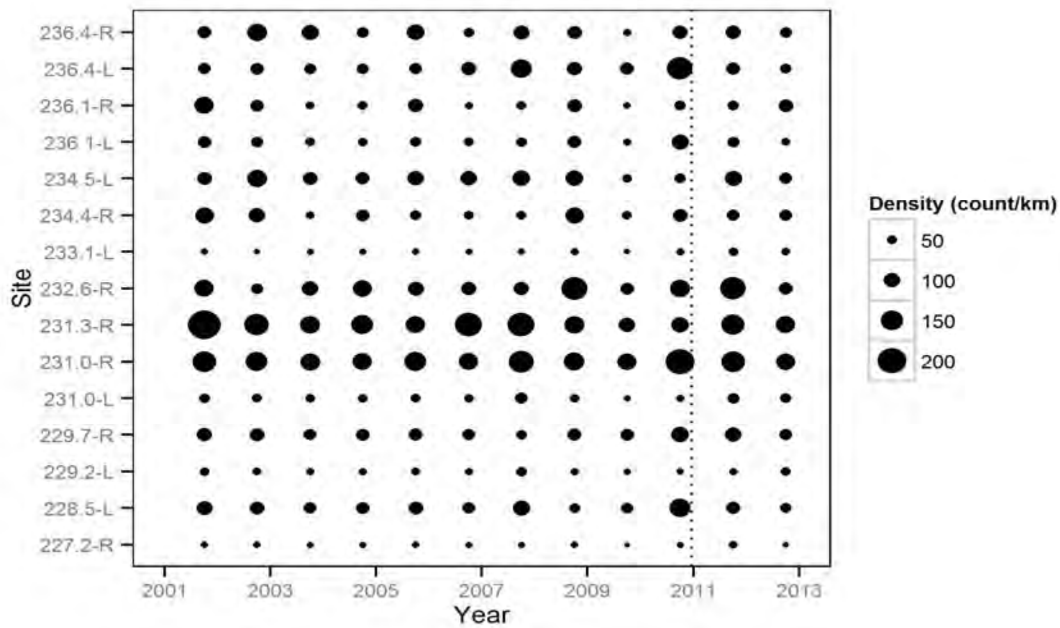

Figure H22. Count density estimates by site and year for Mountain Whitefish (all age classes combined) in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

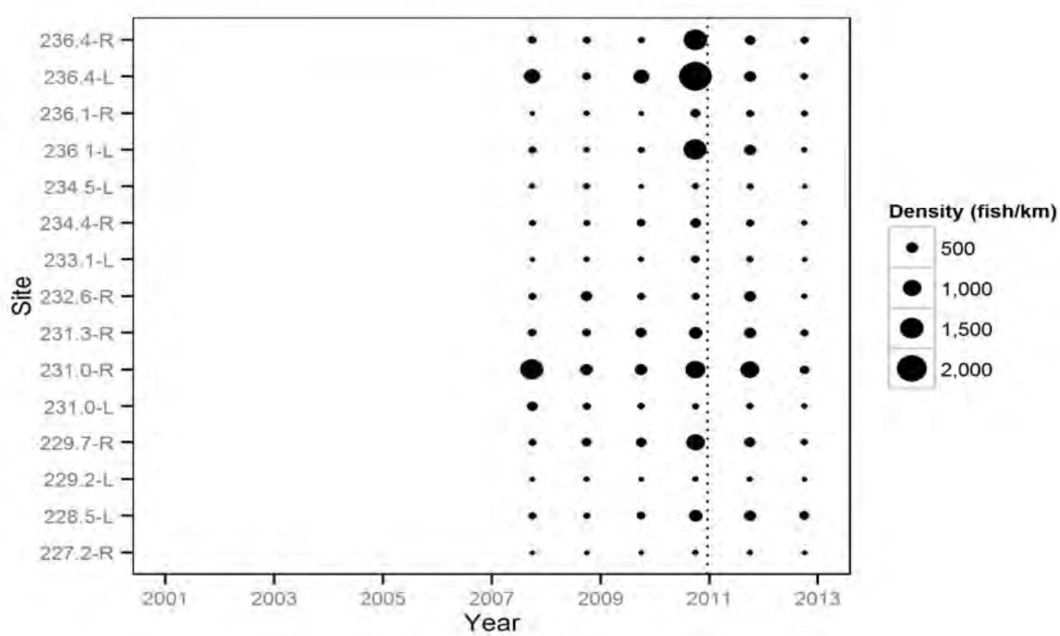

Figure H23. Absolute density estimates by site and year for age-1 Mountain Whitefish in the Middle Columbia River study area, 2007 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

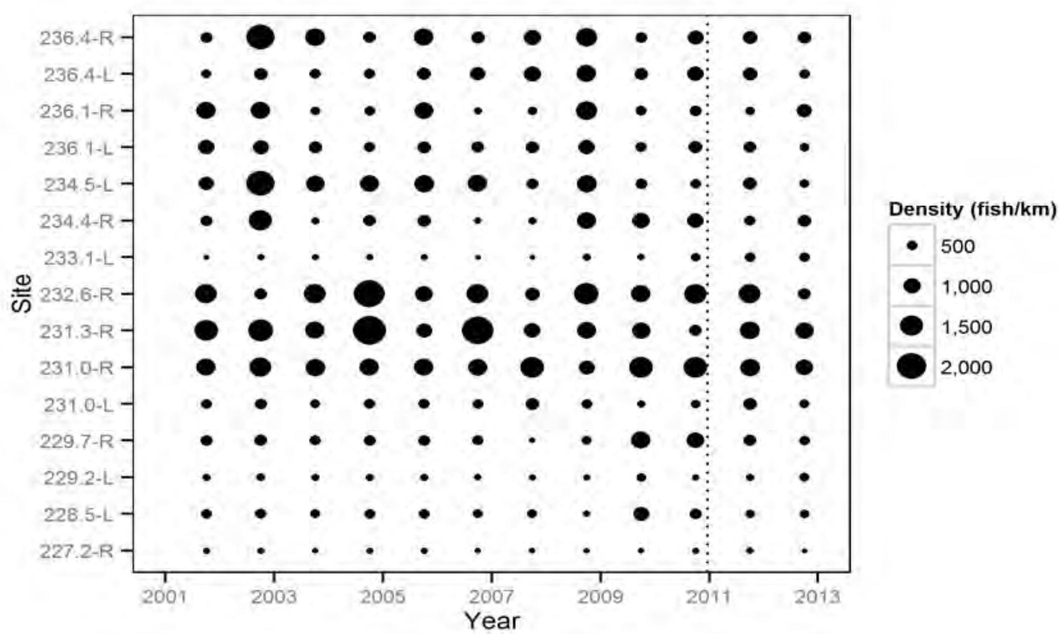

Figure H24. Absolute density estimates by site and year for age-2 and older Mountain Whitefish in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

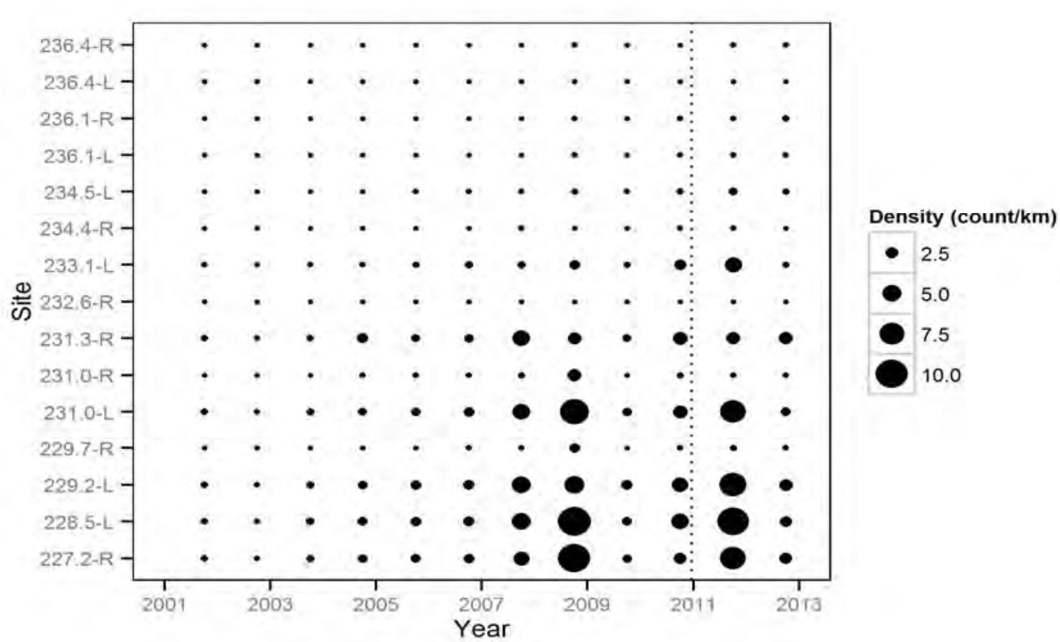

Figure H25. Count density estimates by site and year for Rainbow Trout in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

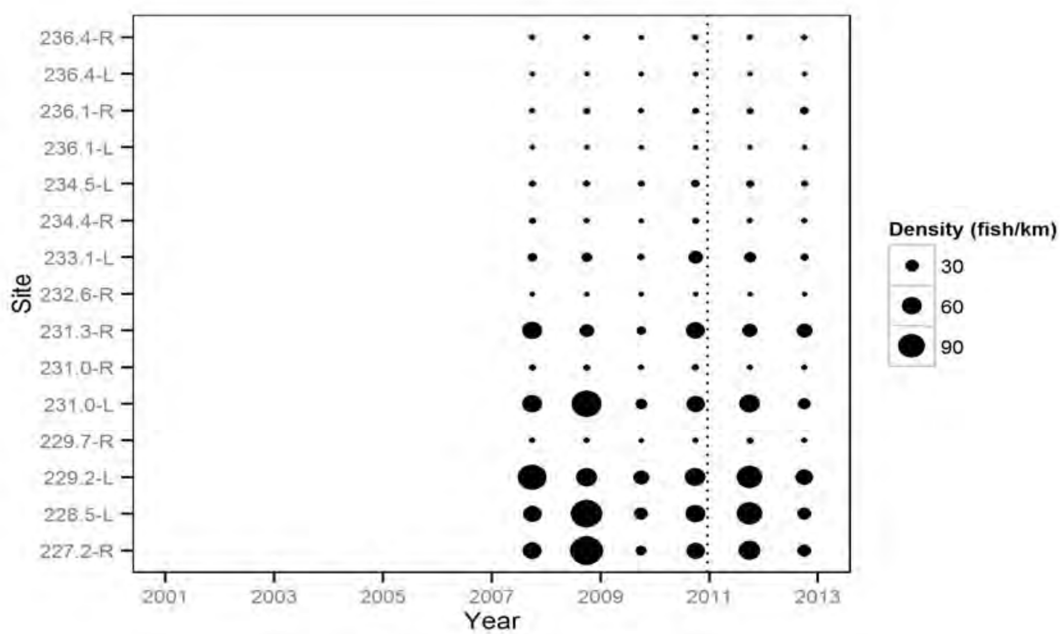

Figure H26. Absolute density estimates by site and year for Rainbow Trout in the Middle Columbia River study area, 2007 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

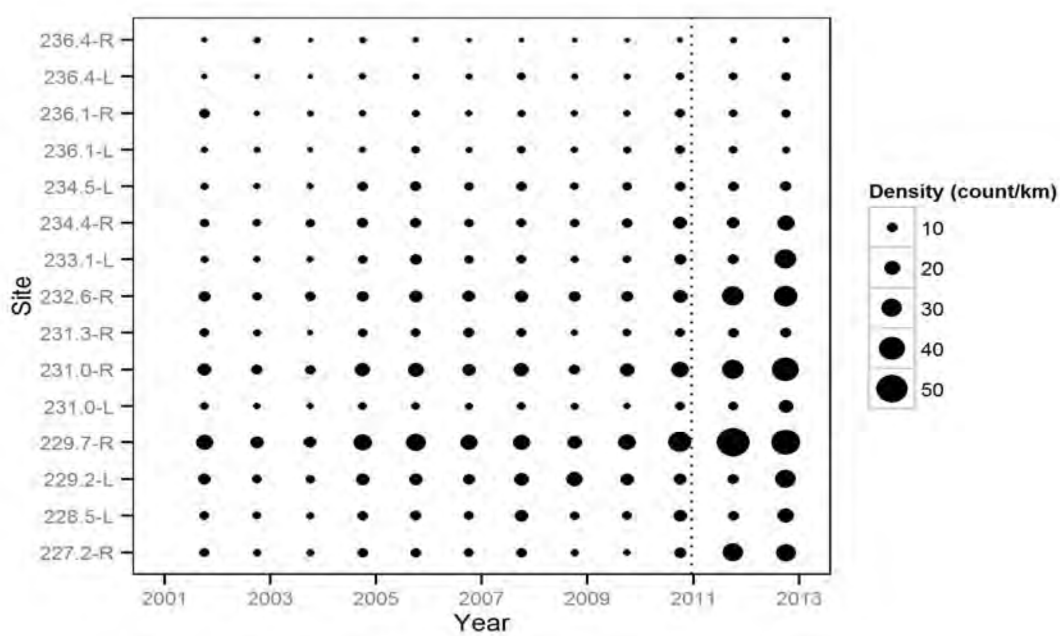

Figure H27. Count density estimates by site and year for Sucker species in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

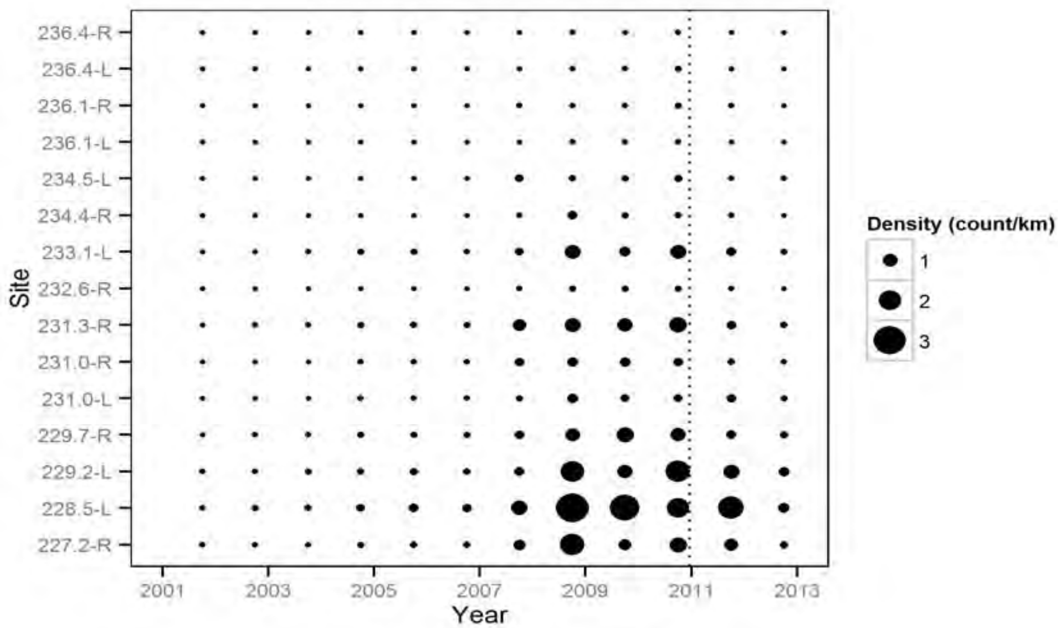

Figure H28. Count density estimates by site and year for Northern Pikeminnow in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

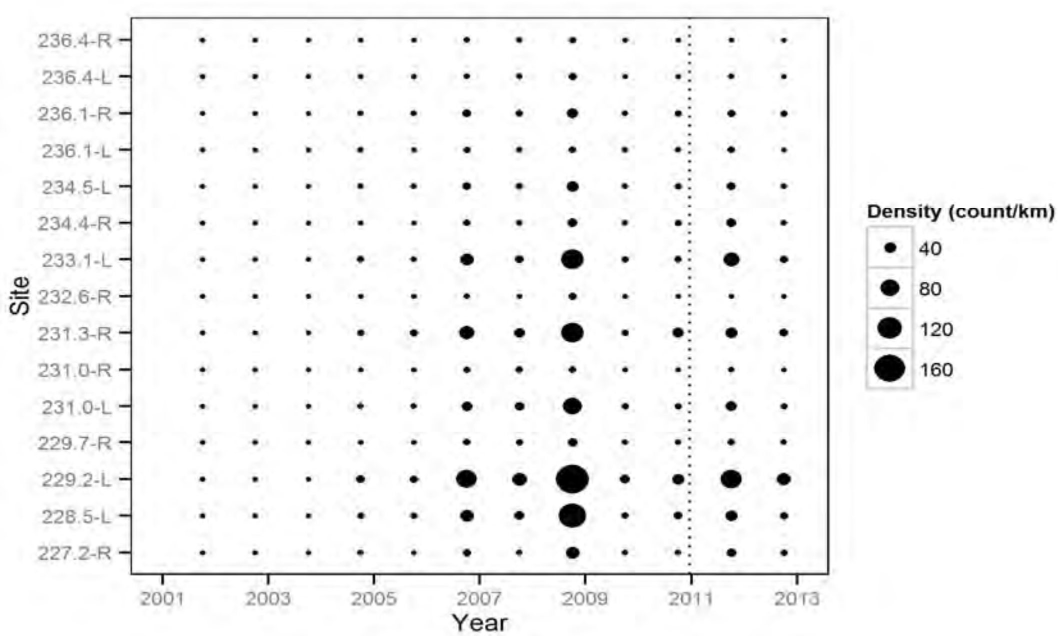

Figure H29. Count density estimates by site and year for Sculpin species in the Middle Columbia River study area, 2001 to 2012. The dotted line represents the implementation of the minimum flow release and REV5 operations.

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