Bridge-Seton Water Use Plan

Lower Bridge River Aquatic Monitoring

Implementation Year 3

Reference: BRGMON-1

2014 Annual Data Report

Study Period: January 1, 2014 – December 31, 2014

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Please cite as: McHugh, A. and Soverel, N.O. 2015. Lower Bridge River Aquatic Monitoring. Year 2014 Data Report. Bridge Seton Water Use Plan. Prepared for St'át'imc Eco Resources, Ltd. and BC Hydro for submission to the Deputy Comptroller of Water Rights, August 2015.

August 2015

Bridge-Seton Watershed

Lower Bridge River Aquatic Monitoring Program
2014 Annual Data Report

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1.0 EXECUTIVE SUMMARY

The main purpose of the Aquatic Ecosystem Monitoring program in 2014 was twofold: 1) to continue empirically measuring the environmental benefits to the aquatic environment from the instream flow release from Terzaghi Dam, and 2) to inform the adaptive management of the Lower Bridge River. This environmental monitoring program was designed to test two main flow releases (Trials 1 and 2) against a zero-flow baseline scenario (Pre-Trial). The Pre-Trial flow release represented baseline ecological monitoring; Trial 1 represented a Low flow scenario (3 m^3s^{-1}, years 2000-2010); and Trial 2 represented a High flow scenario (6 m^3s^{-1}, years 2011-2014). Five monitoring activities were conducted as part of the monitoring program: 1) water temperature and stage level; 2) water chemistry, aquatic invertebrate diversity and periphyton accrual; 3) juvenile salmonid growth sampling; 4) fall standing stock assessment; and 5) habitat surveys. In addition, a rampdown monitoring component was conducted during the summer and

fall seasons to minimize fish stranding risk, salvage fish and to collect information in order to inform an optimal strategy for ramping the river.

The main findings from 2014 are consistent with past years, and demonstrate that higher flows (i.e., Trial 2) may not be better for the overall health of the aquatic ecosystem than lower flows (i.e., Trial 1). Broadly, the continual water release from Carpenter Reservoir has altered the physical habitat and associated ecological, social and cultural benefits of the Lower Bridge River (LBR) since Pre-Trial. Relative to Pre-Trial conditions, the seasonal temperature regime has been modified, and the wetted area of the river is observed to be larger. In both Trials 1 and 2, fall temperatures were distinctly warmer, and spring and summer temperatures were consistently cooler than observed in the Pre-Trial flow data. These effects were strongest in the upper reaches (i.e., Reaches 3 and 4) and weakest in Reach 2 due to the influence of moderating Yalakom River inflows, groundwater and the differing channel morphology. While fall temperature data appears similar across Trials 1 and 2 in the upper reaches (due to similar flow magnitude) temperature trends in the summer under Trial 2 indicate that water was generally cooler than Trial 1. Water chemistry parameters for 2014 were similar to those reported in previous non-pink salmon spawning years and concentrations were within the water quality guidelines established by British Columbia. Two habitat surveys were conducted during 2014: a High Flow survey at 15 m^3s^{-1} and a Low Flow survey at 1.5 $m^3s^{-1.}$ Habitat surveys across the years revealed that higher flows increased the wetted area of the river, however the relative amount of quality juvenile rearing habitat decreased during the highest flows in Trials 1 and 2. Habitat surveys at the 1.5 m^3s^{-1} indicate that in general, habitat classifications remained similar to area and proportions of habitat types during a 3 m^3s^{-1} flow. Lower flows provided more quality juvenile rearing habitat in the LBR during both Trials 1 and 2.

Periphyton accrual rates, biovolume and cell counts were observed to increase throughout the fall field series in 2014 and across Trial 2. 2014 accrual data follow trends that were apparent in both Trials 1 and 2. Regardless of the flow regime under Trials 1 and 2, accrual trends were driven by pink salmon spawning in odd years. Invertebrate data were found to be indicative of ecosystem changes within abundance, diversity and richness. Both Trials followed similar trends among index site locations: sites with higher abundance and diversity among samples occurred downstream of site 33.3. Diversity and abundance increased significantly in Trial 2, as compared to Trial 1. However, several taxa decreased and two genera within Tipulidea and riffle beetles were absent in Trial 2. This may signify a loss of low velocity water sections as species within these genera are adapted to slower depositional habitats. This suggests that the increase in flow during Trial 2 was a disturbance to components of benthic invertebrate communities.

Fish density, relative abundance and spatial distribution derived from standing stock data showed trends. Data suggest that overall total juvenile salmon biomass appeared relatively stable across Trial 1 and Trial 2. Within the reaches, Reaches 2 and 3 appeared relatively stable from 2011 – 2014. However Reach 4 data suggested a decline in fish productivity. For the past 12 consecutive years, Reach 4 had the highest biomass estimates in the LBR. For the first time since Trial 1 began, Reach 4 total biomass estimates (for 2014) dropped below levels in Reach 3. Reach 3 had a higher biomass estimate than Reach 2, but was lower than biomass estimates observed under Pre-Trial conditions. Juvenile species proportions within the biomass estimates have changed. Chinook and Coho represent less of the total proportion of species in 2014, at the end of Trial 2 as compared to 2011, the end of Trial 1 and beginning of Trial 2. This trend is apparent across all Reaches. Total Rainbow trout proportions increased from beginning to the present time within Trial 2.

Fish stranding surveys were successfully implemented based on historical methods, and 4,920 fish were salvaged between the August and October ramp down sessions. Most of the fish salvaged were Rainbow and Coho within age-class 0. These are the fish that typically reside the shallow habitat that normally dewaters during ramp down of the LBR.

The reasons for these observed parameter changes and the differences and similarities between Flow Trials (Pre-Trial, Trial 1, and Trial 2) are varied and uncertain. They are likely influenced by the changed thermal regime of the river, habitat alterations due to differing flow regimes, changes in nutrient inputs and the combined and cumulative effects of the above. Parameter changes are currently being investigated under rigorous testing within the LBR synthesis assessment. This analysis and subsequent flow recommendation will be delivered late in 2015. In addition, there are other influences upon the aquatic ecosystem that are outside the scope of this monitoring program and synthesis assessment.

2.0 INTRODUCTION

The Bridge River, a tributary of the middle Fraser River, is an important fish-bearing river in Southern Interior British Columbia. While it was used historically as a major food source for St'at'imc fishing, today it is used for a variety of purposes including hydroelectric power. Traditionally, fish comprised 60% of the local diet (Kennedy and Bouchard, 1992) some of which originated in the Bridge River. However, the benefits to society from this fish resource extended much farther than just as a source of food. This fishery was also integral to a complex trading network where salmon and salmon oil were highly prized and considered the foundation of commerce in the region. The health and productivity of the Bridge River aquatic ecosystem contributed to the rich fish resource and culture in St’át’imc territory. Overall, this resource generated significant benefits towards the health and well-being of the St’át’imc Nation and trading partners.

In 1960, the Bridge River was fully impounded by Terzaghi Dam (formerly called Mission Dam), which was built at the head of a long, narrow canyon approximately 40 km upstream of the confluence with the Fraser River. This impoundment created Carpenter Reservoir, which serves as a water source for hydroelectric production in the Seton watershed, and fragmented the Bridge River, creating a controlled lower section called the Lower Bridge River. Initially, all flow was diverted to Seton Lake for hydroelectricity, with the exception of infrequent high-water spill over events. Consequently, 4kms of the river directly below the dam were dewatered for 40 years (1960-2000). Downstream of the dewatered reach, groundwater and tributary influence created a flow less than 1% of the historic mean annual discharge upstream of the Yalakom River (Longe and Higgins, 2002).

Concerns were raised and discussed over the lack of water flowing in the Lower Bridge River by the St’át’imc, federal and provincial regulatory agencies, and the public. After discussions in the 1980s, an agreement was reached to continuously release water to provide fish habitat downstream of Terzaghi Dam. An adaptive management approach was used to develop an environmental monitoring program, which was designed to test two main flow releases (Trials 1 and 2) against a zero-flow baseline scenario (Pre-Trial), which represented the previous 40 years. This program gathers empirical data to inform the flow management of the LBR, and aims to generate a better understanding of the effects of the introduction of water from Carpenter Reservoir on the aquatic ecosystem productivity and the ecosystem services, or benefits which the river generates, below the dam. An average 3.0 m^3s^{-1} annualized interim water budget, based on a hydrograph that ranged from a minimum of 2 m^3s^{-1} to a maximum 5 m^3s^{-1} was initially allocated for in-stream flow releases into the Lower Bridge River (LBR). Water was released on August 1, 2000 and continued at this level until spring 2011. Prior to this release, data were collected from 1996-2000, to provide baseline information on the pre-release ecosystem and the ecological services the river provided, and to facilitate measuring and comparing the response of the aquatic environment to different Flow Trials. Currently, a second test flow of an average 6.0 m^3s^{-1} annualized flow is being implemented from 2011-2015.

Data from this monitoring program will be used to inform the management of the Lower Bridge River flow regime, as well as an impending water use decision. Presently, the St'át'imc Nation, the Bridge River Band, BC Hydro, regulatory agencies and other stakeholders will work together to determine a long-term flow release strategy for the LBR. A quantitative comparison of the two flow releases relative to the baseline is currently underway, with the optimal hydrograph to be chosen in a synthesis assessment, followed by a subsequent flow recommendation. This process is ongoing, and a recommendation will be made in late 2015. The existing LBR aquatic monitoring program is scheduled for an additional 6 years after the flow decision, however how this monitoring program will proceed is conditional on the outcome of an interim review following the water use decision and implementation of the flow release strategy. In order to inform any management decisions, a suite of biotic and abiotic aquatic indicators were chosen and are quantified within this report.

This report was prepared to demonstrate compliance with conditions of the Water Use Plan (WUP) Order to release water and monitor the environmental impacts of the flow release on the aquatic ecosystem. It is also used to describe data collection methods and to present results from 2014 under Trial 2, with the water budget hydrograph ranging from ~1.5 m^3s^{-1} to ~15 m^3s^{-1} on a seasonal basis. Ultimately, these data will be used to inform the management of the LBR. The present implementation of this aquatic monitoring program is part of the Bridge-Seton Water Use Plan. St'át'imc Eco- Resources (SER), an incorporated company owned by the St'át'imc Chiefs Council, has been contracted by BC Hydro to undertake this work. Subsequently, Coldstream Ecology, Ltd. has been subcontracted to implement the monitoring program. Detailed descriptions of past monitoring activities and results of past years can be found in McHugh and Soverel (2013 - 2014), Riley et al. (1997, 1998), Higgins and Korman (2000), Longe and Higgins (2002), Sneep and Higgins (2003, 2004), and Sneep and Hall (2005 - 2012).

2.1 Management Questions

The goal of this ecological monitoring program is to utilize an adaptive management framework to reduce uncertainty about the expected benefits of releasing water from Carpenter Reservoir downstream of Terzaghi Dam. Past studies have been unable to provide scientifically defensible predictions of the ecological benefits of the flow releases, and this lack of certainty constitutes a major challenge for decision-making regarding valued ecological resources and energy management. Consequently, the long-term monitoring program was designed to provide defensible data defining the functional relationship between the magnitude of flow releases, and physical and biological responses in the LBR channel. As identified in the WUP Terms of Reference for this monitoring program, four key management questions that directly describe the uncertainties and the learning objectives include:

1) How does the in-stream flow regime alter the physical conditions in aquatic and riparian habitats of the Lower Bridge River ecosystem?

2) How do differences in physical conditions in aquatic habitat resulting from the in-stream flow regime influence community composition and productivity of primary and secondary producers in the Lower Bridge River?

3) How do changes in physical conditions and trophic productivity resulting from flow changes together influence the recruitment of fish populations in the Lower Bridge River?

4) What is the appropriate 'shape' of the descending limb of the 6 m^3s^{-1} hydrograph, particularly from 15 m^3s^{-1} to 3 m^3s^{-1}?

Juvenile salmonid biomass is used as a primary criterion to compare performances of different flow levels because salmon represent a highly valued ecological component of the aquatic ecosystem. In addition, juvenile salmonid biomass integrates the effects of flow on trophic productivity and habitat conditions in the LBR. The monitoring program was designed to test the following hypotheses regarding the ecological benefits and the effects of flow on the fish populations in the LBR:

H_O: "High flow is better"

H_A: "Low flow is better"

The data provided in this annual data report summarize the 2014 program. These data are part of a larger dataset (i.e., 1996-2014), which will address management questions 1-3 (above) during synthesis report preparation in 2015. At the conclusion of this Flow Trial, the synthesis report and recommendation will inform the key WUP flow decision in 2015. The decision will focus on the magnitude of the long-term flow regime chosen (i.e., 3 vs. 6 m^3s^{-1}). The fourth management question (above) is being addressed by a ramp down monitoring component that was integrated into this WUP monitoring in 2012. Information collected from this component will help to mitigate the risk of fish stranding and inform the optimal “shape” of the hydrograph throughout annual ramp down activities.

2.2 Objectives and Scope

The primary objectives of this monitoring program are twofold: 1) to reduce uncertainty regarding the effects of the flow releases on the aquatic productivity of the ecosystem; and 2) to design a summer and fall ramp down strategy that reduces the risk of fish stranding while meeting environmental objectives and to salvage fish during river ramping. To this end, this program monitored the response of key biological and physical indicators to the Trial flows, and the results will be used to inform the long-term flow management of the river. Specifically, monitoring program activities in 2014 continued to focus on:

1) Water temperature, dam discharge, and river stage;
2) Water chemistry parameters, periphyton accrual and diversity, and the relative abundance and diversity of aquatic invertebrates during the fall series; and

3) Growth, distribution, and relative abundance of juvenile salmonids, especially Coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*O. tshawytscha*), steelhead and Rainbow trout[1] (*O. mykiss*), within the study area;
4) Summer and fall ramp down monitoring and salvage activities;
5) 1.5 m^3s^{-1} and 15 m^3s^{-1} flow habitat surveys; and
6) Rainbow[1] life history otolith program implementation.

In future years, the scope will be guided by the outcome of the interim reviews in 2015.

2.3 Approach

The Lower Bridge River Aquatic Monitoring program has been implemented for nearly two decades (i.e. 1996-2014). As such, methodologies for each sampling component have been standardized to facilitate comparisons across Flow Trials. The methods and results are broken down into two distinct sections: the aquatic ecosystem monitoring components and the summer and fall ramp down surveys.

2.4 Study Area

The Bridge River lies within St'át'imc Territory, in Southern Interior British Columbia. The Lower Bridge River is the section between the confluence of the Fraser River and Terzaghi Dam. It is divided into 4 reaches, which are defined in Table 1 and illustrated in Figure 1.

Table 1. Reach break designations and descriptions for the Lower Bridge River.

Reach	Boundary (Rkm) Downstream	Upstream	Description
1	0.0	20.0	Fraser River Confluence to Camoo Creek
2	20.0	25.5	Camoo Creek to Yalakom River confluence
3	25.5	36.8	Yalakom R. confluence to upper extent of groundwater in-flow
4	36.8	40.9	Upper extent of groundwater in-flow to Terzaghi Dam

[1] Throughout this report, juvenile O. mykiss are referred to as Rainbow trout, although a large (but undefined) proportion of these fish in the LBR are anadromous steelhead.

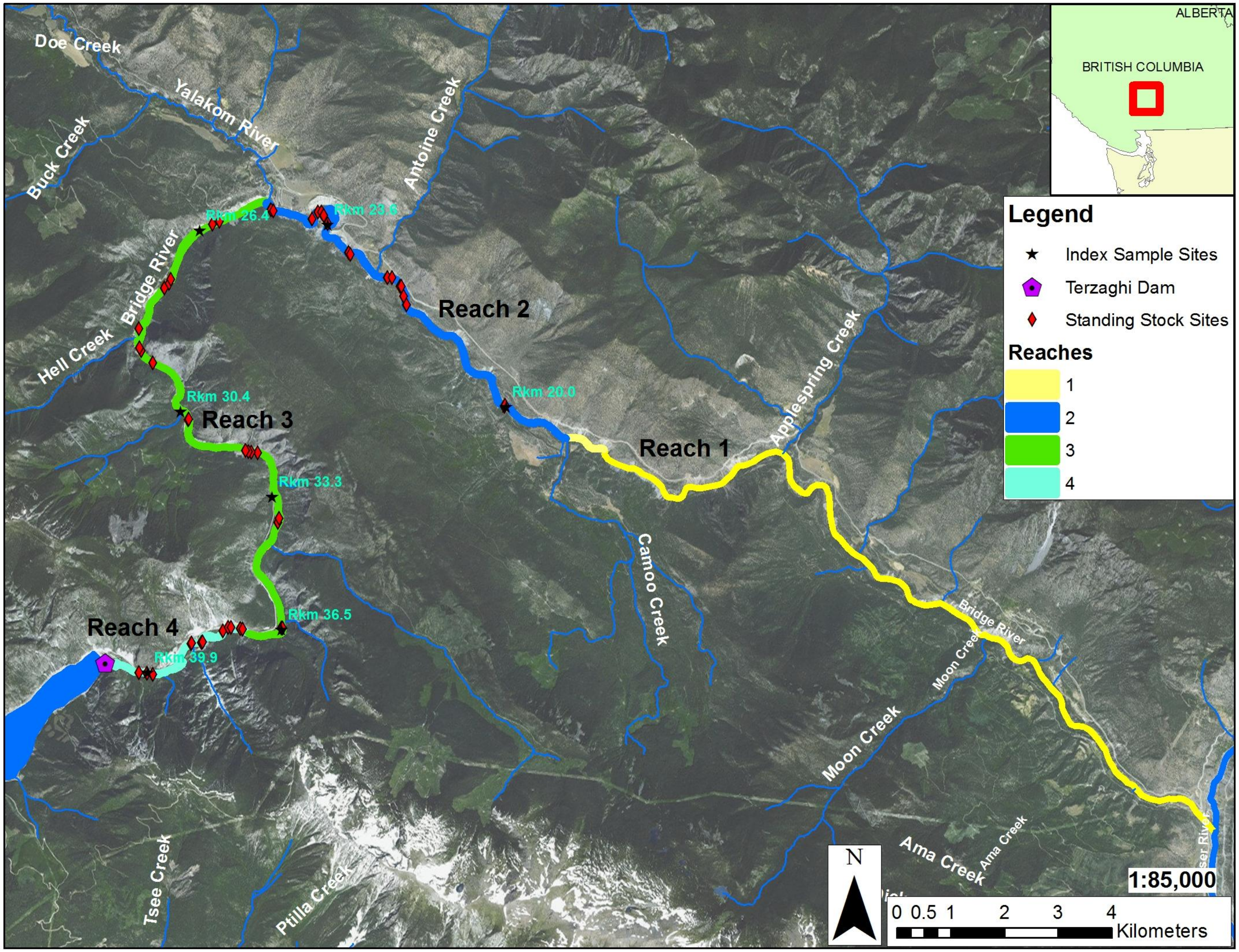


Figure 1.The Lower Bridge River Aquatic Monitoring Program study area, including reach breaks, index sample site locations, the standing stock assessment site locations, as well as tributaries between Terzaghi Dam and the Fraser River.

2.5 Study Period

The monitoring occurred during nine sampling sessions in 2014. A general description of the activities and sampling timing are presented in Table 2. Details are discussed below in section 3.1.1.

Table 2. Schedule of Sampling Sessions, 2014.

Sample Session	2014 Dates	Activities
Spring	20 to 22 May	Electrofishing Growth and Ecology
Summer	10 to 29 July	High flow habitat surveys
Summer	24 to 27 June; 12 to 22 August	Electrofishing Growth and Ecology
Summer Rampdown	18 July; 1 to 24 August; 3 and 4 October	Rampdown surveys: fish salvage and staff stage, temperature and turbidity data collection; Electrofishing
Fall Stock Assessment	2 to 24 September	Depletion Sampling (electrofishing)
Early Fall	1 to 2 October; 3 to 4 October	Deploying algae and bug samplers; Fall Rampdown
Fall	1 to 2 October; 3 Oct to 30 November	Water sampling (nutrients), Discharge transects; low flow habitat surveys
Late Fall	25 to 27 November	Retrieving algae and bug samplers; Water sampling (nutrients); Logger downloads
Early Winter	10 October; 20 November; 8 December	Logger Downloads; Discharge transects

3.0 METHODS

3.1 The Aquatic Monitoring Program

3.1.1 *Overview*

Monitoring methods and protocols utilized in 2014 were identical to those used in 2013 and before. These methods and protocols originated from a general template of monitoring initiated at the start of the baseline flow-monitoring phase (1996 – 2000) and have since undergone adaptations through Trials 1 and 2, as appropriate. The major data collection components of the LBR sampling design include:

- Water temperature,
- River stage,
- Flow release,
- Water nutrient/chemistry,
- Primary Productivity (periphyton),
- Secondary productivity (macroinvertebrate),
- Juvenile salmonid growth,
- Fall standing stock,
- Habitat surveys, and
- Ramp down and salvage surveys.

Data collection in 2014 occurred at seven index sites located at 3 km. intervals along the LBR (Figure 1). In descending order from Terzaghi Dam, these include the following river kilometers: 39.9, 36.5, 33.3, 30.4, 26.4, 23.6, and 20.0. River kilometer (Rkm) 39.9 is a more recent index site where monitoring began at the start of the 3 m^3s^{-1} flow release on 1 August 2000. The timing and frequency of data collection were similar to historic LBR data collection within the program. Water temperature, river stage, and flow release methods are described below.

Water temperature was recorded at an hourly rate on every day of 2014 using data loggers manufactured by the Onset Computer Corporation (UTBI-001). These data loggers were located at the seven site index locations as well as an additional logger located at 100 meters upstream of the confluence of the LBR and the Yalakom River. Temperature loggers were anchored at locations and were submerged by river water. They were both checked and downloaded for data every 3 to 4 months to ensure data quality.

Relative river stage was recorded by PS9000 submersible pressure transducers (Instrumentation Northwest, Inc.), which were coupled with Lakewood 310-UL-16 data recorders. Data were collected at three Rkm locations: 20.0, 26.1, and 36.8. River stage was recorded every 15 minutes per day every day of the year. In addition, discharge data were collected from October – December, during the 1.5 m^3s^{-1} flow at two designated transect locations in Reaches 3 and 4. Water depth and velocity measurements were taken every 0.5 meters.

Data on flow release were provided by BC Hydro Power Records and are maintained by BC Hydro. These data represent hourly discharge from the Lower Level Outlet (LLO) gates at Terzaghi Dam, every day of the year.

3.1.2 *Water Chemistry and Nutrients*

Water chemistry and nutrient data collection occurred in the early fall session on 1-2 October and 25 and 27 November 2014 for the late fall session. During both fall sampling periods, water samples were taken from all site index locations, Carpenter Reservoir, and the following LBR tributaries: Antoine Creek, Camoo Creek, Hell Creek, Michelmoon Creek, Mission Creek, Russell Springs, Yalakom River, and Yankee Creek (refer to Figure 1). These water samples were submitted to ALS Environmental and analyzed for the following nutrient levels: NH_4,

NO_2/NO_3, Soluble Reactive Phosphorus, Total Dissolved Phosphorous, turbidity, and Total Phosphorus; the chemical parameters included total alkalinity and pH. Supplemental water quality data were measured at each site using a WTW handheld field meter and these included conductivity, pH, and spot water temperature.

3.1.3 *Primary and Secondary Productivity Sampling*

Primary productivity was monitored using periphyton accrual as the main indicator parameter. Productivity refers to the rate of generation of biomass in an ecosystem. Macroinvertebrate abundance and diversity were the main indicators of secondary productivity. Abundance, when discussed in this report relates to the overall number or count of individuals within a given population, or location in the river. Diversity is defined as the number of species, genera, or families in that population. At each of the seven index site locations, both periphyton and macroinvertebrate data were collected at three replicate subplot locations spaced approximately 20 meters apart. At each replicate subplot, a depth and velocity measurement was taken using a top-set wading rod and velocity meter manufactured by Swoffer Instruments, Inc. The data were collected in order to assist in the characterization of inter-annual variations of primary and secondary productivity.

The medium used to accrue periphyton consisted of a 30 x 30 x 1 cm cell Styrofoam sheet that was rubber banded to a plywood backing which was bolted to a 30 x 30 x 10 cm concrete block. At each site index, periphyton accrual samplers were placed at each replicate in areas relatively similar in water depth and velocity. Periphyton accrual data were collected approximately every week at all the replicate subplots and for all seven site index locations between October 1st and November 27, 2014. Each weekly sample involved the removal of a core of Styrofoam using the open end of a 7-dram plastic vial (8.5 cm^2 core area). These samples were then sent to ALS Environmental for measurement of Chlorophyll-a concentration. At the end of the fall series, an additional Styrofoam core was extracted and sent to Limnotek so that species composition and cell counts per unit could be measured. More detailed methods regarding LBR specific field techniques for periphyton accrual methods can be found in McHugh and Soverel (2014).

The medium used to measure macro-invertebrate abundance and diversity included a standardized metal basket filled with river gravel and substrate collected at each site. These prepared baskets were placed at similar water depths and velocities at each of the site locations and proximal to the periphyton accrual samplers. The baskets were left undisturbed for the duration of the eight week fall sampling series at which point they were carefully lifted out of the water and placed into buckets. The contained substrates were carefully removed from the baskets and were hand scrubbed in order to remove all attached material. This material was filtered through a mesh sieve (Nitex), and placed into a sample jar that contained 10% formalin solution. As was done in previous years, the sample jars were sent to Mike Stamford at Stamford Environmental to be sorted, identified to family, and enumerated. In addition, the archived samples from the 2011 Fall Field Series were also analyzed in 2014.

3.1.4 *Sampling for juvenile salmonid growth data*

In 2014, juvenile salmonids were collected for growth data at each index site four times (i.e., May, June, August, and September) in order to characterize temporal and spatial patterns of fish growth. The intent of this sampling was to collect a target of approximately 30 salmonids within each age/species class; as this was the target number utilized in previous studies. Live fish were collected using a backpack electroshock approach whereby fish were anaesthetized, identified to species, forklength (nearest millimeter) measurements taken and weights (to the nearest 0.1 gram) recorded. Following a brief recovery, all fish were released very close to their initial collection area.

3.1.5 *Fall Standing Stock Assessment*

The objective of the fall standing stock assessment is to estimate the abundance and distribution of juvenile Chinook salmon, Coho salmon, and Rainbow trout in Reaches 2, 3, and 4. Unlike the fish growth sampling, the standing stock assessment has a much larger geographic scope, spanning 50 sites along the LBR. The fall stock assessment was conducted during the 3 m^3s^{-1} fall flow. The timeframe and flow magnitude during this sampling is the same in Trials 1 and 2 (Figure 2).

Upon arrival to each site, the standing stock survey area was enclosed with three ¼-inch mesh stop nets in size ranging from 50 to 150 m^2. Perpendicular to the bank, two shorter panels were used as stop nets upstream and downstream of the bank while a longer net was used parallel to the bank. Stop nets were attached to bipods and anchored down to the shore so that they were fixed during sampling. As crews changed over the years and the river changed, net placement deviated slightly between crews and was dependent on site habitat and site conditions at the time of sampling. This is minimized to ensure that no sampling biases occur.

A four-pass depletion method using electrofishers was executed within the netted enclosure by using a 400 volts DC. Live fish were anaesthetized, identified to species, forklength (nearest millimeter) measurements taken and weights (nearest 0.1 gram) recorded. Fish were kept in a live basket in the stream until the sampling was complete and fish were then released near the original electroshock location.

Upon completion of the electroshocking, physical (abiotic) data of the site was measured and recorded. Three length and width measurements of the netted enclosure were recorded. The length and width measurements were taken in order to calculate the area sampled. After the net enclosure was removed, water depth and flow velocity was recorded via three transects at upstream, mid, and downstream locations. At each transect five depths and five velocities were measured at equidistant intervals from bank to the offshore extent of the sampled area. Water velocity was measured with a Swoffer™ current meter at a depth of 0.6 m. Maximum depth and velocity were also noted at each site.

Supplementary site data included sampling effort (electrofishing seconds), date, dominant habitat type, D90, substrate composition, and mean particle size.

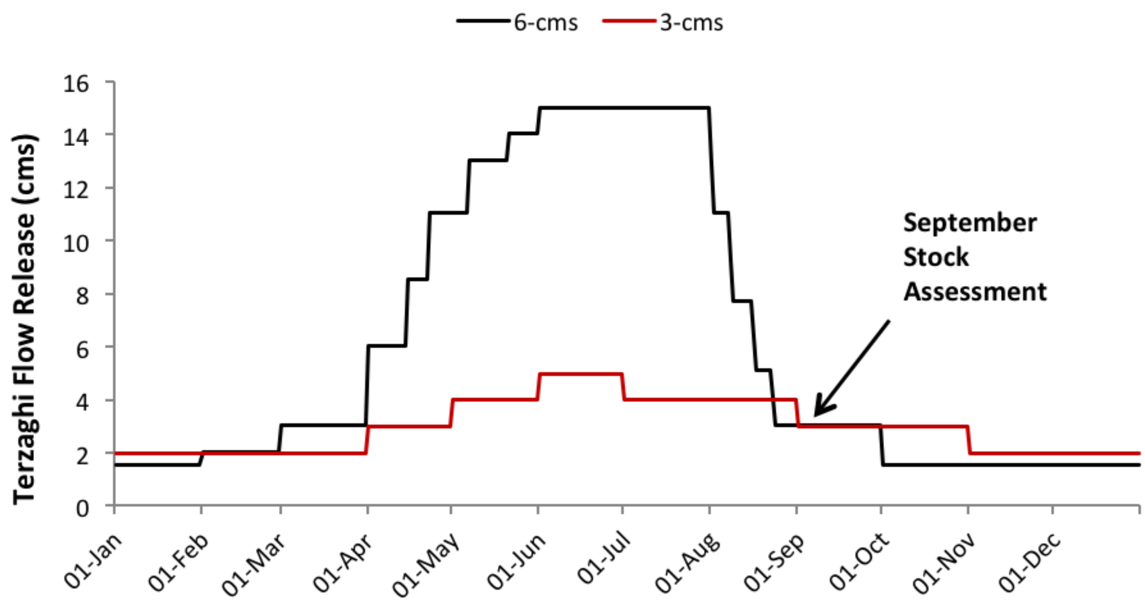


Figure 2. Lower Bridge River hydrographs at the 3 m^3s^{-1} and the current 6 m^3s^{-1} water budgets. Arrow indicates the timing of the annual fall standing stock assessment sampling.

3.1.6 *Aquatic Habitat Methods*

The main objective of the 2014 habitat component was to create two baseline spatial products that depicted habitats under 15 m^3s^{-1} and 1.5 m^3s^{-1} flows, while facilitating comparison of 2014 data with traditional historic habitat data. Two habitat surveys were conducted in 2014. Habitat attributes for Reaches 2, 3 and 4 were measured during July, 2014 during the high summer flow (15 m^3s^{-1}) and from October through November during the low winter (1.5 m^3s^{-1}) flow. Unlike previous years, the two habitat surveys incorporated two methods: traditional field survey data collection and a new spatially-based method. The newly incorporated spatial method allowed for mapping riverine habitat by capturing spatially explicit data within each habitat unit, while the traditional method focused on capturing linear depth, velocity and area measurements. The final spatial products include two geodatabases representing the LBR classified by aquatic habitat types with an emphasis on habitat types important to salmonid species[2]. These habitat type categories are listed in Table 3 (section 3.1.6.2 below). The new geodatabases will improve the precision and communication of information regarding habitat quantity, quality, and the impacts of flow on the aquatic ecosystem. They can be used by natural resource professionals, legislators and the public to make more informed decisions and prioritize conservation and restoration opportunities. Sections 3.1.6.1 through 3.1.6.4 describe spatial image acquisition and processing methods, aquatic habitat classification methods, field data collection and verification methods, and post processing. Details regarding the traditional habitat survey method can be found below in section 3.1.6.3.

[2] These geodatabases are available upon request.

3.1.6.1 Image acquisition and processing for spatial approach

BC Hydro provided all background imagery and initial vector shapefiles depicting river left and river right for the spatial aquatic habitat analysis. The detailed information in Appendix A describes the methods used to create the vector shapefiles. To describe the methods broadly, aircraft captured aerial photography twice in 2013: in June during the highest flow of the LBR at approximately 15 m^3s^{-1} and also on September 11, 2013 during the 3 m^3s^{-1} flow. The final dataset delivered by BC Hydro included a vector shapefile of both river left and river right boundaries. These data provided a suitable foundation for which to begin digitizing aquatic habitats for both the 15 m^3s^{-1} and 1.5 m^3s^{-1} flows[3].

3.1.6.2 Aquatic habitat classification methods

The background imagery and vector shapefiles of river left and river right were used as a baseline and surrogate for digitizing and classifying the habitat within each flow. Initial heads-up digitization of aquatic habitats was employed on both the June and September aerial photography to map the habitat category. Heads-up digitization is the process of using background imagery (i.e., orthophotos) and its characteristics (e.g., a river and its associated habitat types) to trace relevant features. Aquatic features were digitized directly from the aerial photos using ArcMap 9.3.1 (ESRI, 2009). Heads-up digitization of habitat classes was achieved through visual interpretation at an approximate scale of 1:1000 using a combination of features that included water colour, visible white-water and apparent water flow, substrate, river shape, and riparian vegetation. Classification methods employed for the 15 m^3s^{-1} and 1.5 m^3s^{-1} utilized habitat categories and criteria outlined in Table 3. Habitat units were classified by type (i.e., riffle, run, pool, cascade, rapid, sidechannel), and were similar for both flows. Habitat type descriptions were taken from historical methods used for LBR habitat classification as a means for data consistency and effective habitat monitoring. In some cases, habitat subunits were also created. These were defined as small areas of habitat within the larger habitat unit but with distinct physical characteristics. These habitat subunits were classified as part of the main habitat unit but were given their own unique identifier. The geographic areas that were classified included Reaches 4, 3, and 2 of the LBR.

[3] Methods described are from the BC Hydro Photogrammetry department.

Table 3. Outline of descriptions and definitions utilized to identify habitat types.

Habitat Type	Depth	Velocity	Gradient	Instream Cover	Comments
Run	Mod. to High	Mod.	Low to Mod.	Mod.	Moderate, laminar flow; little surface agitation
Riffle	Low to Mod.	High	Mod. to High	Mod. to High	Swift, turbulent flow; Some partially exposed substrate
Pool	High	Low	Low	Low to High	Variety of forms; Can be either 1° or 2° units
Cascade	Mod	High	High	Low	Very steep riffle habitat; Substrate is usually boulders
Rapid	Mod. to High	High	Mod.	Low	Very fast flowing runs, flooded riffles; Around constrictions
SC[a]	Low to Mod.	Low to Mod.	Low to Mod.	High	2° habitat type; Productive but limited quantity in LBR

[a] *SC =Sidechannel*

3.1.6.3 Field verification and historic data collection

While most habitat types in the classification process were easily captured through the heads-up digitization process, certain habitat areas required additional field verification (i.e., ground-truthing), for correction, confirmation, or addition of features. These features included the exact geographic breaks between habitat units, areas that were below the canopy of trees along the river channel, some side channels that were narrow or resembled adjacent rock features, as well as delineation of some aquatic features that highly resemble one another. Field verification of the heads-up digitized spatial data was based on criteria outlined in Table 3. Georeferenced maps were produced for field technicians so that field verification and corrections could be made geographically. An Ipad mini unit was used to collect all spatial data and these data were collected in the application called ‘Pdf Maps 2.4.0’ (Avenza, 2014). These data are easily transferable to an ArcGIS platform in order to execute finalization of the spatial datasets.

Field verification was conducted at the same time as the traditional habitat survey. Traditional survey data for each habitat unit were collected by walking and wading the LBR study area (i.e., Reaches 4, 3, and 2), and classifying the habitat units by type (i.e., based on criteria outline in Table 3). In addition to corrections and additions to the digitized maps, technicians collected the following field data for each habitat unit:

- Habitat class,
- Photographs,
- Wetted width (m),
- Depth (m),
- Velocity (m/s), and
- Length (m).

The lengths of each habitat unit were measured using a laser range-finder (accuracy +/- 1 m). Widths were measured using a laser distance meter (accuracy +/- 1.5 mm). Depths and velocities were measured using a top set wading rod and current meter manufactured by Swoffer Instruments, Inc. At a minimum, one length, two widths, and two depth and velocity measurements were taken and recorded for each habitat unit. In general, the number of measurements was proportional to the length of the unit. The majority of depths and velocities were measured at mid channel (half way across the wetted width). However, additional measurements were taken at 1/4 and 3/4 distance across the channel, as well as adjacent to each bank, to document overall depth and velocity distribution across the channel for each flow release volume being surveyed.

Inaccessibility and high water flows created limitations in data collection during the 15 m^3s^{-1} flow. Most of Reach 2 could not be fully field verified due to lack of accessibility caused by steep canyon walls and winter conditions. In addition, across all Reaches for the 15 m^3s^{-1}flow, many habitat units were inaccessible for field verification and data collection; notably small habitat units such as pools and sidechannels on river right. Field technicians were unable to measure all subsamples of velocity and water depth for the 15 m^3s^{-1}flow as entering the flowing water was dangerous and unsafe. Consequently, midstream velocity was measured using brightly coloured fruit thrown into midstream with total distance and time in seconds recorded. Water velocity was measured as total distance (m) divided by time (s) taken for fruit to travel from a designated start location to its finish. Precise length measurements for 15 m^3s^{-1} habitat units were calculated in ArcMap. For the 15 m^3s^{-1} flow, habitat unit length was measured as the centre line of the channel from the farthest upstream point to the farthest downstream point.

3.1.6.4 Post data processing

After field verification and data collection, all field data were downloaded and imported into ESRI compatible geodatabase files. The initial geodatabases were edited and corrected based upon the field data collected by the technicians. Finally, the spatial dataset was quality controlled by members of the Coldstream staff for any remaining errors. To ensure limited errors existed in digitization, a topology exercise was also employed to detect any final geographic errors in the spatial dataset. Topology searched and detected errors where habitat units overlapped or where habitat units had any gaps. These errors were corrected using topology edit tools provided in ESRI ArcMap 9.3.1.

3.1.7 *Resident Rainbow Trout and Anadromous Steelhead Life History Sampling*

Currently, it is unclear what proportion of juvenile Rainbow trout sampled in this monitoring project each year are steelhead and what proportion are resident Rainbow. To support the analytical determination of the proportion of Rainbow trout that originated from an anadromous female parent or resident parent, otoliths were collected from fish sampled during the fall standing stock assessment and juvenile growth sessions, using a reach- and fish size- (age) stratified design. Comparisons of strontium:calcium (Sr:Ca) ratios in otoliths facilitate the identification of the progeny of the fish sampled. Approximately 40 otoliths were collected, representing each of the study reaches within 1 age-class. These data will provide a snapshot of the proportions in 2014. Analysis of the collected otoliths was subcontracted to Adrian Clark, who specializes and is experienced in the required analysis of otolith microchemistry. He is experienced with LBR otolith microchemisry work as he conducted the previous Chinook otolith assessment conducted for this monitor previously.[4]

3.2 Flow Rampdown Surveys

3.2.1 *Overview*

The focus area of the LBR rampdown occurs between Terzaghi Dam and the confluence of the Yalakom River, a river length of 16 km. At the start of each rampdown day, a preliminary

[4] 2014 analysis is ongoing and will be reported to the LBR synthesis team as soon as it is available.

baseline reconnaissance of the entire 16 km was conducted. The physical progress of the flow reduction was monitored, and close attention was paid to those areas with historically high fish stranding potential.

Based on historical data, reporting, and stage levels for the rampdown component, potential areas with risk were identified daily, and salvage crews were dispatched to those areas. Upon arrival, these crews documented the physical attribute characteristics of the area; and if necessary, crews began fish salvage. As in years past, at the start of the work day, fish salvage efforts started closest to Terzaghi Dam and highest priority was given to the following river habitats: sidechannels, low gradient edge habitats, and 'potholes' from historical gold mining endeavours.

3.2.2 *Communications*

In order to mitigate rampdown operations it was critical that field personnel at various locations along the river were able to communicate promptly with BC Hydro electricians at Terzaghi Dam. Field personnel provided the on-the-ground feedback to the BC Hydro electricians so field personnel could adjust the timing and magnitude of gate changes at Terzaghi Dam.

At the beginning of each rampdown day, all involved parties congregated at a safety tailboard meeting. There all personnel discussed the objective, plans, and logistics for that day. After crews dispersed, two-way radio communications were used with line-of-site radios tuned to BC Hydro's simplex channel (F1) and outside of line-of-site the duplex channel (F2 – Bridge River repeater) were used. Periodic check-ins occurred via radio communication.

3.2.3 *Terzaghi Flow Release and River Stage*

Hourly flow release data were provided by BC Hydro and are determined from the water surface elevation of flows over the top of the weir at the end of the Lower Level Outlet (LLO) gate. Scaling factors were used to transform the water surface elevation readings into flow release data.

River stage was a critical factor during the rampdown because it triggers timing and focus of fish salvage operations downstream. River stage was recorded electronically every fifteen minutes using PS9000 submersible pressure transducers (Instrumentation Northwest, Inc.) coupled to Lakewood 310-UL-16 data recorders. Two staff gauges were permanent (Rkms 36.8 and 33.3) while two were temporary (Rkms 40.9 and 25.0). The electronic stage loggers were maintained by Via-Sat Data Systems Inc. of Burnaby, BC. During the rampdown surveys, rampdown staff also recorded river stage on a manual basis.

3.2.4 *Water Temperature and Turbidity*

Significant fluctuations in temperature and/or turbidity can impact ecological processes as well as have detrimental effects on salmonids. During the rampdown surveys water temperature and turbidity were recorded to measure the amount of change that occurred before, during, and after the steps of the rampdown. Hourly water temperature was recorded electronically by permanent loggers located at Rkms: 39.9, 36.5, 33.3, 30.4, and 26.4. Periodic manual readings of temperature were also recorded using handheld meters by rampdown staff.

In order to collect water turbidity, staff collected water samples just below the plunge pool at the start and end of each rampdown day. A clean sample bottle was used for each sample, rinsed three times with river water, and finally plunged under the surface until full. All turbidity samples were measured using a turbidimeter and the results reported as Nephelometric Turbidity Units (NTUs).

3.2.5 *Fish Salvage*

When crews arrived to an identified fish salvage site, physical habitat attribute information was recorded as noted. These notes included:

- Date, time, full name of crew members, operational changes being assessed:
- General site description (i.e. reach #, river km, bank location, proximity to landmarks, etc.)
- NAD 1983 UTM Zone 10 North coordinates
- Estimated dewatering time for the site
- Additional Comments

Upon arrival at each site, crews assessed the overall abundance of fish present and size of habitat that would likely dewater. A strategy for moving fish out of the affected area and back into the main river was determined. Captured fish were categorized into the following:

- Incidental - fish habitats that were not yet isolated, and fish still had the opportunity to move to deeper areas on their own;
- Isolated – fish in wetted areas that were isolated from the main flow of the river (i.e. strand pools)
- Stranded – fish that were found in habitats that had completely dewatered, but were still alive when salvaged;
- Mortality – fish that were found dead in habitats that were isolated or completely dewatered.

Fish that were herded from shallow water into the main channel were considered ‘incidental’. When sites were completely isolated from the main channel and fish could not be captured in an incidental manner, they were captured by hand, dipnet, and backpack electrofisher. The aforementioned methods used were kept to a minimum (minimal handling and low electroshocker settings) as they can induce a high level of stress to fish. All captured fish were counted and identified to species before returning them back to the main channel. A subset of the captured fish were measured to forklength (to the nearest mm). All fish data were recorded on data sheets developed in 2014.

4.0 AQUATIC MONITORING RESULTS

4.1 Physical Conditions

The Lower Bridge River physical conditions as affected by discharge are controlled by outflow from Terzaghi Dam. In 1960, after the dam was completed, all flow from the Bridge River was diverted to the Seton-Anderson watershed through tunnels in Mission Mountain. These flows feed two generation stations on Seton Lake, Bridge 1 and 2. Consequently, downstream of Terzaghi Dam, the mean annual discharge (MAD) was less than a 1% of that prior to impoundment, with water entering the system only from tributaries and groundwater seepage in Reaches 3 and 4, with the exception of an occasional (i.e., about once per decade) spillover event for flood control above the dam.

Trial 2 was initiated in May 2011 at an annual average water budget of 6 m^3s^{-1}. 2014 was the third full year under the 6 m^3s^{-1} Flow Trial. Details of 2014 hydrograph and flow release are shown in the results below.

4.1.1 *River Stage*

Relative stage data (i.e., mean daily river level) recorded at three sites (Rkm 20.0, 26.1, and 36.8) along with discharge data from LLO are presented in Figure 3.

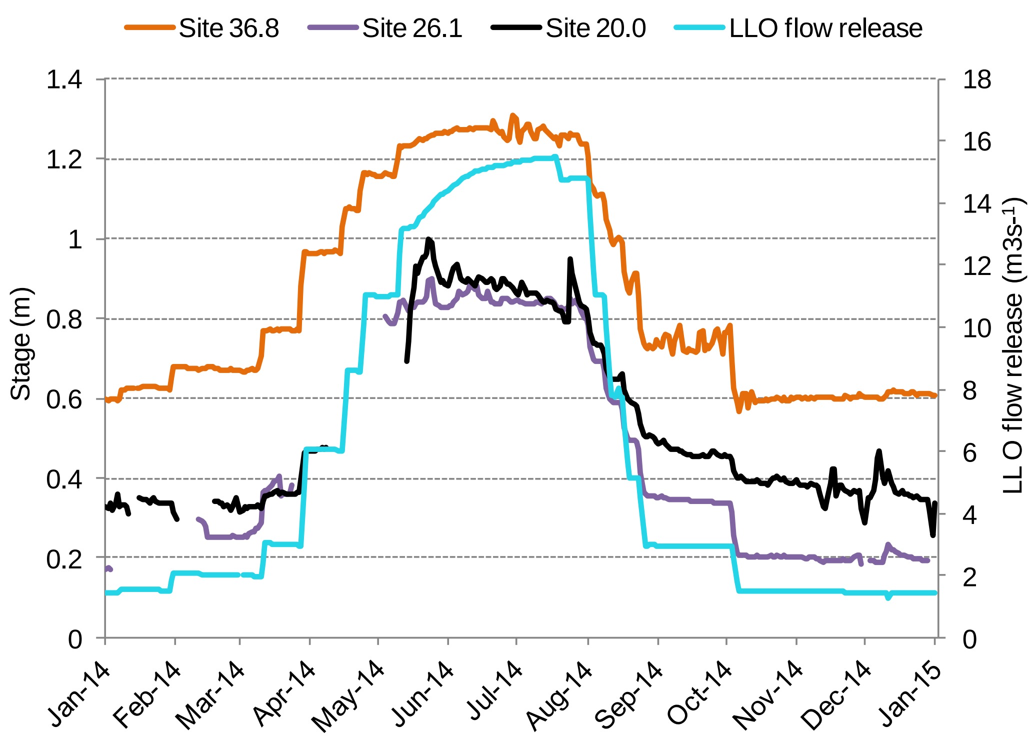


Figure 3. Mean daily river stage levels (primary axis) at three sites on the Lower Bridge River and mean daily flow releases from the LLO (lower level outlet) gate at Terzaghi Dam during 2014 (secondary axis). Missing or erroneous data are shown in this figure as blank data only for sites 20.0 and 26.1.

As shown in Figure 3, under the target Trial 2 hydrograph (i.e., LLO flow release of 6 m^3s^{-1}), target seasonal flows range from a spring and summer peak of approximately 15 m^3s^{-1} (June and July) to a fall and winter low of roughly 1.5 m^3s^{-1} (October to March). In 2014, staged ramp-up from the initial 3m^3s^{-1} began on April 1 and progressed until early July. One short duration ramp down was conducted on 18 July. High flows were maintained until fall rampdown which started on 2 August. During the month of August, the LLO flow release was ramped down from ~15 m^3s^{-1} to 3 m^3s^{-1} in stages. The ramping in August was split across multiple weeks due to the magnitude of the flow reduction (i.e., total change = ~12 m^3s^{-1}, from ca. ~15 to 3 m^3s^{-1}). Consequently, the water reduction was gradual and facilitated successful fish salvage, while decreasing mortality and stranding throughout the rampdown. In October, the LBR was further ramped down to 1.5 m^3s^{-1} over a period of two days. The Trial 2 fall flow release was reduced as compared with Trial 1 so as to minimize the effect of the hypolimnetic water in the upper reaches of the river during the fall spawning and early incubation periods. The intent was to mitigate the effects of the flow release and consequently warmer temperatures on the emergence timing of Chinook alevins that had been observed under Trial 1.

4.1.2 *Water Temperature*

Results of water temperature monitoring are broken down into two sections: 2014 Results (Section 4.1.2.1), Trial 2 Diurnal Temperature Variation (Section 4.1.2.2) and a cross Trial Comparison (Section 4.1.2.3). The sections below demonstrate that in both Trials, fall temperatures were distinctly warmer, and spring and summer temperatures were consistently cooler than observed in the Pre-Trial flow data. These effects were strongest in the upper reaches (i.e., Reaches 3 and 4) and weakest in Reach 2.

4.1.2.1 2014 Results

Annual mean daily water temperatures during 2014 for Reaches 2, 3 and 4 and the Yalakom River are presented in Figure 4. Figure 6 presents data showing maximum and minimum daily water temperatures during the fall period for Trial 2. Additional annual temperature data for the LBR and Yalakom River are presented in Appendix A[5]. Appendix A.1 depicts 2014 temperatures showing the winter, summer and fall periods. Appendix A.2 shows a color ramp of spring and summer temperatures (similar to Figure 6). Appendix A.3 shows the Yalakom River over the course of 2014. Due to logger failures, data were irretrievable from the temperature loggers between approximately 11 April and 18 August 2014.

[5] Appendix A contains unpublished data and can be provided upon request.

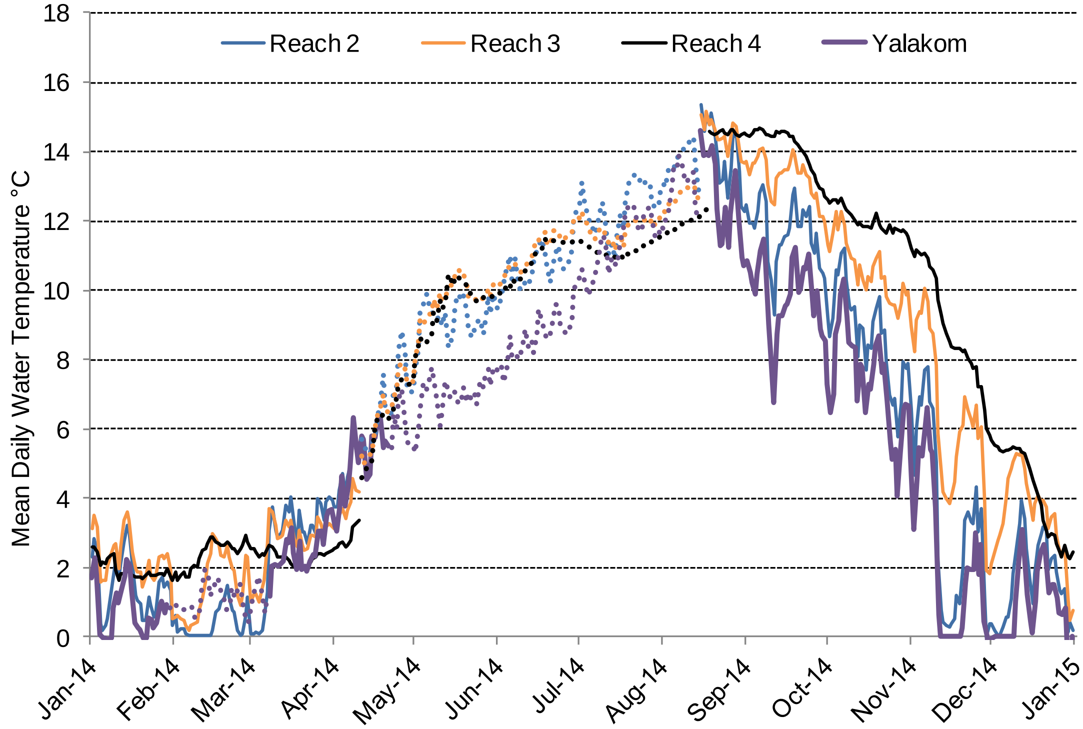
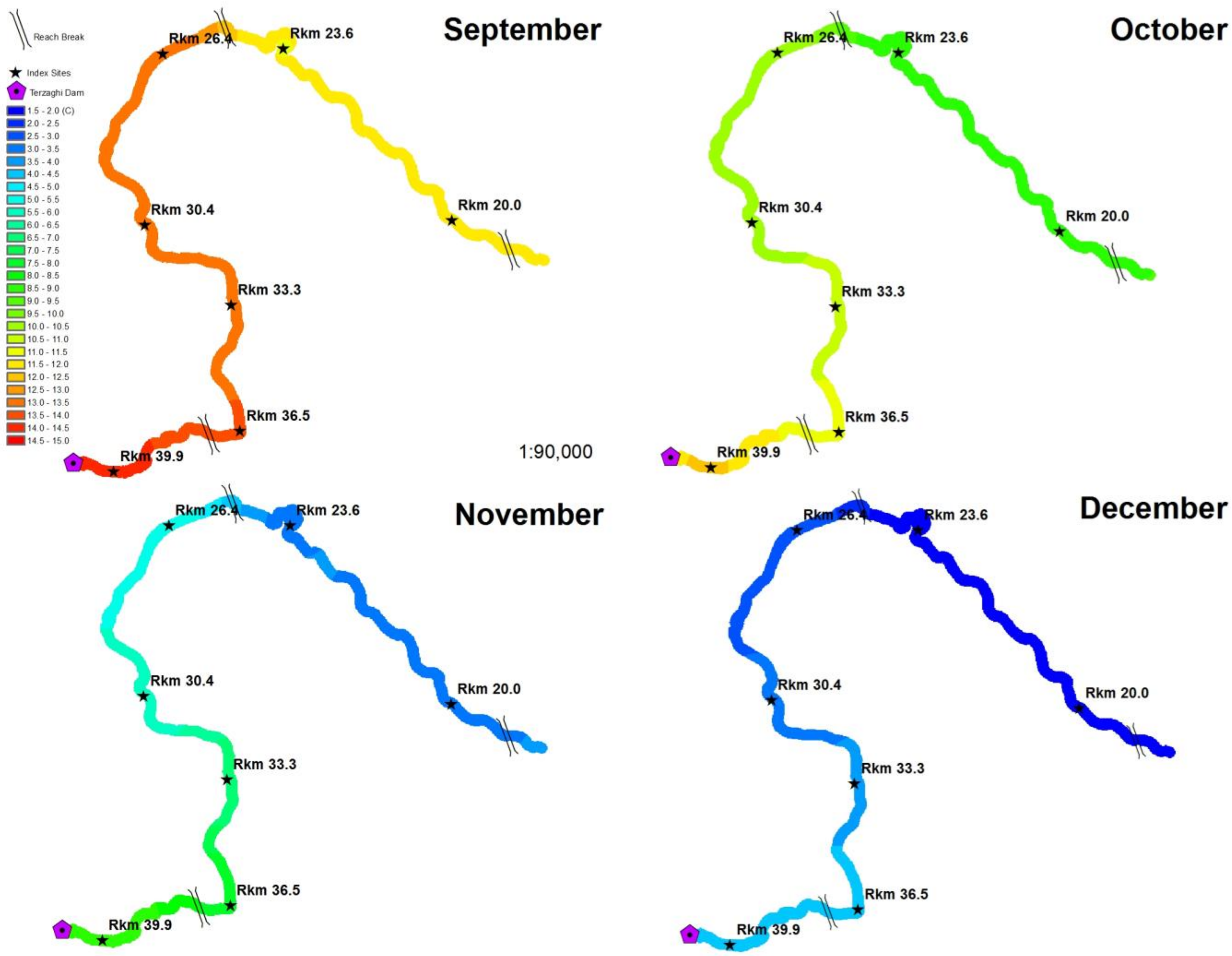


Figure 4. Yalakom River and LBR Reaches 2, 3, and 4 mean daily temperatures between 1 January and 31 December, 2014. Dotted coloured lines within this figure represent 2013 mean daily temperatures as these provide a surrogate for data that were irretrievable from the temperature loggers between approximately 11 April and 18 August, 2014.

Figure 4 shows 2014 temperature. Data during the summer months were unavailable and 2013 data were used as a surrogate. Seasonal temperature trends for 2014 in Reaches 2 - 4 of the Lower Bridge River were similar to those observed throughout Trial 2, (McHugh and Soverel, 2013-2014; Sneep and Hall, 2012). In general, temperatures in Reaches 3 and 4 appear to be warmer in the fall and cooler in the early spring and late summer, as compared to the pre-Trial thermal regime (Figure 7). Water temperatures in Reach 4 reflected the principal influence of the hypolimnetic flow from the reservoir. The hypolimnetic effects of the Trials were not as markedly evident in Reach 2; likely moderated by the influence of the unregulated Yalakom River (Figure 5; Appendix A.3). Data presented in Figure 5 demonstrate temperatures in Reach 4 were 2° C warmer than Reach 2 across the fall period. Early spring temperatures were cooler in Reach 4 than Reaches 2 and 3. Mean temperatures per month, by Reach are presented in Figure 5.

Figure 5 geographically displays the mean through a colour ramp indicating mean monthly temperature during the fall spawning period and early egg incubation period. The colour ramp represents warmest water temperatures with shades of red and decreasing water temperatures progressing into orange and yellow, followed by green and finally the dark blue colour representing the coldest temperatures.



Month	Reach 4	Reach 3	Reach 2
September	14.1	13.3	11.6
October	12.0	10.6	8.7
November	8.8	6.2	3.2
December	4.1	3.5	1.7

Figure 5.Temperature schematic of mean monthly water temperatures (C°) recorded at each site index location along the LBR in September, October, November, and December of 2014. Table in bottom right depicts mean monthly 2014 temperatures per reach per month.

4.1.2.2 Trial 2 Diurnal Temperature Variation

To further examine temperatures in the river over the fall egg incubation period, diurnal temperature variation, i.e., daily minimum and maximum temperatures, through Trial 2 are presented in Figure 6. The range between minimum and maximum temperatures was influenced by tributaries and groundwater, as well as flow from Carpenter Reservoir. Water temperatures fluctuated less seasonally, and showed overall muted diurnal variation in Reach 4 (Figure 6). Reach 3 also showed muted variation compared to Pre-Trial conditions (Appendix A.17). Reach 3 has a wider range of daily temperature fluctuations than Reach 2 (Figure 6) during Trial 2; although this was not the case in Trial 1. This is potentially because Reach 3 and Reach 2 have different volume to surface area ratio, resulting in Reach 3 potentially being more susceptible to influences from ambient air (Sneep, personal communication, 2014). In addition, near site 36.5 several groundwater seeps and springs have a warming influence on the water temperature at this site. This was evident in Pre-Trial data (Appendix A.17). The diurnal temperature variation shows that the minimum and maximum temperatures are negatively influenced by the hypolimnetic flow in both Reaches 3 and 4. For example, on September 11, the minimum temperature in Reach 3 was 10.6°C during Trial 2; 7.9°C during Pre-Trial (Appendix A.17); and 11.3°C during Trial 1 (Appendix A.18). During the early egg incubation period in Reach 3 both the minimum and maximum temperatures remain consistently elevated as compared to Reach 2 and Pre-Trial conditions. When comparing differences between the minimum and maximum temperature differences, the minimum temperature appears to be more different than the maximum temperature, however it is a combination of both on each end of the temperature spectrum that is causing the temperature pollution in the river. Consequently, the hypolimnetic flow has a strong influence on the daily temperature variation in both Reaches 3 and 4 and an overall negative effect on the physical environment and habitat quality in the LBR.

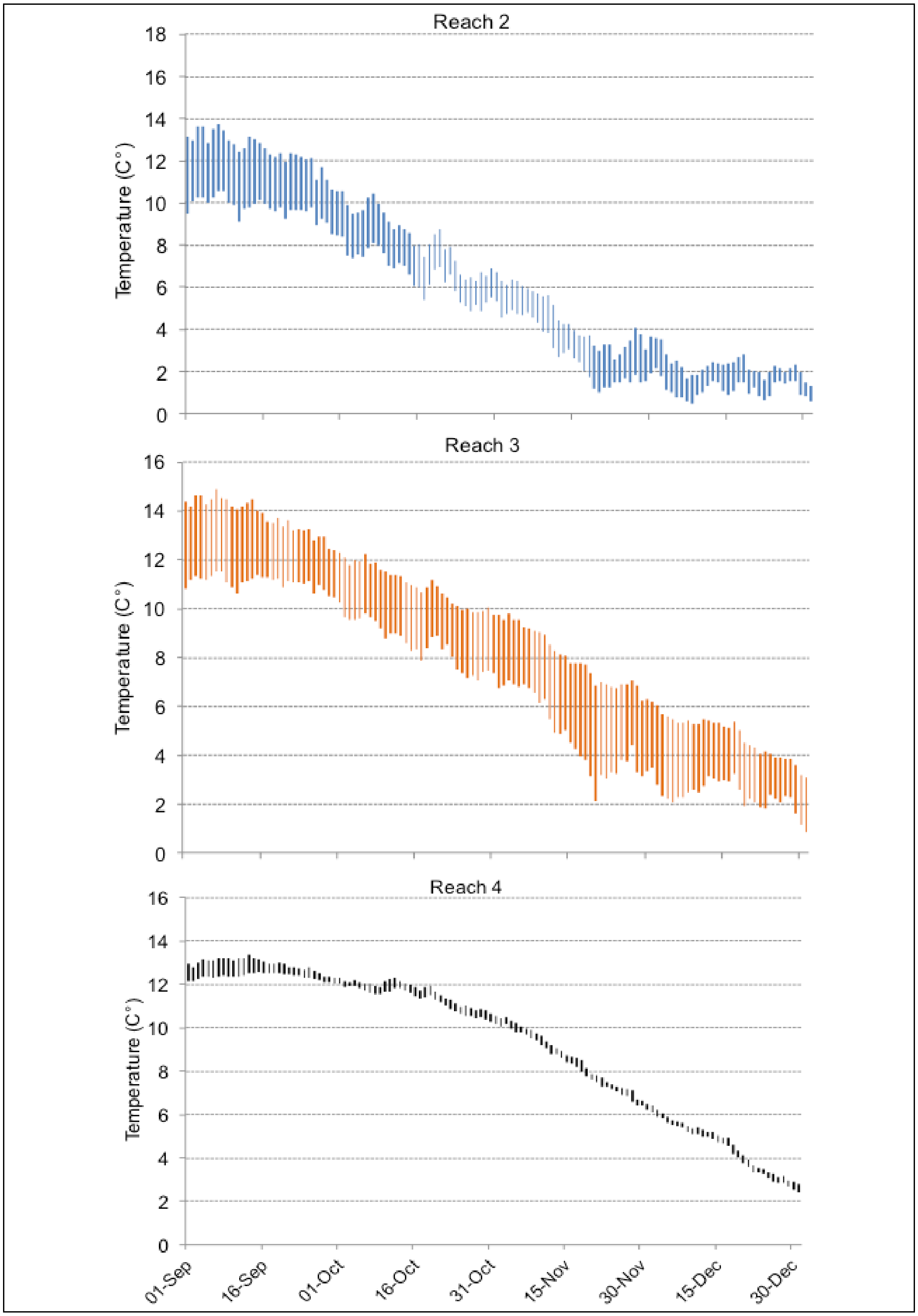


Figure 6. Mean minimum and maximum daily water temperatures (C°) between 1 Sep. – 31 Dec. during Trial 2 for Reaches 2, 3, and 4.

4.1.2.3 Water Temperature Trial Comparison

Annual mean daily temperature trends during Pre-Trial (i.e., 1996-2000) Trials 1 (i.e., 2000-2010) and 2 (i.e., 2011-2014) are presented in Figure 7. Appendix A.1 depicts the winter, spring and fall periods; Appendix A.2 presents summer temperature; A.3 presents Yalakom River annual temperatures. In both Trials, fall temperatures were distinctly warmer, and spring and summer temperatures were consistently cooler than observed in the Pre-Trial flow data. These effects were strongest in the upper reaches (i.e., Reaches 3 and 4) and weakest in Reach 2 due to the influence of moderating Yalakom River inflows, groundwater and the differing channel morphology.

In early October Trial 2's flow release drops to a low of 1.5 m^3s^{-1}, compared to a low flow in Trial 1 of approximately 2 m^3s^{-1}. The 6 m^3s^{-1}hydrograph needed to strike a balance between meeting the annual water budget, without further exacerbating the temperature effect on Chinook incubation timing and emergence, which had been observed under the 3 m^3s-1 hydrograph. In Reach 3, the temperatures in 2014 and the other Trial 2 years appear to be slightly lower than average temperatures in Trial 1 through the fall period. Consequently, a cooling effect of water temperatures appears to have been achieved modestly in Reaches 2 and 3 (Figure 7; Appendix A.1) through the fall and winter. This is apparent in January and February data for Reach 2 (Figure 7). This was also apparent in other Trial 2 data (McHugh and Soverel 2014). While changes were observed and temperature decreased, the effects on the overall thermal regime in the upper reaches were minimal. Between Trials 1 and 2, flows in Reach 4 and most of Reach 3 are still dominated by the hypolimnetic release, and temperatures were therefore still elevated above the pre-flow background. These results were expected by the technical committee.

Figure 7 and Appendix A.4 depicts winter and early spring temperatures. It appears that Pre-Trial temperatures rose much earlier in the spring than water temperatures in Trials 1 and 2. In addition, late summer temperatures under Trial 2 appear to be cooler than both Trial 1 and Pre-Trial data in Reaches 3 and 4 (Figure 7). These trends continue within 2014 data. Slightly cooler spring and summer temperatures are generally part of typical altered thermal regimes under large dams across North America.

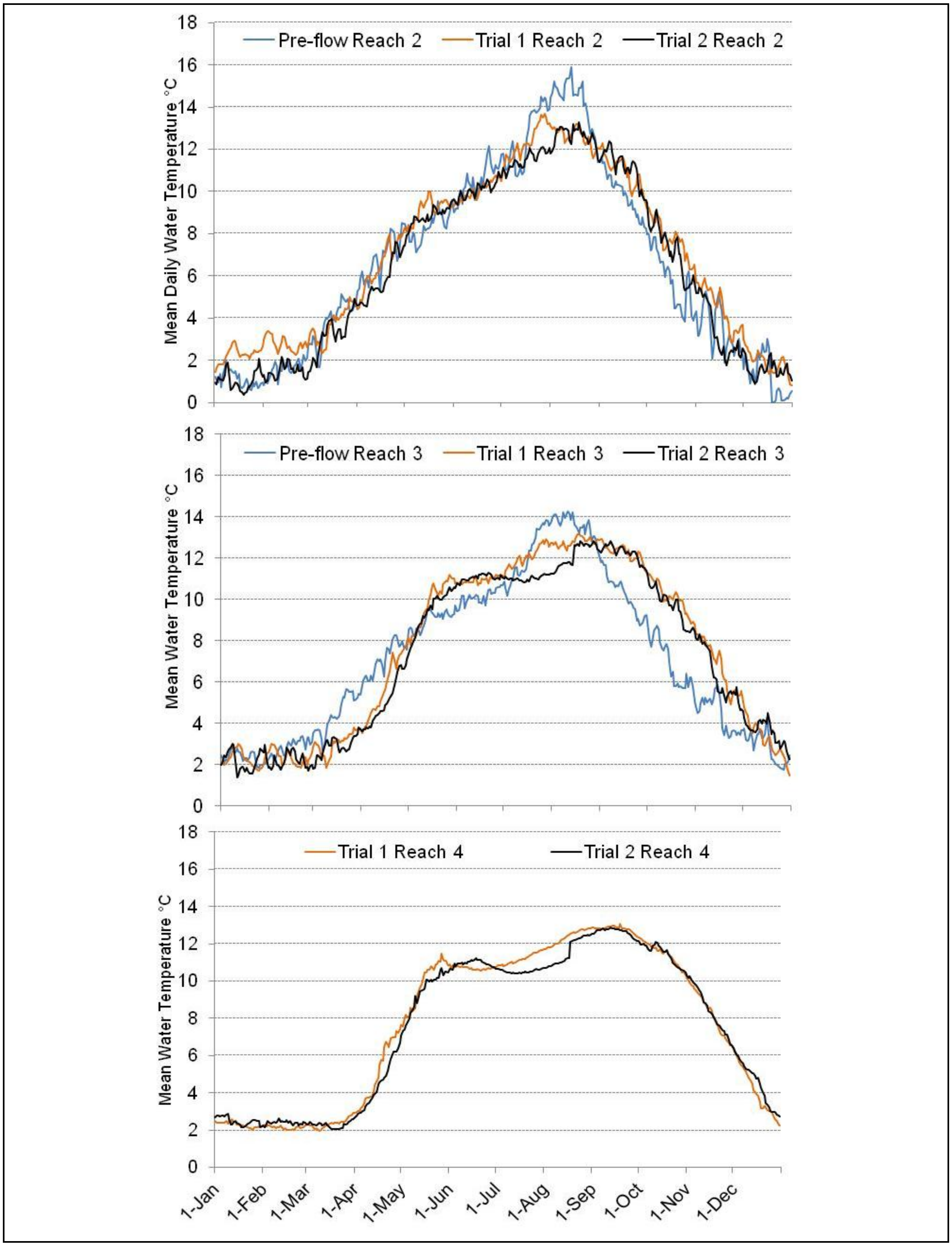


Figure 7. Comparisons of daily mean temperatures for the Pre-flow, Trial 1, and Trial 2 flow treatment, 1 January – 31 December.

4.1.3 *Water Chemistry*

Water chemistry samples were collected from the LBR, Carpenter Reservoir, and tributaries within the study area during October and November 2014. The water chemistry parameters observed in 2014 (i.e., alkalinity levels, concentrations of nitrates and nitrites, and pH) were similar to those reported in previous non-pink salmon spawning years. All levels of parameters measured were within the normal range for freshwater streams in British Columbia. The Lower Bridge River is an alkaline environment. The levels of pH in the main stem remained in the optimal category for most organisms and ranged from 7.67 to 8.13 (see Appendix A). Tributary levels ranged from 8.07 to 8.35, with Carpenter Reservoir measuring 7.82 to 7.84. Alkalinity appears to have dropped from 2012 (i.e., last non-pink spawning year) levels, but water remains very hard. Concentrations of nitrates and phosphate levels are within drinking water standards and have remained relatively stable since the Flow Trials began. As such, these differences cannot be easily distinguished from natural variations between years using descriptive graphical comparison.

4.1.4 *Habitat Attributes*

Results of habitat monitoring are broken down into two sections: Section 4.1.4.1 details 2014 results and Section 4.1.4.2, outlines habitat area within each flow step within the Flow Trial experiment. Data below demonstrate that during higher flows, the amount of quality rearing habitat for juvenile salmon does not increase significantly.

4.1.4.1 2014 Habitat Survey Results

The habitat area presented within this section were derived from GIS-based spatial representations of the river that were field verified and quality controlled. The low flow survey provided a replicate of the 2013 1.5 m^3s^{-1} habitat survey, while this was the first time a survey was conducted during the 15 m^3s^{-1} flow. Various attributes were measured in the field; however, the data summary portrays the information related only to the area, i.e., length and width of aquatic riverine habitat attributes across the Flow Trials. Additional attributes are depicted in the geodatabase products.

Figures 8 – 10 depict both spatial habitat mapping results, the total area values for each habitat class, and the proportion of each habitat class within a Reach. Figure 8 represents Reach 4; Figure 9 represents Reach 3; and Figure 10 showcases Reach 2. The maps depict an example (i.e., only one section of the river) of the spatial habitat data for 2014 at the same location in the LBR. The top left map represents the 15 m^3s^{-1} flow and the bottom left map represents the 1.5 m^3s^{-1} flow. The pie and bar charts (A) and (B) depict the areas values during the 15 m^3s^{-1} flow, while (C) and (D) present the area values within the 1.5 m^3s^{-1} flow within a Reach. The pie charts (A) represent the proportion of each habitat class in that Reach. The bar charts (B) represent the absolute values (100 m^2) of each habitat class within the Reach.

The 1.5 m^3s^{-1} flow provided a total wetted area of 4,893 (100m^2), while the 15 m^3s^{-1} flow had a wetted area of 5,414 (100m^2). Total area values for 2014 data are included in Table 4 (Section 4.1.4.2).

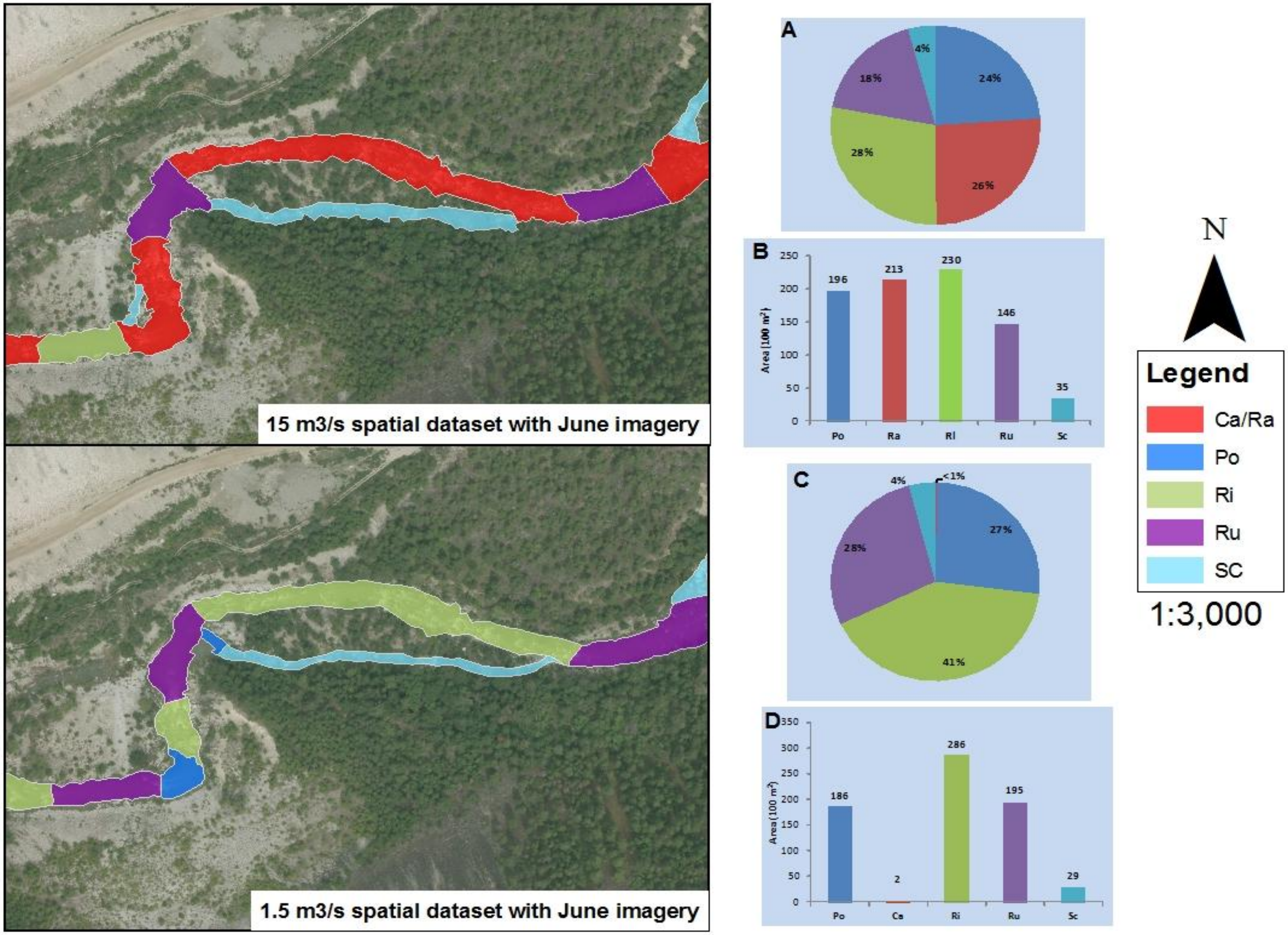


Figure 8. (A) Pie chart represents the proportion of each habitat class across Reach 4 and 15 m^3/s flow; (B) Represents the absolute values (100 m^2) of each habitat class within Reach 4 and 15 m^3/s flow; C) Pie chart represents the proportion of each habitat class of Reach 4 during the 1.5 m^3/s flow; and (D) Represents the absolute values (100 m^2) of each habitat class within Reach 4 and 1.5 m^3/s flow.

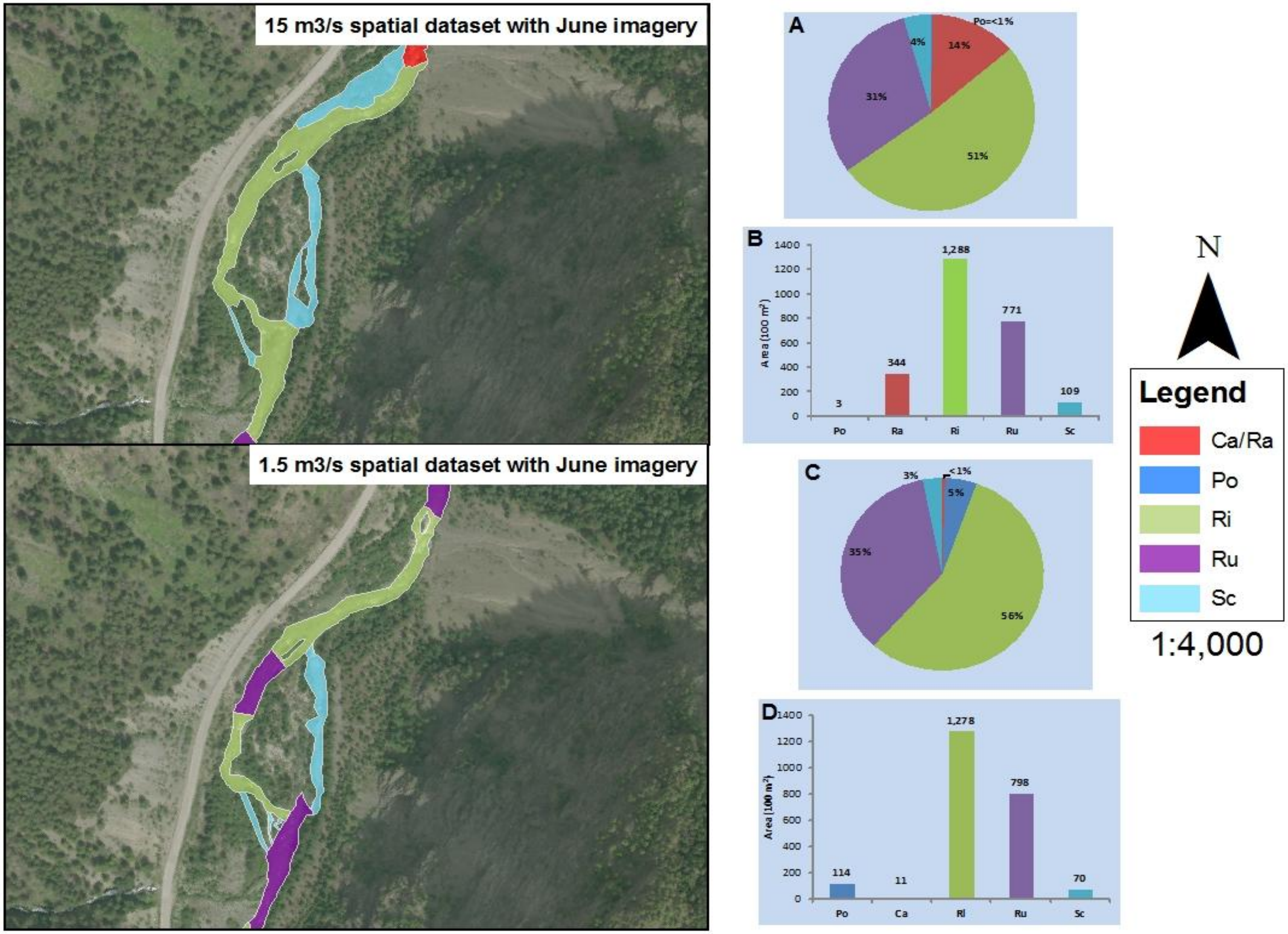


Figure 9. (A) Pie chart represents the proportion of each habitat class across the entirety of Reach 3 and 15 m^3/s flow; (B) Represents the absolute values (100 m^2) of each habitat class within the entirety of Reach 3 and 15 m^3/s flow; C) Pie chart represents the proportion of each habitat class across the entirety of Reach 3 and 1.5 m^3/s flow; and (D) represents the absolute values (100 m^2) of each habitat class within the entirety of Reach 3 and 1.5 m^3/s flow.

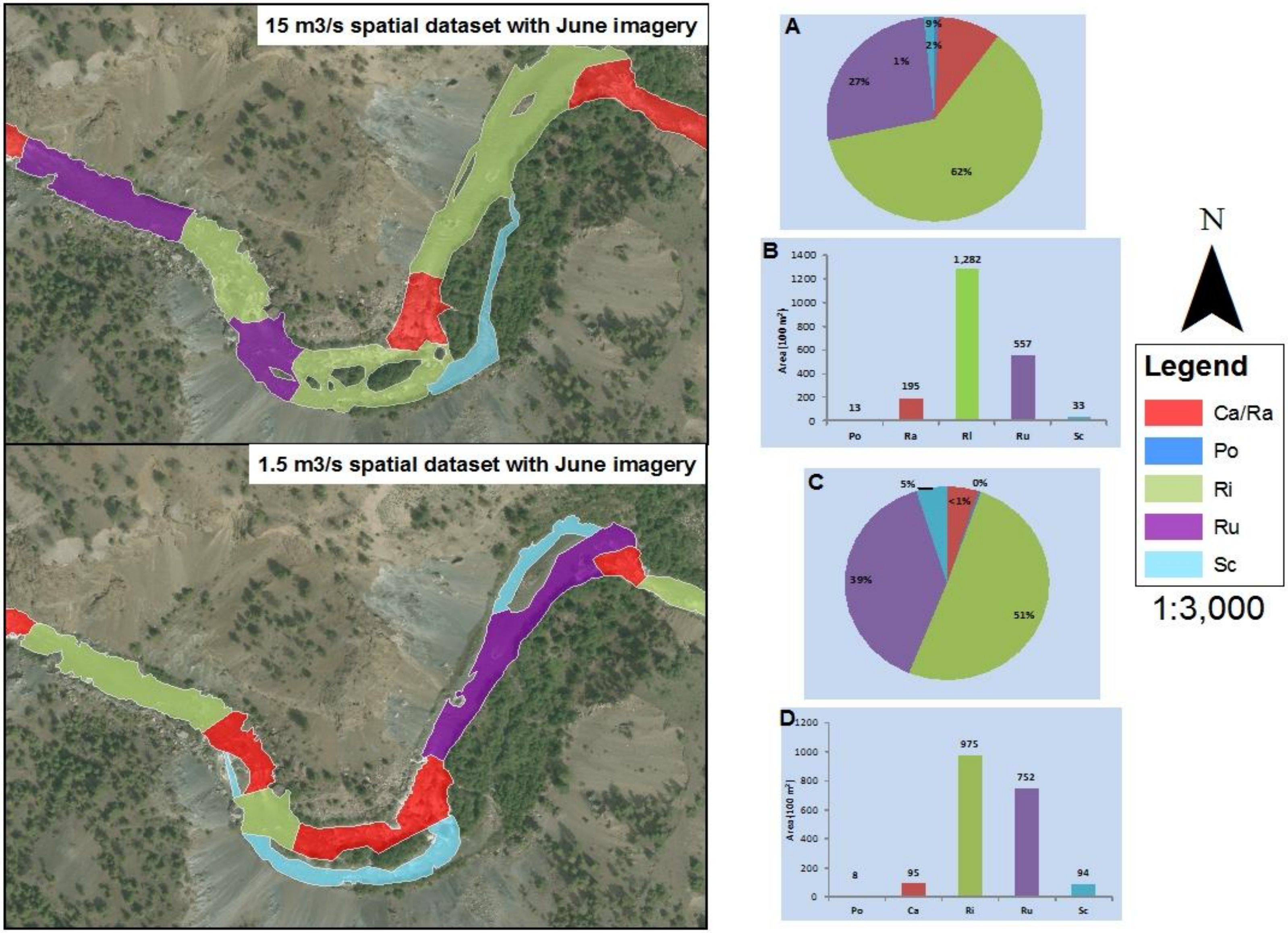


Figure 10. (A) Pie chart represents the proportion of each habitat class across the entirety of Reach 2 and 15 m^3/s flow; (B) Represents the absolute values (100 m^2) of each habitat class within the entirety of Reach 2 and 15 m^3/s flow; C) Pie chart represents the proportion of each habitat class across the entirety of Reach 2 and 1.5 m^3/s flow; and (D) represents the absolute values (100 m^2) of each habitat class within the entirety of Reach 2 and 1.5 m^3/s flow.

4.1.4.2 Habitat Area Across the Flow Levels

Total area of each habitat type (i.e., riffle, run, pool, side-channel, cascade, etc.) and the relative proportions of habitat types in each flow step from 1996 to 2014 are presented below in Table 4 and Figure 11. Table 4 lists the total area of each habitat type measured during each flow level within Reaches 4, 3 and 2. For the 0 m^3s^{-1} and 1.5 m^3s^{-1} a replicate was conducted. Due to the natural dynamics of river systems and observer bias, area calculations differ slightly between replicates.

Table 4. Total area (100 m^{2}) of each habitat type measured during each flow treatment between 1996 and 2014.

		Sep-96	Jul-00	Oct-13	Oct-14	Oct-06	Aug-00	Jun-07	Jul-07	Jul-14
Reach	**Habitat Type**	**0 cms**	**0 cms**	**1.5 cms**	**1.5 cms***	**3 cms**	**4 cms**	**5 cms**	**8 cms**	**15 cms***
4	Run	-	-	140	195	149	145	83	141	146
	Riffle	-	-	247	286	310	489	363	346	230
	Pool	-	-	190	186	223	120	222	260	196
	Ca/Rapid	-	-	-	2	-	-	55	61	213
	SC	-	-	41	29	37	37	55	72	35
Reach 4 Subtotal		-	-	618	697	718	792	778	880	821
3	Run	618	581	630	798	543	818	730	838	771
	Riffle	1,004	1,211	1,296	1,278	1,569	1,186	1,449	1,297	1,288
	Pool	52	54	176	114	183	71	174	124	3
	Ca/Rapid	89	93	-	11	23	30	442	482	344
	SC	-	-	39	70	2	2	45	48	109
Reach 3 Subtotal		1,763	1,939	2,141	2,272	2,319	2,107	2,839	2,741	2,514
2	Run	541	208	-	752	605	555	580	-	557
	Riffle	1,093	1,581	-	975	917	1,288	591	-	1,282
	Pool	18	18	-	8	12	6	15	-	13
	Ca/Rapid	87	105	-	95	254	76	901	-	195
	SC	71	71	-	94	87	87	124	-	33
Reach 2 Subtotal		1,809	1,983	-	1,924	1,876	2,013	2,211	-	2,079

**Habitat results were derived from spatial habitat mapping techniques.*

In general, the 5 m^3s^{-1}, 8 m^3s^{-1}, and 15 m^3s^{-1} flows provided the highest amount of wetted area in the river, while at the same time providing the least amount of relative suitable juvenile rearing habitat across the reaches. During higher flows, much of the pool, riffle and run habitat was replaced by cascades and rapids. Pool habitat was reduced to very little area in Reaches 2 and 3. Additionally, a large portion of the riffle habitat in Reach 4 was replaced by cascades and rapids. Although quality habitat area displacement was different, patterns are similar during the three highest flows, demonstrating that higher flow did not provide more quality habitat for juvenile salmon. Side channel habitat is minimal across the reaches in all flow levels. Riffle and run habitat types were quite variable depending on Reach comparison. While variable, run habitat appears to be similar across the flow levels in Reaches 3 and 4. Overall riffle habitat appears to be similar across the low to mid flow-level ranges, with less overall area evident at higher flows. Reach 2 contained very little pool habitat, while Reach 4 contained the most, regardless of flow. Figure 11 shows relative proportions of habitat types in each flow treatment in Reaches 2, 3 and 4 from 1996 to 2014. Proportionally, the 1.5 m^3s^{-1} flow provided similar quality habitat across the reaches as the 3 m^3s^{-1} flow. Total area suggests that these two flows also contained a similar amount of rearing habitat for juvenile salmon. Total area is presented in graphical form in Appendix A.6.

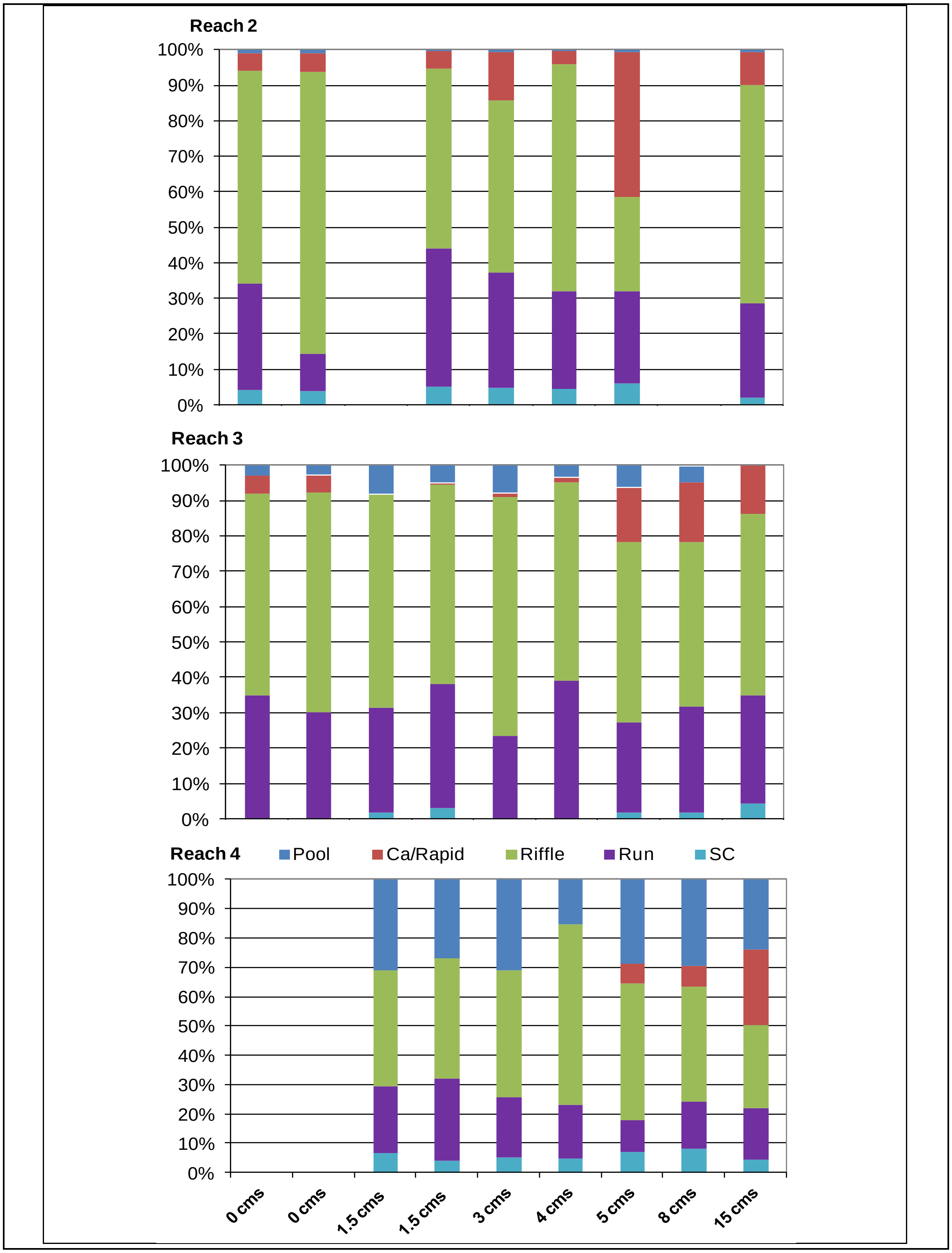


Figure 11. Proportional area of each habitat measured during each flow level (x-axis) within Reaches 2, 3 and 4.

4.2 Periphyton and Macroinvertebrates

4.2.1 *2014 Periphyton Results*

Periphyton accrual rates (measured as cumulative concentration of Chlorophyll-a) are shown throughout the 2014 sampling period (Figure 13). Reaches 2 and 3 showed relatively similar accrual patterns over the field series. Mean chlorphyll-a levels in Reach 3 increased in week 4 (i.e., 26 October 2014), followed by a slight decline, and then a steady increase throughout the rest of the series (Figure 12). Reach 2 followed a comparable curve. Reach 4 slowly increased across the field series with a sharp rise during the last week. 2014 periphyton taxonomy results are included in Appendix A.7 (Mean Biovolume) and Appendix A.8 (Mean Cell Count). Total mean periphyton biovolume was highest in Reach 4, while total mean periphyton cell counts were observed to be highest in Reach 3 (Appendix A.8). At the site level, an apparent spike in Melosira sp. may have contributed to higher periphyton biovolume at index sites 36.5 and 39.9.

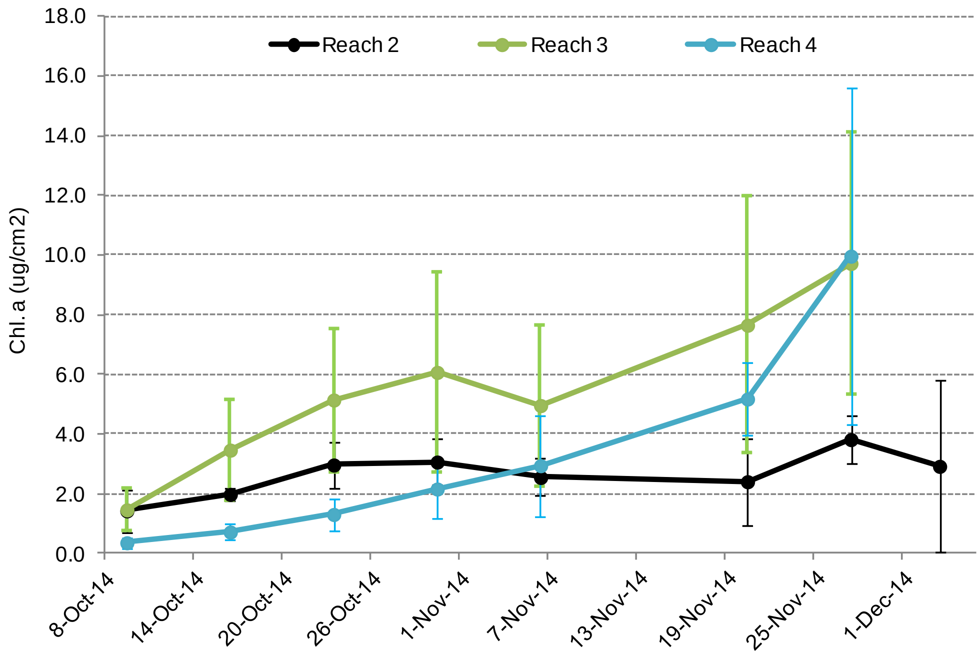


Figure 12. Mean periphyton accrual (measured as Chlorophyll-a) on artificial substrates in the LBR, during the fall series sampling in 2014. Each point represents an average accrual for all stations within a reach; error bars represent (+/-) standard deviation.

4.2.2 *Periphyton Trial Comparison*

Appendix A.19 – Appendix A.23 depict accrual rates during Trial 1 and Trial 2[6]. Graphs are broken into pink and non-pink spawning years, as pink salmon spawn in alternate years in the LBR. Across both trials, trends appeared similar. Trends were driven by the deposition and accumulation of nutrients during pink salmon spawning years. In even (i.e., non-pink) years, like 2014, Reach 4 rates are generally higher than Reach 2 (Figure 12); in odd (i.e., pink) years the opposite is true where Reaches 2 had higher accumulation than Reach 4 (Sneep and Hall 2012;

[6] Data from Pre-Trial years were not compiled in a way to facilitate comparisons in this annual report.

McHugh and Soverel 2014). Trends were observed across Trial 1 and now observed through Trial 2. However, trends between sites in each reach, and even between replicates within sites, were quite variable and standard deviations were very high. Interpretation of the periphyton data based on a more robust analyses will be incorporated into the synthesis report currently being prepared by the technical synthesis team. Results will be presented at the end of 2015.

4.2.3 *Macroinvertebrates*

Abundance and diversity were the primary metrics used to measure benthic invertebrate health within the LBR over the last 20 years. Mean abundance per taxa and mean observed macroinvertebrate diversity (i.e., number of families within taxa) at index site locations are included as Figures in Appendix A.9 – A.12. Figure 13 (below) presents a location and Trial analysis between abundance and diversity across Trial 1 and Trial 2, and is inclusive of the 2011 and 2014 analyses conducted this year.

An analysis of temporal and spatial patterns of benthic invertebrate abundance and diversity in the LBR during the fall in years 2008 – 2014 was conducted by Stamford Environmental (Stamford and Vidmanic 2015) and delivered in the annual report package. The macroinvertebrate dataset spans three years in Trial 1 (2008 – 2010) and four years in Trial 2 (2011 – 2014). Figure 13 (taken from Stamford and Vidmanic, 2015) shows mean abundance and taxonomic richness (i.e., EPT richness) between Trials 1 and 2 and location (upstream or downstream of the Yalakom River) in the LBR. The EPT Index was calculated based on the number of species within the EPT taxa (i.e., Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) that were present within the samples. The index is generally based on the premise that high-quality streams usually have the greatest species richness, or that higher water quality will have a higher EPT richness.

Both Trials followed similar trends among index site locations: sites with higher abundance and diversity among samples occurred downstream of site 33.3. Both abundance and diversity of EPT taxa were observed to be significantly higher in Trial 2 ($p<0.025$) as compared to Trial 1 (Stamford and Vidmanic, 2015). However, several taxa decreased and two genera within Tipulidea and riffle beetles were absent in Trial 2. This may signify a loss of lower velocity water sections. Species within these genera are adapted to slower depositional habitats, potentially suggesting that the increase in flow during Trial 2 was a disturbance to components of benthic invertebrate communities that prefer slower moving water. The proportional abundances of mayflies, stoneflies, and caddisflies (EPT taxa) were lower in Reach 2 relative to Reaches 3 and 4. However, abundance and taxonomic richness within the EPT were significantly higher in downstream sites during both trials. Therefore, it seems that the increased abundances of, in particular Chironomidae and Clitellata taxa, did not displace or exclude the EPT taxa.

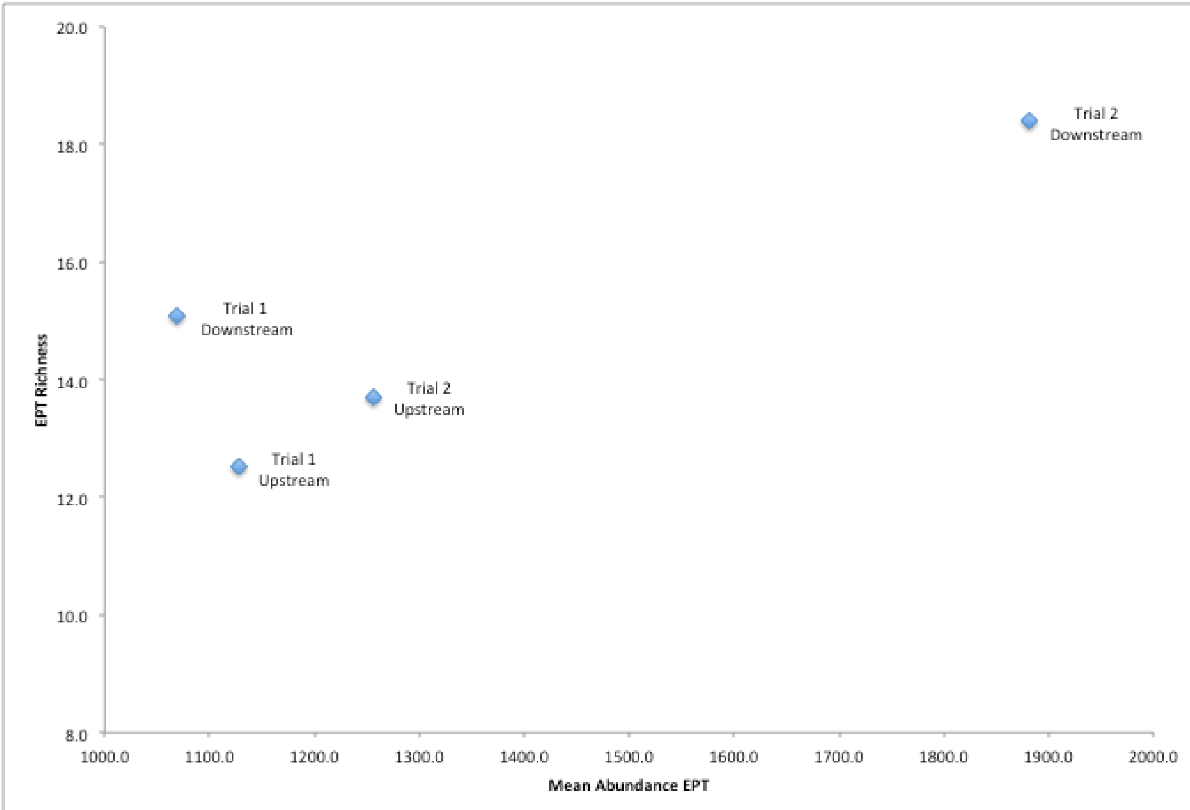


Figure 13. Mean abundance and taxonomic biodiversity within the EPT (Ephemeroptera, Plecoptera, Trichoptera Taxa) (EPT biodiversity) between trials and location (upstream and downstream) in the LBR between 2008 and 2014 (figure taken from Stamford and Vidmanic, 2015).

4.3 Fish Sampling for Abundance and Growth Assessments

A total of 4,495 fish were sampled during backpack electrofishing during the annual fall standing stock assessment (Reach 2, *n*=1074; Reach 3, *n*=2156; Reach 4, *n*=1266), which was conducted between 2 to 24 September 2014. 49 sites were sampled using a stratified sampling design including 17 in Reach 2, 20 in Reach 3, and 12 in Reach 4. During juvenile growth sessions, which occurred in May, June, and August, a total of 2,278 fish were caught during the sessions (Reach 2, *n*=625; Reach 3, *n*=1354; Reach 4, *n*=299). Freshet conditions in the Yalakom River prevented sampling in Reach 2 in May. Water temperatures were less than 5° C throughout the study area during the scheduled November fish growth sampling session prohibited fish sampling, and consequently late fall and winter juvenile growth data was not collected.

4.3.1 *Seasonal Fish Size Index (Fish Growth)*

During 2014, a total of 6,773 [a] fish were measured in all growth sessions. Rainbow trout made up most of the samples, *n*=3,936; Coho *n*=2,027; Chinook *n*=553. A total of 553 Chinook were caught and measured in total across 2014(Reach 2, *n*=280; Reach 3, *n*=261; Reach 4, *n*=12). Chinook capture peaked with a total of 253 during June sampling, and dropped to 91 in August. Eight Age-1 Chinook were caught during May. No Chinook alevins were observed during the late fall and winter. This could be primarily due to winter conditions preventing fish sampling starting in November. 2,027 Coho were caught in 2014 (Reach 2, *n*=406; Reach 3, *n*=1070; Reach 4, *n*=551). Numbers were steady across the sessions. Numbers of Rainbow trout steadily grew across the year as summer juveniles emerged and were sampled (Reach 2, *n*=999; Reach 3, *n*=2,115; Reach 4, *n*=822). Mean weights, standard deviation and total count, per species and age-class, by Reach, are presented in Table 5.

Table 5. Mean fish weight (g), sample size and standard deviation for each species, age-class of salmonids and for all Reaches captured in the Lower Bridge River for growth information, May to September, 2014. The yellow cells indicate those species/age classes that were insufficient in achieving their target sampling size minimum threshold within each Reach.

Species & Age Class	Sampling Month	Reach 2			Reach 3			Reach 4		
		Mean	n	SD	Mean	n	SD	Mean	n	SD
CH - 0+	May	-	-	-	1.3	100	0.4	1.1	5	0.8
CH - 0+	June	1.6	182	0.9	2.6	71	0.9	-	-	-
CH - 0+	August	5.3	58	2.1	6.3	31	1.5	9.8	2	3.1
CH - 0+	September[a]	7.1	40	2.3	7.0	52	1.5	6.8	4	0.5
CH - 1	May	-	-	-	11.8	7	2.4	13.1	1	-
CH - 1	June	-	-	-	-	-	-	-	-	-
CH - 1	August	-	-	-	-	-	-	-	-	-
CH - 1	September[a]	-	-	-	-	-	-	-	-	-
CO - 0+	May	-	-	-	0.4	170	0.2	0.3	61	0.1
CO - 0+	June	0.7	90	0.3	0.8	123	0.4	0.7	45	0.3
CO - 0+	August	2.6	110	1.4	2.7	177	1.2	3.1	52	1.3
CO - 0+	September[a]	3.1	206	1.2	3.0	597	1.1	3.5	385	1.6
CO - 1	May	-	-	-	11.1	2	6.6	11.6	8	2.7
CO - 1	June	-	-	-	-	-	-	-	-	-
CO - 1	August	-	-	-	9.3	1	-	-	-	-
CO - 1	September[a]	-	-	-	-	-	-	-	-	-
RB - 0+	May	-	-	-	5.4	176	2.8	6.5	30	3.6
RB - 0+	June	9.6	64	4.3	8.3	214	4.2	9.4	21	3.7
RB - 0+	August	0.8	87	0.5	0.7	125	0.4	1.2	42	0.7
RB - 0+	September[a]	1.9	805	0.9	1.7	1013	0.8	1.8	484	1.0
RB - 1	May	-			20.6	9	10.1	20.7	3	4.8
RB - 1	June	39.3	5	10.5	31.7	4	6.2	30.8	4	8.4
RB - 1	August	18.0	23	7.3	14.2	138	6.4	22.4	23	9.7
RB - 1	September[a]	15.9	14	5.9	14.4	423	6.7	14.0	201	6.4
RB - 2	May	-	-	-	53.0	1	-	-	-	-
RB - 2	June	-	-	-	-	-	-	-	-	-
RB - 2	August	-	-	-	-	-	-	60.9	1	-
RB - 2	September[a]	-	-	-	51.1	9	16.1	49.3	12	6.0
RB - 3	May	-	-	-	123.3	1	-	-	-	-
RB - 3	June	-	-	-	-	-	-	-	-	-
RB - 3	August	-	-	-	-	-	-	-	-	-
RB - 3	September[a]	-	-	-	-	-	-	-	-	-

[a] Growth data for September were derived from fish sampled during the annual stock assessment.

[b] Dash mark in cells indicate where no fish within this species-age-class were observed or no sampling was conducted.

(-) indicates that either no sampling was conducted or no fish were caught within that species and age-class.

Age -1 Coho and Age-1 Chinook were not caught in great numbers within this Monitoring project during any fish sampling as they typically migrate out of the LBR in early spring. Cells highlighted in yellow demonstrate where the target number of fish per species and age-class (i.e., *n*=30 per site) were not captured within that Reach. Greater than 50% of the sampling conducted in 2014 did not meet the target number of fish captured per site. The potential causal agents for not achieving sample targets may include: 1) it was difficult to wade in the river and catch fish during flows higher than ~8 m^3s^{-1}. Following spring ramp up, high flows made effective sampling difficult from April – July; 2) fish have been potentially displaced out of their normal habitat (Sneep and Hall 2012, McHugh and Soverel 2014); and 3) fish numbers, particularly in Reach 4 have declined. In addition to not achieving sampling thresholds; it is illegal to conduct electrofishing under 5° C and this reduced the number of growth sampling sessions in 2014 and across Trial 2. Temperatures in 2014 were lower than the legal limit from January through mid-April, and during November and December. These challenges, in addition to the variability within the data, confounded interpretation from growth data from 2014 and across the Trials. Keeping these data limitations in mind, Appendix A.13 presents 2014 Fish Growth (g/day) and Appendix A.14 presents a comparison of the average weight (g) of each species/ age-class per Reach between Trial 1 and Trial 2. Appendix A.15 contains a compiled table of the min and max lengths of all years of fish growth monitoring for Trial 2. The synthesis assessment is in the process of conducting a rigorous fish growth analysis (which will take into consideration the limitations discussed above) across the Flow Trials and will present this information to decision makers in late 2015.

4.3.2 *Standing Stock Assessment*

Standing stock assessment data are broken up into three sections: Section 4.3.2.1 presents 2014 data; Section 4.3.2.2 presents a Trial 2 summary; and 4.3.2.3 shows a comparison across Pre-Trial, Trial 1 and Trial 2 estimates.

4.3.2.1 2014 Standing Stock Assessment Results

Standing stock assessment data were used to calculate mean estimated biomass by species and Age-class and by Reach. Since the same sites are sampled each year, these values represent a reasonable index of biomass that can be compared between years. Estimated mean biomass of Chinook, Coho and Rainbow by age-class in 2014 are presented in Table 6. Mean biomass and total count data were both highest in Reach 3 during 2014. For the past 12 consecutive years, Reach 4 had the highest biomass estimates in the LBR. For the first time since Trial 1 began, Reach 4 total biomass estimates (for 2014) dropped below levels in Reach 3. Reach 4 data suggest a decline in fish productivity. Reach 3 had a higher 2014 biomass estimate than Reach 2, but was lower than biomass estimates observed under Pre-Trial conditions. All of the target species (i.e., Chinook, Coho, and Rainbow) were represented in each reach; however not all age-classes were represented per reach. Age-1 Coho and Chinook were not captured as they typically migrate out of the system prior to the fall sampling. Age-2 Rainbow were not captured in Reach 2. Less than 100 juvenile Chinook were caught in total in 2014 andv only 4 were captured in Reach 4. Comparison of 2014 stock assessment results with previous years are included in Sections 4.3.2.2 and 4.3.2.3. Detailed information regarding standing stock assessments prior to 2011 can be found in Sneep and Hall (2012).

Table 6. Estimated mean biomass (g/100 m^2) of salmonids captured in the Lower Bridge River during the standing stock assessment, September, 2014.

Species-Age Class	Reach 2	Reach 3	Reach 4
CH - 0+	23	21	3
CH - 1	0	0	0
CO - 0+	41	99	122
CO - 1	0	0	0
RB - 0+	112	96	78
RB - 1	16	378	262
RB - 2	0	28	55
RB - 3	0	0	0
Total	**192**	**621**	**520**

Figures 14 and 15 present 2014 standing stock information spatially. The labels indicate standing stock site number. Biomass and species representations are geographically site specific. The circle size indicates total mean biomass per stock assessment site. Pie chart proportions represent total mean biomass/species. Figure 14 depicts Reach 4 and Figure 15 shows Reach 3 (left) and Reach 2 (right)[7]. Reach 4 data show that biomass increases as distance from the dam increases (Figure 15). Chinook is depicted in the colour orange, and was found at only a few sites. Reaches 2 and 3 and shown in Figure 16. Rainbow trout (inclusive of Steelhead) made up a total proportion of 77% of the total LBR biomass among all Reaches in 2014; Coho made up ~20%; Chinook made up ~3%. In general the father downstream sites had proportionally less Rainbow and more Chinook and Coho than upstream sites.

[7] The scales are different between Figures 14 and 15 simply for display purposes.

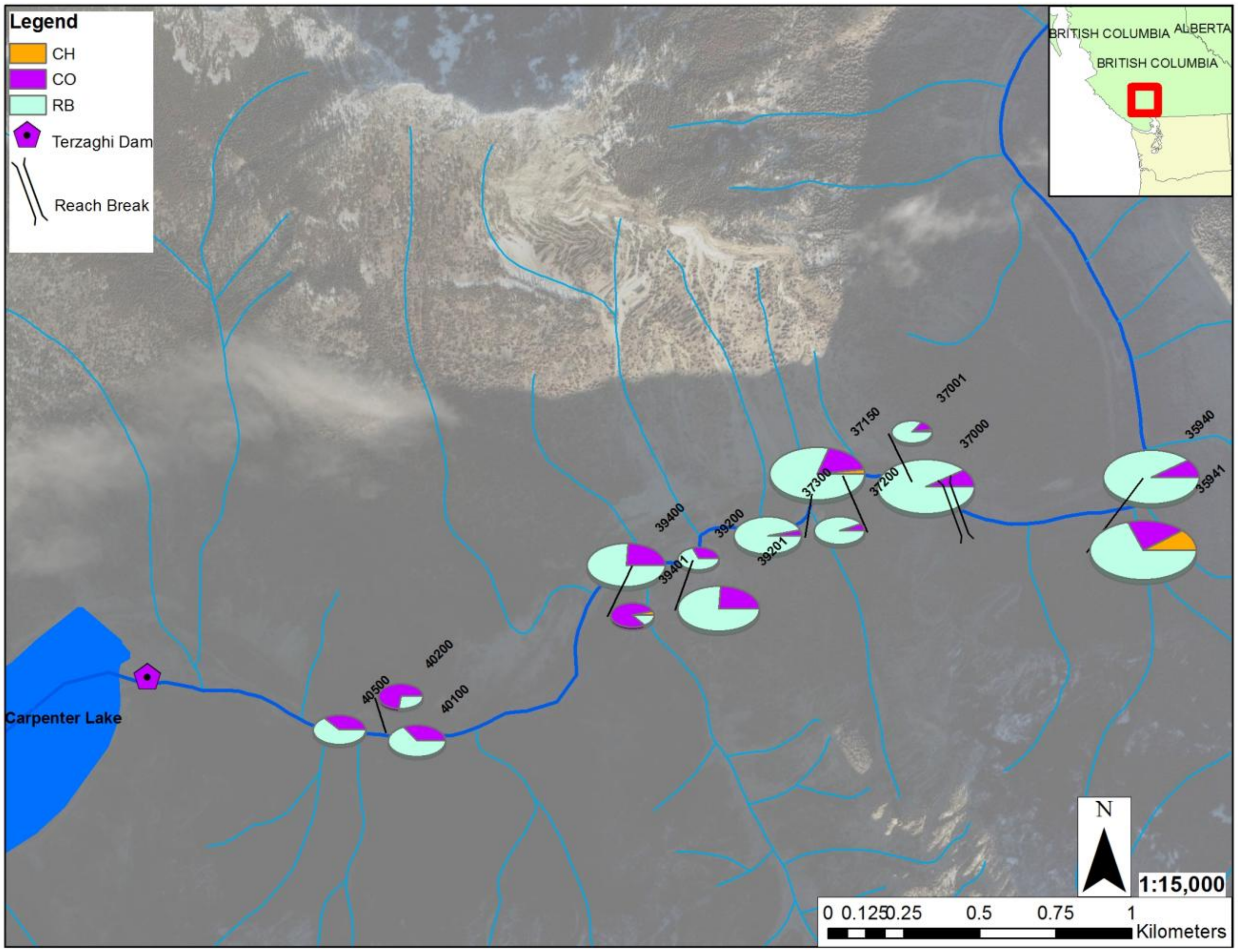


Figure 14. Map of total mean biomass for LBR's Reach 4. Each pie chart within the map is geographically located at each standing stock site as labeled. The size of each pie chart is representative of the total mean biomass in relation to the other pie charts (i.e. larger equates to larger total mean biomass). In addition, each pie chart depicts the proportion of each species represented at each standing stock site.

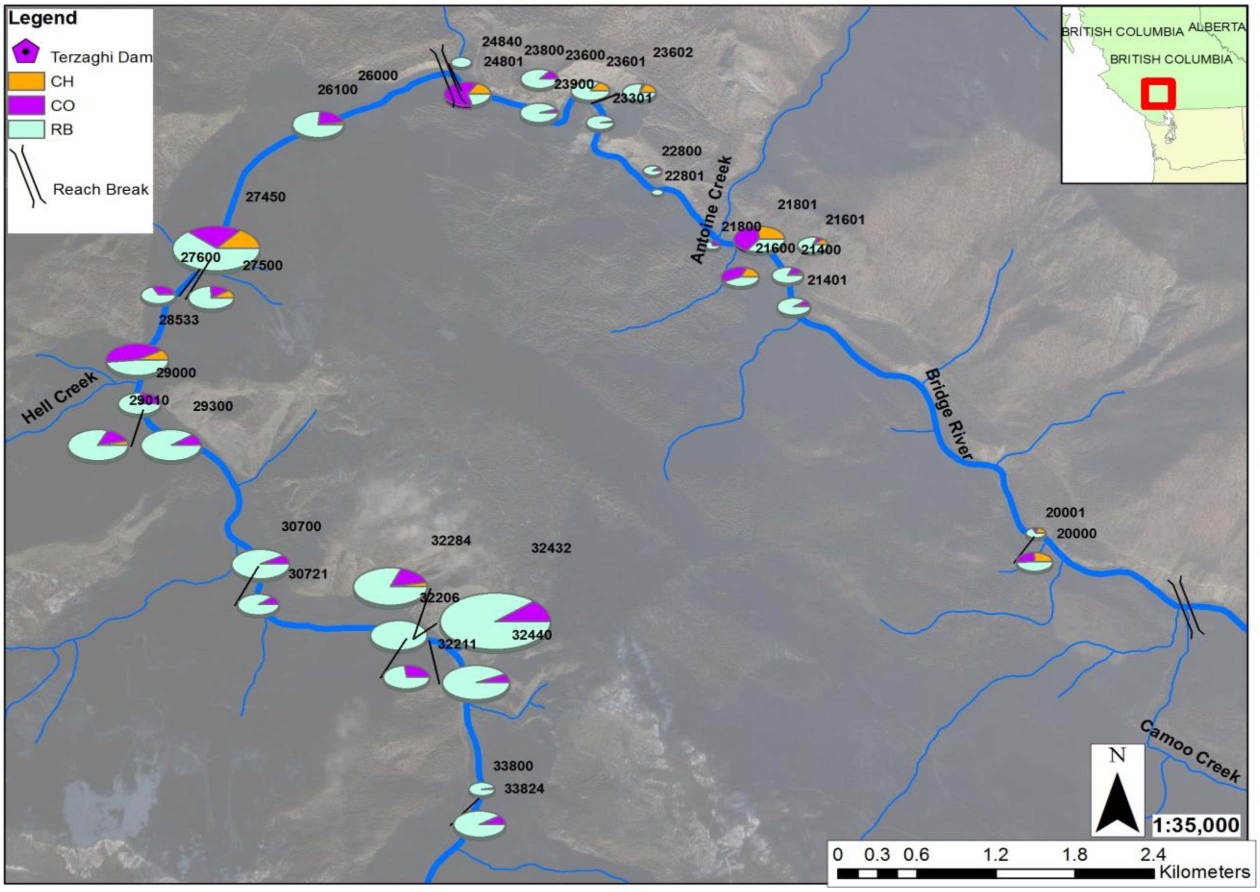


Figure 15. Map of total mean biomass for LBR's Reaches 3 and 2. Each pie chart within the map is geographically located at each standing stock site as labeled. The size of each pie chart is representative of the total mean biomass in relation to the other pie charts (i.e. larger equates to larger total mean biomass). In addition, each pie chart depicts the proportion of each species represented at each standing stock site.

4.3.2.2 Standing Stock Assessment Results Across Trial 2

Total biomass estimates (species combined) peaked for Trial 2 in 2011, and stayed at similar levels through 2014 (Table 7; Figure 16). In 2014, estimates of the total mean biomass within sample sites for all Reaches was 1,333 g/100m^2. The Trial 2 average biomass estimate was 1,331 g/100m^2. Mean annual biomass estimates in Reaches 2 appeared stable, while Reach 3 estimates appeared to increase in 2014 and Reach 4 estimates declined across Trial 2 (Figure 16; Tables 7, 8, and 9).

Table 7. Estimated mean biomass (g/100 m^2) of salmonids captured in the Lower Bridge River during the standing stock assessment through Flow Trial 2: 2011-2014.

Year	Reach 2	Reach 3	Reach 4	Total
2011	164	411	856	1,431
2012	139	402	808	1,349
2013	187	425	599	1,211
2014	192	621	520	1,333
Trial 2 Average	**171**	**465**	**696**	**1,331**

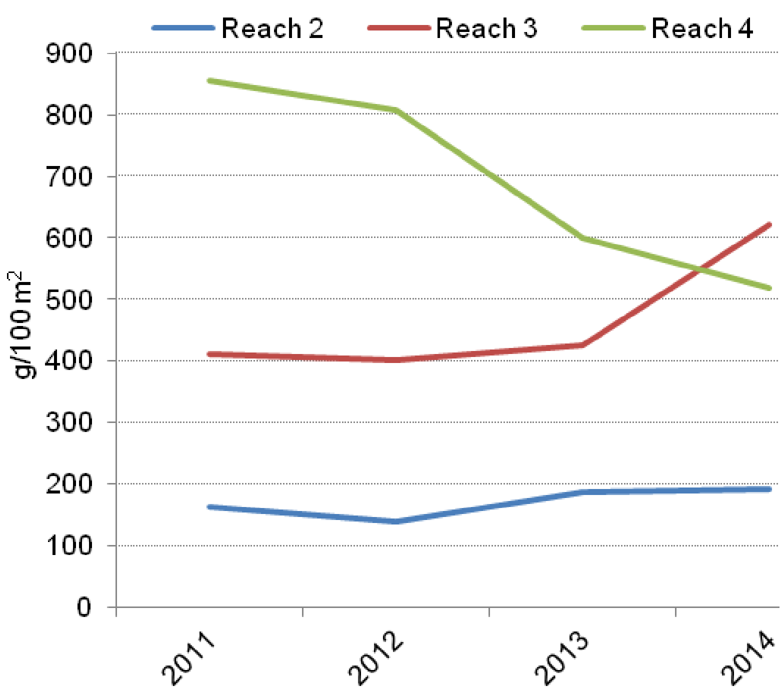


Figure 16. Standing stock mean annual biomass results (g/100 m^2) for years 2011-2014 in LBR Reaches 2, 3, and 4.

Table 8 depicts total fish count from the stock assessment through Trial 2: 2011 – 2014. Chinook numbers remain very low across Trial 2, particularly in Reach 4. Four Chinook were caught in Reach 4 during the stock assessment in 2014. This is the lowest Chinook catch since Trial 1 began. Total Chinook biomass across all reaches for 2014 was 47 g/100m^2. A similar total was estimated for 2012 and 2013. Biomass estimates for 2014 for juvenile Chinook, across all reaches, were 62% lower than total biomass estimates were in 2011. Coho numbers from 2011 - 2014 were variable, but appear to have declined in Reaches 3 and 4. In 2014 Coho biomass declined 60% from a 2011 peak, totaling 122 g/100m^2 for Reach 4. In Reach 3 Coho biomass declined 36% from a 2011 peak, totaling 99 g/100m^2. However, additional statistical analysis is required to test the significance, and this level of analysis is planned for the synthesis assessment, which is in progress. Rainbow numbers generally appeared to increase, with the exception of species-age-class Rainbow-0+ in Reach 4. Rainbow estimates continued to rise, particularly in Reach 3. Rainbows, mainly Age-0+ and Age-1, made up 77% of the total biomass in Reaches 2, 3 and 4 for 2014. This is higher than 2011, where they comprised 60% of the total. Table 9 summarizes mean biomass, by species and per reach, per year for Trial 2.

Table 8. Total fish count (catch) assessed from data taken from September Stock Assessments in years 2011, 2012, and 2014. Data are compiled for Reaches 2, 3, and 4.

Species Age-Class	Reach 2				Reach 3				Reach 4			
	2011	*2012*	*2013*	*2014*	*2011*	*2012*	*2013*	*2014*	*2011*	*2012*	*2013*	*2014*
CH - 0+	147	32	37	40	54	67	42	52	6	8	10	4
CH – 1+	-[a]	-[a]	1	-[a]	-[a]	-[a]	3	-[a]	-[a]	1	-[a]	-[a]
CO - 0+	165	141	100	206	975	619	345	597	753	347	159	385
CO – 1+	-[a]	-[a]	-[a]	-[a]	1	-[a]	3	-[a]	6	-[a]	1	-[a]
RB - 0+	470	318	814	805	946	537	1,245	1,013	1,620	599	1,141	484
RB – 1+	25	28	23	14	199	254	113	425	182	250	110	200
RB – 2+	1	-[a]	2	-[a]	13	11	4	9	18	21	9	14
RB – 3+	-[a]	-[a]	-[a]	-[a]	-[a]	1	-[a]	-[a]	2	1	-[a]	-[a]
Total[b]	**808**	**519**	**977**	**1,065**	**2,188**	**1,489**	**1,755**	**2,096**	**2,587**	**1,227**	**1,430**	**1,087**

[a] A dash (-) indicates age class not sampled.
[b] Total fish count (catch) for all species and age classes in each reach.

Table 9. Mean biomass (g/100 m^2) assessed from data taken from September Stock Assessments in years 2011, 2012, and 2014. Data are compiled for Reaches 2, 3, and 4.

Species Age-Class	Reach 2				Reach 3				Reach 4			
	2011	*2012*	*2013*	*2014*	*2011*	*2012*	*2013*	*2014*	*2011*	*2012*	*2013*	*2014*
CH - 0+	52	15*	19	23	19	23	21	21	5	6	7	3
CH – 1+	-[a]	-[a]	1	-[a]	-[a]	-[a]	2	-[a]	-[a]	2	-[a]	-[a]
CO - 0+	33	37	35	41	154	99	85	99	292	151	98	122
CO – 1+	-[a]	-[a]	-[a]	-[a]	1	-[a]	3	-[a]	8	-[a]	2	-[a]
RB - 0+	46	54	103	112	57	46	157	96	182	127	259	78
RB – 1+	31	33	23	16	148	186	139	378	241	376	190	262
RB – 2+	2	-[a]	6	-[a]	31	33	18	28	94	128	42	55
RB – 3+	-[a]	-[a]	-[a]	-[a]	-[a]	14	-[a]	-[a]	33	19	-[a]	-[a]
Total[b]	**164**	**139**	**187**	**192**	**411**	**402**	**425**	**621**	**856**	**808**	**599**	**520**

[a] Total mean biomass for all species and age classes in each reach.
*4 CH 0+ escaped, however if median weight estimated for these fish, Reach 2 average biomass increases to ~18g/ 100 m^2.

Through Trial 2, Reach 4 had an overall decline. This decline was only observed in Reach 4 and not the other reaches. Total biomass dropped to a low of 520 g/100m^2 (Table 7; 9); down from 2011 levels of 856 g/100m^2. In past years, biomass estimates during the flow Trials have indicated a stabilization for Reach 4 within the range of 700 – 800 g/100m^2, which was comparable to Reach 3 estimates prior to the Trial 1 flow release (Sneep and Hall, 2012). Declines were spread across the Reach 4. Rainbow trout juveniles, particularly Ages 0+ and 1+, made up the majority of biomass in this reach. Coho estimates were similar to 2012 levels in Reach 4 but appeared to drop 58% since 2011. Chinook biomass estimates were similar to past years in Trial 2. Levels have been low, and remain low through Trial 2.

Reach 3 biomass estimates during 2014 totaled 621 g/100m$^{2.}$ Data depict an increase under Trial 2. The 2011 estimated biomass was reported as 411 g/100m2 (Sneep and Hall, 2012). Most of this increase appeared to be in the Rainbow age-1+ age class. Chinook estimates did not change in Reach 3 through Trial 2. Coho age-0+ estimates in Reach 3 appeared to be stable from 2012 – 2014, but exhibit at 36% decline since 2011. This Coho decline may be attributed to a fluctuation in the number of adult Coho spawners in the LBR. This question is being addressed by BRGMON-3 and adult numbers are being incorporated into the synthesis assessment and flow recommendation.

Total Reach 2 estimates have remained stable throughout the entire study period, relative to the changes observed in the upper reaches. The total biomass estimate for 2014 was slightly higher than other years under Trial 2, at 192 g/100m^2, compared to 2011 levels of 164 g/100m^2. Coho fry (Age-0+) stayed relatively stable across Trial 2; however Chinook fry biomass estimates have dropped by 55% to a low of 23 g/100m^2, as compared to 2011.

Figure 17 describes species and age-class proportions across Trial 2 within the mean annual biomass estimations, by reach, from 2011 – 2014. General trends here depict Chinook and Coho representing less of the total proportion in 2014, at the end of the Trial 2 versus 2011, the beginning of Trial 2. This trend is apparent across all Reaches as the blue (i.e., Chinook) and red (i.e., Coho) pie chart areas take up less space over time and the colours representing Rainbow trout (i.e., green, purple and orange) increase through Trial 2.

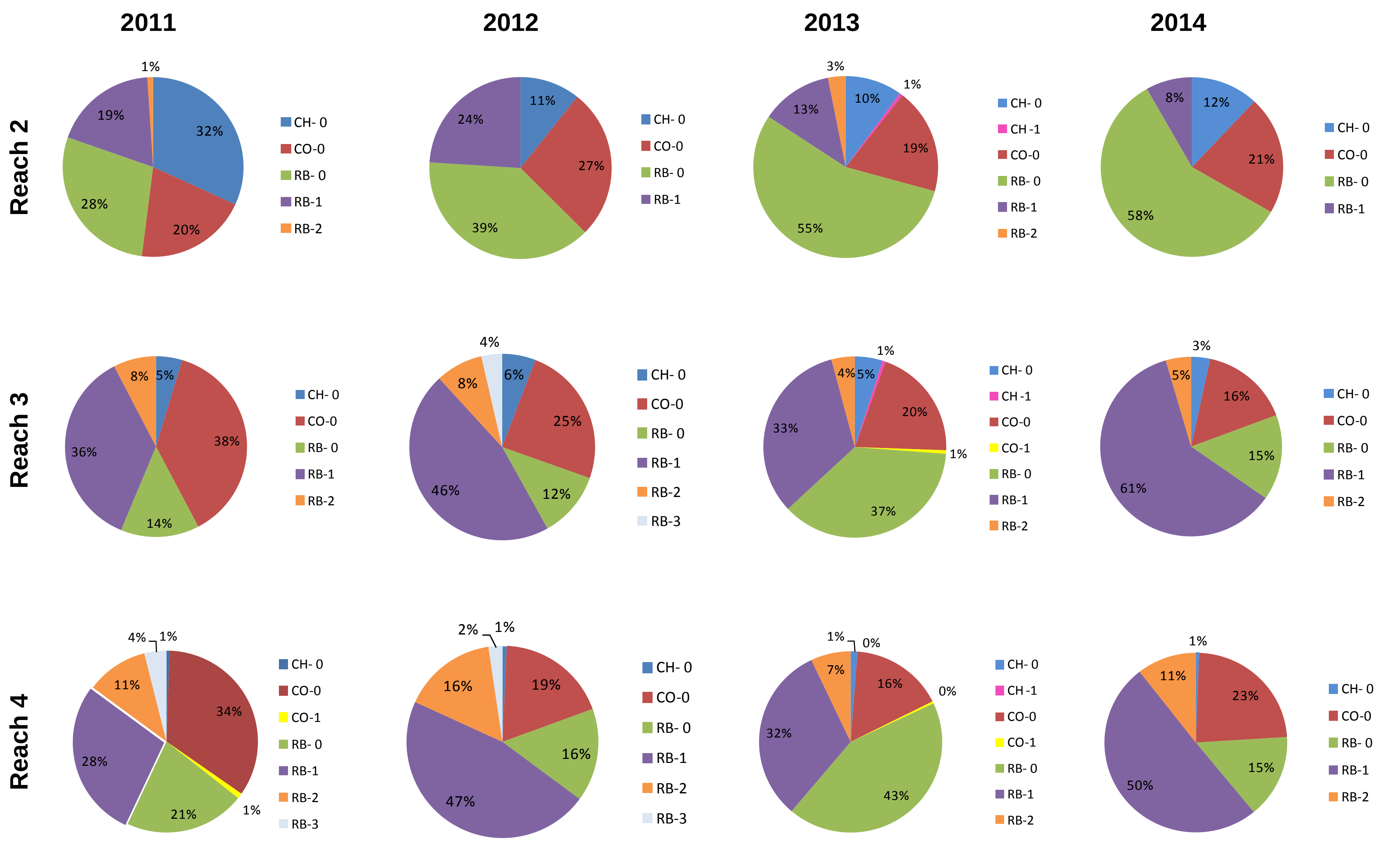


Figure 17. The proportions of total mean biomass (g/100m^2) of species-age classes for years 2011 – 2014 and Reaches 2, 3, and 4.

4.3.2.3 Standing Stock Assessment Results: Flow Trial Summary

The relative biomass contribution of each species and Age-class per Reach and a comparison of total biomass values for all study years (1996- 2014) are presented in Figure 18 and Figure 19. Proportions of species and age-class, when averaged across the years within Trials 1 and 2, appear similar for all of the reaches. Chinook levels remain very low at the end of Trial 2. They were also very low during Trial 1. Mean biomass of Coho may have increased during Trials 1 and 2, from their Pre-Trial means. Overall the mean biomass in Reach 3 was higher during the Pre-Flow Trial than Trials 1 and 2. Total mean biomass in Reach 4 appears similar across Trials 1 and 2.

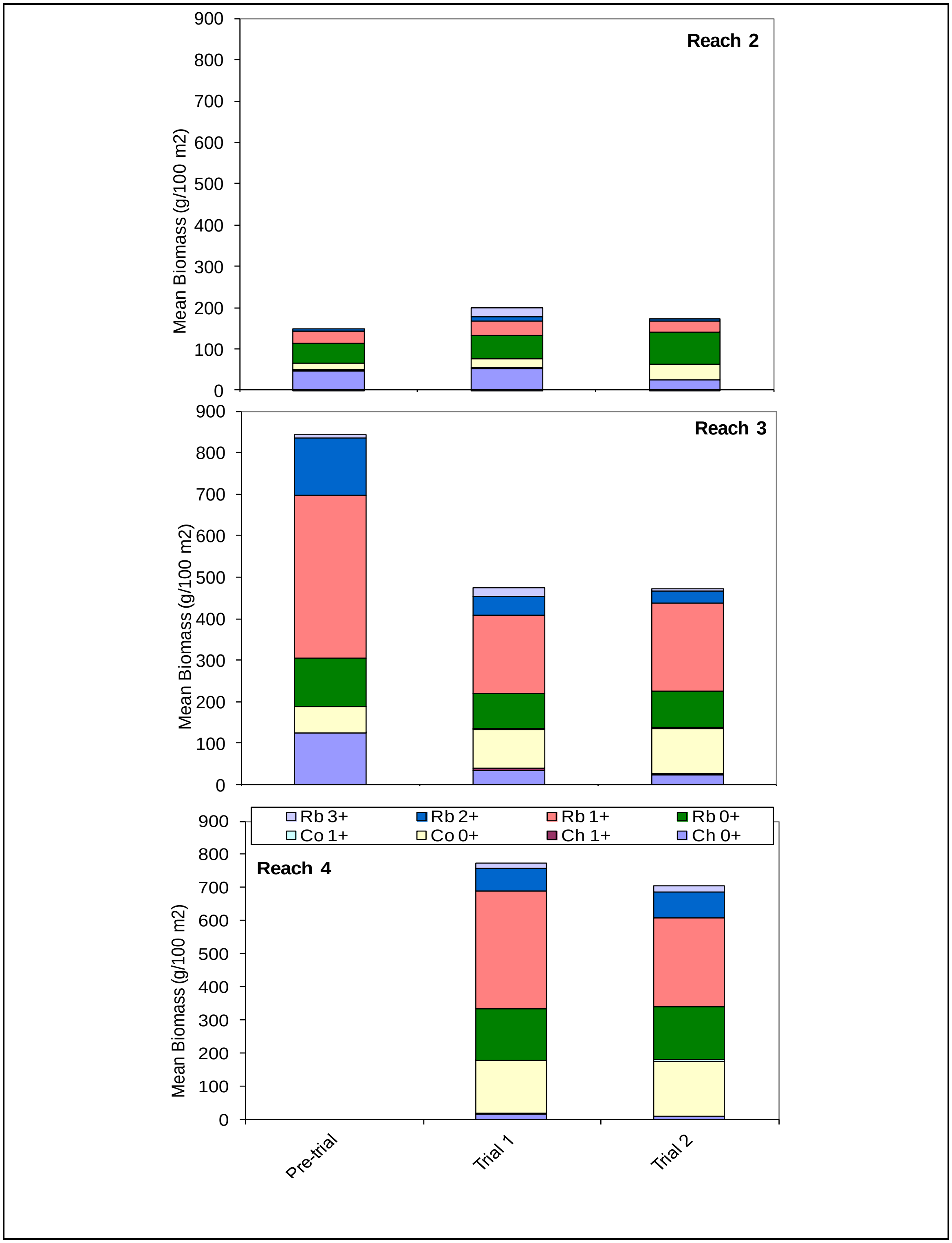


Figure 18. (A) Mean biomass by species and age-class for Reaches 2, 3 and 4 and for for Pre-trial, Trial 1, and Trial 2 flows.

Mean biomass for all reaches (with species and age-classes combined) is presented in Figure 19. A comparison of total biomass for all study years (1996 - 2014) is presented in Appendix

A.16. The mean Trial 1 estimate for total biomass in Reach 4 was 755 g/100m^2 (ranging between 666 and 826 g/100m^2). The mean Trial 2 estimate was 696 g/100m^2. While means appear to be similar, declining trends in Reach 4 should be monitored in the future.

Reach 3 pre-flow release estimates ranged from approximately 600 to 1,200 g/100m2 from 1996 to 1999 (mean ≈ 840 g/100m^2). The Reach 3 Trial 2 mean biomass estimate was 465 g/100m^2 and ranged from 402 g/100m^2 to 621 g/100m^2. This value is similar to the estimates for Trial 1 which varied between approximately 330 and 588 g/100m^2 (mean ≈ 461g/100m^2) and reflected a mean drop of approximately 375 g/100m2 between Pre-Trial and the end of Flow Trial 2 (Sneep and Hall, 2012).

While similarities seem apparent across Trial 1 and Trial 2, data were variable across 20 years. A rigorous assessment of the differences in mean biomass per species and age class across the years and Pre-Trial, Trial 1 and Trial 2 is currently underway in the synthesis assessment. Results will be presented in the fall of 2015.

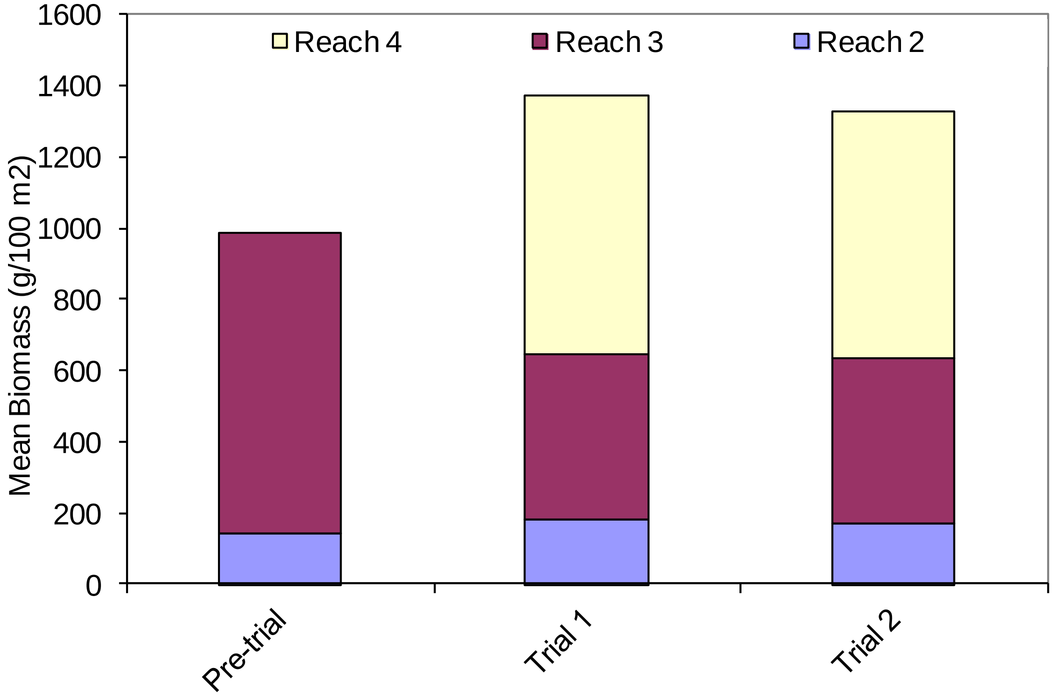


Figure 19. Mean biomass for all reaches for Pre-trial, Trial 1, and Trial 2 treatments (1996-2014).

4.3.3 *Chinook Estimated Emergence*

Chinook fry abundance is still very low at the end of Trial 2 relative to the Pre-Trial estimates (Figure 18; Appendix A.16). The causes of this apparent decline within the LBR study area are currently not well understood, but relevant literature indicates that temperature and dissolved oxygen are correlated with survival, development and growth in Chinook salmon (Geist et al., 2006). Development in freshwater fish, invertebrates and other cold-blooded organisms responds to temperature conditions (i.e., ATUs: accumulated thermal units above a threshold). Both chronic and acute temperature thresholds have been documented for survival of some fish species, (Olden and Naiman 2010). Research shows that survivorship from egg to emergence generally occurs when the water temperature ranges below 16.5 C (Geist et al., 2006) during the first 40 days of post-fertilization egg development. Fall temperatures in Reaches 3 and 4 that are warmer than the Pre-Trial conditions, may be contributing to early emergence in the LBR. Emergence timing is important and must be timed with adequate food supply and appropriate habitat. An early emergence of Chinook alevins, relative to the pre-release incubation period, was observed in several years since 2002 under the Trial 1 flows (Sneep and Hall, 2011). Given this information, there is still uncertainty if and how the altered temperature regime is contributing to this observed decline in fry. As part of the adaptive management program, a reduction in fall flow magnitude, as per the modified flow reduction schedule, was implemented during Trial 2. Reducing flows to a low of 1.5 m^3s-1 (from 2.0 m3s-1) was intended to partially mitigate this warming effect and avoid exacerbating the influence of Carpenter Reservoir flow on the incubation of eggs in the fall. Reducing the volume of flow at this time of the year should amplify the cooling effect of the air temperature on river water, and reduce the acceleration of egg development. It is not clear what affect this modification in the flow schedule, and subsequent modest temperature reduction has had on Chinook alevin emergence and fry recruitment. Emergence dates based on estimated spawning date and temperatures at three index sites over the flow trail are presented in Table 10 and Figure 20 and discussed below.

No field work was conducted from mid-November – late winter. Consequently, early emergence was not observed in the 2014 field visits and could not be confirmed. Predicted emergence dates, calculated based on ATUs overlaid on mean daily temperature by reach, over the course of the Flow Trial experiment are displayed in Figure 20. Observed temperatures for site 20.0 (Reaches 2), site 30.4 (Reach 3) and site 39.9 (Reach 4) were below the 15.5° C-16° C temperature threshold for the fall salmon egg incubation period, so survival from egg to emergence may not be inhibited by incubation temperature alone. However, if alevins emerge in winter, conditions are harsh, food availability is low, and appropriate habitat may not be available, which likely results in high mortality or low over-winter survival and growth rates. The graphs show predicted emergence dates for Chinook salmon alevins for index sites within Reaches 2, 3 and 4, respectively. Table 10 summarizes dates for all three graphs. According to predicted emergence timing, alevins in Reach 4 emerged earlier than any other location in the LBR, with an emergence date of November 19th. Estimated emergence timing for Site 39.9 did not change between Trials 1 and 2. For Reach 3, Trial 2 emergence dates appear to be slightly earlier than Trial 1 (Table 10). Emergence dates in Reach 2 appear to be similar to Pre-Trial dates, with emergence only 11 days apart. Data suggest a modest improvement under the Trial 2 hydrograph, relative to Trial 1, as was expected under the modified flow.

Table 10. Predicted mean emergence dates for all three index sites for various flow trials.

Flow Regime	Index site 20.0	Index site 30.4	Index site 39.9
Pre-flow	*16-Apr*	*11-Apr*	*N/A*
Trial 1	*22-Mar*	*06-Dec*	*19-Nov*
Trial 2	*02-Apr*	*22-Dec*	*18-Nov*

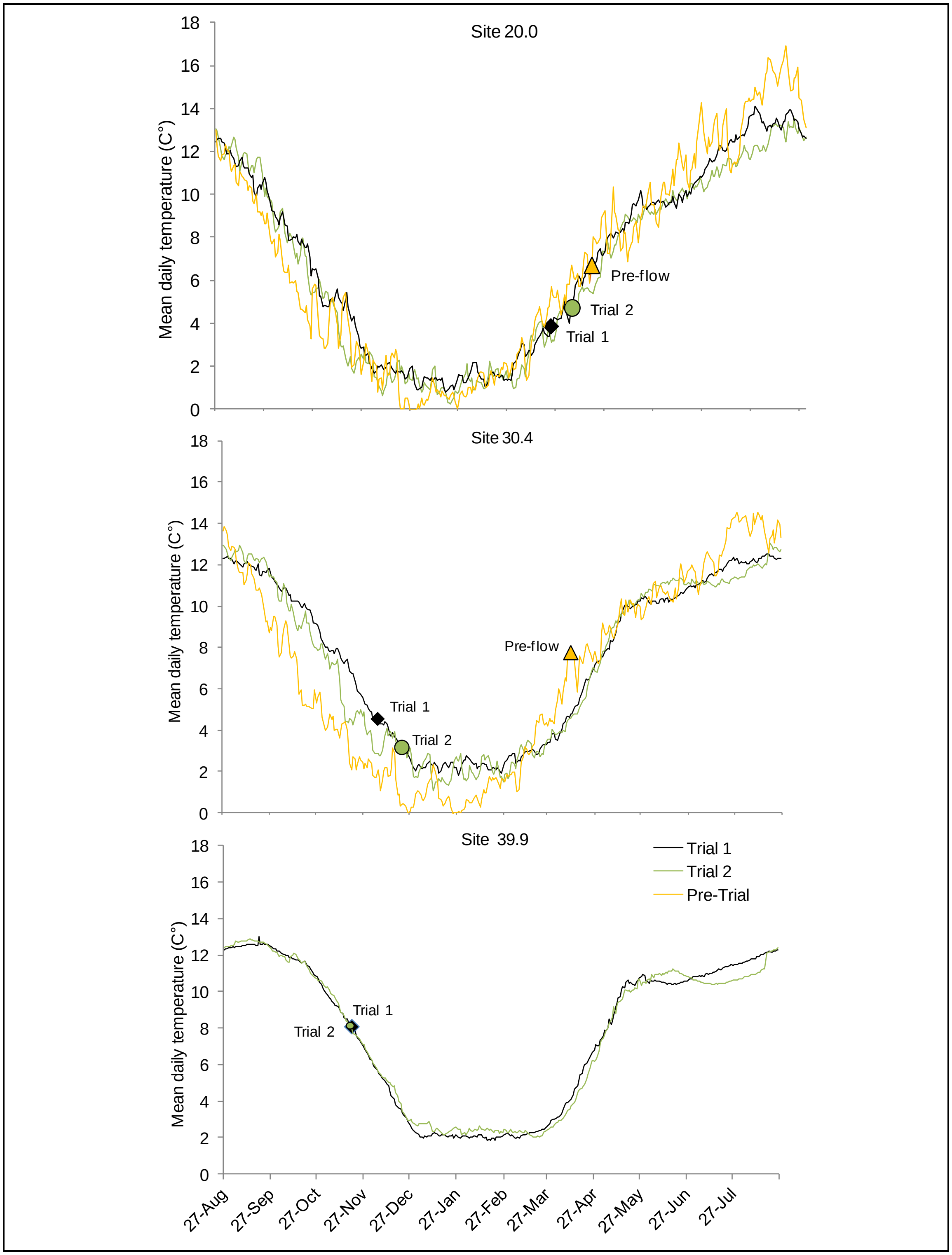


Figure 20. Predicted emergence dates (coloured dots) and mean daily temperatures of the Pre-Trial, Trial 1 and Trial 2 (coloured lines) for index sites 20.0 (top), 30.4 (middle), and 39.9 (bottom) for dates 27 Aug – 27 Aug.

It is still uncertain how temperature and other factors are influencing early life history, migration and dispersal in the LBR. Juvenile salmonids have been shown to have diverse life-histories, and change their behavior in response to environmental conditions (Walsworth et al., 2014). Juvenile Chinook in the LBR have displayed varying behaviour and physiology at the individual and site-based levels (Bradford and Higgins 2001). A knowledge gap exists in early life history information of how juveniles have responded to the increased flow. We have observed that abundance has generally declined annually sometime after the initiation of the flow release and higher spring flows in Reaches 3 and 4. Questions linger as to how flow affects physiology and migration behavior for LBR Chinook. Conner et al. (2003) found differing survival rates of migrating juvenile Chinook depending on when they undertook migration. Subyearling fall Chinook that migrated downstream in May had survival rates of 65 – 90%, versus lower rates of 5 – 20% for those that waited to migrate until later in the summer when water temperatures were warmer. Juvenile Chinook in the LBR could be changing their migration and rearing behaviour based on potential early emergence, higher flow, and other environmental cues associated with the flow release. Collecting data to specifically address this issue and provide more insight into the early life history and dispersal of Chinook has become important for understanding the impacts of the flow release on this important Bridge River species. Consequently, a pilot study was implemented in an attempt to gain information about early dispersal and behavior patterns using otolith microchemistry techniques. Although this approach has been used to identify the rearing locations and movements of juvenile Chinook salmon in nearby watersheds (Shrimpton et al., 2009), it did not work at the site-specific level within the LBR and a model to discriminate the reach-based rearing habitats selected during the juvenile phase could not be developed (Clark et. al., 2014) to meet the requirements of this program. Consequently, alternative methods need to be investigated that will aim to provide insight into life history and movement of juvenile Chinook in the LBR above the Yalakom confluence.

5.0 DISCUSSION

5.1.1 *Answering the Management Questions and Current Challenges*

This report summarized data collected in implementation Year 3 for BRGMON-1 in the Bridge-Seton WUP. It presents data from 2014 and context to compare and contrast with other years in Trial 2 (2011 - 2013). This report will support a future synthesis assessment across the Flow Trials, but does not attempt to differentiate statistical differences between parameters, which will be addressed during synthesis report preparation.

The key relevant management questions, listed below, drive the program. They are intended to directly describe and reduce uncertainties about the effects of flow on the LBR aquatic ecosystem:

1) How does the in-stream flow regime alter the physical conditions in aquatic and riparian habitats of the Lower Bridge River ecosystem?
2) How do differences in physical conditions in aquatic habitat resulting from the in-stream flow regime influence community composition and productivity of primary and secondary producers in the Lower Bridge River?
3) How do changes in physical conditions and trophic productivity resulting from flow changes together influence the recruitment of fish populations in the Lower Bridge River?
4) What is the appropriate 'shape' of the descending limb of the 6 m^3s-1 hydrograph, particularly from 15 m^3s-1 to 3 m^3s-1?

Questions 1-3 are addressed below, and question 4 is addressed in Section 6.0 Flow Rampdown Survey Result. As part of a structured decision-making process (Failing et al., 2004; Failing et al., 2013) key benefits from the aquatic ecosystem were identified, and parameters were chosen and monitored during 2014 as they have been historically over the course of the Flow Trial experiment. The focus of the LBR WUP includes the physical conditions in the aquatic and riparian habitats, biomass and growth of juvenile salmonids, periphyton and benthic invertebrate abundance and diversity as a proxy for river health. Due to the nature of an adaptive management program such as the LBR and the importance of integrating new knowledge and information into assessments as time progresses, it is important to annually evaluate if the program is on track to answering these questions and address any challenges. Towards this effort, the discussion below attempts to summarize how the flow regime influenced the physical conditions and habitat, the primary and secondary benthic invertebrate response, and ultimately how these factors influenced the recruitment of juvenile fish populations in the LBR.

5.1.2 *Abiotic Response*

5.1.2.1 Altered Thermal Regime and Future Characterization

Terzaghi dam has significantly altered the thermal regime in the Lower Bridge River. The integrity of the entire system depends on the natural dynamics of the thermal regime (Olden and Naiman, 2010). It is well documented that temperature influences both growth and reproduction of the organisms within aquatic communities. Thermal regimes have distinct ecological relevance. They differ in their variability, predictability of annual temperatures and monthly temperatures, and thermal events (i.e., the magnitude, frequency, duration time and rate of change in event). Fish and invertebrates depend on certain temperatures as environmental cues, to complete their life cycle. Fish assemblages are influenced by individual and interactive effects of flow and thermal modification (Olden and Naiman, 2010). In addition to physiological responses, behavioral responses have also been observed in other river systems. At elevated temperatures, Kuehne et al. (2012) found multiple and cumulative stressors changed juvenile behavior and these responses ultimately influenced development and reproduction, and the overall growth of organisms within the aquatic community.

Changes in the thermal regime in the LBR were evident in 2014 data and in Trial 1 and Trial 2. Diurnal high and low temperatures for 2014 were basically eliminated in Reach 4 (Figure 6); overall muted diurnal variation was evident in both Reaches 3 and 4. This could potentially be reducing the abundance of food for juvenile salmon in the upper reaches. Reach 3 temperatures (i.e., the mean, the minimum and the maximum) were also warmer across the critical fall early egg incubation period, compared to Pre-Trial conditions. Both the mean and the minimum temperatures were warmer in the upper reaches during fall in Trial 1 and Trial 2 compared to Pre-Trial conditions. Reducing flows to a low of 1.5 m^3s^{-1} in Trial 2 was intended to mitigate this warming effect and reduce the influence of Carpenter Reservoir flow on the incubation of eggs in the fall. During the modified low-fall flow, data from 2014 and other years in Trial 2 demonstrate that this effect was achieved in Reach 2, and modestly in Reach 3 through the fall and winter. However this was not the case in Reach 4. Therefore the low-fall flow did not serve the intended purpose in Reaches 3 and 4 during Trial 2. Data still point to the corroboration of the “thermal inversion” hypothesis, which predicted that growing season temperatures in the LBR would be reduced by on average 2°C and fall/early winter temperatures, would increase by 2°C. The thermal inversion modeling helped formulate part of the “Low Good” hypothesis in the LBR SDM process, which predicted that reservoir releases would negatively affect habitat quality in the LBR (Failing et al., 2004; 2012).

Therefore, juvenile Chinook alevins are likely still emerging during winter, where conditions are not optimal for survival and growth. If juvenile salmon that emerged early in winter are surviving, temperatures were, in general, cooler in the spring and summer in both Trials versus Pre-Trial conditions. These changes have been observed following initiation of the flow release under both the 3 m^3s^{-1} and now 6 m^3s^{-1} water budget.

Managers should consider developing goals within components of the program, such as critical egg incubation periods, that include performance measures for thermal targets. Examples could include targets for magnitude, frequency and duration of temperature events (e.g. daily maximum temperatures, frequency and duration of high and low pulses, 30-day minimum/ maximum temperatures, timing of annual seasonal events), and target temperatures during growing degree periods, etc. Data used to create these performance measures should include the Yalakom River and Pre-Trial conditions as potential thermal regime references.

5.1.2.2 Yalakom River Influence

We recognize that the Yalakom River has strong tributary influence on the LBR. Data suggest that the LBR aquatic riverine ecosystem responds positively to Yalakom River tributary inflow. The other tributaries and groundwater sources in Reach 3 moderate the effects of flow release as well, but do so to a more moderate extent due to less flow. The unregulated, instream Yalakom River flow helps buffer the impacts of the hypolimnetic flow release on the aquatic ecosystem. In particular, the natural thermal regime of the Yalaklom aids in thermal recovery and/or mitigation of impacts, particularly in Reach 2. Benthic invertebrates and biomass assessments both reflect this observation and potentially corroborates the use of Reach 2 as a “control” reach in the flow trial experiment.

5.1.2.3 Aquatic Habitat

Two habitat surveys were conducted in 2014: a replicate of the low winter flow at 1.5 m^3s^{-1} and a high flow survey at 15 m^3s^{-1}. These surveys, combined with the other surveys through Trials 1 and 2 helped to reduce uncertainty regarding the flow volume on habitat quality. In general, the 5 m^3s^{-1}, 8 m^3s^{-1}, and 15 m^3s^{-1} flows provided the most amount of wetted area in the river, while at the same time providing the least amount of relative suitable juvenile rearing habitat across the reaches. During higher flows some of the quality juvenile rearing habitat was replaced by cascades and rapids. This finding seems to be corroborated but the disappearance of two genera of invertebrates during Trial 2 that prefer to live in slower moving water. Habitat surveys at the 1.5 m^3s^{-1} indicate that in general, habitat classifications remained similar to proportions of habitat types during a 3 m^3s^{-1} flow. Habitat area during the Trial 2 low winter flow also remained similar to the area in habitat classes during a 3 m^3s^{-1} flow. In general, higher flows do not increase the overall quantity and quality of habitat in the upper Reaches of the LBR. Spawning habitat is being addressed under BRGMON-3.

5.1.3 *Biotic Response*

5.1.3.1 Community Dynamics and Productivity: Primary and Secondary Producers

Benthic invertebrates form a main food source for LBR rearing fish, and can be used as an indicator of water quality and available habitat in rivers. Healthy invertebrate communities and their contributions to stream integrity are integral to salmonid life history and influence growth rates, survival and recruitment of juvenile fish. Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are common within the benthic invertebrate community. These taxa are used in an EPT Index, with the premise being high quality streams usually have the greatest species richness. Stamford and Vidmanic (2015) assessed both abundance and diversity of EPT between Trial 1 and Trial 2 and location (upstream or downstream of the Yalakom River). Both abundance and diversity of EPT taxa were observed to be significantly higher in Trial 2 ($p<0.025$). Several taxa decreased in abundance or were absent in Trial 2, namely Tipulidea and riffle beetles. This may signify a loss of slower water sections as species within these genera are adapted to slower depositional habitats. This potentially suggests that the increase in flow during Trial 2 was a disturbance to components of benthic invertebrate communities that prefer slower moving water. Stamford and Vidmanic (2015) explain these increases and disturbances in the following excerpt:

> “Higher disturbances can also promote increases in diversity by diminishing influences from community dynamics (e.g. competition and predation). Consequently, increased diversity, fewer distinct invertebrate assemblages associated with specific locations (sample sites) in the river, loss of some rare taxa during Trial 2 suggest disturbances have increased. Higher disturbances to locations in the river can change the predictability to feeding locations for fish. Salmonids often home to specific areas in streams to spawn if these locations provide temporally stable foraging success for their offspring (i.e. higher recruitment). Although increasing the flow regime from 3cms to 6cms appears to have promoted higher abundance and diversity in the invertebrates in the river, a diminished location effect might signify disturbance to locations that provided important early rearing areas for fish with lower discharge (i.e. during Trial 1), which could have affected their recruitment success.”

Periphyton accrual rates (measured as cumulative concentration of Chlorophyll a) mean periphyton biovolume and total mean periphyton cell counts were observed to be variable in 2014 and across Trial 2. Data follow trends observed since the flow release began, namely that spawning pink salmon drive nutrient accumulation in the LBR during odd years. These data will be evaluated statistically during the synthesis analysis.

5.1.3.2 Fish population recruitment

Biomass and growth rates are a key benefit as defined under the WUP. Data suggest that overall total juvenile salmon biomass appeared relatively stable across Trial 2. Within the reaches, Reaches 2 and 3 appeared relatively stable from 2011 – 2014. However, data suggest that species specific total juvenile salmon biomass further declined in 2014. Observational data suggest an overall decline in Trial 2 from Trial 1; most of this decline has occurred in Reach 4. In addition, both Chinook and Coho estimates have declined. As predicted under the Structured Decision-making and adaptive management research by Failing et al. (2004; 2012), biomass peaked during the 3cms and has begun to decline in the following years under Flow Trial 2. While Reaches 3 and 4 have varied over the years and changed between flow trials, Reach 2 has had relatively stable estimates across the flow Trials for total biomass. Biomass results for Reach 2 may reflect the moderating influence of the Yalakom River on the effects of the flow release in that reach.

While biomass remained relatively stable in Trial 2, fish species composition has changed. Juvenile Chinook numbers and biomass remain very low across the LBR. Coho estimates have declined in Trial 2, while an increase in Rainbow biomass has occurred. Catch inefficiencies during higher flows lead to poor growth data through Trial 2, which inhibited a robust comparison of growth across the trials at this time. If flows continue to be high post 2015, juvenile growth sampling may not provide any additional insight towards the uncertainties the program aims to reduce.

Despite having a comprehensive juvenile fisheries and aquatic ecosystem dataset for the LBR, we still do not fully understand the mechanism behind the observed decline in juvenile Chinook and Coho abundance given that this result was not predicted when the study was originally designed. Alevins could be emerging early; they could be changing their life history behaviour and migrating earlier in response to higher flows, colder temperatures or poor environmental conditions; or perhaps the habitat created in Reach 4 is inferior to that of Reaches 2 and 3 for these species, and unsuitable for necessary life stages. Interacting and cumulative factors are potentially involved, which may not be fully described by the adopted study design. However, the ongoing synthesis assessment will provide tests of statistical significance across the Trials for both biomass and growth rates, and will direct a way forward for addressing the questions and management objectives in this Monitor.

5.1.4 *Relevant findings for Reach 4*

Three relevant findings for Reach 4 have become apparent: 1) the relationship between water flow and water temperature is direct and ambient air temperature effects may be limited; 2) dirurnal temperature variation is muted; and 3) fish recruitment and productivity appears to be declining.

Little to no tributary in-flow occurs in Reach 4 and thus flow from the dam makes up nearly all of the total volume of water in Reach 4. It is well established that Reach 4 is affected by the flow from Terzaghi dam more than the other Reaches in the LBR. Water temperature in Reach 4 during fall was similar during Trials 1 and 2, despite the decreased flow initiated in Trial 2. The warmer temperatures continue to influence egg development and this has obvious implications to Chinook and other salmon species that rely on cooler water temperatures during egg incubation. The ATU analysis within this report indicates that emergence dates for site 39.9 (effectively Reach 4) were nearly identical between Trials 1 and 2. Changes in the ATU for Reach 3 were also minimal.

Diurnal temperature variation in Reach 4 is muted. This potentially limits growth not only of salmon, but also of the food that they depend on for survival. Further thermal regime characterization and subsequent restoration is required to mitigate these effects, as suggested in Section 5.1.2.1.

Fish recruitment and productivity appears to be declining in Reach 4. For the first time since the Flow Trials began, Reach 4 standing stock biomass estimates dropped below levels in Reach 3. While Reaches 3 and 4 biomass estimates have varied over the years, Reach 2 has had relatively stable biomass estimates across the Flow Trials. The cause for these results in Reach 4 is unclear, however this biomass decline should be monitored and mitigated in future years as current data suggest this Reach has not be restored by the addition of water.

5.1.5 *Summary Table of Hypothesis, Management Questions, and Status at Implementation Year*

The primary objective of this monitoring program is to reduce uncertainty about the dynamic between the magnitude of the flow release from Terzaghi Dam and the relative productivity of the Lower Bridge River aquatic ecosystem. The two competing hypotheses about the effects of flow on the LBR are:

H_O: "High flow is better"

H_A: "Low flow is better"

The following table gives a status update for implementation year 3 on each management question and is intended to portray whether the study is on track to answering the management questions (Implementation Year 3).

Table 11 summarizes the management questions and status update for implementation year 3.

Table 11. Summary of the management questions and status update for implementation year 3.

1) How does the in-stream flow regime alter the physical conditions in aquatic and riparian habitats of the Lower Bridge River ecosystem?	**Temperature conclusion:** undetermined. Both flows appear to cause undesirable temperature affects: growing season temperatures in the LBR were reduced by on average 2°C and fall/early winter temperatures, were increase by 2°C. The ongoing synthesis assessment will determine which flow harms the system the least. The hypolimnetic flow has a strong influence on the daily temperature variation in both Reaches 3 and 4 and an overall negative effect on the physical environment and habitat quality in the LBR. Both high and low flows exhibit these traits.
	Habitat conclusion: Low flow is better. In general, the 5 m^3s^{-1}, 8 m^3s^{-1}, and 15 m^3s^{-1} flows provided the most amount of wetted area in the river, but did not significantly increase the amount of suitable juvenile rearing habitat across the reaches. The 1.5 m^3s^{-1} flow provided similar quality habitat across the reaches as the 3 m^3s^{-1} flow. Total area suggests that these two lower flows also contained a similar amount of rearing habitat for juvenile salmon.
	Riparian conclusion: This remains outside the scope of this monitoring project. Please read recent report from BRGMON-11.
2) How do differences in physical conditions in aquatic habitat resulting from the in-stream flow regime influence community composition and productivity of primary and secondary producers in the Lower Bridge River?	**Periphyton conclusion:** Data appear to be similar between Trial 1 and Trial 2 show similar accumulation trends. Trends in both Trials 1 and 2 depict the influence of pink salmon nutrients on the LBR ecosystem.
	Invertebrate conclusion: Higher flows appear better for diversity and abundance. However, it eliminates some important species that are adapted to slower water conditions and this causes disturbance within community composition. This may reduce the reliability of food supplies for fish. In addition, downstream communities (Reach 2, below the Yalakom River) are healthier, regardless of flow.
3) How do changes in physical conditions and trophic productivity resulting from flow changes together influence the recruitment of fish populations in the Lower Bridge River?	**Fish conclusion:** Total biomass appears stable across Trials 1 and 2, but healthiest under Pre-Trial conditions. Trial 1 appears to be better than Trial 2 as Reach 4 Trial 2 trends indicate a decline in fish populations. Trial 1 also appears to be better for fish species composition as Chinook and Coho proportions have declined in Trial 2. Fish growth data are inconclusive at this time. The sampling design may need to be revised if high flows continue. These data are being integrated into the synthesis assessment, and are being correlated with the adult Monitor (BRGMON-3) to determine if adult spawning numbers are influencing fish recruitment. This information is currently being incorporated in the Synthesis Assessment, which is in progress.

5.1.6 *Data limitations*

Inherent limitations in the monitoring program affect the data quality and its interpretation. Overall, juvenile growth sampling has provided less data in Trial 2 as compared to previous Trials. Catch efficiencies during summer juvenile growth sampling sessions have gone down with the initiation of the high flow. These measurement errors were expected during the structured decision-making process, where experts examined and predicted the potential of high measurement error under the higher hydrograph in Trial 2 (Failing et al., 2012). In addition, the

Monitoring project no longer collects growth information in the early and late winter periods. If high flows continue, data limitations with this parameter will also continue and a review of the sampling design and monitoring approaches should be conducted.

To date, only two complete fall seasons of salmon enumeration have occurred under the fish counter for BRGMON-3, the adult WUP program. Consequently, adult enumeration has yet to be correlated with juvenile data for the Trials. More data (additional years) may need to be collected in BRGMON-3 to correlate escapement numbers with current and historical data. The synthesis technical team will be working with BRGMON-3 to address this gap with currently available data.

5.1.7 *Incorporating spatial components to aquatic inventory and monitoring*

2014 was a pilot year for the incorporation of spatial components into the LBR aquatic monitoring program. The starting point for this work was habitat data collection. Because they depict the physical state and diversity of the LBR at various flows, these data are inherently spatial and provide the foundation for future analysis of additional aquatic data components. The datasets produced in 2014 include the physical components of the LBR: size and extent, type, geotagged photos, as well as valuable habitat attributes normally collected. The final deliverables included two geodatabases, one depicting the 15 m^3s^{-1} and another depicting the 1.5 m^3s^{-1} flows. Both include metadata[8].

The new geodatabases will improve the precision and communication of information regarding habitat quantity, quality, and the impacts of flow on the aquatic ecosystem. In addition, it may be most appropriate to incorporate future field data into a geodatabase rather than a traditional database system so as to most effectively organize, analyze and interpret these multiple and inherently geographic datasets.

Future spatial analyses may be the most efficient and effective way to address specific or broad-scale management questions related to the LBR WUP monitoring project. Similar techniques using geospatial analysis to determine aquatic habitat quality are outlined in Vyas et al. (2013) and Thomson et al. (2001). At a broader scale; spatial analysis would assist managers in understanding the overall impacts of flow and complex management decisions, while providing a powerful tool for testing the effects of the trade offs and cost and benefits of the program to an extent not available using traditional methods. These results could be used in adaptive management of the LBR to continue working for habitat characterization and exploration of flow effects across different flow regimes (Maloney et al., 2015).

5.1.8 *Future Research and Monitoring*

Ecosystems are complex, and have multiple interactive and cumulative factors and linkages. Management success is predicated on being able to accurately predict the response of the aquatic ecosystem to flow changes. This report reduces some uncertainty regarding the predicted and observed benefits and ecosystem response to the instream flow release. However uncertainties still confound questions regarding the long-term ecological benefits and costs from the release of instream flow from Carpenter Reservoir. We recommend that

[8] These geodatabases can be made available upon request.

multivariate testing approaches be adopted during the synthesis assessment to integrate the analysis of biotic and abiotic components of the program. This is currently being conducted in the synthesis assessment. Following the synthesis analyses and flow recommendation, continued monitoring of the river to assess ecosystem response to the new hydrograph and flow magnitude is recommended. Results should continue to be included in the adaptive management of the LBR.

6.0 FLOW RAMPDOWN SURVEY RESULTS

6.1 General Discussion

Due to morphological characteristics and predominately coarse in-stream substrate, the Lower Bridge River is sensitive to fish stranding. Potential mortality is directly associated with the ramping rate, particularly within higher risk stage elevation ranges. In general, the slower the river is ramped down, the lower the risk for adverse effects on fish. The cross-sectional channel shape is also influential; as the river volume drops, the effect of each 1 cm flow reduction on river stage elevation increases. Consequently, to maintain a target stage change rate, the amount of flow reduction that can be accomplished must decrease on each successive ramp down date (Crane Creek Enterprises, 2012). A target ramp maximum rate of 2.5cm of stage change per hour was selected for all BC Hydro Bridge River Generation facilities. In addition, daily ramping duration is constrained by a target daily stage change of less than 15 cm at Rkm 36.8, as well as accounting for the time lag effects of ramping to reach the bottom of the study area (up to 5 hours to reach the Yalakom River confluence).

Specific data results, compilations, and findings for rampdown can be found in Appendix B[9]. A brief descriptive summary of results is presented below.

6.2 Flow Rampdown Survey Results

6.2.1 *Terzaghi Dam Flow Release and River Stage Results*

During the August ramp down event, the relative stage data decreased across all sites in correspondence with the decrease in flow coming from the LLO gates at Terzaghi Dam. Manual readings, located at the top of Reach 4 (plunge pool), the break between Reaches 4 and 3 (Rkm 36.8), the middle of Reach 3 (Rkm 33.3), and the Yalakom River were also recorded from both permanent and temporary staff gages throughout the rampdown events.

Quarter-hourly river level (relative stage) recorded by three data loggers located at or near the reach breaks (i.e., Rkms 36.8, 26.1, and 20.0), and mean hourly flow releases from Terzaghi Dam for the rampdowns in July/ August and October 2014 (hereafter reported as August and October, respectively), are presented in Appendix B.1 during: (A) August, and (B) October.

Appendix tables B.2 – B.4 summarize the total changes in the river stage elevation and the flow release volume for each ramping date in August and October. The maximum daily flow change was observed both on August 1 and 2, with a drop of 1.9 m^3s^{-1} (Appendix B.2). Throughout the rampdown, the plunge pool site exhibited the most stage reduction, and these effects

[9] Appendix B can be provided upon request.

diminished as distance from Terzaghi Dam increased. Appendix B.3 presents the ramp hourly duration as measured at site Rkm 36.8, the maximum hourly change and the mean hourly change for each day of the ramp down in the summer and fall. The maximum observed changed was -2.5cms observed on August 9 and Oct 4. Mean hourly change ranged from -1.3cm and -1.8cm. Appendix B.4 shows the same data observed from the Plunge Pool (PP).

6.2.2 *Water Temperature and Turbidity*

Hourly water temperatures during the ramp down are presented in Appendix B.5 for four sites within the study area: Rkm 39.9, 36.5, 33.3, and 30.4. No obvious changes in water temperature were observed. Mean water temperatures in Reaches 3 and 4 did not change more than 2° C/day during the duration of the rampdown events.

Changes in turbidity measurements were observed to be minimal during the ramp down events. The October turbidity measurements were slightly higher than August and were similar from start to finish of the ramp.   This higher turbidity in the fall can likely be attributed to Bridge Glacier silt, which settles in the old Bridge River channel at the bottom of Carpenter Lake during summer glacial melt. The sediments from this melt gradually making its way through the dam and into the Lower Bridge River through the LLO gates during the early fall season. No turbidity were observed in the results that could be attributed to direct impacts from planned flow ramp down events.

6.2.3 *Physical Habitat Attributes*

Data from previous salvage years, including three other years in Trial 2 (2011 – 2014) were used to guide rampdown monitoring and salvage activities. No sites were added or omitted for surveys in 2014. Due to access issues and safety considerations related to high river stage, it was not possible to survey much of the river-right side of the channel on most of the August rampdown dates.

Figure 20 presents summations of salvage operations, per site, per flow release level in August and October 2014. The graph below depicts salvage sites and flow release level, and shows the particular timing (i.e., which flow level or stage) where sites are sensitive to fish stranding and must be salvaged. This figure should be used as a tool for timing and salvage operations per level of flow release in future years.

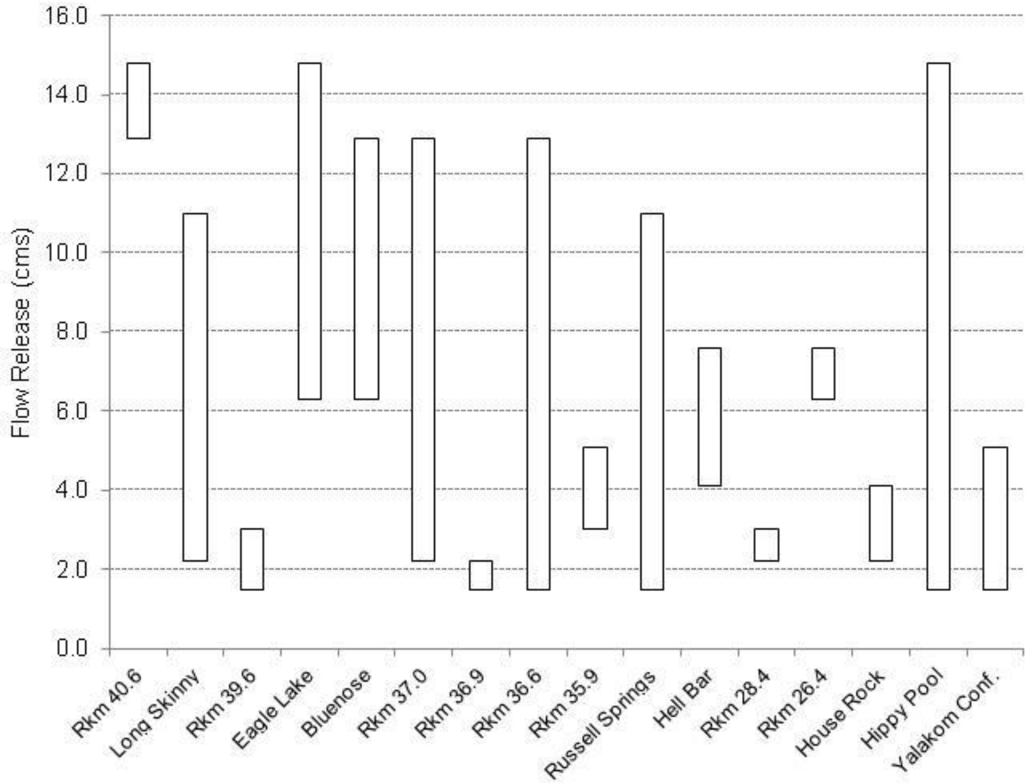


Figure 21. Range of flows and sites where fish salvage operations were required during rampdown in 2014.

6.2.4 *Fish Salvage*

Most of the fish salvaged (i.e., 98%) during the ramp down event were age-0+ Coho and Rainbow trout. Most of these fish (i.e., the age-0+ class) prefer shallow, grassy, protected habitat for rearing. Unfortunately, this habitat type is likely to dewater when flows are ramped down in the Lower Bridge River. Tables 12 – 13 below summarize the number of fish salvaged by date, type of activity (e.g. incidental "push" or active salvage), species and age-class, and reach. In total, approximately 3,500 fish were salvaged during the ramp down events in August and 1,439 in October. Fish that were still in wetted habitat but were isolated from the main channel, made up the majority of salvage type throughout both of the ramp down events. Very few fish were observed mortalities (*n=61*), and even fewer (*n=35)* were found stranded in dewatered habitat. The remainder of fish were considered incidental captures, which means that fish were occupying habitat that was still connected to the main flow, and were "pushed" or encouraged to vacate habitat areas that would isolate or dewater as the ramp down continued.

Appendix B.7 presents the number of fish captured per site, by salvage condition in August and October, respectively. Appendix B.8 depicts fish numbers salvaged per Reach. Appendix B.6 presents the mean, minimum and maximum forklength measured by species and age-class. As in recent years, during August, Eagle Lake, Bluenose and Rkm 35.9 and Russell Springs (Rkm 30.4) all represented significant salvage locations with >400fish being salvaged per site. Site 36.6 required salvage for ~300 fish. Numbers of fish salvaged at the remaining sites were less than 200. In October, Site 37.0 was the most significant site in the salvage, requiring the capture of >600 fish. Site 39.6 had nearly 400 fish salvaged, all of them isolated. All other sites where active salvage activity occurred in October retrieved fewer than 100 fish.

Table 12. Fish salvage totals categorized by salvage type on each day of the rampdown, 2014.

Date	Incidental	Isolated	Mortality	Stranded
18-Jul-14	-	-	-	-
01-Aug-14	20	27	-	-
02-Aug-14	16	127	7	-
08-Aug-14	192	307	24	4
09-Aug-14	73	210	10	-
16-Aug-14	160	279	16	3
17-Aug-14	128	280	1	28
23-Aug-14	-	714	-	-
24-Aug-14	52	803	-	-
August Totals	**641**	**2,747**	**58**	**35**
03-Oct-14	311	624	-	-
04-Oct-14	143	356	3	2
October Totals	**454**	**980**	**3**	**2**

Table 13. Summary of number of fish salvaged by species and age class, August and October, 2014.

Month	Species & Age Class	Incidental	Isolated	Mortality	Stranded	Total	% of total catch
August	CH - 0+	1	7	2	-	10	<1%
	CO - 0+	359	1,201	24	15	1,599	46%
	RB - 0+	258	1,485	32	20	1,795	52%
	RB - 1	20	48	-	-	68	2%
October	CH - 0+	2	1	-	-	3	<1%
	CO - 0+	80	450	3	-	533	37%
	RB - 0+	364	495	-	2	861	60%
	RB - 1	7	27	-	-	34	2%
	SK-0	-	1	-	-	1	<1%

7.0 DISCUSSION AND RECOMMENDATIONS

7.1.1 *Discussion*

Overall, data demonstrated that a successful transition occurred throughout both rampdown events on the LBR in 2014. The initial rampdown event occurred transitioned the river from 15 m^3s^{-1} to 3 m^3s^{-1}. In the subsequent October rampdown, flow from the lower-level outlet gates was reduced from 3 m^3s^{-1} to 1.5 m^3s^{-1} as per the Trial 2 hydrograph. Total change per day was well under the 15cm/day limit for all days in the rampdown, and the 2.5cm/hr limit was never exceeded. This demonstrates a major improvement from 2013, where this limit was exceeded 8 out of 10 ramp down days. Crews were deployed to document and respond to fish stranding and to salvage fish as they became stranded, and water quality was monitored. Most of the salvage operations in 2014 were conducted in isolated habitat, where the fish were already stranded. However, due to the low visible mortality at sites, data suggest these effects were mitigated by having salvage crews on site to relocate fish throughout the ramp down. Consequently, the majority of fish were successfully salvaged prior to stranding, and ramp down efforts were considered a success.

7.1.2 *Recommendations:*

Ramping down the LBR should continue to be done slowly, over many steps. As was done in 2014, target rates of stage change in future years should not exceed 2.5 cm/hr or 15 cm/day. However they may be exceeded if the number of recommended fish salvage crews are in place. Salvage crews should be on site throughout the duration of rampdown and downstream effects. Keeping the stage change, to this rate will increase the success of salvage efforts and reduce mortality in isolated and dewatering habitats, as occurred in 2014.

Significant habitat modifications need to be made to at least three major areas in Reaches 3 and 4 of the LBR to reduce stranding potential during rampdown events and subsequent low fall/winter flows. Sites that could use machine work include Grizzly Bar, Eagle Lake, and House Rock. Grizzly Bar is a large side-channel in Reach 3 on the right hand side of the channel (i.e., river-right). This slow moving, wide side channel is important habitat for juvenile salmonid, in particular Coho that have been observed there in high numbers. However the flow is generally blocked by early fall due to log jams. Every October, salvage crews clear by hand the upper inlet area, allowing water to flow unimpeded into the habitat. When this manual labour is conducted by hand, flows keep a portion of the sidechannel habitat wetted over the fall and winter periods, reducing over-wintering mortality. However, this is a large sidechannel, and more of this important habitat could be utilized over winter if machine habitat modifications were made. Recommended machine work includes the excavation and recontouring of the inlet to allow more water to naturally flow into the side channel all winter long.

Habitat modifications, including the creation of a trenched gradient using shallow cuts, should be made at Eagle as this site makes up a large component of the salvage effort. Further connectivity improvements could be made between salvage sites Long Skinny and Eagle Lake, as well as House Rock and the main stem of the LBR. At lower flows, several pools at these sites become isolated. This isolation and subsequent stranding and dewatering could be mitigated, with minor excavation activities by opening or deepening the wetted connections.

8.0 ACKNOWLEDGEMENTS

The authors would like to thank its major project partners: St’át’imc Eco-Resources for administration and providing the field technicians, and the Bridge River band for their partnership in program implementation and safety. Thanks also go to all field technicians who worked on the program, in particular Elijah Michel, Chris John and Kathleen Street. We'd like to thank Instream Fisheries Research Inc. for providing supplemental funding for the spatial habitat data collection, and other Bridge-Seton WUP project managers for data sharing and program support, specifically Don McCubbing, Jeff Sneep, Odin Scholz and Kim North. Finally this program acknowledges and thanks BC Hydro for providing both funding for the program and its employees, particularly Ahmed Gelchu and Dorian Turner for support through effective collaboration and communication.

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10.0 SUMMARY COST

Table 14. Summary Cost Table: Costs per study are shown as a total per year including inflation and contingency.

Lower Bridge River Aquatic Monitoring	***2014***
BRGMon-1	Implementation Yr 3
Total cost	$231,338.27

11.0 APPENDIX A

11.1 Additional Tables and Figures

(Note: The appendix tables and figures are contained in a separate file and can be obtained from St’át’imc Eco-Resources or BC Hydro upon request)

12.0 DISCLAIMER

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