QUA AND CURTIS CREEKS CRYSTAL GREEN NUTRIENT RESTORATION PREPARATION

PROJECT COL- F17-F-1410

FINAL REPORT

July 17, 2017

Prepared for the: Fish and Wildlife Compensation Program

Prepared by:

Gerry Nellestijn
The Confluence Approach
Box 718, Salmo, BC
V0G 1Z0

Robyn Irvine
Poisson Consulting Ltd.
4216 Shasheen Road, Nelson, BC
V1L 6X1

Prepared with financial support of the Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and public stakeholders.

SALMO WATERSHED Streamkeepers SOCIETY

Poisson CONSULTING

Executive Summary

During the 2016 growing season, Curtis and Qua Creeks in the Salmo River watershed were sampled for the second of a three year project (2015-2017) of the Nutrient Restoration Preparation Project. Sampling included water chemistry to assess trophic status, periphyton growth to assess primary productivity, invertebrate diversity to assess secondary productivity and fish abundance and condition. This assessment of the overall productivity of these two creeks is to determine if either creek is suitable for nutrient restoration with the addition of Crystal Green pelletized fertilizer in future years to augment juvenile Bull and Rainbow Trout as a restoration action within the priority Salmo watershed. The set-up of the study applies a Before-After-Control-Impact-Paired experimental and analytic design.

Key results and observations from the second year of the study included three juvenile Bull Trout in Site 2 in Curtis Creek confirming that spawning does occur in at least one of these streams. A result of significance is that the main chemistry, primary productivity, secondary productivity and fish metrics were quite similar between the two selected creeks meaning that they would likely be suitable replicates for a Before-After-Control-Impact analysis as was proposed.

Total Nitrogen to Total Phoshporus (TN:TP) ratios ranged from a low of 13:1 to a high of 62:1 in Curtis Creek and between 28:1 to 57:1 in Qua Creek in the two sampling periods (June in early season and September in late season). Peak chlorophyll a densities were assessed as an index of primary productivity and in Curtis Creek peaked at 6.5 ug and in Qua Creek peaked at 9.3 ug. Invertebrate diversity as measured by the Shannon diversity indices ranged between 1.3 – 2.1 in both creeks, with the highest diversity found in lower Curtis creek. Lineal density was slightly higher in Qua Creek for the second year in a row ranging from 1.3-1.6 ind/m for all fish species. In Curtis Creek, the lineal density ranged from 0.9-1.2 ind/m. Temperatures in both creeks were appropriate for Bull Trout and Rainbow Trout rearing and for Bull Trout presence.

Proposed fertilization using this background study will require delivery of 10 kg bags of fertilizer pellets to a chosen fertilization site. As such, accessible options along each creek was also discussed. The access to mid- and upper-Qua creek is limited to hiking (or helicopter) and the access to upper Curtis creek is by foot or mountain or trail bike. The access to lower Qua and lower and mid-Curtis Creeks is by 4x4 vehicle on logging roads.

These two creeks are likely suitable for fertilization treatment after further baseline data are collected should a compensation option in the watershed be desired. Further information on the effects of fertilization on Rainbow Trout and the overall health of the streams should be completed before the fertilization occurs if the information is available in the literature. Another compensation option would be the translocation of adult Bull Trout into the Salmo River to bolster the very low numbers of Bull Trout spawning in the Salmo watershed. This option would require significant background research on the associated risks and benefits of translocation. Augmenting the adult population could eventually seed these creeks with juvenile Bull Trout through increasing spawner density and utilization.

Table of Contents

EXECUTIVE SUMMARY .... **I**

LIST OF TABLES .... **III**

INTRODUCTION **4**

GOALS AND OBJECTIVES **5**

STUDY AREA **6**

METHODS **11**
- Water Chemistry 11
- Periphyton Growth 11
- Invertebrate Diversity and Biomass 11
- Fish Abundance and Condition 12
- Water Temperature 12
- Habitat Surveys 13
- Analysis 13

RESULTS **13**
- Water Chemistry 13
- Periphyton Growth 24
- Invertebrate Diversity and Biomass 25
- Fish Abundance and Condition 35
- Water Temperature 39
- Habitat Surveys 40

DISCUSSION **40**

RECOMMENDATIONS **41**

CLOSURE **43**

REFERENCES **44**

LIST OF FIGURES

Figure 1 Overview map showing the locations of Curtis and Qua Creeks in the context of the Salmo and Pend d'Oreille River watersheds. 8

Figure 2 Sampling sites for water temperature, periphyton, fish and invertebrates from Curtis Creek. 9

Figure 3 Sampling sites for water temperature, periphyton, fish and invertebrates from Qua Creek. 10

Figure 4 Total Nitrogen (N) and Phosphorus (-P) concentrations for Curtis Creek, by period (early and late) and sampling locations (Lower, Middle and Upper) in 2015 and 2016. 14

Figure 5 Total Nitrogen (N) and Phosphorus (P) concentrations for Qua Creek, by period (early and late) and sampling locations (Lower, Middle and Upper) in 2015 and 2016. 14

Figure 6 Micrograms of chlorophyll-a through time for two, six-week growth periods in Curtis and Qua Creeks, 2015 and 2016. 25

Figure 7 Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) from three-minute standard kick sample by creek and location for 2015 and 2016. 26

Figure 8 Shannon Diversity index for invertebrates by creek and sampling site for 2015 and 2016. 27
Figure 9 Length (mm) frequency for Rainbow Trout by year, creek and location (electrofishing sampling site). 36
Figure 10 Body mass (g) by fork length (mm) for Rainbow Trout by year, creek and location (electrofishing sampling site). 37
Figure 11 Lineal density (ind/m) of Rainbow Trout by creek and location (electrofishing sampling site) in 2016 Error bars represent 95% credible intervals. Note, only fish > 50 mm were included in this analysis. 38
Figure 12 Capture efficiency of Rainbow using backpack electrofishing in both creeks by year. 38
Figure 13 Water Temperature (°C) for upper and lower stations on Curtis and Qua Creeks for 2015 and 2016. The blue horizontal lines mark 9°C and 12°C, preferred ranges for Rainbow Trout. 39

List of Tables

Table 1 TN: TP ratios by location, period and year for Curtis and Qua Creeks. 15
Table 2 Water chemistry results all analytes for Curtis and Qua Creeks for June (month=6) and September (month=9), 2016. 16
Table 3 Sampling dates for periphyton growth study by series for Curtis and Qua Creeks. 24
Table 4 Benthic macroinvertebrate diversity by count and family for Curtis Creek in 2015 and 2016. 27
Table 5 Benthic macroinvertebrate diversity by count and family for Qua Creek in 2015 and 2016. 31

Introduction

The Salmo River has been identified by the FWCP as a priority river in the Columbia and is the only major tributary of the Pend d'Oreille watershed in Canada or the United States that supports a population of Bull Trout (*Salvelinus confluentus*). Bull Trout are blue-listed in the province of B.C.. Bull Trout within the Salmo watershed are focal species in the FWCP Species of Interest Action Plan and are considered to have a provincial C1 or high risk conservation status due to the severity, scope and immediacy of the threats and the low spawner numbers (Hagen and Nellestijn 2015).

Redd count numbers through time (1998-2009) ranged from 38-109 in the Salmo watershed and spawner abundance is approaching less than 50 spawners (Hagen and Decker, 2011). Since 2007 only two years have shown adult spawner escapement exceeding 100, there were 54 redds enumerated in 2009 and 53 in 2015 indicating a population of 108 and 106 respectively based on a multiplier of 2.0 (Hagen and Decker 2011). The decline of Bull Trout in this system has multiple causes, likely including entrainment losses through Seven Mile Dam, restricted migration relative to historical availability due to dams, the loss of anadromous salmonid populations and their attendant nutrient influxes into the watershed, the presence of invasive Brook Trout (*Salvelinus fontinalis*) populations in the Salmo mainstem, water temperature increases through time which are negatively correlated with Bull Trout abundance (Parkinson and Haas, 1996), lack of a robust prey fish base, and habitat losses of riverine habitat at the watershed scale (Decker, 2010; Hagen, 2008; Hagen and Decker, 2011).

Along with Bull Trout, Rainbow Trout are also a focal species of interest to the compensation program. When surveyed in 2004, less than 200 adults (fish >400mm) were enumerated in the mainstem of the Salmo River (Hagen and Baxter, 2004) so this species is also of conservation concern and is considered a key indicator species for increasing Ecosystem Health in the Salmo watershed by the Watershed Planning Team (WPT). When the Salmo Watershed Streamkeepers Society (SWSS) and the Fish and Wildlife Compensation Program (FWCP) reconvened the WPT, a trans-boundary (Canada/US) multi-stakeholder collaborative group of Stewardship interests, First Nations, industry, and government agencies from both nations worked to build an action-based plan. The plan re-evaluated restoration, research, monitoring and educational status of their watershed-based Fish Sustainability Plan, both Rainbow and Bull Trout were included as indicators to provide performance measures for improving ecosystem health. The Qua, Curtis Crystal Green Restoration Preparation Project (QCRP) was unanimously endorsed by the WPT.

The QCRP was motivated by the need to explore and implement restoration options within the watershed to preserve and enhance the populations of Bull and Rainbow Trout. In order to do this, the two headwater creeks of focus within the Salmo watershed have begun to be assessed for their viability to support nutrient restoration projects. Qua and Curtis Creeks are headwater tributaries of the Clearwater and Sheep Creek respectively. The Clearwater and Sheep Creeks flow into the Salmo River (Figure reference). The creeks' viability to support nutrient restoration is being assessed by measuring: the trophic status of each creek with water chemistry, the primary productivity by assessing periphyton growth, the benthic macroinvertebrate diversity and the density and size of Rainbow Trout and Bull Trout.

In order to assess the effectiveness of any restoration, pre-restoration data are a critical part of the monitoring and evaluation process and are often neglected in the rush to restore for the species of concern. This project is a proposed three-year endeavor that aims to scientifically assess the baseline productivity of the streams to allow assessment in future if restoration options are implemented in the creeks.

Stream fertilization is one restoration and compensation option for ecosystems that have been impacted by hydro-electric development to partially address the loss of productivity from the deprivation of marine nutrients brought in by anadromous fish to the system. Findings thus far on the use of pelletized fertilizers have pointed to the efficacy and ease of application of Crystal Green pellets in flowing water systems to raise nitrogen and phosphorus levels sufficiently to have a biologically and statistically significant effect. They are particularly well suited to remote systems such as Curtis and Qua Creeks since they have a slow dissolution rate and can therefore be hiked in or helicopter or quad dropped only once or twice per season.

We are proposing to fertilize one of the two study creeks with Crystal Green after adequate baseline data on water chemistry, productivity and fish densities are obtained. Qua Creek and Curtis Creek were selected for this study because they are ideally suited for a paired statistical design where one creek is restored with nutrient addition and the other is retained as a control. In the Salmo watershed, the nutrient addition project on Sheep Creek project has demonstrated to increase fish production, through both gains in size and in abundance depending upon species and life stage as well as increasing primary productivity up to four times greater than unfertilized levels and increasing density of benthic macroinvertebrates (Decker 2010). These effects were obtained with the addition of liquid fertilizer in the Sheep Creek BACI study, but have also resulted from the addition of Crystal Green pellet fertilizer (5-27-0 N-P-K) in Vancouver Island Streams (Pellett, 2011).

This project primarily aligns with the FWCP's Columbia Region Streams Action Plan. Within this plan the Salmo River is listed as a first priority stream. This plan also lists assessing and restoring habitat for Bull Trout as Priority 1 Actions and conducting inventory as Priority 2 . It also lists Habitat Restoration as a Priority Action for fluvial Rainbow Trout. Fertilization is listed as a Priority 3 Action for streams and rivers, and baseline inventories, evaluation, and planning to refine target streams in this project is required for better understanding and opportunity to restore and enhance streams through fertilization

With a focus on enhancing habitat for Bull Trout and Rainbow Trout, this project also aligns with the FWCP's Species of Interest Action Plan. In this plan, they are listed as Priority 2 and Priority 1 species in streams, respectively. This project covers actions within "Research and Information Acquisition" and "Monitoring and Evaluation" for each of these species.

Goals and Objectives

The overall objective of the Qua and Curtis Nutrient Restoration Preparation Project is to assess baseline productivity and to evaluate the streams as candidates for nutrient restoration using Crystal Green pellet solid fertilizer (produced using Ostara Technologies). Depending on the outcomes of this study, fertilization could be used to enhance the food web system for juvenile fish by increasing nutrient availability which will in turn increase periphyton growth, invertebrates feeding on periphyton, and finally, fish feeding on invertebrates. This second year of the project was designed to replicate what was done in the first year of 2015 and obtain the necessary geographic and monitoring data on primary productivity and fish abundance and condition prior to potential fertilization. The study is designed as a Before-After-Control-Impact (BACI) study to allow the determination of any net effects of future restoration in a statistically robust way. The initial monitoring activity of this study will be completed in the fall of 2017.

The objectives for this program are as follows:

1) Determine the access options for each creek taking into consideration the potential to bring in 10kg bags of pellet fertilizer in the future.
2) Set up three, long-term monitoring sites for algal productivity in each creek near the confluence, midway along the length of the accessible creek and near the upper end of the accessible creek.
3) Obtain baseline water chemistry and primary productivity data from Curtis and Qua Creek to:
   a) compare to other creeks in which fertilization has been successful at augmenting fish production and to
   b) provide a 'before' data series to allow statistical comparison if fertilization occurs.
4) Obtain invertebrate community diversity (to the family level) and biomass estimates for Curtis and Qua Creek.
5) Determine that Bull Trout spawn and rear in Curtis and Qua Creeks through backpack electrofishing sampling of the creeks. Gather relative abundance and condition data on fish captured at four sites within each creek
6) Provide a basic habitat overview of Curtis and Qua Creek within the surveyed section to estimate spawning and rearing potential.
7) Install water temperature loggers near the confluence of Curtis and Qua Creek and in the most upstream accessible site to track the temperature suitability for Bull Trout in Curtis and Qua Creek.

Study Area

The Salmo River is a 5th order system rising from the Selkirk Mountains 12 km southeast of Nelson, BC. (Figure 1). The river progresses in a southerly direction for approximately 60 km from its origin to the confluence with the Pend d'Oreille River (Seven Mile Reservoir) and the area of its catchment is 123,000ha.

Elevation in the basin ranges from 564 metres above sea level (masl) at its confluence to the Pend d'Oreille River to 2,343 masl at the height of land. Within this elevation range, the system comprises two biogeoclimatic zones (Braumandl and Curran 1992). At lower elevations, the valley lies within the Interior Cedar-Hemlock (ICH) zone, while areas in the higher elevations are found within the Englemann Spruce-Subalpine Fire (ESSF) zone. The Salmo River has a total of ten 2nd and 3rd order tributaries (including Curtis and Qua Creeks, Apex Creek, Clearwater Creek, Hall Creek, Barrett Creek, Ymir Creek, Porcupine Creek, Erie Creek, and Hidden Creek) and two 4th order tributaries (Sheep Creek and the South Salmo River) **(**Figure 1). The Water Survey of Canada maintains a gauging station on the Salmo River near the town of Salmo (Anonymous 1947). Mean annual discharge in the Salmo River (1949-1976) was 32.5 $m^3 \cdot sec^{-1}$, with mean monthly minimum and maximum values of 7,5 and 128.6 $m^3 \cdot sec^{-1}$, respectively. Runoff reaches a peak in May, with the highest flows between April and July each year.

All field study components were completed within Curtis and Qua Creeks in the Salmo River watershed (Figure 1). Curtis Creek is a 2nd order, lake-headed stream with strong year round flow that meets Sheep Creek approximately 200 m downstream of a known Bull Trout passage barrier on the Sheep. The elevation at Curtis at its source is ~1860 masl and it drops about 670 m to an elevation of 1190 masl at its confluence over its 5.9 km length (Figure 2). Qua Creek is a 2nd order, lake-headed stream that drops approximately 600 m over a 5.2 km distance from 1720 masl to 1120 masl where it meets Clearwater Creek (Figure 3).

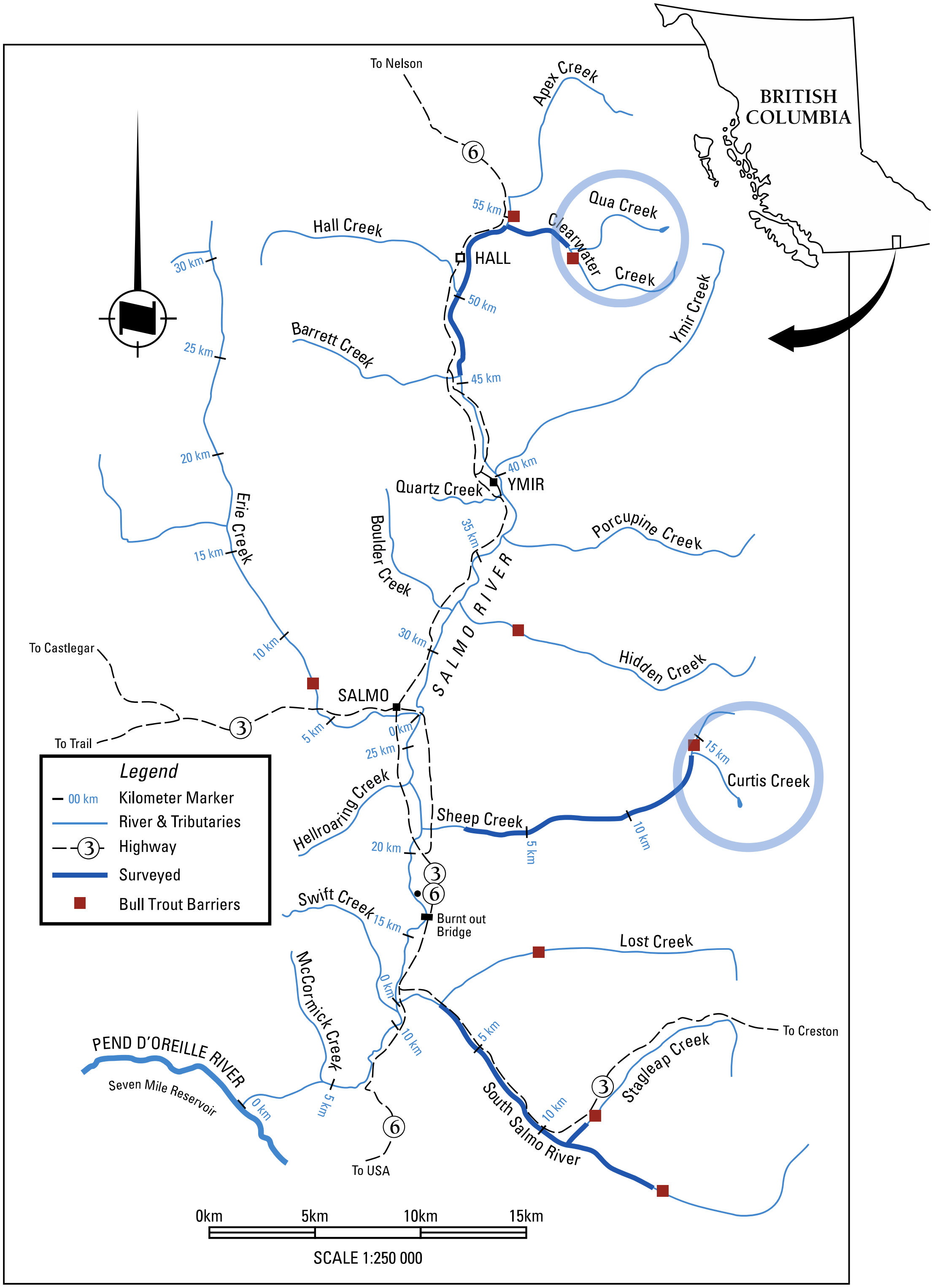


Figure 1 Overview map showing the locations of Curtis and Qua Creeks in the context of the Salmo and Pend d'Oreille River watersheds.

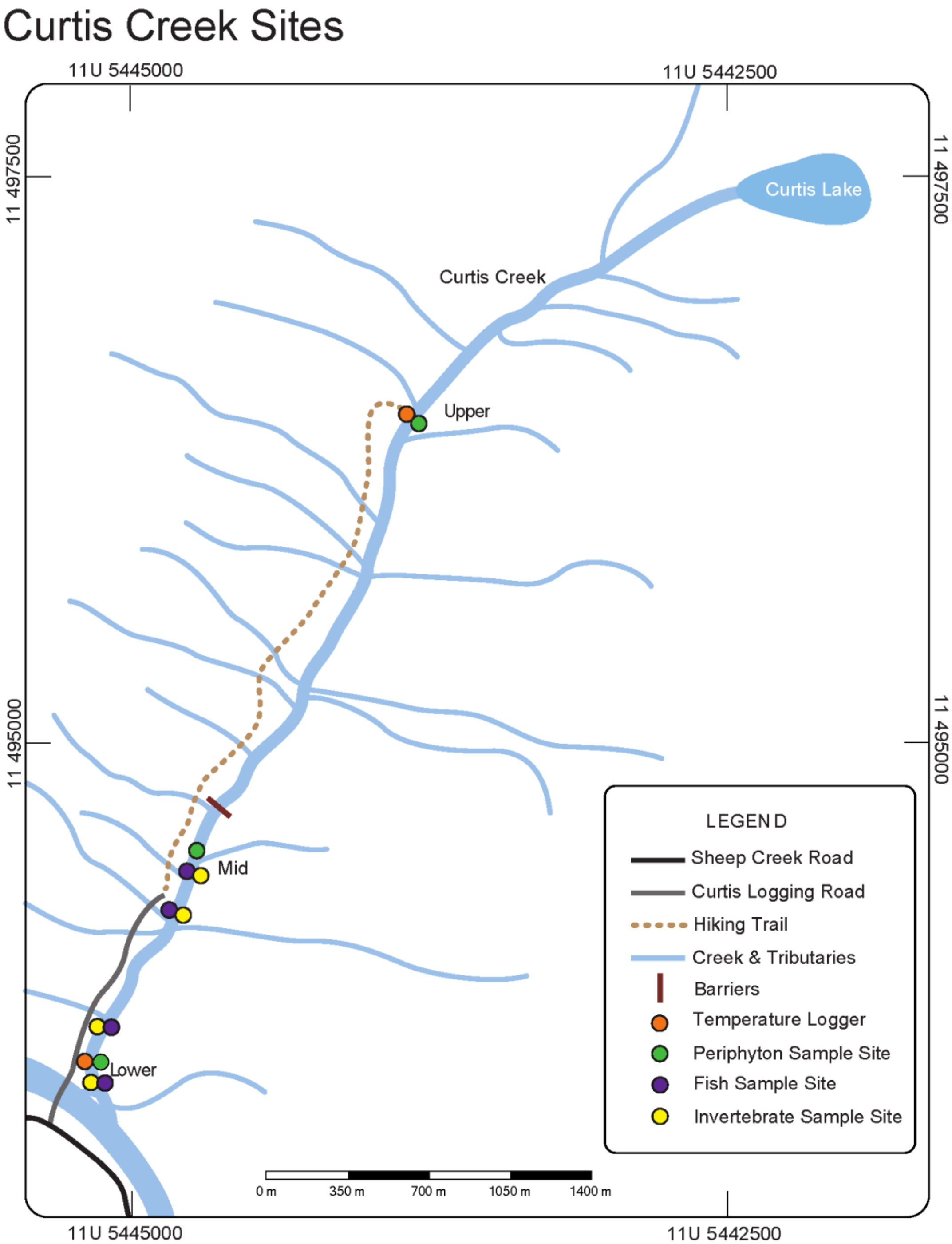


Figure 2 Sampling sites for water temperature, periphyton, fish and invertebrates from Curtis Creek.

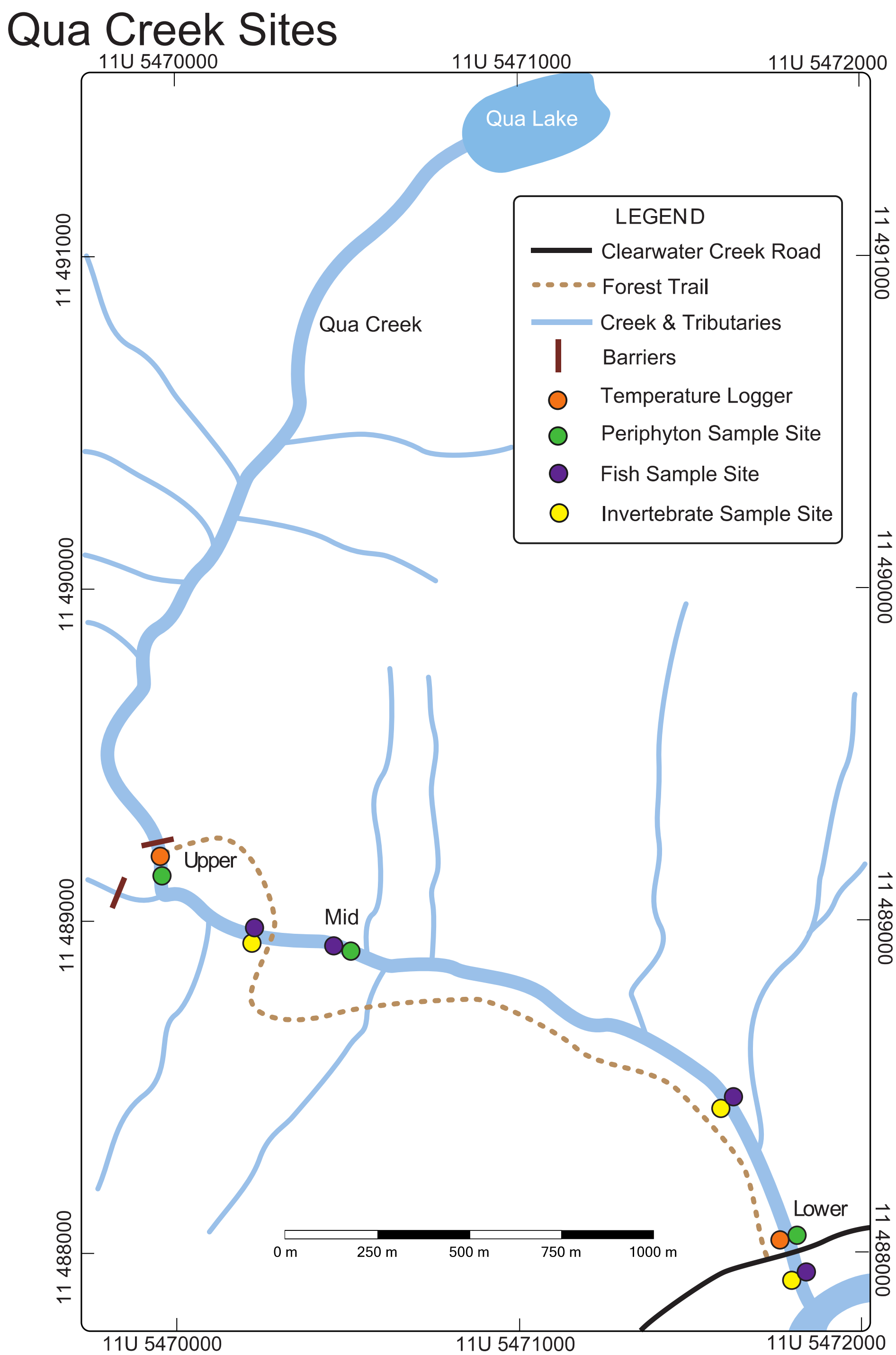


Figure 3 Sampling sites for water temperature, periphyton, fish and invertebrates from Qua Creek.

Methods

The methods used to meet the study objectives were based on the currently accepted scientific approaches and those utilized in the Sheep Creek Fertilization: Food for Fish Fertilization Project nutrient restoration program (Decker, 2010; Nellestijn, 2014) to allow ready comparisons across systems and projects as well as within the project sample set. The methods for each of the main tasks are outlined in further detail below.

Water Chemistry

To assess the natural trophic status of the study streams, water samples were collected at each of three sites in Qua Creek and Curtis Creeks on June 28th, 2016 (early) and on September 12th, 2016 (late), similar to timeframes conducted in 2015 (3 samples per creek at two times in the year). All water samples were analyzed for pH, conductivity, alkalinity, nitrogen, phosphorus, and total metals. The nutrient assessment used the measures of Total Nitrogen (TN) and Total Phosphorus (TP). All samples were collected into bottles provided by the lab with fixatives in the bottles themselves, then immediately placed in coolers with freezer packs and shipped by courier to CARO Analytics in Kelowna, B.C within 24 hours.

Periphyton Growth

Three sites were selected in the accessible section of each stream: upper, mid and lower locations. The first set of periphyton blocks (growth series 1) were installed at each site in both creeks on June 28th, 2016 and were sampled each week thereafter for six weeks following the protocols set out in (Perrin and Richardson, 1997) . A second set of periphyton blocks (growth series 2) were then installed on August 10th, 2016 after the first six-week period concluded and sampled weekly until September 13th, 2016 when the blocks were removed from the streams. The blocks were constructed of ¼" florist foam sheets cut to fit a half of a concrete patio stone and attached with six rubber bands in a grid pattern to hold the foam and concrete together. Blocks were installed in full light locations at a set depth below surface to control for light attenuation and variability amongst sites. Samples of the periphyton were taken by pressing a 7 dram plastic vial into the florist foam and removing the resulting circle of known diameter (25mm). Samples were immediately put on ice to retard further growth and were stored in a freezer at less than 4°C until shipping to CARO Analytics for analysis in a chilled cooler. The analyte from the foam samples was mg/m^2 of chlorophyll *a*. These data were used to generate a growth curve and estimate peak biomass levels. The biomass of each sample was analyzed for chlorophyll *a* concentration using standard lab fluorometric procedure after extraction in 90% acetone as initially described by Holm-Hansen et al. (1965), and Nusch (1980).

Invertebrate Diversity and Biomass

Field crews sampled benthic macroinvertebrate abundance and diversity in riffle habitat in each stream on September 13th, 2016, during the time period that is recommended by the CABIN protocol for maximum diversity and abundance of most common invertebrate families (Environment Canada 2012). Sample collection was timed with the Sheep Creek project (Decker et al. 2002) to allow for data comparison. Three replicate samples were collected in each creek

(6 samples in total) using a 3-minute kick net sampling methodology from sites selected to be the closest riffle to the fish sampling sites. The sites were distributed with two downstream of the potential fertilization input station and one upstream of the potential distribution point. During the three minutes, the sampling person tracked a zigzag pattern across the riffle whilst constantly kicking and twisting to float the benthic macroinvertebrates to the surface where the current pushed them into the net being held downstream. The net used had a 400 um nitex mesh net and is the standard sized and shaped triangular kick nets as used for Canadian Aquatic Biomonitoring Network (CABIN) sampling (Environment Canada 2012). Samples were immediately preserved with 70% ethanol and were labeled on the outside and inside of the samples according to CABIN protocols. These samples were sent to Westcott Environmental Services (Smithers, BC) for taxonomic identification to family level. Once the samples were processed, it was determined that the small size and early instar stages of the invertebrates dominating the samples and the heavy detritus load did not allow the ash-free biomass to be calculated.

Fish Abundance and Condition

Four locations were sampled for fish relative abundance and condition in each of the two study systems (Figure 2 and Figure 3). Electrofishing surveys were conducted from August 2nd - 3rd, 2016 to assess length (mm), lineal density (ind/m), standing stock and weight (g) for each species. Sites were the same as in the first year of the study (Irvine and Nellestijn, 2016) and multiple-pass electrofishing (either three passes or two passes) was used as the method to estimate juvenile salmonid (Rainbow Trout and Bull Trout) abundance at all sites in each stream (Wyatt, 2002). Capture efficiency for each stream was estimated by modeling the depletion at sites in each habitat type and is more fully described in the analysis section. The capture efficiency is the probability of capturing an individual fish on a single pass (Wyatt, 2002). It is a nuisance parameter in the sense that it is not of direct interest but needs to be estimated in order to estimate the abundance (Kéry and Schaub, 2011). It is estimated from the rate of decline in the number of fish caught on each subsequent pass assuming a constant capture probability on each pass (Wyatt, 2002). Prior to electrofishing, the downstream boundary of each site was enclosed with stop nets that spanned the wetted width of the stream and was secured to the substrate with cobbles. Electrofishing was initiated at the upstream end of the site and consisted of a thorough search in a downstream direction to the stop net at the bottom of the site. The stop net was searched at the end of each pass to ensure capture efficiency estimates were inclusive of the effort per pass. A three-person crew conducted sampling, with one person operating the electrofisher (Smithroot LR-24 backpack unit) and one netter as well as one person setting up gear on the bank and monitoring fish health. All fish captured during electrofishing were identified to species, measured for fork length and weight, and released back into the site following the completion of sampling.

Water Temperature

Two temperature loggers (Hobo Water Temperature Pro V2) were placed in each stream in 2015 and remained in situ throughout the winter to get the full temperature profile. In each stream, one logger was placed toward the headwaters and another close to the confluence. In both 2015 and 2016, the loggers were downloaded in September for the collected data.

Habitat Surveys

Broad physical habitat categories of each creek were examined during the fall Bull Trout spawner and habitat survey conducted as part of another study project in the watershed in 2015 (Irvine and Nellestijn, 2016).

Analysis

After completion of data collection, all data were entered into comma-delimited spreadsheets and were then collated into a customized SQLLite (Access compatible) database. The analytic software R 3.3.0 (R Core Team 2015) then executed SQL commands that ran validation tests on the data and extracted datasets for subsequent analysis. This approach not only eliminates any possible confusion associated with multiple datasets, but also allows reports to be generated and analyses rerun immediately following data entry or data correction. All entered data were plotted extensively to look for errors and outliers.

Juvenile fish estimates of density were obtained from the electrofishing by implementing a depletion model in a Bayesian context to obtain the capture efficiency and then by dividing the total catches by the estimates of capture efficiency (Kéry and Schaub, 2011). The periphyton growth was plotted to assess growth rates and absolute levels of primary productivity at each site within each creek. Water chemistry and macroinvertebrate diversity and biomass were databased and presented in plots to enable understanding of trends and patterns.

The data were queried from the database and analysed using hierarchical Bayesian methods. The analyses were performed using R 3.3.0 (R Core Team 2015), JAGS >= 3.3.0 (Plummer, 2003) and the jaggernaut >= 0.1.6 R package (Thorley, 2013). Plots were produced using the ggplot2 >= 0.9.3 R package (Wickham, 2009). The model descriptions, parameter definitions and estimates can be found in the analytic online report at the link below provided by Poisson Consulting as custodial support for the SWSS and the FWCP:

http://www.poissonconsulting.ca/f/234261667

Results

Water Chemistry

The TN: TP ratios ranged from 12.9 – 53 in Curtis Creek and from 15.2 – 31.5 in Qua Creek (**Table 1**). The analyses of the two seasonal water samples in 2016 showed that nitrogen is relatively abundant in the two study streams throughout the summer season (Error! Reference source not found.**,** Figure 4).

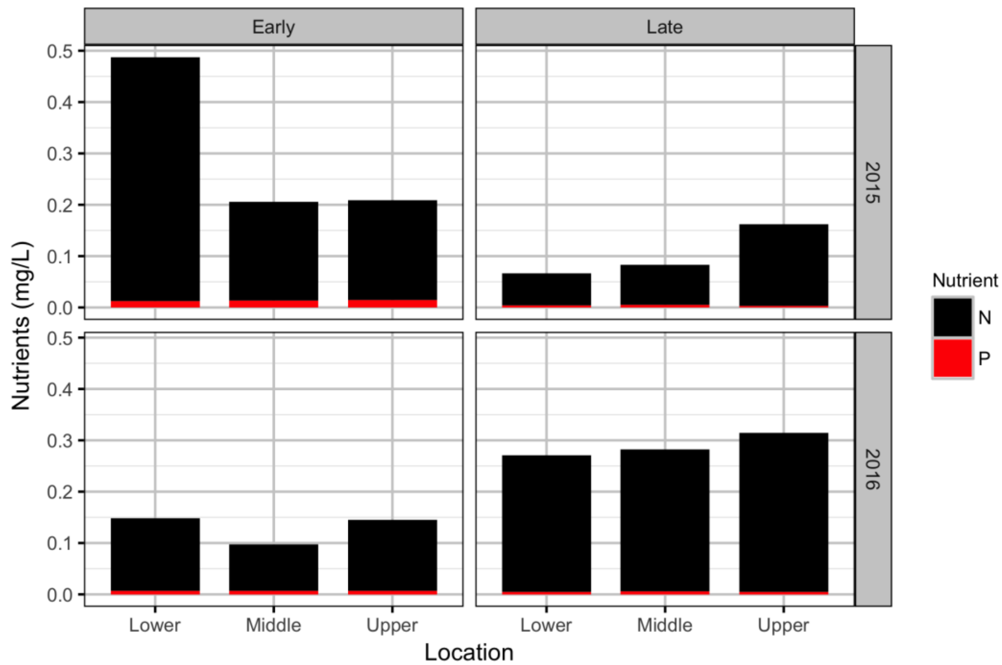


Figure 4 Total Nitrogen (N) and Phosphorus (-P) concentrations for Curtis Creek, by period (early and late) and sampling locations (Lower, Middle and Upper) in 2015 and 2016.

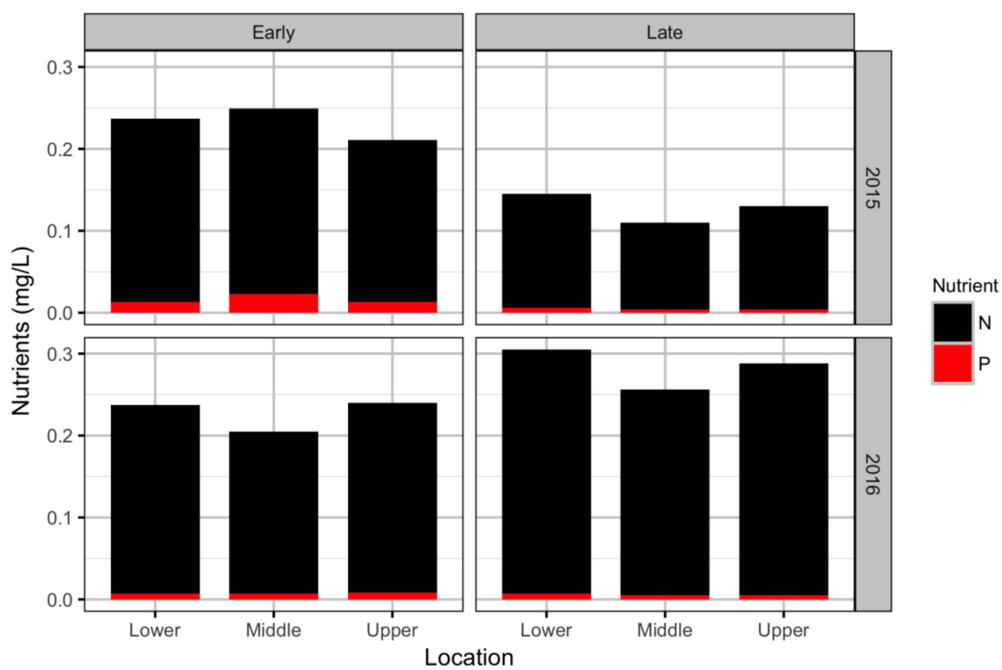


Figure 5 Total Nitrogen (N) and Phosphorus (P) concentrations for Qua Creek, by period (early and late) and sampling locations (Lower, Middle and Upper) in 2015 and 2016.

Total nitrogen was compared to total phosphorus in a TN: TP ratio for each station in early and late season in 2015 and 2016. In 2015, the ratio in Curtis Creek and Qua Creek ranged from 12.9-53.0 and 9.8-31.5, respectively. In Curtis Creek, in 2016 the ratio ranged from 12.9 in early season at the middle site to 61.8 in late season in the upper site (Table 1). In Qua Creek in 2016, the ratio ranged from 28.3 in early season at the middle site to 56.6 in late season in the upper site (Table 1). Results will be compared to the water quality guidelines and to other fertilization program systems in the third year analytic report in 2017/18.

Table 1 TN: TP ratios by location, period and year for Curtis and Qua Creeks.

		Curtis Creek			Qua Creek		
Year	Period	Curtis Creek-Lower	Curtis Creek-Mid	Curtis Creek - Upper	Qua Creek - Lower	Qua Creek - Mid	Qua Creek - Upper
2015	Early	39.6	14.8	12.9	17.2	9.8	15.2
	Late	15.8	15.6	53.0	23.2	26.5	31.5
2016	Early	20.1	12.9	19.7	32.9	28.3	29.0
	Late	53.2	46.0	61.8	42.6	50.2	56.6

Table 2 Water chemistry results all analytes for Curtis and Qua Creeks for June (month=6) and September (month=9), 2016.

Analyte	Units	Period	Year	Curtis Creek - Lower	Curtis Creek - Mid	Curtis Creek - Upper	Qua Creek - Lower	Qua Creek - Mid	Qua Creek - Upper
Alkalinity, Total as CaCO3	mg/L	Early	2015	22	4	5	27	23	27
Alkalinity, Total as CaCO3	mg/L	Late	2015	16	5	7	25	21	25
Alkalinity, Total as CaCO3	mg/L	Early	2016	8	3	3	12	10	12
Alkalinity, Total as CaCO3	mg/L	Late	2016	24	4	11	27	22	25
Aluminum, total	mg/L	Early	2015	<0.05	0.09	<0.05	<0.05	0.07	<0.05
Aluminum, total	mg/L	Late	2015	0.07	0.12	0.11	<0.05	<0.05	<0.05
Aluminum, total	mg/L	Early	2016	0.05	0.06	0.06	<0.05	<0.05	<0.05
Aluminum, total	mg/L	Late	2016	0.04	0.115	0.039	0.012	0.015	0.015
Antimony, total	mg/L	Early	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony, total	mg/L	Late	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony, total	mg/L	Early	2016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony, total	mg/L	Late	2016	3e<05	<2e-05	3e<05	<2e-05	2e<05	<2e-05
Arsenic, total	mg/L	Early	2015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic, total	mg/L	Late	2015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic, total	mg/L	Early	2016	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic, total	mg/L	Late	2016	<1e-04	<1e-04	1e<04	1e<04	1e<04	2e<04
Barium, total	mg/L	Early	2015	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium, total	mg/L	Late	2015	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium, total	mg/L	Early	2016	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium, total	mg/L	Late	2016	0.018	0.017	0.022	0.006	0.005	0.005
Beryllium, total	mg/L	Early	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Beryllium, total	mg/L	Late	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth, total	mg/L	Early	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth, total	mg/L	Late	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth, total	mg/L	Early	2016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth, total	mg/L	Late	2016	<2e-05	<2e-05	<2e-05	<2e-05	<2e-05	<2e-05
Boron, total	mg/L	Early	2015	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Boron, total	mg/L	Late	2015	<0.04	0.08	0.06	<0.04	<0.04	<0.04
Boron, total	mg/L	Early	2016	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Boron, total	mg/L	Late	2016	0.002	0.003	0.004	<8e-04	<8e-04	8e<04
Cadmium, total	mg/L	Early	2015	<1e-04	<1e-04	<1e-04	<1e-04	<1e-04	<1e-04
Cadmium, total	mg/L	Late	2015	<1e-04	<1e-04	<1e-04	<1e-04	<1e-04	<1e-04
Cadmium, total	mg/L	Early	2016	<1e-04	<1e-04	<1e-04	<1e-04	<1e-04	<1e-04
Cadmium, total	mg/L	Late	2016	8e<06	7e<06	5e<06	8e<06	6e<06	5e<06
Calcium, total	mg/L	Early	2015	7.8	<2	3.4	9.7	8.1	9.4
Calcium, total	mg/L	Late	2015	5.7	<2	2.6	8.4	6.7	7.8
Calcium, total	mg/L	Early	2016	3.7	<2	<2	5.7	4.8	5.2
Calcium, total	mg/L	Late	2016	9.1	2.3	4	10.3	7.9	9.2
Chromium, total	mg/L	Early	2015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium, total	mg/L	Late	2015	<0.005	0.016	<0.005	<0.005	<0.005	<0.005
Chromium, total	mg/L	Early	2016	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium, total	mg/L	Late	2016	4e<04	3e<04	3e<04	2e<04	1e<04	1e<04
Cobalt, total	mg/L	Early	2015	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04
Cobalt, total	mg/L	Late	2015	<5e-	<5e-04	<5e-	<5e-	<5e-	<5e-

				04		04	04	04	04
Cobalt, total	mg/L	Early	2016	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04
Cobalt, total	mg/L	Late	2016	4e<05	0.00016	4e<05	<1e-05	<1e-05	1e<05
Conductivity (EC)	uS/cm	Early	2015	52	22	28	60	49	55
Conductivity (EC)	uS/cm	Late	2015	45	23	21	59	48	56
Conductivity (EC)	uS/cm	Early	2016	22	11	11	30	25	28
Conductivity (EC)	uS/cm	Late	2016	60	25	28	63	51	56
Copper, total	mg/L	Early	2015	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
Copper, total	mg/L	Late	2015	<0.002	<0.002	0.002	<0.002	<0.002	<0.002
Copper, total	mg/L	Early	2016	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper, total	mg/L	Late	2016	2e<04	7e<04	4e<04	2e<04	2e<04	1e<04
Hardness, Total (Total as CaCO3)	mg/L	Early	2015	23.7	<5	10.7	26.5	22.4	25.5
Hardness, Total (Total as CaCO3)	mg/L	Late	2015	18.1	<5	8.3	23.4	18.7	21.6
Hardness, Total (Total as CaCO3)	mg/L	Early	2016	10.8	<5	<5	15.3	12.7	14
Hardness, Total (Total as CaCO3)	mg/L	Late	2016	27.8	9.51	12.7	28.4	21.9	25
Iron, total	mg/L	Early	2015	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron, total	mg/L	Late	2015	<0.1	0.6	<0.1	<0.1	<0.1	<0.1
Iron, total	mg/L	Early	2016	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron, total	mg/L	Late	2016	0.03	0.08	0.05	0.007	0.009	0.02
Lead, total	mg/L	Early	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead, total	mg/L	Late	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead, total	mg/L	Early	2016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead, total	mg/L	Late	2016	<2e-	5e<05	2e<05	<2e-	<2e-	<2e-

				05			05	05	05
Lithium, total	mg/L	Early	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lithium, total	mg/L	Late	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lithium, total	mg/L	Early	2016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lithium, total	mg/L	Late	2016	5e<04	6e<04	2e<04	2e<04	1e<04	1e<04
Magnesium, total	mg/L	Early	2015	1	0.7	0.5	0.5	0.5	0.5
Magnesium, total	mg/L	Late	2015	1	0.7	0.4	0.6	0.5	0.5
Magnesium, total	mg/L	Early	2016	0.4	0.3	0.3	0.2	0.2	0.2
Magnesium, total	mg/L	Late	2016	1.25	0.89	0.67	0.62	0.53	0.53
Manganese, total	mg/L	Early	2015	<0.002	0.004	<0.002	<0.002	0.007	0.002
Manganese, total	mg/L	Late	2015	<0.002	0.007	0.003	<0.002	<0.002	<0.002
Manganese, total	mg/L	Early	2016	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Manganese, total	mg/L	Late	2016	0.0014	0.0046	0.0032	2e<04	2e<04	5e<04
Molybdenum, total	mg/L	Early	2015	<0.001	<0.001	<0.001	0.001	0.008	0.002
Molybdenum, total	mg/L	Late	2015	<0.001	0.003	<0.001	0.002	0.001	<0.001
Molybdenum, total	mg/L	Early	2016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum, total	mg/L	Late	2016	9e<05	6e<05	1e<04	0.0012	0.001	0.001
Nickel, total	mg/L	Early	2015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel, total	mg/L	Late	2015	<0.002	0.003	0.002	<0.002	<0.002	<0.002
Nickel, total	mg/L	Early	2016	0.003	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel, total	mg/L	Late	2016	3e<04	6e<04	2e<04	<4e-05	4e<05	<4e-05
Nitrate as N	mg/L	Early	2015	0.325	0.054	0.052	0.072	0.052	0.074
Nitrate as N	mg/L	Late	2015	<0.01	<0.01	<0.01	0.025	0.031	0.039
Nitrate as N	mg/L	Early	2016	<0.01	<0.01	0.01	0.017	<0.01	0.015
Nitrate as N	mg/L	Late	2016	0.012	0.011	0.028	0.047	0.041	0.054
Nitrate+Nitrite as N	mg/L	Early	2015	0.325	0.054	0.052	0.072	0.052	0.074
Nitrate+Nitrite as N	mg/L	Late	2015	<0.01	<0.01	<0.01	0.025	0.031	0.039

Nitrate+Nitrite as N	mg/L	Early	2016	<0.01	<0.01	0.01	0.017	<0.01	0.015
Nitrate+Nitrite as N	mg/L	Late	2016	0.012	0.011	0.028	0.047	0.041	0.054
Nitrite as N	mg/L	Early	2015	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite as N	mg/L	Late	2015	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite as N	mg/L	Early	2016	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite as N	mg/L	Late	2016	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen, Dissolved Kjeldahl	mg/L	Early	2015	0.09	0.09	0.14	0.1	0.17	0.12
Nitrogen, Dissolved Kjeldahl	mg/L	Late	2015	0.06	0.08	0.14	0.09	0.07	0.08
Nitrogen, Dissolved Kjeldahl	mg/L	Early	2016	0.07	0.12	0.1	0.18	0.14	0.3
Nitrogen, Dissolved Kjeldahl	mg/L	Late	2016	0.07	0.16	0.1	<0.05	0.07	0.12
Nitrogen, Total	mg/L	Early	2015	0.475	0.193	0.194	0.224	0.226	0.198
Nitrogen, Total	mg/L	Late	2015	0.063	0.078	0.159	0.139	0.106	0.126
Nitrogen, Total	mg/L	Early	2016	0.141	0.09	0.138	0.23	0.198	0.232
Nitrogen, Total	mg/L	Late	2016	0.266	0.276	0.309	0.298	0.251	0.283
Nitrogen, Total Dissolved	mg/L	Early	2015	0.419	0.148	0.191	0.17	0.226	0.192
Nitrogen, Total Dissolved	mg/L	Late	2015	0.06	0.084	0.137	0.117	0.105	0.123
Nitrogen, Total Dissolved	mg/L	Early	2016	0.067	0.123	0.111	0.199	0.139	0.311
Nitrogen, Total Dissolved	mg/L	Late	2016	0.082	0.166	0.125	<0.05	0.109	0.172
Nitrogen, Total Kjeldahl	mg/L	Early	2015	0.15	0.14	0.14	0.15	0.17	0.12
Nitrogen, Total Kjeldahl	mg/L	Late	2015	0.06	0.08	0.16	0.11	0.08	0.09
pH	pH units	Early	2015	7.51	6.86	6.68	7.56	7.39	7.42
pH	pH units	Late	2015	7.23	6.93	6.95	7.46	7.34	7.47
pH	pH units	Early	2016	7.04	6.45	6.71	7.25	7.16	7.24
pH	pH units	Late	2016	7.43	6.77	7.16	7.54	7.44	7.49
Phosphorus, total	mg/L	Early	2015	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Phosphorus, total	mg/L	Late	2015	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Phosphorus, total	mg/L	Early	2016	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
Phosphorus, total	mg/L	Late	2016	0.009	0.005	<0.004	<0.004	<0.004	0.005
Phosphorus, Total as P	mg/L	Early	2015	0.012	0.013	0.015	0.013	0.023	0.013
Phosphorus, Total as P	mg/L	Late	2015	0.004	0.005	0.003	0.006	0.004	0.004
Phosphorus, Total as P	mg/L	Early	2016	0.007	0.007	0.007	0.007	0.007	0.008
Phosphorus, Total as P	mg/L	Late	2016	0.005	0.006	0.005	0.007	0.005	0.005
Potassium, total	mg/L	Early	2015	0.5	0.4	0.5	0.9	0.9	0.9
Potassium, total	mg/L	Late	2015	<0.2	<0.2	<0.2	0.4	0.3	0.3
Potassium, total	mg/L	Early	2016	<0.2	<0.2	<0.2	0.2	0.3	0.3
Potassium, total	mg/L	Late	2016	0.37	0.32	0.33	0.69	0.64	0.63
Selenium, total	mg/L	Early	2015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Selenium, total	mg/L	Late	2015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Selenium, total	mg/L	Early	2016	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Selenium, total	mg/L	Late	2016	<1e-04	<1e-04	<1e-04	5e<04	3e<04	3e<04
Silicon, total	mg/L	Early	2015	<5	<5	<5	<5	<5	<5
Silicon, total	mg/L	Late	2015	<5	<5	<5	<5	<5	<5
Silicon, total	mg/L	Early	2016	<5	<5	<5	<5	<5	<5
Silicon, total	mg/L	Late	2016	2.6	2.3	2.1	3.1	2.9	2.5
Silver, total	mg/L	Early	2015	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04
Silver, total	mg/L	Late	2015	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04
Silver, total	mg/L	Early	2016	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04	<5e-04
Silver, total	mg/L	Late	2016	<1e-05	4e<05	1e<04	<1e-05	<1e-05	<1e-05
Sodium, total	mg/L	Early	2015	0.7	0.6	0.5	1	1.2	0.9

Sodium, total	mg/L	Late	2015	0.4	0.6	0.3	0.7	0.6	0.6
Sodium, total	mg/L	Early	2016	<0.2	<0.2	<0.2	0.2	0.2	0.2
Sodium, total	mg/L	Late	2016	0.87	0.7	0.65	1.08	0.97	0.89
Strontium, total	mg/L	Early	2015	0.05	0.03	0.05	0.05	0.05	0.04
Strontium, total	mg/L	Late	2015	0.04	0.03	0.04	0.05	0.04	0.04
Strontium, total	mg/L	Early	2016	0.02	0.01	0.02	0.02	0.02	0.02
Strontium, total	mg/L	Late	2016	0.053	0.03	0.055	0.051	0.041	0.041
Sulfur, total	mg/L	Early	2015	21	11	<10	16	16	20
Sulfur, total	mg/L	Late	2015	<10	<10	<10	<10	<10	<10
Sulfur, total	mg/L	Early	2016	<10	<10	<10	<10	<10	<10
Sulfur, total	mg/L	Late	2016	0.5	0.9	0.8	<0.2	0.2	<0.2
Tellurium, total	mg/L	Early	2015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tellurium, total	mg/L	Late	2015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tellurium, total	mg/L	Early	2016	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tellurium, total	mg/L	Late	2016	<4e-05	<4e-05	<4e-05	<4e-05	<4e-05	<4e-05
Thallium, total	mg/L	Early	2015	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04
Thallium, total	mg/L	Late	2015	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04
Thorium, total	mg/L	Early	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium, total	mg/L	Late	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium, total	mg/L	Early	2016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium, total	mg/L	Late	2016	<2e-05	2e<05	2e<05	<2e-05	<2e-05	<2e-05
Tin, total	mg/L	Early	2015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tin, total	mg/L	Late	2015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tin, total	mg/L	Early	2016	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tin, total	mg/L	Late	2016	1e<04	1e<04	1e<04	1e<04	1e<04	7e<05

Titanium, total	mg/L	Early	2015	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Titanium, total	mg/L	Late	2015	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Titanium, total	mg/L	Early	2016	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Titanium, total	mg/L	Late	2016	<0.001	0.002	0.001	<0.001	<0.001	<0.001
Uranium, total	mg/L	Early	2015	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04
Uranium, total	mg/L	Late	2015	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04
Uranium, total	mg/L	Early	2016	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04	<2e-04
Uranium, total	mg/L	Late	2016	8e<05	4e<05	5e<05	6e<05	4e<05	5e<05
Vanadium, total	mg/L	Early	2015	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium, total	mg/L	Late	2015	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium, total	mg/L	Early	2016	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium, total	mg/L	Late	2016	<2e-04	<2e-04	<2e-04	3e<04	2e<04	2e<04
Zinc, total	mg/L	Early	2015	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Zinc, total	mg/L	Late	2015	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Zinc, total	mg/L	Early	2016	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Zinc, total	mg/L	Late	2016	0.003	0.005	0.003	0.002	0.003	0.002
Zirconium, total	mg/L	Early	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zirconium, total	mg/L	Late	2015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zirconium, total	mg/L	Early	2016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zirconium, total	mg/L	Late	2016	<2e-05	2e<05	3e<05	<2e-05	<2e-05	<2e-05

Periphyton Growth

Periphyton values are plotted in absolute micrograms per sample and the samples were extracted from a standardized 25mm diameter punch of the florist's foam growth substrate. The blocks were sampled on an approximately weekly basis (Table 3). The growth patterns in 2016 were similar to 2015, but the absolute levels of chlorophyll grown were substantively less at some sites (such as Curtis Lower and Qua Middle) (Figure 6). The peak chlorophyll a level reached in 2016 in Lower Qua Creek was 9.3ug and in Upper Curtis Creek was 6.5ug per 25mm area.

Table 3 Sampling dates for periphyton growth study by series for Curtis and Qua Creeks.

Sampling Dates	Growth Series
June 28	1
July 7	1
July 14	1
July 21	1
July 28	1
August 4	1
August 10	2
August 16	2
August 23	2
August 30	2
September 6	2
September 13	2

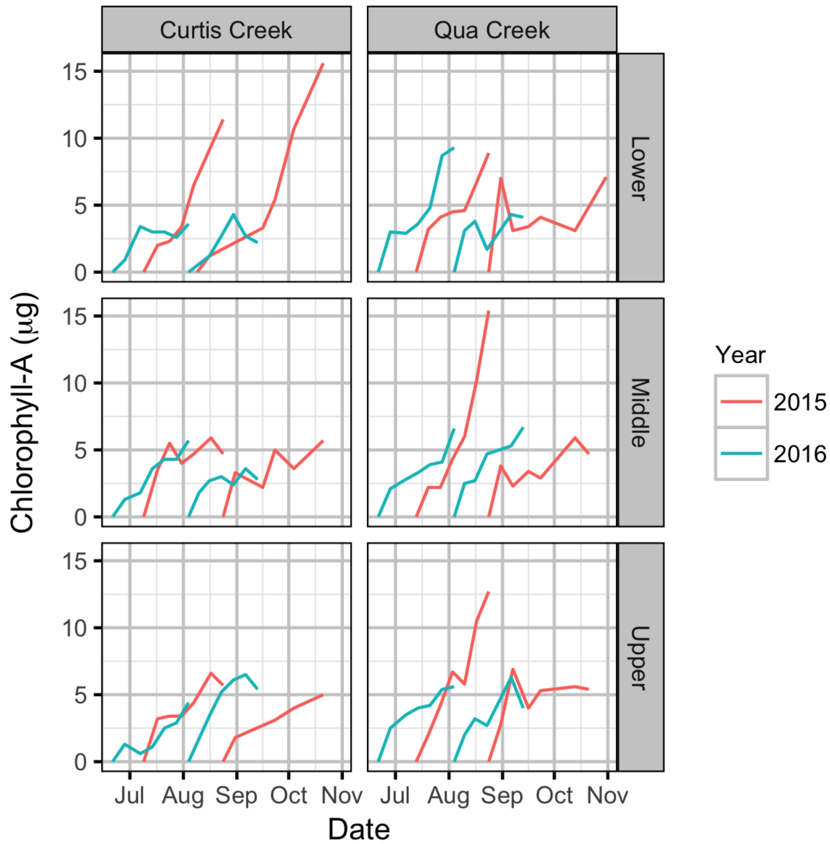


Figure 6 Micrograms of chlorophyll-a through time for two, six-week growth periods in Curtis and Qua Creeks, 2015 and 2016.

Invertebrate Diversity and Biomass

Invertebrate samples contained very early instar larvae and substantive amounts of organic debris that could not be separated from the invertebrates using elutriation due to the similarity in weights of the detritus and the sample. In order to accurately calculate biomass, every small wood piece would have to be picked out of the sample, which was not possible within the constraints of processing time per sample. The samples have been retained should biomass be sufficiently important to warrant the expense of the intensive picking that would be required, but only diversity is reported here. The Ephemeroptera, Plecoptera, Trichoptera (EPT) numbers were highest in the middle reach of Curtis Creek, in both years but showed a very different pattern in Qua Creek in 2016 with much higher numbers of EPT in the middle site in 2016 while that site had the lowest numbers in 2015 (Figure 7). The diversity of invertebrate species when calculated by the Shannon diversity index (an index that takes into account both evenness (how equally the community is distributed among the species present) as well as abundance of species present) ranged between 0.9 and 2.1 and was highest at the lower site of Curtis in both years and varied between years and sites for Qua Creek (Figure 8). The benthic macroinvertebrate diversity of each creek in totality is represented in two tables (Table 4 and Table 5).

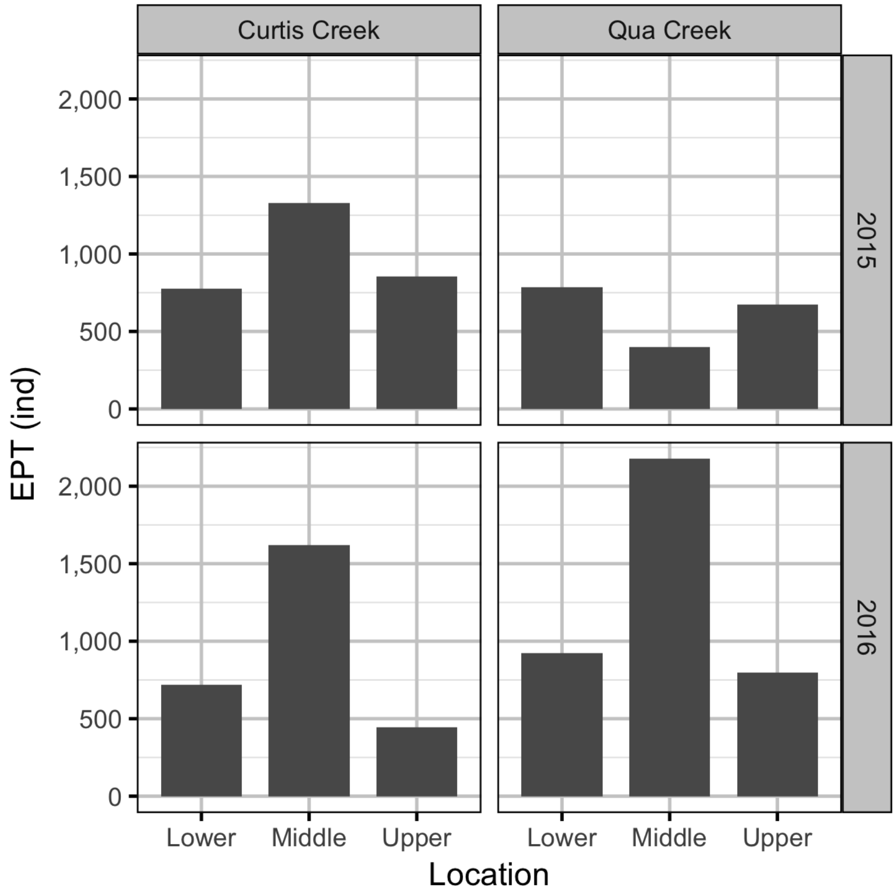


Figure 7 Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) from three-minute standard kick sample by creek and location for 2015 and 2016.

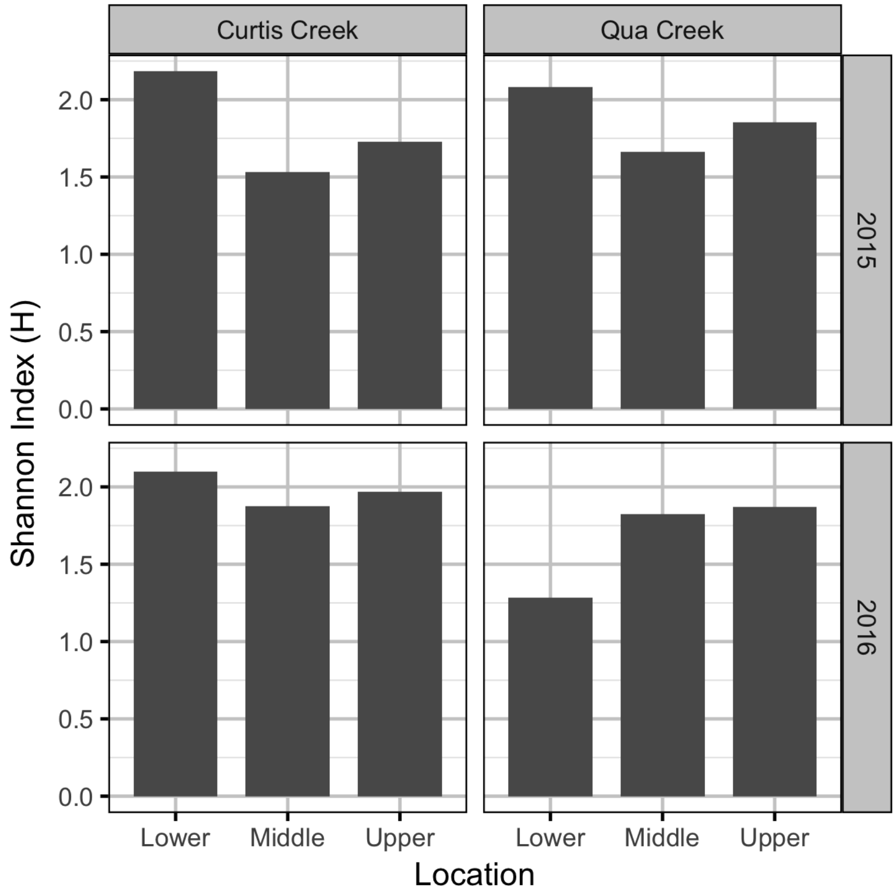


Figure 8 Shannon Diversity index for invertebrates by creek and sampling site for 2015 and 2016.

Table 4 Benthic macroinvertebrate diversity by count and family for Curtis Creek in 2015 and 2016.

Date	Creek	Location	Taxon	Family	Count	Percent Subsampled
2015-09-18	Curtis Creek	Lower	Coleoptera	Elmidae	8	20
2015-09-18	Curtis Creek	Lower	Diptera	Ceratopogonidae	1	20
2015-09-18	Curtis Creek	Lower	Diptera	Chironomidae	147	20
2015-09-18	Curtis Creek	Lower	Diptera	Psychodidae	0	20
2015-09-18	Curtis Creek	Lower	Diptera	Tipulidae	5	20
2015-09-18	Curtis Creek	Lower	Ephemeroptera	Ameletidae	11	20
2015-09-18	Curtis Creek	Lower	Ephemeroptera	Baetidae	46	20
2015-09-18	Curtis Creek	Lower	Ephemeroptera	Ephemerellidae	9	20
2015-09-18	Curtis Creek	Lower	Ephemeroptera	Heptageniidae	1	20
2015-09-18	Curtis Creek	Lower	Ephemeroptera	Leptophlebiidae	1	20
2015-09-18	Curtis Creek	Lower	Ephemeroptera	NA	14	20
2015-09-18	Curtis Creek	Lower	Hydracarina	NA	5	20

2015-09-18	Curtis Creek	Lower	Oligochaeta	NA	2	20
2015-09-18	Curtis Creek	Lower	Ostracoda	NA	57	20
2015-09-18	Curtis Creek	Lower	Plecoptera	Chloroperlidae	4	20
2015-09-18	Curtis Creek	Lower	Plecoptera	NA	22	20
2015-09-18	Curtis Creek	Lower	Plecoptera	Nemouridae	8	20
2015-09-18	Curtis Creek	Lower	Plecoptera	Peltoperlidae	2	20
2015-09-18	Curtis Creek	Lower	Plecoptera	Perlidae	1	20
2015-09-18	Curtis Creek	Lower	Plecoptera	Perlodidae	0	20
2015-09-18	Curtis Creek	Lower	Trichoptera	Glossosomatidae	8	20
2015-09-18	Curtis Creek	Lower	Trichoptera	Hydropsychidae	6	20
2015-09-18	Curtis Creek	Lower	Trichoptera	Limnephilidae	5	20
2015-09-18	Curtis Creek	Lower	Trichoptera	Rhyacophilidae	17	20
2015-09-18	Curtis Creek	Lower	Trichoptera	Brachycentridae	1	20
2015-09-18	Curtis Creek	Lower	Trichoptera	NA	0	20
2016-09-13	Curtis Creek	Lower	Coleoptera	Elmidae	6	29
2016-09-13	Curtis Creek	Lower	Diptera	Ceratopogonidae	0	29
2016-09-13	Curtis Creek	Lower	Diptera	Chironomidae	72	29
2016-09-13	Curtis Creek	Lower	Diptera	NA	2	29
2016-09-13	Curtis Creek	Lower	Diptera	Psychodidae	0	29
2016-09-13	Curtis Creek	Lower	Diptera	Simuliidae	0	29
2016-09-13	Curtis Creek	Lower	Diptera	Tipulidae	2	29
2016-09-13	Curtis Creek	Lower	Ephemeroptera	Ameletidae	8	29
2016-09-13	Curtis Creek	Lower	Ephemeroptera	Baetidae	16	29
2016-09-13	Curtis Creek	Lower	Ephemeroptera	Ephemerellidae	18	29
2016-09-13	Curtis Creek	Lower	Ephemeroptera	Heptageniidae	0	29
2016-09-13	Curtis Creek	Lower	Ephemeroptera	NA	95	29
2016-09-13	Curtis Creek	Lower	Hydracarina	NA	7	29
2016-09-13	Curtis Creek	Lower	Ostracoda	NA	23	29
2016-09-13	Curtis Creek	Lower	Plecoptera	Chloroperlidae	0	29
2016-09-13	Curtis Creek	Lower	Plecoptera	NA	55	29
2016-09-13	Curtis Creek	Lower	Plecoptera	Nemouridae	6	29
2016-09-13	Curtis Creek	Lower	Plecoptera	Peltoperlidae	0	29
2016-09-13	Curtis Creek	Lower	Trichoptera	Glossosomatidae	1	29
2016-09-13	Curtis Creek	Lower	Trichoptera	Hydropsychidae	1	29
2016-09-13	Curtis Creek	Lower	Trichoptera	Limnephilidae	3	29
2016-09-13	Curtis Creek	Lower	Trichoptera	Rhyacophilidae	6	29
2016-09-13	Curtis Creek	Lower	Trichoptera	Brachycentridae	0	29
2016-09-13	Curtis Creek	Lower	Trichoptera	NA	7	29
2015-09-18	Curtis Creek	Middle	Coleoptera	Elmidae	2	7

2015-09-18	Curtis Creek	Middle	Diptera	Ceratopogonidae	0	7
2015-09-18	Curtis Creek	Middle	Diptera	Chironomidae	202	7
2015-09-18	Curtis Creek	Middle	Diptera	Psychodidae	0	7
2015-09-18	Curtis Creek	Middle	Diptera	Tipulidae	2	7
2015-09-18	Curtis Creek	Middle	Ephemeroptera	Ameletidae	4	7
2015-09-18	Curtis Creek	Middle	Ephemeroptera	Baetidae	9	7
2015-09-18	Curtis Creek	Middle	Ephemeroptera	Ephemerellidae	4	7
2015-09-18	Curtis Creek	Middle	Ephemeroptera	Heptageniidae	4	7
2015-09-18	Curtis Creek	Middle	Ephemeroptera	Leptophlebiidae	2	7
2015-09-18	Curtis Creek	Middle	Ephemeroptera	NA	25	7
2015-09-18	Curtis Creek	Middle	Hydracarina	NA	2	7
2015-09-18	Curtis Creek	Middle	Oligochaeta	NA	1	7
2015-09-18	Curtis Creek	Middle	Ostracoda	NA	7	7
2015-09-18	Curtis Creek	Middle	Plecoptera	Chloroperlidae	8	7
2015-09-18	Curtis Creek	Middle	Plecoptera	NA	5	7
2015-09-18	Curtis Creek	Middle	Plecoptera	Nemouridae	22	7
2015-09-18	Curtis Creek	Middle	Plecoptera	Peltoperlidae	0	7
2015-09-18	Curtis Creek	Middle	Plecoptera	Perlidae	0	7
2015-09-18	Curtis Creek	Middle	Plecoptera	Perlodidae	1	7
2015-09-18	Curtis Creek	Middle	Trichoptera	Glossosomatidae	3	7
2015-09-18	Curtis Creek	Middle	Trichoptera	Hydropsychidae	0	7
2015-09-18	Curtis Creek	Middle	Trichoptera	Limnephilidae	1	7
2015-09-18	Curtis Creek	Middle	Trichoptera	Rhyacophilidae	5	7
2015-09-18	Curtis Creek	Middle	Trichoptera	Brachycentridae	1	7
2015-09-18	Curtis Creek	Middle	Trichoptera	NA	2	7
2016-09-13	Curtis Creek	Middle	Coleoptera	Elmidae	1	10
2016-09-13	Curtis Creek	Middle	Diptera	Ceratopogonidae	1	10
2016-09-13	Curtis Creek	Middle	Diptera	Chironomidae	119	10
2016-09-13	Curtis Creek	Middle	Diptera	NA	0	10
2016-09-13	Curtis Creek	Middle	Diptera	Psychodidae	0	10
2016-09-13	Curtis Creek	Middle	Diptera	Simuliidae	0	10
2016-09-13	Curtis Creek	Middle	Diptera	Tipulidae	0	10
2016-09-13	Curtis Creek	Middle	Ephemeroptera	Ameletidae	2	10
2016-09-13	Curtis Creek	Middle	Ephemeroptera	Baetidae	0	10
2016-09-13	Curtis Creek	Middle	Ephemeroptera	Ephemerellidae	4	10
2016-09-13	Curtis Creek	Middle	Ephemeroptera	Heptageniidae	4	10
2016-09-13	Curtis Creek	Middle	Ephemeroptera	NA	63	10
2016-09-13	Curtis Creek	Middle	Hydracarina	NA	7	10
2016-09-13	Curtis Creek	Middle	Ostracoda	NA	4	10

2016-09-13	Curtis Creek	Middle	Plecoptera	Chloroperlidae	1	10
2016-09-13	Curtis Creek	Middle	Plecoptera	NA	45	10
2016-09-13	Curtis Creek	Middle	Plecoptera	Nemouridae	29	10
2016-09-13	Curtis Creek	Middle	Plecoptera	Peltoperlidae	0	10
2016-09-13	Curtis Creek	Middle	Trichoptera	Glossosomatidae	5	10
2016-09-13	Curtis Creek	Middle	Trichoptera	Hydropsychidae	2	10
2016-09-13	Curtis Creek	Middle	Trichoptera	Limnephilidae	3	10
2016-09-13	Curtis Creek	Middle	Trichoptera	Rhyacophilidae	4	10
2016-09-13	Curtis Creek	Middle	Trichoptera	Brachycentridae	0	10
2016-09-13	Curtis Creek	Middle	Trichoptera	NA	13	10
2015-09-18	Curtis Creek	Upper	Coleoptera	Elmidae	0	11
2015-09-18	Curtis Creek	Upper	Diptera	Ceratopogonidae	0	11
2015-09-18	Curtis Creek	Upper	Diptera	Chironomidae	186	11
2015-09-18	Curtis Creek	Upper	Diptera	Psychodidae	0	11
2015-09-18	Curtis Creek	Upper	Diptera	Tipulidae	4	11
2015-09-18	Curtis Creek	Upper	Ephemeroptera	Ameletidae	4	11
2015-09-18	Curtis Creek	Upper	Ephemeroptera	Baetidae	17	11
2015-09-18	Curtis Creek	Upper	Ephemeroptera	Ephemerellidae	16	11
2015-09-18	Curtis Creek	Upper	Ephemeroptera	Heptageniidae	1	11
2015-09-18	Curtis Creek	Upper	Ephemeroptera	Leptophlebiidae	0	11
2015-09-18	Curtis Creek	Upper	Ephemeroptera	NA	12	11
2015-09-18	Curtis Creek	Upper	Hydracarina	NA	10	11
2015-09-18	Curtis Creek	Upper	Oligochaeta	NA	8	11
2015-09-18	Curtis Creek	Upper	Ostracoda	NA	7	11
2015-09-18	Curtis Creek	Upper	Plecoptera	Chloroperlidae	3	11
2015-09-18	Curtis Creek	Upper	Plecoptera	NA	18	11
2015-09-18	Curtis Creek	Upper	Plecoptera	Nemouridae	9	11
2015-09-18	Curtis Creek	Upper	Plecoptera	Peltoperlidae	0	11
2015-09-18	Curtis Creek	Upper	Plecoptera	Perlidae	0	11
2015-09-18	Curtis Creek	Upper	Plecoptera	Perlodidae	1	11
2015-09-18	Curtis Creek	Upper	Trichoptera	Glossosomatidae	3	11
2015-09-18	Curtis Creek	Upper	Trichoptera	Hydropsychidae	2	11
2015-09-18	Curtis Creek	Upper	Trichoptera	Limnephilidae	1	11
2015-09-18	Curtis Creek	Upper	Trichoptera	Rhyacophilidae	7	11
2015-09-18	Curtis Creek	Upper	Trichoptera	Brachycentridae	0	11
2015-09-18	Curtis Creek	Upper	Trichoptera	NA	4	11
2016-09-13	Curtis Creek	Upper	Coleoptera	Elmidae	3	43
2016-09-13	Curtis Creek	Upper	Diptera	Ceratopogonidae	1	43
2016-09-13	Curtis Creek	Upper	Diptera	Chironomidae	78	43

2016-09-13	Curtis Creek	Upper	Diptera	NA	1	43
2016-09-13	Curtis Creek	Upper	Diptera	Psychodidae	1	43
2016-09-13	Curtis Creek	Upper	Diptera	Simuliidae	0	43
2016-09-13	Curtis Creek	Upper	Diptera	Tipulidae	1	43
2016-09-13	Curtis Creek	Upper	Ephemeroptera	Ameletidae	32	43
2016-09-13	Curtis Creek	Upper	Ephemeroptera	Baetidae	4	43
2016-09-13	Curtis Creek	Upper	Ephemeroptera	Ephemerellidae	3	43
2016-09-13	Curtis Creek	Upper	Ephemeroptera	Heptageniidae	9	43
2016-09-13	Curtis Creek	Upper	Ephemeroptera	NA	93	43
2016-09-13	Curtis Creek	Upper	Hydracarina	NA	11	43
2016-09-13	Curtis Creek	Upper	Ostracoda	NA	0	43
2016-09-13	Curtis Creek	Upper	Plecoptera	Chloroperlidae	0	43
2016-09-13	Curtis Creek	Upper	Plecoptera	NA	39	43
2016-09-13	Curtis Creek	Upper	Plecoptera	Nemouridae	4	43
2016-09-13	Curtis Creek	Upper	Plecoptera	Peltoperlidae	1	43
2016-09-13	Curtis Creek	Upper	Trichoptera	Glossosomatidae	0	43
2016-09-13	Curtis Creek	Upper	Trichoptera	Hydropsychidae	0	43
2016-09-13	Curtis Creek	Upper	Trichoptera	Limnephilidae	0	43
2016-09-13	Curtis Creek	Upper	Trichoptera	Rhyacophilidae	6	43
2016-09-13	Curtis Creek	Upper	Trichoptera	Brachycentridae	0	43
2016-09-13	Curtis Creek	Upper	Trichoptera	NA	15	43

Table 5 Benthic macroinvertebrate diversity by count and family for Qua Creek in 2015 and 2016.

Date	Creek	Location	Taxon	Family	Count	Percent Subsampled
2015-09-18	Qua Creek	Lower	Coleoptera	Elmidae	10	18
2015-09-18	Qua Creek	Lower	Diptera	Ceratopogonidae	2	18
2015-09-18	Qua Creek	Lower	Diptera	Chironomidae	149	18
2015-09-18	Qua Creek	Lower	Diptera	Psychodidae	0	18
2015-09-18	Qua Creek	Lower	Diptera	Tipulidae	4	18
2015-09-18	Qua Creek	Lower	Ephemeroptera	Ameletidae	13	18
2015-09-18	Qua Creek	Lower	Ephemeroptera	Baetidae	49	18
2015-09-18	Qua Creek	Lower	Ephemeroptera	Ephemerellidae	6	18
2015-09-18	Qua Creek	Lower	Ephemeroptera	Heptageniidae	5	18
2015-09-18	Qua Creek	Lower	Ephemeroptera	Leptophlebiidae	1	18
2015-09-18	Qua Creek	Lower	Ephemeroptera	NA	22	18
2015-09-18	Qua Creek	Lower	Hydracarina	NA	6	18
2015-09-18	Qua Creek	Lower	Oligochaeta	NA	4	18
2015-09-18	Qua Creek	Lower	Ostracoda	NA	12	18

2015-09-18	Qua Creek	Lower	Plecoptera	Chloroperlidae	5	18
2015-09-18	Qua Creek	Lower	Plecoptera	NA	21	18
2015-09-18	Qua Creek	Lower	Plecoptera	Nemouridae	9	18
2015-09-18	Qua Creek	Lower	Plecoptera	Peltoperlidae	0	18
2015-09-18	Qua Creek	Lower	Plecoptera	Perlidae	0	18
2015-09-18	Qua Creek	Lower	Plecoptera	Perlodidae	0	18
2015-09-18	Qua Creek	Lower	Trichoptera	Glossosomatidae	5	18
2015-09-18	Qua Creek	Lower	Trichoptera	Hydropsychidae	0	18
2015-09-18	Qua Creek	Lower	Trichoptera	Limnephilidae	1	18
2015-09-18	Qua Creek	Lower	Trichoptera	Rhyacophilidae	4	18
2015-09-18	Qua Creek	Lower	Trichoptera	Brachycentridae	1	18
2015-09-18	Qua Creek	Lower	Trichoptera	NA	5	18
2016-09-13	Qua Creek	Lower	Coleoptera	Elmidae	6	8
2016-09-13	Qua Creek	Lower	Diptera	Ceratopogonidae	1	8
2016-09-13	Qua Creek	Lower	Diptera	Chironomidae	226	8
2016-09-13	Qua Creek	Lower	Diptera	NA	1	8
2016-09-13	Qua Creek	Lower	Diptera	Psychodidae	0	8
2016-09-13	Qua Creek	Lower	Diptera	Simuliidae	0	8
2016-09-13	Qua Creek	Lower	Diptera	Tipulidae	5	8
2016-09-13	Qua Creek	Lower	Ephemeroptera	Ameletidae	5	8
2016-09-13	Qua Creek	Lower	Ephemeroptera	Baetidae	0	8
2016-09-13	Qua Creek	Lower	Ephemeroptera	Ephemerellidae	3	8
2016-09-13	Qua Creek	Lower	Ephemeroptera	Heptageniidae	2	8
2016-09-13	Qua Creek	Lower	Ephemeroptera	NA	31	8
2016-09-13	Qua Creek	Lower	Hydracarina	NA	13	8
2016-09-13	Qua Creek	Lower	Ostracoda	NA	4	8
2016-09-13	Qua Creek	Lower	Plecoptera	Chloroperlidae	0	8
2016-09-13	Qua Creek	Lower	Plecoptera	NA	29	8
2016-09-13	Qua Creek	Lower	Plecoptera	Nemouridae	0	8
2016-09-13	Qua Creek	Lower	Plecoptera	Peltoperlidae	0	8
2016-09-13	Qua Creek	Lower	Trichoptera	Glossosomatidae	3	8
2016-09-13	Qua Creek	Lower	Trichoptera	Hydropsychidae	0	8
2016-09-13	Qua Creek	Lower	Trichoptera	Limnephilidae	0	8
2016-09-13	Qua Creek	Lower	Trichoptera	Rhyacophilidae	1	8
2016-09-13	Qua Creek	Lower	Trichoptera	Brachycentridae	0	8
2016-09-13	Qua Creek	Lower	Trichoptera	NA	3	8
2015-09-18	Qua Creek	Middle	Coleoptera	Elmidae	5	24
2015-09-18	Qua Creek	Middle	Diptera	Ceratopogonidae	0	24
2015-09-18	Qua Creek	Middle	Diptera	Chironomidae	189	24

2015-09-18	Qua Creek	Middle	Diptera	Psychodidae	1	24
2015-09-18	Qua Creek	Middle	Diptera	Tipulidae	1	24
2015-09-18	Qua Creek	Middle	Ephemeroptera	Ameletidae	15	24
2015-09-18	Qua Creek	Middle	Ephemeroptera	Baetidae	21	24
2015-09-18	Qua Creek	Middle	Ephemeroptera	Ephemerellidae	2	24
2015-09-18	Qua Creek	Middle	Ephemeroptera	Heptageniidae	6	24
2015-09-18	Qua Creek	Middle	Ephemeroptera	Leptophlebiidae	3	24
2015-09-18	Qua Creek	Middle	Ephemeroptera	NA	17	24
2015-09-18	Qua Creek	Middle	Hydracarina	NA	7	24
2015-09-18	Qua Creek	Middle	Oligochaeta	NA	0	24
2015-09-18	Qua Creek	Middle	Ostracoda	NA	6	24
2015-09-18	Qua Creek	Middle	Plecoptera	Chloroperlidae	2	24
2015-09-18	Qua Creek	Middle	Plecoptera	NA	18	24
2015-09-18	Qua Creek	Middle	Plecoptera	Nemouridae	6	24
2015-09-18	Qua Creek	Middle	Plecoptera	Peltoperlidae	0	24
2015-09-18	Qua Creek	Middle	Plecoptera	Perlidae	0	24
2015-09-18	Qua Creek	Middle	Plecoptera	Perlodidae	0	24
2015-09-18	Qua Creek	Middle	Trichoptera	Glossosomatidae	0	24
2015-09-18	Qua Creek	Middle	Trichoptera	Hydropsychidae	1	24
2015-09-18	Qua Creek	Middle	Trichoptera	Limnephilidae	4	24
2015-09-18	Qua Creek	Middle	Trichoptera	Rhyacophilidae	1	24
2015-09-18	Qua Creek	Middle	Trichoptera	Brachycentridae	0	24
2015-09-18	Qua Creek	Middle	Trichoptera	NA	8	24
2016-09-13	Qua Creek	Middle	Coleoptera	Elmidae	5	9
2016-09-13	Qua Creek	Middle	Diptera	Ceratopogonidae	0	9
2016-09-13	Qua Creek	Middle	Diptera	Chironomidae	108	9
2016-09-13	Qua Creek	Middle	Diptera	NA	0	9
2016-09-13	Qua Creek	Middle	Diptera	Psychodidae	0	9
2016-09-13	Qua Creek	Middle	Diptera	Simuliidae	1	9
2016-09-13	Qua Creek	Middle	Diptera	Tipulidae	4	9
2016-09-13	Qua Creek	Middle	Ephemeroptera	Ameletidae	1	9
2016-09-13	Qua Creek	Middle	Ephemeroptera	Baetidae	3	9
2016-09-13	Qua Creek	Middle	Ephemeroptera	Ephemerellidae	7	9
2016-09-13	Qua Creek	Middle	Ephemeroptera	Heptageniidae	7	9
2016-09-13	Qua Creek	Middle	Ephemeroptera	NA	54	9
2016-09-13	Qua Creek	Middle	Hydracarina	NA	10	9
2016-09-13	Qua Creek	Middle	Ostracoda	NA	0	9
2016-09-13	Qua Creek	Middle	Plecoptera	Chloroperlidae	0	9
2016-09-13	Qua Creek	Middle	Plecoptera	NA	100	9

2016-09-13	Qua Creek	Middle	Plecoptera	Nemouridae	5	9
2016-09-13	Qua Creek	Middle	Plecoptera	Peltoperlidae	0	9
2016-09-13	Qua Creek	Middle	Trichoptera	Glossosomatidae	4	9
2016-09-13	Qua Creek	Middle	Trichoptera	Hydropsychidae	11	9
2016-09-13	Qua Creek	Middle	Trichoptera	Limnephilidae	0	9
2016-09-13	Qua Creek	Middle	Trichoptera	Rhyacophilidae	4	9
2016-09-13	Qua Creek	Middle	Trichoptera	Brachycentridae	0	9
2016-09-13	Qua Creek	Middle	Trichoptera	NA	3	9
2015-09-18	Qua Creek	Upper	Coleoptera	Elmidae	6	18
2015-09-18	Qua Creek	Upper	Diptera	Ceratopogonidae	0	18
2015-09-18	Qua Creek	Upper	Diptera	Chironomidae	183	18
2015-09-18	Qua Creek	Upper	Diptera	Psychodidae	1	18
2015-09-18	Qua Creek	Upper	Diptera	Tipulidae	2	18
2015-09-18	Qua Creek	Upper	Ephemeroptera	Ameletidae	11	18
2015-09-18	Qua Creek	Upper	Ephemeroptera	Baetidae	17	18
2015-09-18	Qua Creek	Upper	Ephemeroptera	Ephemerellidae	9	18
2015-09-18	Qua Creek	Upper	Ephemeroptera	Heptageniidae	9	18
2015-09-18	Qua Creek	Upper	Ephemeroptera	Leptophlebiidae	11	18
2015-09-18	Qua Creek	Upper	Ephemeroptera	NA	13	18
2015-09-18	Qua Creek	Upper	Hydracarina	NA	9	18
2015-09-18	Qua Creek	Upper	Oligochaeta	NA	0	18
2015-09-18	Qua Creek	Upper	Ostracoda	NA	2	18
2015-09-18	Qua Creek	Upper	Plecoptera	Chloroperlidae	7	18
2015-09-18	Qua Creek	Upper	Plecoptera	NA	21	18
2015-09-18	Qua Creek	Upper	Plecoptera	Nemouridae	13	18
2015-09-18	Qua Creek	Upper	Plecoptera	Peltoperlidae	0	18
2015-09-18	Qua Creek	Upper	Plecoptera	Perlidae	3	18
2015-09-18	Qua Creek	Upper	Plecoptera	Perlodidae	0	18
2015-09-18	Qua Creek	Upper	Trichoptera	Glossosomatidae	2	18
2015-09-18	Qua Creek	Upper	Trichoptera	Hydropsychidae	0	18
2015-09-18	Qua Creek	Upper	Trichoptera	Limnephilidae	3	18
2015-09-18	Qua Creek	Upper	Trichoptera	Rhyacophilidae	2	18
2015-09-18	Qua Creek	Upper	Trichoptera	Brachycentridae	0	18
2015-09-18	Qua Creek	Upper	Trichoptera	NA	2	18
2016-09-13	Qua Creek	Upper	Coleoptera	Elmidae	6	19
2016-09-13	Qua Creek	Upper	Diptera	Ceratopogonidae	2	19
2016-09-13	Qua Creek	Upper	Diptera	Chironomidae	113	19
2016-09-13	Qua Creek	Upper	Diptera	NA	0	19
2016-09-13	Qua Creek	Upper	Diptera	Psychodidae	0	19

2016-09-13	Qua Creek	Upper	Diptera	Simuliidae	0	19
2016-09-13	Qua Creek	Upper	Diptera	Tipulidae	4	19
2016-09-13	Qua Creek	Upper	Ephemeroptera	Ameletidae	5	19
2016-09-13	Qua Creek	Upper	Ephemeroptera	Baetidae	1	19
2016-09-13	Qua Creek	Upper	Ephemeroptera	Ephemerellidae	1	19
2016-09-13	Qua Creek	Upper	Ephemeroptera	Heptageniidae	1	19
2016-09-13	Qua Creek	Upper	Ephemeroptera	NA	78	19
2016-09-13	Qua Creek	Upper	Hydracarina	NA	28	19
2016-09-13	Qua Creek	Upper	Ostracoda	NA	3	19
2016-09-13	Qua Creek	Upper	Plecoptera	Chloroperlidae	0	19
2016-09-13	Qua Creek	Upper	Plecoptera	NA	47	19
2016-09-13	Qua Creek	Upper	Plecoptera	Nemouridae	2	19
2016-09-13	Qua Creek	Upper	Plecoptera	Peltoperlidae	0	19
2016-09-13	Qua Creek	Upper	Trichoptera	Glossosomatidae	11	19
2016-09-13	Qua Creek	Upper	Trichoptera	Hydropsychidae	2	19
2016-09-13	Qua Creek	Upper	Trichoptera	Limnephilidae	0	19
2016-09-13	Qua Creek	Upper	Trichoptera	Rhyacophilidae	4	19
2016-09-13	Qua Creek	Upper	Trichoptera	Brachycentridae	1	19
2016-09-13	Qua Creek	Upper	Trichoptera	NA	6	19

Fish Abundance and Condition

Rainbow Trout was the predominant species captured in Curtis and Qua Creeks in 2016 and the only species captured in 2015 so the following discussions about abundance, efficiency, body mass and condition and lineal density refer to Rainbow Trout. In 2016 three juvenile Bull Trout were caught in Curtis Creek; a single fish was captured at site 2 and two fish were captured at site 1; fish at site 2 had a fork length of 92mm and a mass of 10g, and the two at site 1 had lengths of 91mm and 95mm and masses of 10g and 10g respectively (Bull Trout data not shown). There was a greater range of sizes of Rainbow Trout captured in Qua Creek in both years (Figure 9). The range of Rainbow Trout sizes in 2016 was from 46 – 234mm with a mean fish size of 121 mm. The largest fish from 2016 was slightly larger than the 219mm fish captured at the top of the range in 2015 (Figure 9).

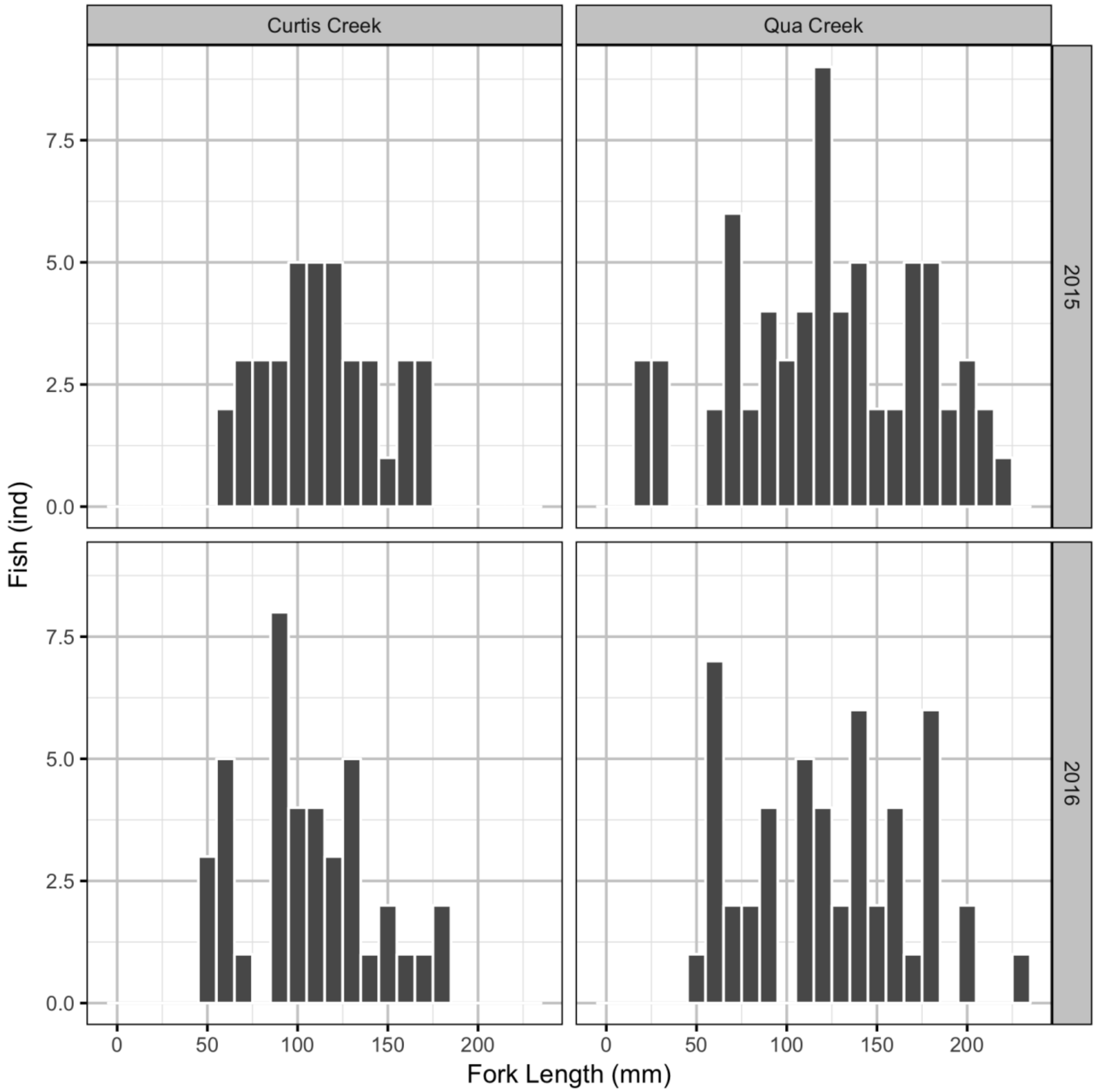


Figure 9 Length (mm) frequency for Rainbow Trout by year, creek and location (electrofishing sampling site).

Body mass in grams was plotted against the fork length in mm for all captured fish, a greater range of sizes of fish were captured in Qua Creek (Figure 10). Increased measurement error was evident in 2016 showing a potential problem with the scale. This will have to be remedied to keep controllable error minimized so that fish condition before and after the fertilization can be compared as clearly as possible. There may be a biological reason for the variability as well though none are immediately obvious.

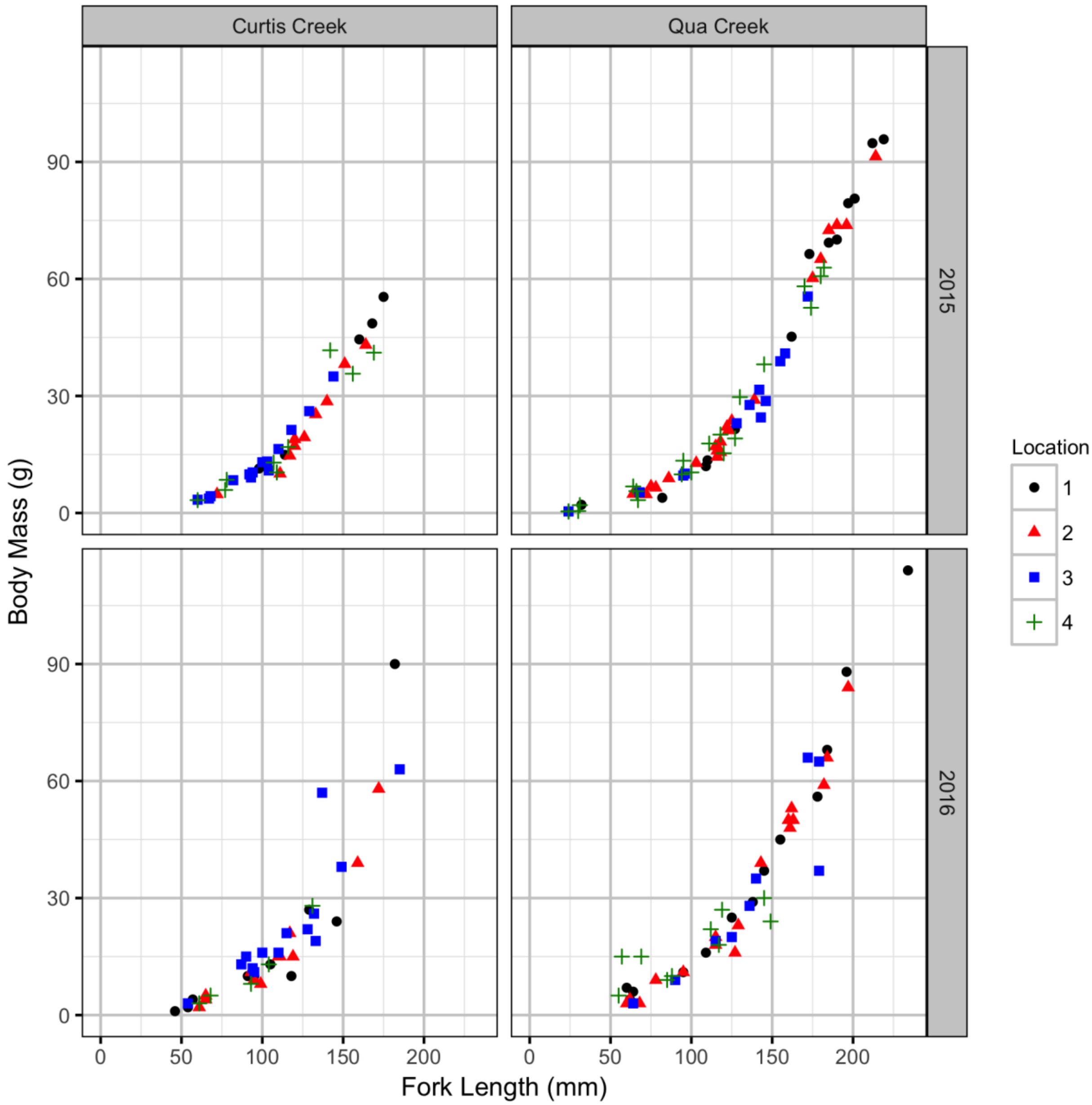


Figure 10 Body mass (g) by fork length (mm) for Rainbow Trout by year, creek and location (electrofishing sampling site).

Lineal density is the number of fish per metre of stream. Areal density is the number of fish per square metre of wetted area. Unlike areal density, lineal density does not depend on discharge and is easily converted to a total abundance. The lineal density (ind/m) was slightly higher overall in Qua Creek with a range in ind/m from 1.3 – 1.6 whereas in Curtis Creek the density ranged from 0.9 – 1.1 (Figure 11). There was no difference between years in the density of fish by creek and little support for any differences between sites.

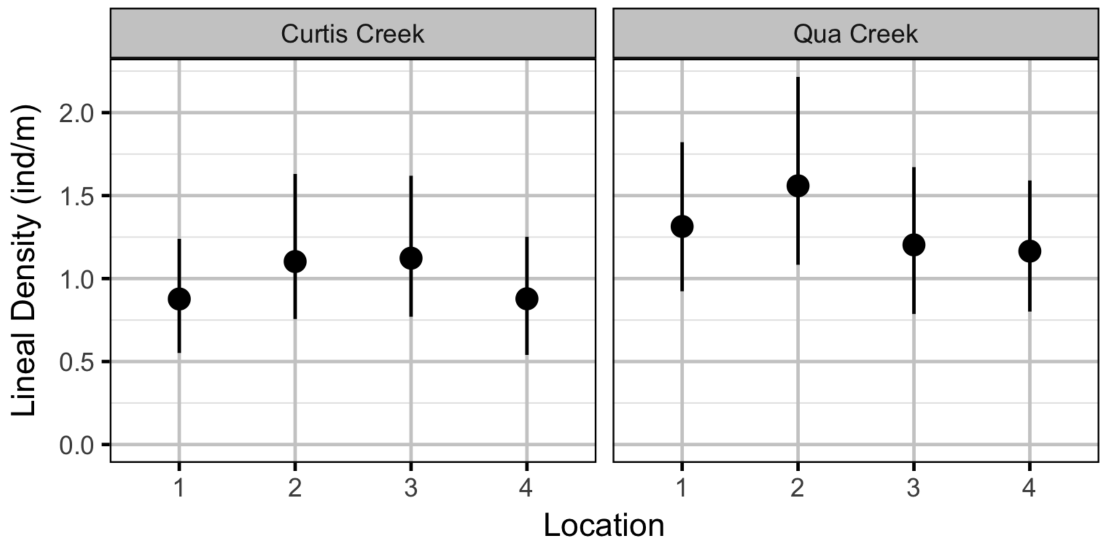


Figure 11 Lineal density (ind/m) of Rainbow Trout by creek and location (electrofishing sampling site) in 2016 Error bars represent 95% credible intervals. Note, only fish > 50 mm were included in this analysis.

The capture efficiency for Curtis and Qua Creeks in 2015 was estimated to be 57% (95% Credible Intervals 44-70%) and for 2016 was estimated at 30% (95% Credible Intervals 22-40%) (Figure 12). The reason for the decline in the capture efficiency is unclear though it may be due to slight increases in turbidity leading to lower netter efficiency or other environmental variability.

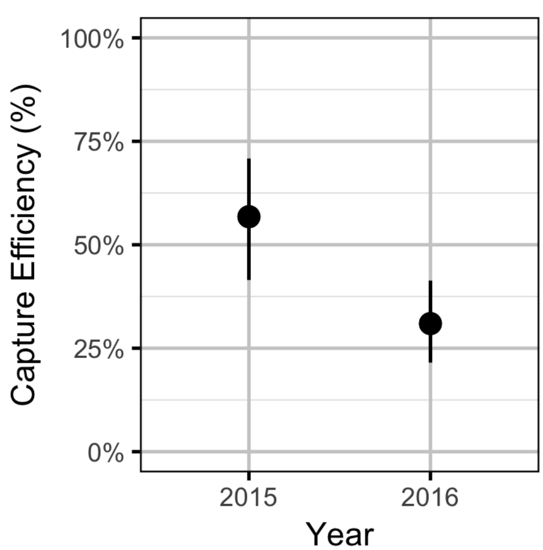


Figure 12 Capture efficiency of Rainbow using backpack electrofishing in both creeks by year.

Water Temperature

Curtis and Qua Creeks are cool, headwater creeks with temperatures in the summer less than 16°C. Upper Qua and lower Curtis showed the coolest average temperatures of the four sites. All measured sites for water temperature were within the suitable range for Bull Trout spawning and for salmonid rearing and incubation (Figure 13).

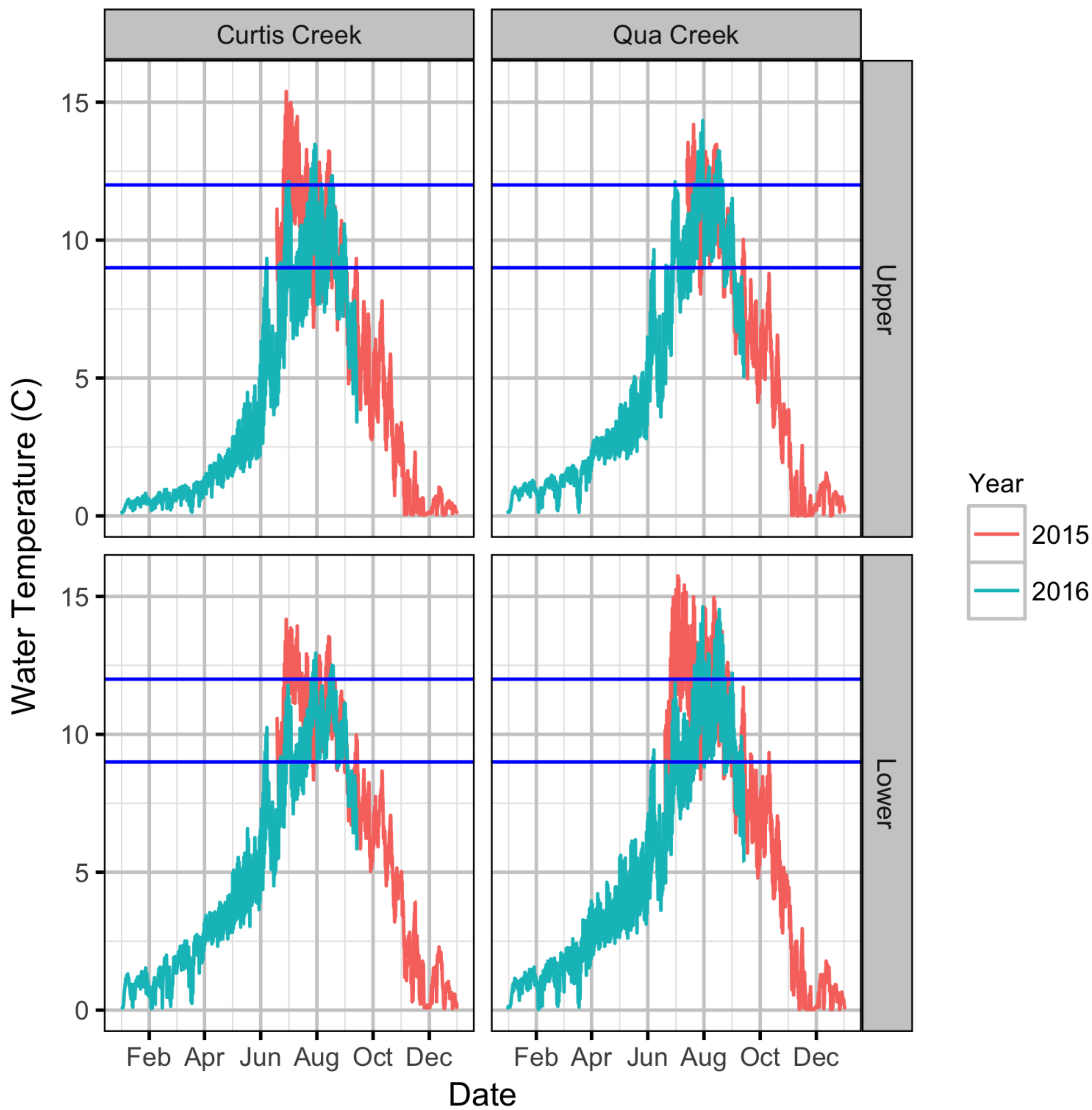


Figure 13 Water Temperature (°C) for upper and lower stations on Curtis and Qua Creeks for 2015 and 2016. The blue horizontal lines mark 9°C and 12°C, preferred ranges for Rainbow Trout.

Habitat Surveys

Four habitat breaks including the Bull Trout barrier were identified in 2015 within Curtis Creek and the percent of cascade, pool, riffle and glide were estimated for each unit (Irvine and Nellestijn 2016). Six habitat breaks were identified within Qua Creek and the habitat units for each were mapped and the percentage of each habitat type estimated (Irvine and Nellestijn 2016)**.** The habitat surveys were not repeated in 2016, but it is recommended that it be repeated every 3 years to assess gross changes in habitat types and breaks.

Discussion

The performance measures of this project match with several priority actions identified in the Species of Interest and Rivers/Streams Action plans. These measures include: 1) conducting the assessment and inventory of focal species in order to enable future habitat restoration and conservation efforts and wise management for sustainable use of this traditional First Nations and recreational resource, and 2) conducting monitoring to enable habitat restoration or enhancement.

The discussion is structured to follow the goals from the proposal. The field work, databasing, plotting and analysis aided in determining the access options, set up long term monitoring sites for periphyton productivity within the accessible reaches, and obtained baseline water chemistry, primary productivity, benthic invertebrate and fish data throughout the growing season. With regards to all of these goals, the second year for the Curtis and Qua Creeks Nutrient Restoration Preparation Project was a success with the main find being the presence of juvenile Bull Trout in Curtis Creek at two sites.

1) *Determine the access options for each creek taking into consideration the potential to bring in 10kg bags of pellet fertilizer in the future.*

The foot access to Qua creek is a narrow hiking trail which takes about 2 hours to get to the upper site. Access with small truck or ATV is not possible for this creek so fertilizer would have to be dropped by helicopter or hiked in (depending on volume). Curtis Creek has reasonable access in the lower to mid sections with a logging road that becomes a poorly defined track just before the mid-Curtis site. Due to rock blockades near the middle site, only foot access or mountain biking is now possible into the upper sections of Curtis Creek. These constraints need to be considered when planning for logistics and budget going forward with fertilization.

2) *Set up three, long-term monitoring sites for algal productivity in each creek near the confluence, midway along the length of the accessible creek and near the upper end of the accessible creek.*

The long term monitoring sites for primary productivity were set up in the 2015 season in order to cover the range of habitats within each creek and to balance access and representative sampling. The upper end of Qua Creek was not possible to access in a repeated way throughout the growing season as is needed for a project like this without helicopter usage so a compromise was made. The selected sites worked well for the growth study in 2015 as evidenced by the periphyton accrual during the two, 6-week experimental periods. The periphyton growth curves differed considerably in 2016 in some sites like lower Curtis showing increases and decreases rather than a steady growth pattern.

3) *Obtain baseline water chemistry and primary productivity data from Qua and Curtis Creeks to compare to other creeks in which fertilization has been successful at augmenting fish production and to provide a 'before' data series to allow statistical comparison if fertilization occurs.*

Baseline water chemistry and primary productivity data were obtained which will allow comparison to other creeks that have these data in order to assess what impact the fertilization may have on Curtis and Qua Creeks should that compensation option be further explored. Once all 3 years of baseline data are collected, they can be summarized, plotted and compared to other systems in which fertilization options have been exercised.

4) *Obtain invertebrate community diversity (to the family level) and biomass estimates for each creek.*

The Shannon diversity index ranged from 1.5 - 2.2 in the two creeks in 2015 and from 1.3 - 2.1 in 2016 and the data obtained will allow the comparison of diversity at the family level for benthic macroinvertebrates between these creeks to others in the watershed and elsewhere in the Columbia basin once additional baseline data are obtained. The lack of biomass data for benthic invertebrates in these study creeks due to the small size of the early instar larvae captured in each year is a challenge for allowing comparison to other projects where these data are available.

5) *Verify or refute the anecdotal evidence and assumption that Bull Trout spawn and rear in Curtis and Qua Creeks through backpack electrofishing sampling of the creeks. Gather relative abundance and condition data on fish captured through backpack electrofishing methods at four sites within each creek*

The backpack electrofishing data show evidence of Bull Trout spawning in Curtis Creek and evidence of Rainbow Trout spawning in both Curtis and Qua Creeks. The habitat assessment completed in Fall, 2015 showed a barrier to Bull Trout spawners in Qua Creek near the confluence with Clearwater Creek (Irvine and Nellestijn 2016), a likely cause for lack of Bull Trout in the system.

Recommendations

The Qua and Curtis Creeks Crystal Green Nutrient Restoration Preparation project was designed to identify and implement restoration opportunities for Bull Trout and Rainbow Trout in two of the headwaters of the Salmo River. The capture of three juvenile Bull Trout in 2016 in Curtis Creek was a great find after only Rainbow Trout were captured in the 2015 study year. It means that any restoration projects in the future can leverage gains for both important species, at least in Curtis Creek. Qua Creek habitat assessment in fall 2015 showed that mature logjams likely prevent adult Bull Trout migration into the upper reaches. It is likely that Bull Trout spawning in the study creeks may be limited by the number of spawners utilizing the system as a whole as well as limited habitat. We are aware that local knowledge has identified Qua as a Bull Tout spawning tributary, if the log jam can be modified to allow passage, there is suitable spawning and rearing habitat above it totaling approximately 6km of prime spawning and rearing area. Curtis has limited habitat with only approximately 1 km of suitable area.

Recommendations emerging after two years of this project include:

- Continue the project for 1 more year as planned in order to obtain an assessment of variability in the productivity metrics.

- Complete a literature review of the status of the Rainbow Trout population in the Salmo River watershed and the efficacy of fertilization on enhancing Rainbow Trout populations in similar systems to ensure that the program is targeted appropriately to the species currently present in year 3 of the project.

- Investigate the potential of translocation of spawning adults or transplantation of Bull Trout eggs into suitable rearing streams which would include a review of completed genetic analyses (if any) on Bull Trout within the Columbia Basin and an assessment of potential capture and transport methods for adult Bull Trout should appropriate translocation stock be located.

Acknowledgements

The authors gratefully acknowledge the financial support of the Fish and Wildlife Compensation Program that made this study possible.

The authors gratefully acknowledge the financial and field support of the Salmo Watershed Streamkeepers Society and in particular the field assistance of Tanya Chi Tran who was extremely valuable to the successful completion of this project.

Alice Nellestijn for providing safety check-in and field support to the project.

Garry Quist of Frank Communications Inc. provided graphic design services.

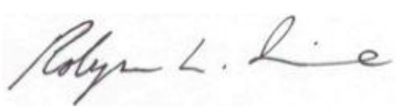
Lynn Westcott of Westcott Environmental Services for taxonomic identification of the benthic macroinvertebrates.

CARO Analytic for exemplary service in providing water chemistry and periphyton analysis.

Dr. Joe Thorley and Dr. Patrick Hogan for the analysis and plotting of periphyton and fish data.

Closure

We are pleased to submit this final report for FWCP's consideration in completion of the project requirements.



Dr. Robyn Irvine, R.P.Bio., Fisheries Ecologist, Poisson Consulting Ltd.

Mr. Gerry Nellestijn, Fisheries Technologist, The Confluence Approach

References

Decker, S. (2010). Sheep Creek Nutrient Addition Study 2001-2009 (Castlegar, B.C.: BC Hydro).

Environment Canada (2012). Canadian Aquatic Biomonitoring Network Field Manual Wadeable Streams (Dartmouth, NS).

Hagen, J. (2008). Impacts of dam construction in the upper Columbia Basin, British Columbia, on bull trout (Salvelinus confluentus) production, fisheries, and conservation status (Nelson, BC: Fish and Wildlife Compensation Program).

Hagen, J., and Baxter, J. (2004). Conservation status of Salmo River Rainbow Trout: Radio Telemetry Investigations of Habitat Use and Abundance (Nelson, B.C.: B.C. Hydro).

Hagen, J., and Decker, S. (2011). The status of Bull Trout in British Columbia: A synthesis of Available Distribution, Abundance, Trend and Threat Information (Victoria, B.C.: Ministry of Environment, Ecosystem Protection & Sustainability Branch, Aquatic Conservation Science Section).

Holm-Hansen, O., Lorenzen, C.J., Holmes, R.W., and Strickland, J.D.H. (1965). Fluorometric determination of chlorophyll. J. Cons. Int. Explor. Mer. *30*, 3–15.

Irvine, R.L., and Nellestijn, G. (2016). Qua and Curtis Creeks Crystal Green Nutrient Restoration Preparation Project F-F16-15 (Castlegar, B.C.: Fish and Wildlife Compensation Program - Columbia).

Kéry, M., and Schaub, M. (2011). Bayesian population analysis using WinBUGS : a hierarchical perspective (Boston: Academic Press).

Nellestijn, G. (2014). Sheep Creek Fertilization Project 2013 (Castlegar, B.C.: Fish and Wildlife Compensation Program).

Nusch, E.A. (1980). A comparison of different methods for chlorophyll and pheopigment analysis. Ergeb. Limnol. *14*, 14–36.

Parkinson, E.A., and Haas, G.R. (1996). The role of macrohabitat variables and temperature in defining the range of Bull Trout. (Vancouver, B.C.: Province of British Columbia).

Pellett, K. (2011). A review of twenty years of nutrient enrichment in the Salmon River watershed, Vancouver Island (1989-2010) (Nanaimo, BC: Fish and Wildlife Compensation Program - Coastal Region).

Perrin, C.J., and Richardson, J.S. (1997). N and P limitation of benthos abundance in the Nechako River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences *54*, 2574–2583.

Plummer, M. (2003). JAGS: a program for analysis of Bayesian graphical models using Gibbs sampling. In Proceedings of the 3rd International Workshop on Distributed Statistical Computing (DSC 2003), K. Hornik, F. Leisch, and A. Zeileis, eds. (Vienna, Austria), p.

R Core Team (2015). R: A Language and Environment for Statistical Computing (Vienna, Austria: R Foundation for Statistical Computing).

Thorley, J.L. (2013). jaggernaut: an R package to facilitate Bayesian analyses using JAGS (Just Another Gibbs Sampler) (Nelson, B.C.: Poisson Consulting Ltd.).

Wickham, H. (2009). ggplot2: Elegant Graphics for Data Analysis (New York: Springer).

Wyatt, R.J. (2002). Estimating riverine fish population size from single- and multiple-pass removal sampling using a hierarchical model. Canadian Journal of Fisheries and Aquatic Sciences *59*, 695–706.