Bridge River Project Water Use Plan

Seton River Habitat and Fish Monitor

Implementation Year 4 (2016)

Reference: BRGMON-9

Bridge-Seton Water Use Plan Monitoring Program: Seton River Habitat and Fish Monitor.

Study Period: March 1st to December 31st, 2016

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Executive Summary

The objective of this monitoring program is to monitor the response of fish habitat and fish populations to variations in Seton Dam flow operations.

This monitor is in year 4 of 10 and combines old and new approaches to better understand the status of the Seton River fish populations and how different life histories may be affected by Seton Dam operations.

Through monthly juvenile surveys, 13 species of fish were observed, including six species of salmonids. Of these species, only Rainbow Trout, Coho and Chinook were caught in sufficient numbers to show the presence of discrete age classes. Four distinct age classes of Rainbow Trout were observed, while two age classes were identified for Coho and Chinook. High discharge events from mid-May to July prevented the sampling of pre-established growth sampling sites on the mainstem river. Alternatively, effort was directed at examining the presence and distribution of juvenile fish in the Seton River during high discharge periods. Four side channel habitats were identified, and 10 fish species were observed within them.

Fall electrofishing surveys were used to estimate juvenile Rainbow Trout standing crop in the Seton River. Rainbow Trout densities for age 0 fish in 2016 ranged from 0.1 to 1.5 fish/m compared to densities of 0.1 to 1.0 fish/m in 2015 and 0.1 – 3.7 fish/m in 2014. Model adjustments are being made to provide reach level and river-wide abundance estimates in future reports. In March 2016, snorkel surveys of all juvenile species, for indexing purposes were completed in the Seton River. Results were similar to previous years and indicate that larger/older fish (Age 1-3) occur at low densities in the Seton River (129 fish total over 25 sites).

Enumeration of all species of adult salmonids spawning in the Seton River continued in 2016. Six adult Steelhead were radio and PIT tagged at the Seton and Fraser River confluence. Three of these fish moved into the Seton River. Two passed Seton Dam and one was assumed to have spawned in the Seton River. Visual surveys for Steelhead on Seton

River were not completed in 2016 as high discharges during spawning period (April – June) created poor visibility conditions. Visual surveys, for Steelhead, in spawning channels were also not completed as upstream access to the spawning channels to adults was blocked due to the infrastructure put in place for a separate juvenile outmigration study. In future years Instream will communicate with proponents of that study to provide access to fish including spawning Steelhead and juveniles attempting to enter spawning channel. Very few adult Chinook were observed in 2016. One individual was observed in the LSC, and two individuals were observed downstream of the Seton Dam. A total of 93 Coho were observed through visual surveys in 2016. The majority were observed in the upper and lower spawning channels, 25 and 64 respectively. Four Coho were observed holding in the mainstem Seton River, downstream of Seton Dam.

A river bed topographical survey was completed in September 2013 and 2015 at an area 135 m downstream of Seton Dam. This area is where the majority of spawning (Salmon and Steelhead) has been observed. Analysis of topographical data shows some sections (main thalweg) of the area sampled experienced substrate erosion out while other sections (margins) experienced deposition. Results of substrate survey transects within the spawning area suggest that substrate composition has coarsened suggesting movement of smaller substrate downstream. Spawning habitat elsewhere in the Seton River is limited and can be attributed to the relatively restricted nature of the river that has been extensively dyked or armoured throughout.

On March 23, 2016, we monitored the impacts of the shutdown of the Seton Generating Station on fish stranding at two sites on the Fraser River. The shutdown resulted in a 10% flow reduction in the Fraser River downstream of the Fraser-Seton confluence. The average rate of stage reduction was 0.21 m/h and 0.10 m/h for the two sites, exceeding DFO ramp down guidelines of <0.05 m/h. Area dewatered at sites one and two was 997 m^2 and 471 m^2 respectively. Overall, the area available to be dewatered in this section of the Fraser River is low due to the channelized/canyon profile of the river and presents a low risk to fish stranding.

High flows in the Seton River will affect how various components of the monitor are carried out and ultimately how direct effects of the high flows on habitat and rearing are monitored. Monitoring methods in 2017 should be modified to monitor side channels wetted during high flows to quantify habitat created and verify their use by fish. This can be done through habitat suitability surveys (depth, substrate and velocity) and detailed electrofishing surveys.

BRGMON-9 Status of objectives, management questions and hypotheses after Year 4

Study Objectives	Management Questions	Management Hypotheses	Year 4 (2015-2016) Status
1. Monitor the response of fish habitat and fish populations to Seton Dam operations (implemented hydrograph).	1. What are the basic biological characteristics of the rearing and spawning populations in Seton River in terms of relative abundance, distribution, and life history?	. H1A: Juvenile standing crop biomass per unit area is inversely related to flow velocity. H1B: Juvenile standing crop biomass per unit area is independent of flow depth. H1C: Juvenile standing crop biomass per unit area is independent of both flow velocity and depth.	Management question is being answered through collection of baseline biological data of fish species in Seton River. - Monitoring has idenitfied 13 species of fish in the Seton River. Salmonids include:, Coho, Chinook, Rainbow Trout, Steelhead Trout, Whitefish and Bull Trout. Juveniles of all these species have been observed but samples are dominated by Rainbow Trout followed by Coho and Chinook. Steelhead and Coho adults have been observed in Seton with majority of them spawning in the spawning channels. Higher flows in the Seton River during spawning migration of Steelhead (April-June) will have implications on visual surveys (low visibility) and may affect spawning distribution of Steelhead. PIT and radio telemetry will help inform these potential effects. - Modelling of length-weight relationships will provide insight into year effect (flow conditions) on juvenile growth. - No adult Chinook have been observed spawning in the Seton River, but juveniles are consistently captured, suggesting that juveniles from other systems may be using the Seton River for rearing. DNA analysis will verify if this is the case. - Juvenile standing crop surveys have been completed (2014-2016). To date a relationship between standing crop and discharge has not been identified. No significant differences in Rainbow Trout densities have been observed at the site level and between years. Future years of study and further analysis will provide reach and river wide abundance estimates that will provide a better year to year comparison. That is, have the discharges experienced adults in spring and juveniles in summer affected numbers observed in the fall surveys.
	2. How does the proposed Seton hydrograph influence the hydraulic condition of juvenile fish rearing habitats downstream of Seton Dam?	H1: The amount of hydraulic habitat that can be inhabited by juvenile fish is independent of discharge from Seton Dam	- Habitat suitability (HSI) surveys have been used to create a discharge and habitat suitability relationship for juvenile Rainbow Trout and Chinook and Coho Salmon. As discharge increases suitable habitat decreases for all species, particularly at discharges above 60 cms. At 60 cms weighted useable area decreased to one third of what was observed at 12 cms. Can reject hypothesis (H1), but future surveys can be completed to identify most favorable discharge between 27 and 60 cms and how higher flows may have changed habitat suitability in the river. - Higher flows will affect how mainstem monthly juvenile growth sampling surveys will be carried out and how fish are distributed.

			- Timing and duration of high flows is critical and can have direct effect on emergent rainbow trout in July - HSI surveys to identify weighted useable area should be completed in side channel habitat created during high flows along with standing crop biomass to quantify habitat available and understand use by juvenile fish. - These surveys will also explore whether side-channel habitat created during these periods is enough to compensate for loss of habitat in mainstem
	2. What is the potential risk for salmon and Steelhead redds dewatering due to changes in flow between spawning and incubation periods imposed by the Seton hydrograph?	H2. The selected Seton River hydrograph does not result in dewatering of salmon or Steelhead redds.	Partially addressed. No redd dewatering events have been observed to date. The area where Salmon (Pink and Coho) and Steelhead spawn remains wetted throughout the year. Data collected through visual surveys will continue to add to data series. - Spawning habitat for all species is limited in Seton mainstem and can be attributed to the relatively restricted nature of the river that has been extensively dyked or armoured throughout. This creates higher velocities in the river and no areas for substrate to be deposited. - There is little to no spawning in high gravel bars (no suitable substrate)
	3. How will the Seton hydrograph influence the short term availability of gravel suitable for use by anadromous and resident species for spawning and egg incubation?	H3. The selected Seton River hydrograph does not result in mobilization of gravel or net loss of gravel from the system.	- Riverbed elevation surveys (2013 and 2015) of a key spawning area have shown minor changes in elevation and substrate composition Sections of the study area have eroded while other sections have shown deposition and that there has seen some movement of smaller substrate (gravel and small conbble) downstream. Net gain/loss has yet to be determined. - These surveys (at same site) are to be completed yearly to monitor effects of high spill/discharges.
	4. Does discharge from Seton Generating Stations impact fish habitat in the Fraser River above and beyond natural variation in Fraser River discharged?		- Shutdowns of Seton Generating station have resulted in up to 10% reduction in flow in the Fraser River and ramping rates that exceed DFO guidelines of < .05m/h. - Affects are variable and dependent on discharge of the Fraser River. - Very few fish have been stranded (N=3) - Future surveys will quantify area dewatered and stranding at two sites. In 2016, area dewatered at sites one and two was 997 m^2 and 471 m^2 respectively - Area available to be dewatered in this section of the Fraser River is low due to the channelized/canyon profile of the river and presents a low risk to fish stranding.

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1. INTRODUCTION

1.1 Background

BRGMON-9 was initiated as a ten-year monitoring program in 2012 (with first data collection in 2013), according to the general guidance laid out in a Terms of Reference (BC Hydro, 2012). This section provides some background of the monitoring program as outlined in the scope of work in the Terms of Reference.

The Seton River flows east from Seton Lake (Seton Dam) and joins the Fraser River 4.0 km downstream at Lillooet, BC. Seton Dam is the final dam of the Bridge River Hydroelectric development structures, which, along with the Seton Canal, were constructed between 1927 and 1960 (Figure 1). The dam was built through the Seton Lake Reservoir development and was completed in 1956. It consists of an 18m concrete dam that incorporates a fish ladder and a diversion canal. From the dam, a portion of the Seton River's flow is diverted via the Seton Canal to the Seton Powerhouse, which in turn drains into the Fraser River (Figure 2)

Cayoosh Creek joins the Seton River approximately 1km downstream of the dam. A small run-of-the-river generating station operates on Cayoosh Creek and as a result, flows in the Creek can vary greatly on a seasonal basis.

The Seton River corridor has high fisheries and wildlife value for the local community. The river supports anadromous salmonid populations of Steelhead (*Oncorhynchus mykiss*), Coho Salmon (*O. kisutch*), Chinook Salmon (*O. tshawytscha*), Pink Salmon (*O. gorbuscha*), Rainbow Trout (*O. mykiss*), Bull Trout (*Salvelinus confluentus*), Mountain Whitefish (*Prosopium williamsoni*), and various species of minnows (Cyprinids).

Since the construction of Seton Dam, the flows of the Seton River have been regulated by BC Hydro. In 1999, the Bridge River Water Use Plan (BRG WUP) consultative process was initiated and was completed in 2001. The goal of the Water Use Plan process is to identify a better balance between competing uses of water (water supply, fish and wildlife, recreation, heritage, flood control and electrical power needs), which are environmentally, socially and economically acceptable (BC Hydro 2017). The Bridge-Seton Water Use Plan (WUP) was developed in the early 2000s and formally adopted in 2011. This year (2016) will mark the fourth year of data collection for BRGMON-9.

A critical environmental concern expressed throughout the creation of the Bridge-Seton WUP was the development of an acceptable instream flow regime for Seton River. The Bridge-Seton Consultative Committee (BRG CC) set environmental objectives for Seton River that are measured in terms of the abundance and diversity of fish populations using the river. Very little information is available that links changes in flow to changes in habitat and fish populations in the Seton River.

To evaluate alternative instream flow regimes for Seton River, performance measures were developed to reflect the quality and quantity of the spawning and rearing habitats for several selected key species and life stages, with assumptions that this ultimately is related to population abundance and species diversity. Discussion of physical habitat simulation model outputs lead to uncertainty about the use of the physical habitat simulation approach for establishing the flow regime and the desire to manage the instream flow releases to provide more naturalized conditions in the river. Uncertainties in the physical habitat simulation models resulted in the development of new fish performance measures that reflected the degree to which the hydrograph shape and magnitude conformed to that observed prior to operation of the Bridge diversion. Application of these new performance measures was also found to be problematic because there is no objective way to weight the value of conformity of the different measures of the "natural hydrograph". With increasing acknowledgement of technical uncertainty, performance measure development progressed in a recursive fashion, where there was a trend from very detailed mechanistic analysis of habitat conditions, to criteria for naturalized conditions, and finally to the application of simple three stage (i.e., 0-bad, 1- OK, 2-better) qualitative scoring system.

Despite the vital role that Seton Dam flow releases played in development of the BRG WUP, the fish habitat performance measures for Seton River fish populations remained uncertain. The BRG CC expressed concern about uncertainty about how habitat changes would influence fish abundance and diversity and they recommended habitat and population monitoring studies to help validate or refute the selection of the hydrograph and to provide information needed to develop more certain and effective performance measures for future water use planning purposes.

Following the CC process, concern was raised about the potential impact of Seton Generating Station (SGS) operations on fish habitat in the Fraser River during times of low Fraser River discharge, typically in the winter, (summarized in Higgins 2010). The hydrological response of the Fraser River to Seton Generating Station winter shutdowns has been examined, and the likely biological impacts associated with these changes have been estimated (Higgins 2010). The fisheries monitoring program for Seton River was therefore designed to further investigate these potential impacts in the Fraser River at two sites near the Seton Generating Station. The two sites are approximately 2 and 11 km respectively downstream of SGS and provide additional physical and biological information to help reduce uncertainty on the effects to fish and fish habitat.

In 2016, BC Hydro implemented modifications to La Joie Dam operations in response to dam safety risks. La Joie Dam impounds Downton Reservoir, a key flow-management tool in the Bridge-Seton system. Specifically, the La Joie modifications meant that maximum water elevation in Downton would be decreased from 749 meters above sea level (MASL) to 734 MASL, significantly decreasing the storage capacity. The act of drawing the reservoir down to the new operating level in 2016 also resulted in a prolonged, atypical flow release from La Joie, ultimately routing through Seton River. The net effect for 2016 was a hydrograph that significantly exceeded the WUP targets for Seton River through most of the spring and summer (Figure 3). These high flow events had implications for monitoring activities as high flows prevented access to sites and methods outlined in the Terms of Reference. The magnitude and duration of deviation from WUP targets for Seton River creates potential effects that were not contemplated in the Terms of Reference. Therefore, the 2016 monitoring program approach was changed to address these changes. Monitoring focused on identifying side channel habitat created during high flows and verifying fish presence within them.

1.2 Management Questions

The five primary management questions identified in discussion of the effects of the flow regime on fish habitat in Seton River are:

1. What are the basic biological characteristics of the rearing and spawning populations in Seton Rivers in terms of relative abundance, distribution, and life history?

2. How does the proposed Seton hydrograph influence the hydraulic condition of juvenile fish rearing habitats in downstream of Seton Dam?

3. What is the potential risk for salmon and steelhead redds, dewatering due to changes in flow between spawning and incubation periods imposed by the Seton hydrograph?

4. How will the Seton hydrograph influence the short term and long term availability of gravel suitable for use by anadromous and resident species for spawning and egg incubation?

5. Does discharge from Seton Generating Station impact fish habitat in Fraser River above and beyond natural variation in Fraser River discharge?

Small changes in Seton River discharge can have considerable impact on the hydraulics (depth, velocity) in the Seton River mainstem river channel. Similarly, the impacts of high flow levels on juvenile fish was assumed to be buffered by 1) overflow of the Seton River main stem into side channels that provide favorable habitat for juvenile and sub-adult fish and 2) a possible “dynamic equilibrium” of suitable hydraulic conditions (i.e., for different flow levels there is a fixed volume of hydraulic habitat that conforms to tolerances or preferences of small fish). There was concern that seasonal changes in flow regime between the spawning period and the emergence of fry could create the potential for redd dewatering. The potential for dewatering is largely unknown because of the dependence on where fish deposit eggs and the interaction between channel geometry and the observed flow regime. The selected hydrograph may also impact on the quantity of suitable gravel for spawning because 1) it is assumed there is little (if any) gravel recruitment to the river channel below the dam and 2) the implemented hydrograph may result in river discharges that mobilize spawning gravel. The combination of redd dewatering and gravel mobilization may erode the quantity and effectiveness of spawning habitats in the river.

To obtain improved understanding of the operational impacts of the implementation of the Seton hydrograph on fish habitat, the BRG CC recommended the implementation of a study to assess how the implemented hydrograph performed with respect to critical habitat issues. The recommended focus of this monitoring was: 1) documenting the hydraulic conditions in the river that are provided by the hydrograph; 2) collect further information on juvenile fish habitat use in the Seton River as it pertains to flow; 3) monitor the salmon and Steelhead spawning locations to assess the potential for redd dewatering impacts; and 4) monitoring changes in quantity and spatial location of gravel suitable for fish spawning. The purpose is to document how the implemented hydrograph influences habitat and to gain further information useful in the refinement of future performance measures for fish resources in Seton River and provide information on the most suitable shape of the hydrograph for fish production.

1.3 Management Hypotheses

Three primary null hypotheses (and sub-hypotheses) associated with the management questions are:

H_1: The amount of hydraulic habitat that can be inhabited by juvenile fish is independent of discharge from Seton Dam.

- H_{1A}: Juvenile standing crop biomass per unit area is inversely related to flow velocity.
- H_{1B}: Juvenile standing crop biomass per unit area is independent of flow depth.
- H_{1C}: Juvenile standing crop biomass per unit area is independent of both flow velocity and depth.

H_2: The selected Seton River hydrograph does not result in dewatering of salmon or Steelhead redds.

H_3: The selected Seton River hydrograph does not result in mobilization of gravel or net loss of gravel from the system.

Each of these hypotheses could have important consequences for the predicted impacts of operations on fish, and data from this program will be collected to explicitly test these null hypotheses.

1.4 Key Water Use Decision Affected

The Seton Dam and generating station are a 'hydraulic bottleneck' in the Bridge-Seton system, and changes in the management of the upstream Carpenter and Downton reservoirs or the generating station can have considerable impact on the instream flow regime of the Seton River. This hydraulic characteristic has two practical consequences. First, there are periodic high flows in the Seton River that are necessitated by water management concerns. For example, in high inflow years water in the Bridge-Seton system is managed to prevent excessive flow releases from Terzaghi Dam which could result in environmental impacts in the lower Bridge River. Because the Seton power canal imposes a limitation on the quantity of water that can be "generated" out of the system, water management may require release of water discharge rates from Seton Dam that are greater than that the target hydrograph for Seton Dam. Second, variable inflow patterns to the system on seasonal and inter-annual basis have resulted in highly variable and unpredictable changes in flow in Seton River which could reduce the productive capacity of the habitat for fish. Implicit in the decision to select a given operation target is a trade-off between providing instream flow regimes to protect/enhance fish resources in Seton River and protecting the productive capacity of other waterways. This monitoring program directly addresses this uncertainty by estimating the effects of both target and high flow hydrographs on the Seton River to support water use management decisions.

2. METHODS

2.1 Objectives

The objective of this monitoring program is to monitor the response of fish and fish habitat to Seton Dam operations.

2.2 Monitoring Approach

This monitoring program will conduct field studies to provide three critical pieces of information that will improve decisions regarding flow management at Seton Dam:

1. Field studies will directly examine uncertainties regarding the impacts of the hydrograph on the quality of juvenile habitats, redd dewatering, and gravel scour in the river channel.
2. The collection of simultaneous habitat and population data will improve understanding about the short-term impacts of habitat alteration on population abundance and diversity.
3. The monitoring studies will provide time series data for juvenile and adult populations that will allow long term inferences about the effect of the flow regime on population abundance and diversity. The approach to the work will be to collect coincident habitat and population information on Seton River fish populations and use this information to better understand the effects of the flow regime on critical habitat characteristics and to relate how habitat conditions influence habitat use and relative productivity.

Annual surveys will be conducted to index population abundance and distribution in relation to habitat conditions, quantify redd dewatering, and quantify/map changes in spawning gravel location and quantity. Standardized data management, analysis, and base mapping continues to be developed to determine the linkage between fish use and abundance observations and habitat inventories.

2.3 Juvenile Rearing Habitat

To determine how the Seton River hydrograph influences the hydraulic conditions of juvenile fish rearing habitats downstream of Seton Dam, a habitat-based Instream Flow Incremental Methodology (IFIM) was applied. Habitat instream flow methods use data on water depth and velocity collected at different discharge levels to link discharge and habitat suitability (Jowett 1997). Discharge-habitat suitability curves can be used to determine the point where suitable habitat area begins to decrease rapidly and are based on the principle that habitat features such as depth and velocity are directly related to discharge (Jowett 1997). At the core of these methods, are Habitat Suitability Index (HSI) curves. These suitability curves may be defined by different criteria, including species, life stage, and seasonal requirements (Bovee 1986). HSI curves used in this project derived from Ptolmey et al. (1994). Data requirements for this methodology include cross-sectional water depth and velocity surveys and habitat suitability criteria.

The objective of this work was to create a habitat-discharge relationship curve to assess habitat suitability at various discharges from Seton Dam. Surveys were completed in 2014 and 2015 covering a range of discharges (6 total). No additional surveys were performed in 2016 as desired target flows for the habitat-discharge curve were not observed and thus results will not be discussed in this report. See Ramos-Espinoza (2016) for complete methods and results from BRGMON-9 Year 2 and 3.

2.4 Juvenile Growth Sampling

Fish growth and distribution was assessed through monthly (April through October) open-site electrofishing surveys using a Smith-Root LR-24 backpack electrofisher. Electrofishing crews consisted of two or three technicians, with the crew leader equipped with the electrofisher and one or two dip netters collecting and sampling fish. Fish were captured via single-pass electrofishing at established sites distributed from the Seton Dam to the Fraser River confluence (Figure 4). In 2016, a total of 7 sites (50 m of shoreline per site) were sampled on the Seton River mainstem when flows allowed (April, August, September and October). High flows in May and June prevented the sampling of some of these sites and during these high discharge periods, 6 of the 7 sampling sites could not be accessed due to safety concerns and electrofishing surveys were not completed at those sites (Table 1). The two spawning channels were sampled randomly throughout their entire lengths monthly from April to October and coincided with the monthly sampling on the mainstem river (Figure 4). Monitoring of the spawning channels was not in the original scope of the Terms of Reference, but due to the proximity and good accessibility of fish to move between the river and the spawning channels we thought that fish could either move between the habitats (i.e. the spawning habitats could be seeding the river) or there may be two distinct populations. PIT telemetry data will aid in verifying movement in and out of the spawning channels.

To reduce handling stress, fish were placed in aerated buckets of fresh water until the electrofishing was completed at a site. Sampled fish were anaesthetized with a diluted solution of clove oil dissolved in ethanol (1:10 parts clove oil). A minimum of 30 fish per species and age class, were sampled for fork length (mm), weight (g) and scales during each monthly sampling session. Scales were collected from the area above the lateral line and immediately below the dorsal fin and stored in labelled coin envelopes. Length and scale data were analyzed from a stratified sample to a maximum of 5 fish per 5 mm group (Ward and Slaney 1988). Scales were mounted directly on glass slides and aged under a microscope using methods outlined in Ward and Slaney (1988). Two analysts independently determined age without knowing the size, time and location of capture of the sampled fish. Samples were discarded if a consensus between both readers could not be reached. Age data were used to create an age-length relationship and a subsequent length-age key that assigned ages to the entire sample of fish. The age-length key was constructed using methods described in Isermann and Knight (2005) and the FSA package in R (Ogle, 2013).

2.4.1 Length vs Weight

Salmonid length and weight are highly correlated for fish within a particular habitat, and the relationship can be used to monitor gross changes in fish health and growth. Log-linear regression modeling was used to describe the annual length (L) vs weight (W) relationships for each species (Ogle 2016a):

$$W_i = \alpha L_i^{\beta} 10^{\epsilon_i} \qquad \text{Eq 1}$$

$$\log(W_i) = \log(\alpha) + \beta \log(L_i) + \epsilon_i \qquad \text{Eq 2}$$

where α and β are intercept and slope parameters, and ε is multiplicative model error. In future years and with more data available we will examine the effect of year on the length-weight relationship by comparing the length-weight model above to a model including a year variable using one-way analysis of variance (ANOVA) testing (alpha 0.05; modelling completed using R package *FSA*, Ogle 2016b).

In addition to length, weight, and scale sampling, all Rainbow Trout, Bull Trout and Mountain Whitefish >75 mm in length were scanned for Passive Integrated Transponder (PIT) tags and untagged fish were implanted with a 12 mm PIT tag (Oregon, RFID). Tags were inserted into the body cavity using a 12-gauge needle. Fish <150 mm were tagged in the ventral stomach cavity and fish >150 mm were tagged in the dorsal sinus. Recaptured fish were analyzed for growth and movement between capture events. PIT recapture data (between sampling events and between years) will also assists in verifying the size/age classes of tagged fish collected in successive sampling surveys.

2.4.2 DNA Sampling

There are uncertainties on the presence and use of the Seton River by adult Chinook for spawning as few individuals have been observed in the river. Throughout the years of the monitor, age zero (young of the year) Chinook juveniles have been captured during growth sampling indicating that Chinook may be spawning in the Seton River or conversely that they are coming from other locations such as Bridge River or other tributaries of the Fraser River. and rearing/migrating in the Seton River. We communicated with DFO biologists (Richard Bailey and John Candy) to verify that DNA analysis would provide stock origin and in 2016 DNA samples were collected from a subset of the Chinook captured. DNA samples will be submitted to the Molecular Genetics Lab at the Pacific Biological Station in Nanaimo.

2.5 High Flow Monitoring

In the spring of 2016, Seton River discharge was increased to levels outside of the WUP targets (~60 m^3/s) for an extended time (April to July) (Figure 3).

Juvenile fish (Coho, Chinook, Rainbow Trout, and Mountain Whitefish) are present throughout the year in the Seton River and concerns were raised as to the impacts the extended high discharge periods may have on fish and habitat availability. Under high flow conditions, juvenile fish may become displaced, seek refuge in existing functional side channels, or move into newly formed side channel habitat (Figure 5). Monitoring activities included identifying potential high-discharge electrofishing indexing sites in the Seton River mainstem and performing electrofishing surveys at these sites following the methods described in section 2.4.

2.5.1 Site selection

To identify sites that could serve as useable habitat during high flows, a crew of two people walked the length of Seton River (on both banks). Crews recorded (geo-referenced) and clearly marked each site. A site was deemed potentially suitable if:

1. Flows would permit sampling (electrofishing) and were wadeable (safe for crews). This included mainstem river and side channel habitat.
2. Access to side channels was good. Would water levels permit fish to access the new habitat?

All the sites were then classified into two categories, mainstem river or side channel habitat and baseline data including water depth and wetted width were collected.

2.5.2 Fish sampling

Once the sites had been identified a crew of three returned to each site to assess for the presence or absence of fish. The crew electrofished starting at the downstream extent of the channel and spot sampled (focus on suitable fish habitat) the entire length of the habitat. Fish captured were sampled as described in section 2.4.

2.6 Juvenile Standing Crop

A juvenile standing crop survey was conducted in September 2016. This survey followed the methods outlined in Korman et al. (2010a; 2010b) and Hagen et al. 2010. This methodology involved single-pass electrofishing surveys at index sites and an electrofishing mark-recapture study. Mark recapture studies were conducted to estimate capture probability, which was the used to expand counts from index sites sampled to un-sampled habitat units using a hierarchical Bayesian mark-recapture model. The original intent of the study/methodology was to combine results from two survey types (fall open-site electroshocking and spring snorkel surveys) for estimating species specific standing crop of juvenile salmonids present in the Seton River (Coho, Chinook, Rainbow Trout/Steelhead, Bull Trout, and Mountain whitefish). The combination of electroshocking and snorkeling was intended to maximize detection capture probability across juvenile life stages and habitat types. For example, capture probabilities using electrofishing are high for small juvenile Rainbow Trout (<60 mm) but low for larger juveniles (>60 mm) whereas the opposite is true for snorkel surveys (Korman et al., 2010a). Capture probabilities also vary by water depth for both methods, with shallow water favouring electrofishing and deeper water favouring snorkel surveys (Korman et al., 2010a). A hierarchical Bayesian model would then be used to estimate fish abundance using these two methods (Korman 2010a and Wyatt 2002). This modeling approach would allow for a mixture of enumeration methods while accounting for variation in detection probabilities among sites. However, low densities of juveniles observed during the snorkel surveys prevented the execution of mark recapture experiments and thus, the hierarchical Bayesian model was not run for the snorkel survey data from 2014 to 2016. Moving forward the hierarchical Bayesian model will not be run for the snorkel survey data and instead annual snorkel survey data will be used as an index of abundance for juvenile rainbow trout (Age-1 and Age-2).

2.6.1 Site selection:

The method used to sample each habitat type was determined by discharge, the life stages of fish present, and method-specific limitations. Given these criteria, electrofishing standing crop surveys were completed in the fall and snorkel indexing surveys of larger/older fish were completed in the spring of the following year.

Fall Electrofishing Standing Crop

Twenty-five electrofishing standing crop index survey sites were selected at random from the 125 habitat sites assessed during the habitat survey described in Section 2.3 of Ramos-Espinoza et al. 2016 (Figure 6). These sites were further classified into riffle, shallow, and deep habitats according to criteria outlined in Korman (2010b). Sites were distributed throughout the extent of the river from the dam to the Seton-Fraser confluence. An additional six mark-recapture sites were selected to represent a shallow riffle and glide habitat in each of the three reaches.

Spring Snorkel Indexing

Nineteen index snorkel sites were selected at random from the deeper habitat sites within the pool of 125 habitat sites assessed during the habitat surveys described in Section 2.3 of Ramos-Espinoza et al. 2016 (Figure 6). These sites included deeper riffle, glide and pool habitats that could not be effectively sampled through electrofishing. Snorkel sites were distributed throughout the extent of the river.

2.6.2 Fish sampling

Electrofishing sites were sampled during the day by a three-person crew using a Smith-Root LR-24 backpack electrofisher. Each site (50 m in length) was sampled systematically by traversing the site in an upstream direction and attempting to capture all fish observed. The sites were not enclosed, and sampling was conducted as far into the river as safely possible. Side-channels or narrower sections of the river were sampled across the entire width. Mark-recapture studies consisted of an initial capture survey, where all fish of interest caught at a site were marked with a fin clip and released, and a recapture survey, where the survey was repeated after 24 hours and the number of recaptured tags/marks was recorded (Korman, 2010a).

Snorkel survey sites were assessed using methods in Decker et al. (2009). Sites were surveyed at night with a single diver navigating the site in an upstream direction searching for and enumerating fish with the assistance of an under-water light. Fork length of fish was visually estimated by snorkeler. This was done by holding up a ruler/marked measuring board to the fish. Fork lengths were estimated and rounded to the nearest 5 mm. A safety person on-shore would record the data as the snorkeler would call out what they observed. Mark-recapture studies were originally proposed for snorkel surveys but due to the low densities of fish observed in 2014 and 2015 they were not continued in 2016.

2.6.3 Data Analysis

The hierarchical Bayesian mark-recapture model consists of two levels: an observation model and a population model. The observation model uses data from the mark-recapture surveys to estimate site-specific capture probabilities and hyper-distributions for capture probability. Capture probability is the proportion of marked fish recaptured in the second pass at mark-recapture site *i* (Table 2). The hyper distribution for capture probability estimated from mark-recapture site *i* was then used in the population model to estimate density for index site *j* using catch data collected (site length and capture probability) from the single pass at the index site (Table 2 and Table 3).

The number of marked fish recaptured from a single pass in mark recapture site *i* was assumed to be binomial distributed and capture probabilities were assumed to follow a beta distribution. The only species/life stage with enough data to produce reliable estimates of capture probability was for 0+ Rainbow Trout/Steelhead. Catches from index sites were assumed to follow a binomial distribution and the abundance at index sites was assumed to follow a Poisson distribution. Densities were assumed to be lognormal-distributed. Densities from 2014 to 2016 are presented together for comparison. All priors used in the observation model were uninformative (Table 3). The model was run with three chains and 1000 iterations. The first half of the samples were discarded as the burn in and the remaining 500 samples made up the posterior distributions. A convergence threshold of 1.1 was used.

In future reports, the abundance of fish in the shorelines that were not sampled will be estimated based on the average fish densities and variation in density across the sampled sites and habitat types. The total estimate of abundance for specific reaches or the entire river will then be calculated by summing the estimates from sampled and unsampled shorelines. This will be completed for all monitoring years and mean abundances/ densities between years will be examined for statistical differences. If differences are observed we will examine what is driving the differences (i.e. discharge, temperature).

2.7 Radio Telemetry

2.7.1 Tag Application and Bio-sampling

Skilled anglers attempted to capture fish throughout the Seton River and at the Seton-Fraser Confluence. In 2016, no Coho or Chinook adults were captured and only six Steelhead adults were tagged by gastrically implanting a TX-PSC-I-1200-M radio tag (44 x

16 x 16 mm; Sigma Eight Inc., Ontario, Canada) using methods described in Burnett et al. (2016). A 32 mm HDX PIT tag was also implanted into the dorsal musculature of each fish. Fork length and gender were recorded during tagging and scale samples were taken from all adults for ageing. After tagging, fish were held in a submersible holding tube for a minimum of 30 minutes prior to release to ensure fish health and proper tag placement, and to confirm that the tag had not been regurgitated.

Tag application effort was distributed throughout the migration period. An effort to ensure even distribution of tags between sexes was also made in consideration of the migration behaviour and run timing differences between males and females (Korman et al. 2010b; Troffe et al. 2010). The tagging schedule was adaptive as suitable capture locations proved to be limited on the Seton River, and application timing depended on capture success, angling conditions, and fish behaviour.

2.7.2 Mobile Tracking

Weekly mobile tracking with a hand-held Lotek W31 radio receiver was conducted for Steelhead from April 4th to June 1st throughout the Seton River (4 km in length). Tracking occurred during the period tags were known to be present in the area (based on fixed station analysis) and coincided with weekly visual surveys. Mobile tracking was completed by vehicle or foot and in isolation of the technicians conducting the visual surveys to avoid observer bias. Fish location and tag code were recorded as well as visual sighting of tagged and untagged individuals of all species.

2.7.3 Fixed Station Telemetry Receivers

Fixed station logging was conducted from April 4th to June 5th at one site located on the Seton River 1.3 km upstream of the Seton River - Fraser River confluence (Figure 7). The fixed station used a Lotek W31 receiver linked to one Yagi 6-prong directional aerial oriented downstream. Fixed station data were used to corroborate fish locations determined during mobile tracking, identify entry and exit timing into the Seton River, and collect basic data on Steelhead adult migration and spawning in the Seton River.

2.8 Visual Counts

Visual stream counts were performed weekly throughout the Seton River and spawning channels to enumerate spawning Steelhead, Rainbow, Chinook and Coho salmon and identify any visible redds. Visual surveys provide indices of abundance as opposed to total counts or total abundances. Survey methods were conducted using methods outlined in BRGMON-3 (Burnett et al. 2016), where two observers walked along the riverbank in a downstream direction looking for fish and any spawning activity. Fish were classified by species and location and recorded in field notebooks along with viewing conditions, cloud cover and lateral water visibility. Surveys were not completed in the mainstem river for Steelhead in 2016 due to high discharges and low water visibility. Chinook surveys commenced on August 8th and were completed on December 2nd, while Coho surveys began on October 4th and were completed on December 12th.

2.8.1 Estimating Escapement from Visual Counts and Telemetry Data

Area Under the Curve (AUC) was originally proposed to estimate escapement for all species; however, data collected in 2014, 2015 and 2016 were low for all target species and insufficient to produce an estimate.

2.9 Passive Integrated Transponder Tagging

PIT tagging has occurred in the Seton River since the initiation of BRGMON-9 in 2013. Each adult or juvenile salmonid > 70 mm captured through angling or electrofishing has been implanted with a 12 mm or 32 mm PIT tag. Upon recapture (manually or using fixed stations), length, weight, and location data are recorded for each tagged fish, allowing for the detailed tracking of movement and growth rates for individual fish in the Seton River.

The movement of PIT-tagged fish was assessed using four fixed PIT antenna arrays installed in the Seton River System (Figure 7). Fixed station data was analyzed to assess fish location, identify movement of each fish into each region, and collect basic data on fish migration and spawning behavior in the Seton River. Stations were distributed throughout a variety of habitats:

1) Seton Dam fishway (mains power-operated year-round since 2013)
2) Lower spawning channel outlet (mains power-operated year-round since 2014)
3) Cayoosh Creek 650m upstream of Seton confluence (battery powered-operated April-Dec since 2014)
4) Upper spawning channel outlet (mains power –operated year-round since May 2015)

2.10 Fraser River Fish Habitat

Methods for assessing the effects of Seton Generating Station discharge reductions on Fraser River fish and fish habitat were consistent with those used during previous monitoring (Genes Tisdale, pers. comm.). Two locations on the Fraser River were identified for monitoring (Figure 8). These sites were identified as critical sites as they are both low-gradient gravel bar areas that are susceptible to dewatering during shutdown events (Higgins, 2010).

Each site was visited the morning before the scheduled shutdown of the generating station. A portable staff gauge was installed prior to the ramp down and water depth was recorded at five-minute increments throughout the ramp down period. The wetted edge was also marked at ~ 20 m intervals before and after the shutdown to calculate the total area dewatered. At the peak of the flow reductions resulting from the shutdown, the dewatered gravel bar was surveyed for stranded fish. All stranded fish were recorded, sampled for length and weight, and released into flowing water if alive.

2.11 Gravel Mobilization

Bennett Land Surveying Ltd. (BLS) was contracted in September of 2013 and 2015 to conduct riverbed topographic surveys of the Seton River at an area 150 m downstream of Seton Dam (Figure 9); methods described in Ramos-Espinoza et al. 2016). This area was identified as the major source of gravel and more importantly where the majority of spawning occurs. Riverbed topographic surveys were not completed in 2016; however, substrate measurements were completed in early 2016 to characterize the substrate composition during the topographic survey from September of 2015. Four transects were identified and sampled within the area surveyed by BLS. Each transect consisted of running a measuring tape or marked line across the width of the river, from bankfull pin to bankfull pin, or to a point of safe wading access. At every meter interval along the transect line the proportion of each substrate type was estimated to the nearest 5% within a 1 m^2 section of river bed along the entire length of the transect or to the furthest point of safe access. Substrate types were classified using the Wentworth scale (Wentworth, 1922), which separates substrate into 7 categories (fines, sand, small gravel, large gravel, small cobble, large cobble, boulder and bedrock). For analysis purposes a dominant substrate was then assigned for each transect. Substrate classification data were managed, analyzed and visualized in R (Version 3.2.3; R Core Team 2014).

3. RESULTS

3.1 Physical Parameters

In 2016, Seton River saw extremely high flows which deviate drastically from WUP targets. Starting on April 12, 2016 flows increased steadily from the WUP target flows of 15 cms, reaching a maximum of 102 cms on April 20th (Figure 4). Flows stayed consistently high until May 30th when the flows reduced slowly, and ultimately returned to WUP targets on July 31, 2016. With the exception of a couple days in late August, flows were maintained at WUP target levels for the remainder of the year.

These high flows interfered with sampling procedures set up in previous years and resulted in a shift to sampling off channel habitat.

3.2 Juvenile Rearing habitat

Due to the high flow experienced in 2016, only side channel habitats were assessed for habitat suitability and no habitat surveys were performed at the standing crop sites. The extent of the assessment at side channel habitats was preliminary and more detailed surveys should be completed in future years to support HSI modelling.

During the high flow period in May and June, four potential side channel habitat areas were identified for electroshocking surveys (Figure 5). All four habitat areas were side channels that became wetted when the Seton River discharge increased above 60 m^3/s. These side channels ranged in length from 34 m at OCH-08 to 184 m at OCH-09. Potential wetted useable area ranged from 482 m^2 at OCH-01 to 1137 m^2 at OCH-09 (Table 4).

3.3 Juvenile Growth Sampling

Juvenile growth sampling surveys commenced on April 12, 2016 and were conducted every six weeks until October 25, 2016 (6 surveys in total). Due to the modified operations at Seton Dam and the increased Seton River flows, the mainstem Seton River sites (Figure 4) were only sampled in April, August, September and October. In May and June (during high discharge periods) the new side channel habitats (Figure 5) described in section 3.1 were sampled. The spawning channel sites (Figure 4) were sampled during all surveys (Table 1).

In total, 13 species of fish were observed during growth sampling in April through October (Seton River mainstem sites and spawning channel sites; (Table 5) including six species of salmonids (Rainbow Trout, Bull Trout, Coho, Chinook, Sockeye and Mountain Whitefish), and seven species of non-salmonids (Bridgelip Sucker, Prickly Sculpin, Coastrange Sculpin, Longnose Dace, Redside Shiner, Peamouth Chub and Northern Pikeminnow). During the high flow periods, 10 species were observed in the new side-channel habitats, with the largest number of species (6) being recorded at the largest site (OC-9). In contrast with the mainstem and spawning channels, Prickly Sculpin, Northern Pikeminnow, and Mountain Whitefish were not captured in any of the new side-channel habitats. Catches of Chinook, Coho, Longnose Dace, and Rainbow Trout were consistently high in all three habitats (i.e., mainstem, spawning channel, and side-channel; Table 5).

Of the species observed during growth sampling, only Rainbow Trout, Coho and Chinook Salmon were caught in sufficient numbers to show the presence of discrete size classes. Catches from the Seton River mainstem and the spawning channels were pooled to increase sample sizes for all age analyses. This was done under the assumption that fish can and do move freely between the two habitat types. Smaller size classes, (particularly young of the year fish), were captured more frequently than larger fish and thus provided a sufficient sample size for monthly and annual growth rate calculations.

3.3.1 Rainbow Trout

A total of 643 Rainbow Trout were sampled in the Seton River and spawning channels throughout the 2016 growth sampling, with lengths ranging from 27 mm to 216 mm. Monthly average, minimum, and maximum fork lengths for Rainbow Trout in the Seton River mainstem and spawning channel are presented in Table 6 (sample sizes were highly variable).

Age Analysis

Rainbow Trout scales were pooled for the Seton River mainstem and spawning channel habitats to determine age distributions and length-at-age for 2016. Scale age analysis identified four distinct age classes of Rainbow Trout, from age 0 (young-of-year) to age 3. All Rainbow Trout that have survived one winter were classified as age 1+. These criteria were also used to classify age 2+ and age 3+ Rainbow Trout.

Length-at-age frequencies in Figure 10 show the distribution of age and size classes throughout the 6 sampling sessions. In April, age 1, 2, and 3 Rainbow Trout were captured, with overlapping fork length ranges. Age 0 fish first appeared in growth sampling during the June session. Some of these fish were quite small (<45 mm; designated as age 0) and scales could not be collected or aged as they had not yet formed. Age 3 Rainbow Trout were only captured during the April and October sampling sessions (N = 1 during both sampling sessions). Despite small sample sizes, length frequencies in Figure 10 demonstrate an increasing trend in fork lengths for individual age classes throughout the study period. This is particularly noticeable for age 0 Rainbow Trout, for which fork lengths increased from June to October, and for age 1 Rainbow Trout from April to May. Trends in size distributions for age 1, 2 and 3 fish are difficult to identify due to small sample sizes resulting in substantial overlap between these higher age classes (Figure 11).

Growth Analysis

Age and length data collected throughout the growth sampling was were used to assess growth rates of distinct Rainbow Trout age classes in the Seton River mainstem and spawning channels, combined. Log-linear length-weight analysis showed a strong relationship between the logarithm of length and weight of all Rainbow Trout captured in the Seton River and spawning channels (R-squared = 0.94; Figure 12). In future years and with more data available we will examine the effect of year on the length-weight relationship by comparing the length-weight model above to a model including a year variable using one-way analysis of variance (ANOVA).

In 2016, age 0 Rainbow Trout were first observed in June and only in the side channel habitats off the mainstem river, because the mainstem river could not be sampled. Average fork lengths and weights for age 0 Rainbow Trout increased each month from June to October (Figure 13 and 14, and Table 6 and 7). Overall, age 0 Rainbow Trout average fork length increased by 45 mm from June to October (0.34 mm/day), which agrees with growth rates from 2014 (0.31 mm/day) and 2015 (0.36 mm/day).

Age 1 Rainbow Trout were captured in all 6 growth sampling sessions (April through October); however, sample sizes were lower than for age 0 fish, making it difficult to assess growth rates. Average fork lengths of age 1 fish decreased in August (Figure 13 and Table 6); however, only one individual was captured in August, clearly biasing average lengths. Despite the small sample size, an increasing trend in fork length was observed through time for age 1 fish (this trend is less apparent in average weights; Figure 14 and Table 7).

Overall, age 1 Rainbow Trout average fork length increased by 57 mm (0.46 mm/day) from April to October.

Overall growth rates could not be assessed for age 2 and 3 Rainbow Trout due to small sample sizes. Low catches of these larger fish are likely due to limitations inherent in open-site electroshocking. Larger fish are generally faster and more challenging to capture using this method. Despite small sample sizes (N=33 for all year), Figure 13 and Figure 14 show a general increase in length and weight for age 2 Rainbow Trout in the Seton River mainstem and side channel habitats.

PIT Tag Recaptures

In 2016, 196 Rainbow Trout were PIT tagged (using all sampling methods), 12 of which were recaptured and retraced to their original tagging date (Figure 15). The duration between tagging and recapture varied from 32 days to 42 days. Eight of the recaptured Rainbow Trout were assessed as age 0 (fish >70 mm in length), three were age 1, and one was age 2. Most age 0 recaptures occurred from September to October, and the average growth of recaptured age 0 Rainbow Trout was 0.09 mm/day (Table 8). This is lower than the corresponding September to October growth of untagged Rainbow Trout (0.17 mm/day). Age 1 recaptured were more evenly distributed throughout June to October, and these fish increased by an average fork length of 0.58 mm/day over the study duration (Table 8). This growth rate is higher than the growth rate calculated for untagged age 1 Rainbow Trout over the same period (0.46 mm/day).

3.3.2 Coho Salmon

A total of 143 Coho Salmon were sampled in the Seton River and spawning channels throughout the growth sampling in 2016, with lengths ranging from 37 mm to 113 mm (Table 6).

Age Analysis

Coho scales were pooled for the Seton River mainstem and spawning channel habitats to determine age distributions and length-at-age for 2016. The life history of Coho in the Seton River differs from Rainbow Trout as Coho spend only 1 to 2 years in freshwater before migrating to the ocean to rear for 1.5 years. Therefore, age 0 (young of year) Coho are typically encountered throughout the year and age 1 and age 2 fish are encountered only in the early spring. This age structure was observed during the 2016 Seton River growth sampling. Three age classes (age 0, 1 and 2) were identified during the April growth sampling survey, but catches were almost entirely age 0 fish in May through October (Table 6 and 7). A small number of age 1 Coho were captured in August and September, possibly representing Coho rearing for a second year in the river or migrating uncharacteristically late. Length frequencies for age 0 Coho in Figure 16 show unimodal length frequencies increasing in mean fork length over time. Figure 17 shows length at age by month.

Growth Analysis

Age and length data collected throughout the growth sampling was were used to assess growth rates of distinct Coho age classes in the Seton River mainstem and spawning channels, combined. Log-linear length-weight analysis showed a strong relationship between the logarithm of length and weight of all Coho captured in the Seton River and spawning channels (R-squared = 0.96; Figure 18).

Age 0 Coho were encountered during all monthly surveys, and average fork lengths and weights generally increased each month (Figure 19 and Figure 20). From September to October, average fork lengths showed a slight decrease; however, this is likely due to small sample sizes (N = 12). Overall, from April to October, age 0 Coho fork lengths increased at a rate of 0.24 mm/day. Age 1 Coho were encountered in April, August, and September, but sample sizes were not large enough to perform growth rate calculations.

3.3.3 Chinook Salmon

A total of 211 Chinook Salmon were sampled in the Seton River and spawning channels throughout the growth sampling in 2016 (Table 6), with lengths ranging from 37 mm to 130 mm.

Age Analysis

As with Coho juveniles sampled in 2016, age 0 Chinook dominated growth sampling catches, with age 1 fish only being captured in the spring and fall. Length frequency histograms in Figure 21 show typical unimodal length distributions for age 0 Chinook, with average lengths increasing over time. In April and May, age 0 and age 1 length distributions are distinct, while in September and October the distributions overlap.

Growth Analysis

Age and length data collected throughout the growth sampling were used to assess growth rates of Chinook age classes in the Seton River mainstem and spawning channels, combined. Log-linear length-weight analysis showed a strong relationship between the logarithm of length and weight of all Chinook captured in the Seton River and spawning channels (R-squared = 0.95; Figure 22).

Age 0 Chinook were encountered during all monthly surveys, and average fork lengths and weights increased each month (Table 6 and 7, Figure 23 and 24). Overall, from April to October, age 0 Chinook fork lengths increased by 52 mm. Age 1 Chinook were encountered in April, May, September, and October, but sample sizes were not large enough to perform growth rate calculations.

3.4 Juvenile Standing Crop

In March of 2016, 19 snorkel index sites were surveyed, accounting for a total of 965 m (11.1 %) of shoreline. In the September standing crop surveys, 25 index sites and five mark-recapture sites were sampled using electroshocking, accounting for a total of 1,574 m (approximately 18%) of shoreline.

3.4.1 Snorkel Surveys

During the March snorkel surveys, 8 species of fish were observed at the index sites: Coho Salmon, Rainbow Trout, Mountain Whitefish, Bull Trout, Redside Shiner, sculpins, and lamprey (Table 9).

The most abundant species was Rainbow Trout, with 129 fish observed. Mean fork length of Rainbow Trout was 88.7 mm with a range of 60 mm to 280 mm. The number of Rainbow Trout observed at the index sites ranged from 1 to 16 individuals (Table 9). A mark-recapture experiment was not attempted due to the small number of individuals observed. Discharge at the Water Survey of Canada (WSC) gauge (08ME003) was 14.0 m^3/s during the March survey (Figure 3).

3.4.2 Electrofishing Surveys

During the September electrofishing surveys, only age 0+ (young of the year) Rainbow Trout were captured in high enough numbers to estimate density using the mark-recapture method. Six mark-recapture sites were originally selected, but due to low catches at one of the sites the mark-recapture study at that site was not completed. It appears like more fish were caught at mark-recapture sites because those sites were sampled twice. The mark-recapture sites were also selected because they are known to have higher densities of fish that would produce enough marks/sample for the experiments. Mean fork length for 0+ Rainbow Trout at mark-recapture and index sites were 66 mm (39 mm to 85 mm) and 68 mm (50 mm to 85 mm), respectively. Discharge in the Seton River during the September survey was 14 m^3/s (WSC gauge, September 20-29) (Figure 3).

During the mark-recapture sampling, a total of 150 Rainbow Trout (0+) were marked and 40 recaptured, resulting in an overall capture probability of 0.27 (0.1 to 0.46 between sites). The capture probability from the observations model resulted in a mean of 0.39 (mean of hyper distribution). Figure 25 shows the posterior distribution of the capture probability of Rainbow Trout at the five different mark recapture sites sampled in 2016.

Mark-recapture density estimates of age 0+ Rainbow Trout in the Seton River were similar to those of past years. Densities in 2016 ranged from 0.07 fish/m to 1.57 fish/m, compared to 0.1 fish/m to 3.7 fish/m in 2014 and 0.1 fish/m to 1.0 fish/m in 2015. Reach 1 (Sites 2-11 and 34-39) had lower Rainbow Trout densities (0.07 fish/m to 1.38 fish/m), particularly near the dam. A wider range of densities were observed in Reach 2 (Sites 12 – 24 and sites 41 to 47), ranging from 0.07 fish/m to 1.52 fish/m. In Reach 3 (sites 25-31 and 47 to 54), densities ranged from 0.11 fish/m to 1.4 fish/m (Figure 26, Table 10).

In future years of the study, abundance of fish along shorelines that were not sampled will be estimated based on the average fish densities and variation in density across the sampled sites. The total estimate of abundance for specific reaches or the entire river will then be calculated by summing the estimates from sampled and unsampled shorelines. This will be completed for all monitoring years and will allow for the comparison of abundance estimates between years.

3.5 Adult Salmonids

3.5.1 Steelhead

Tag Application and Bio-sampling

In 2016, Steelhead angling took place from the beginning of March to the end of April, when migration into the Seton River is finished (based on run-timings from other Fraser River systems; Braun et al. 2016). Six Steelhead were captured and PIT and radio tagged at the Seton-Fraser confluence. Three of those individuals were later detected on the Seton Fixed Station. The mean fork length of radio-tagged individuals that moved into Seton was 655 mm (600 mm to 740 mm, n=3) (Table 11).

Fixed and Mobile Tracking

Radio tags were detected by a series of fixed telemetry stations combined with mobile tracking on the Seton and Lower Bridge Rivers. Three of the six Steelhead Trout tagged at the Seton – Fraser confluence (via BRGMON-3) were detected on a radio receiver located at the Lower Spawning Channel confluence (1.42 km upstream of Seton-Fraser confluence) (Figure 7). Having the radio receiver at this location ensured that fish were committed to the Seton River and would eliminate detections of fish that moved into the river for a short period of time. Three of the six Steelhead trout (Codes #55, 60, 63) tagged at the Seton – Fraser confluence were detected through mobile radio tracking and PIT antennas located at Cayoosh Creek and Seton Dam (Figure 2). Of the three fish detected in the Seton River, two individuals (Codes #55, 63) passed Seton Dam on April 4 and 13, respectively (Figure 27). One radio tag (Code #63) was detected at the tagging site after the fish passed Seton Dam (confirmed passage through PIT data); suggesting this individual regurgitated its radio tag shortly after tagging. All tagged Steelhead appeared to make upstream movements in response to increases in temperature, particularly for Codes #55, 60, whose movements were associated with fluctuations in temperature (Figure 27).

Visual Counts – Streamwalks

Visual counts of Steelhead Trout were not conducted in 2016 due to high flow releases from the Seton Dam resulting in poor visibility. Visual surveys in the two spawning channels were also not conducted because upstream access into the spawning channels was blocked by the infrastructure put in place to monitor out-migrating fry and smolts (Splitrock Environmental).

3.5.2 Coho Salmon

Tag Application and Bio-sampling

There was no effort to capture Coho salmon adults in the Seton River in 2016. However, one individual (Code #171) tagged through BRGMON-03 sampling efforts was detected in the Seton River. Code #171 was tagged on October 16 near the confluence between the Bridge and Fraser Rivers and passed Seton Dam 21 days later (Figure 27).

Visual Counts – Streamwalks

Visual counts of Coho salmon in the lower and upper spawning channels were conducted from October 4 to December 12, 2016, at which point the spawning migration was complete (Burnett et al 2017, Casselman et al 2016). A total of 64 and 25 individuals were observed in the LSC and USC, respectively and peak counts occurred on November 4 (LSC) and November 11 (USC). Water visibility was adequate (1.0 m to 2.0 m) throughout the survey. Mean daily discharge in the Seton River remained stable during the surveys and ranged from 13 to 15 m^3/s (Figure 3). Only four Coho were observed in the mainstem Seton River downstream of Seton the Dam on November 11 (Table 12).

3.5.3 Chinook Salmon

Efforts to capture and PIT tag adult Chinook salmon were unsuccessful, and therefore, no distribution data are available for 2016.

Visual Counts

Visual counts of Chinook salmon in the LSC and USC were conducted from August 8 to December 2, at which point the spawning migration was complete according to run timing data from BRGMON-3 and BRGMON-14 (Burnett et al. 2017, Casselman et al. 2016). One individual was observed on October 4 in the LSC, and two individuals were observed on November 10 downstream of Seton Dam (Table 13). These individuals did not show signs of active spawning and were not observed the following week and we assume they moved on upstream past the dam. Mean daily discharge in the Seton River during the surveys ranged from 13 to 31 m^3/s (Figure 3).

3.5.4 Adult Resident Fish

Adult resident fish species (Rainbow Trout and Bull Trout) were sampled and PIT tagged throughout 2016. The majority of resident fish were captured as by-catch during angling of adult anadromous fish and trash-rack salvage activities at the Seton generating station penstock forebay. (Table 14). Trash rack fish were tagged on an opportunistic basis to asses if there is movement from Seton Lake populations into the Seton River downstream. As these fish were captured at the penstock forebay they most likely moved in from Seton Lake.

Rainbow Trout

In 2016, 11 adult resident Rainbow Trout were captured and PIT tagged as angling by-catch and 13 were collected and tagged during the trash rack salvage on April 18th, 2016. Mean fork length of PIT tagged Rainbow Trout from the trash-rack cleaning was 295 mm (222 mm to 440 mm, while mean length of angling by-catch fish was 374 mm (310 mm to 482 mm) (Table 14).

Bull Trout

A total of 18 Bull Trout were captured and sampled during angling events at the Seton Fraser confluence from March 7 to April 18. Fourteen of these fish were implanted with PIT tags. Four Bull Trout were recaptured in 2016. Two of the four recaptures were tagged earlier in the year at the same location (one month and four days before) and other two were from previous years or other monitors. Further PIT telemetry analysis will be completed in the future to asses where these recaptured Bull Trout came from. The mean length of the Bull Trout sampled in 2016 was 427 mm (340 mm to 580 mm) (Table 14).

3.6 Fraser River Habitat

A shutdown of the Seton Generating Station (SONGS) occurred on March 23, 2016 at 08:30 am. At the time, Fraser River discharge was 885 m^3/s at the Texas Creek gauge (08MF040) on the Fraser River. After the shutdown was completed, discharge at the Texas Creek gauge had decreased to 795 m^3/s (Figure 28) and the water level (stage height) had decreased by 0.16 m.

At a sampling site located ~ 1.7 km downstream of SONGS, the effects of the shutdown were already apparent when the crew arrived at 08:45:00 am. The shutdown was originally was scheduled for 09:00 but was completed earlier that day. At that time, the temporary gauge read 0.65 m and the gauge level decreased for a further 60 minutes until the water level stabilized at 0.44 m at ~ 9:45:00 am. the stage height decreased by a total of 0.21 m and the total area dewatered was 997 m^2. The rate of stage reduction was approximately 0.21 m/h. After water levels had stabilized, a stranding survey was conduction in the dewatered area. Two Longnose Dace were observed alive during the stranding survey and released into flowing water.

At a second site, located 10.9 km downstream of SONGS, the effects of the shutdown were already apparent when the crew arrived at 09:20:00 am. It is likely, that the start of the ramp-down was likely missed and therefore the entire stage change was not measured. The Texas Creek gage showed changes started occurring at 09:00 am. The initial reading of the temporary staff gauge was 0.56 m. Water elevation decreased for 1 hr and 50 minutes before stabilizing at 0.34 m at 11:20:00. The overall reduction in water elevation was 0.22 m (the same reduction as Site 1). The rate of stage reduction at Site 2 was 0.1 m/h, slightly lower than the rate of reduction at Site 1. the total area dewatered at Site 2 was 471 m^2. One Longnose Dace was observed during a stranding survey that occurred at Site 2 once water levels had stabilized at their lowest level. Stranding risk at the site was low.

3.7 Gravel mobilization

Analysis of the elevation data showed that elevation change was variable within and between transects (Ramos-Espinoza et al. 2016). Further analysis of substrate composition also showed variable substrate changes in the area (Figure 29). The uppermost transect (G1B) saw in increase in substrate size from large gravel to boulder. The two middle transects did not see any change and the lowest transect saw a decrease in substrate size from boulder to small cobble (Table 15).

4. DISCUSSION

The primary objective of this program is to monitor the response of fish habitat and fish populations to Seton Dam operations. Data collected in 2016 was the fourth year of the 10-year program and continues to build on the knowledge of fish habitat and fish populations gained in previous years (2013-2015).

In 2016, juvenile rearing habitat surveys were not completed as discharges of interest (17-20 m^3/s) did not occur. Completing a survey at these discharges would still provide valuable information to identify habitat units that are sensitive to flow changes in the 12 – 25 m^3/s range. These sites could be used:1) as indicators of habitat conditions during certain flows or 2) they could be identified as sites susceptible to stranding risks during ramp downs (Ramos-Espinoza et al. 2016). In 2017, discharges at Seton Dam will be closely monitored and communications with BC Hydro operations will be continued to aid in the planning of these surveys. High flow events in 2016 may have redistributed substrate, moved bed load throughout the system, and ultimately changed the shape of the stream channel. This would have consequences on fish habitat downstream of the dam. Completing surveys at base flows again (12 -15 m^3/s) would allow us to compare pre-high flow habitat suitability to post- high flow habitat suitability. The effects of spill-related habitat gains or losses are particularly relevant to answering the management questions of the program and BRGMON-9 activities will continue to inform habitat suitability and responses in the Seton River.

In the spring of 2016, Seton River discharge was increased to levels outside of the WUP targets (~60 m^3/s) for 90 days (April 15 to July 13) (Figure 3). During these high discharge periods, 6 of the 7 growth sampling sites could not be accessed due to safety concerns and electrofishing surveys were not completed at those sites. Extra effort was put into identifying new growth sampling sites and assess the habitat use of juvenile fish during these high discharge events. Four side channels that were wetted during high discharge were identified and sampled and all showed presence of fish (10 species and 179 fish total). The next step will be to quantify the amount of habitat that these areas provide, through HSI surveys, and assess residence time of fish within the new habitat. This would also provide an opportunity to investigate a key assumption of the existing WUP, as stated in the 2012 Terms of Reference for BRGMON-9: "*the impacts of high flow velocity levels on juvenile fish was assumed to be buffered by 1) overflow of the Seton River main stem into side channels that provide favorable habitat for juvenile and subadult fish; 2) a possible "dynamic equilibrium" of suitable hydraulic conditions (i.e., for different flow levels there is a fixed volume of hydraulic habitat that conforms to tolerances or preferences of small fish)"* (p. 3). Completing HSI surveys would allow us to quantify the amount of useable area available to juveniles and assess whether the new habitat is enough to compensate for the loss during high discharges. The The timing and duration of spill events should take the following into account: 1) emergence of Rainbow Trout and 2) monitoring activities. One of the periods of concern is the month of July as it coincides with the beginning of Rainbow Trout fry emergence. High discharges during this time potentially puts these fish at high risk at a vulnerable point in their life history as emergent fry have the potential to be displaced from the mainstem Seton River. High discharges will also affect how various components of the monitor are carried out (high flows prevent sampling activities) and ultimately how management questions 1 and 2 will be answered.

In 2016, valuable biological data continued to be collected to identify the species present in the Seton River. Four age classes of Rainbow Trout (0, 1, 2, and 3), and two age classes of juvenile Coho and Chinook were observed (0 and 1). In future years and with more data available, we will examine the effect of year on the length-weight relationship of each of the juvenile species. This will allow us to see if growth rates differ between years.

The presence of juvenile Chinook continues to be unexpected as very few (1 in 2014) adult Chinook have been observed in the Seton River. In 2016 a sub sample (N = 116) of the Chinook captured were sampled for DNA. DNA analysis will potentially confirm where these age-0 juveniles are coming from the Seton River or if they are migrating into the Seton from other locations. Various studies (Murray & Rosenau 1989 and Daum & Flannery

2012) have shown that in some stream-type populations of Chinook, juveniles rear and sometimes over-winter in non-natal streams as they migrate to the ocean. This is certainly a possibility as there are various Chinook stocks (Bridge River, Portage Creek, Chilcotin River etc.) that migrate past the Seton River on their way to the ocean.

Juvenile standing crop surveys were completed for age 0 Rainbow Trout in September 2016. Mark recapture experiments resulted in a recapture probability of 0.26. Results from the 2016 Hierarchical Bayesian Model (HBM) showed a range of densities throughout the river of 0.07 to 1.57 fish/m of shoreline. This was similar to ranges observed in 2015 (0.1 to 1.0 fish/m). It should be noted that not all the sites sampled in 2016 were sampled in 2014 and 2015 and vice versa, but the majority of common sites (6 of 7) sampled between the three years showed a decrease in fish densities. Due to limited sample sizes at sites, broad credible intervals were observed. Some of the lower and upper credible intervals were as large as 20 to 400% of the mean estimate, respectively. Future expansions of densities to reach and river wide abundances will provide better means to compare juvenile abundances between years and understand how the Seton hydrograph may influence abundance of juveniles in the river.

The index snorkel surveys completed in March of 2015 and 2016 indicated that larger/older fish occur at low densities. The number of fish observed at each site were low, ranging from 1 – 25 fish for all species. Continuing snorkel surveys in future years will provide an annual index of density for these age classes. Future surveys throughout the river may also reveal sites of higher densities where mark recapture experiments could be completed.

Adult salmonid abundance and distribution continued to be difficult to assess. Through collaborations with BRGMON-3, three Steelhead were radio and PIT tagged and were observed in the Seton River. Two passed Seton Dam and one was assumed to have remained and potentially spawned in the Seton River. The combination of PIT and radio technology has allowed us to collect more detailed information on Steelhead distribution and use of the Seton corridor. We can now conclude with more certainty that Steelhead are spawning in the lower spawning channel (2015 data) and/or are migrating past the Seton Dam to spawn in systems upstream. There is still some uncertainty on the use of the Seton mainstem river. More years of tagging and distribution data will assist in strengthening our understanding of Steelhead adult use of the mainstem of the Seton River. Visual surveys for Steelhead in the Seton River and spawning channels were not completed because of poor visibility and blocked access into the spawning channels (juvenile outmigration study). We will communicate with Splitrock Environmental in 2017 to make modifications to juvenile outmigration study infrastructure so that access to the spawning channels can be restored and continue to perform weekly visual surveys on the mainstem river and spawning channels.

Three Chinook adults were observed in the Seton River during visual counts and thus our proposed methods (AUC) for assessing use and estimating abundance have not been possible. In 2016 age zero (young of the year) chinook juveniles were captured during growth sampling indicating that Chinook may be spawning in the Seton or conversely that they are coming from other locations and rearing/migrating. One hundred DNA samples were collected in 2016 and analysis will identify their origin. Samples will continue to be collected in future years of the monitor.

Coho, like Chinook, were difficult to observe/sample in the Seton River, but through the efforts of BRGMON-03 in 2015 we were able to make more certain inferences about their migration patterns and behavior in the area. It was unexpected to observe fish tagged at the Bride River-Fraser confluence double back and moved up into the Seton River. In 2016, only one of the 43 Coho tagged in the Bridge River through BRGMON-3 was observed in the Seton River and eventually passed the Dam. The doubling back behavior of Coho to the Seton River is a bonus of the tagging efforts of MON -3. But this data/behavior cannot be relied on to answer management questions around Coho. A total of 73 Coho were observed through visual surveys in 2016. The majority were observed in the upper and lower spawning channels, 25 and 64 respectively. Continuation of stream walks (visual counts) is important as it will allow us to continue collecting valuable index data and help corroborate PIT distribution data.

Adult Bull trout and Mountain Whitefish were observed in the Seton River, but were caught as by-catch in efforts to collect anadromous species. These species likely do not use the Seton River for spawning and rearing, rather as a migration corridor, as very few if any juveniles were observed in all sampling years. Instead these two species likely use the river as a migratory and feeding corridor. Bull trout are known to be food driven migrators (Ladell et. al. 2010) as are Mountain Whitefish (Mcphail, 2007). Verifying this migratory behavior would allow agencies to better manage these species. Continuing the efforts of PIT tagging will allow us to monitor some of this migration behaviour, as other monitors in the watershed have PIT antennas installed in other areas. For example, on multiple occasions adult Bull Trout PIT tagged in the Bridge River (at the Yalakom confluence) have been detected at fixed PIT telemetry stations in the Seton River. Collaboration with the other monitors will be critical for collecting this valuable fish movement data.

Monitoring of the effects of the Seton Generating Station shutdown showed a 10% reduction in the of the total discharge at the Texas Creek WSC gauge. Ramping rates exceeded DFO thresholds of <0.05m/h at both assessment sites. At site one, 997 m^2 of shore line were dewatered. At site two, 471 m^2 of shoreline were dewatered. Overall, stranding risk in this section of the river is low due to the steep channel banks, a single channel and steep gradient. The two sites monitored through this program were previously assessed to be at high risk, but there are certain uncertainties that should be considered when assigning risk:

Are these critical habitat areas? Do fish spawn here or do juveniles rear here? Does the timing of the dewatering at these sites coincide with vulnerable stages of Salmon development? Continued monitoring and life history information from nearby streams collected through this program will help inform these uncertainties.

Results from the riverbed topographic surveys showed that elevation changes within the area monitored was variable within and between transects (Ramos-Espinoza et al. 2016). Substrate surveys showed that the upper (upstream) section of the area saw a shift in substrate composition. Substrate size increased from large gravel to boulder. Middle section substrate composition remained the same with large cobble being the dominant substrate. At the lowest (downstream) section a decrease in substrate from boulder to small cobble was observed. This suggests movement of smaller substrate from the top section downstream. Subsequent topographic and substrate surveys will continue to inform these inferences. Further review of data will identify if the rate of elevation change is within the natural variance expected within rivers.

5.0 RECOMMENDATIONS

The work undertaken in 2016 continued to quantify juvenile habitat, fish standing crop and distribution in the Seton River. A number of recommendations are provided that may improve the ability to answer the management questions.

1. Complete a Level 1 Habitat assessment of side channel habitat during high flow events to understand microhabitat distribution in these areas.
2. Complete HSI surveys at new side channel habitats during high flow events to quantify available suitable habitat for juvenile salmonid species.
3. Complete HSI surveys on mainstem Seton River to assess whether high flow events have changed habitat suitability in river.

6.0 TABLES

Table 1. Schedule of Growth Sampling in 2016

Site	April	May	June	July	August	September	October
GS9a		*					
GS9b		*					
GS9c		*					
GS3	*				*		*
GS8					*		*
GS10					*		
GS11	*		*				*
GS12	*				*		
GS13			*				
OCH1		*					
OCH2		*					
OCH8		*					
OCH9			*				
LSC	*		*		*		*
USC	*		*		*		*

Table 2. Definitions of variables used in hierarchical model

Variable	Definition
Data	
m_i	Marks released at mark recapture site *i*
r_i	Recaptured marked fish at mark recapture site *i*
c_j	Fish caught at index site *j*
l_j	Length of index site *j*
Site-specific parameters	
θ_i	Estimated capture probability for mark recapture site *i*
θ_j	Simulated capture probability at index site *j*
λ_j	Estimated density (fish/m) at index site *j*
Hyper parameters	
μ_θ	Mean of beta hyper-distribution for capture probability
τ_θ	Precision of beta hyper distribution for capture probability
μ_λ	Mean of normal hyper-distribution for log density
τ_λ	Precision of normal hyper-distribution for log density
Derived variables	
N_j	Estimated abundance at index site *j*

Table 3. Equations for hierarchical model. The letters *i* and *j* represent the mark recapture and index sites, respectively.

Observation Model
$r_i \sim dbin(\theta_i, m_i)$
$\theta_i \sim dbeta(\alpha, \beta)$
Population Model
$\theta_j \sim dbeta(\alpha, \beta)$
$c_j \sim dbin(\theta_j, N_j)$
$N_j \sim dpois(\lambda_j, l_j)$
$\log(\lambda_j) \sim dnorm(\mu_\lambda, \tau_\lambda)$
Priors and transformations
$\mu_\theta \sim dunif\,(0, 1)$
$\sigma_\theta \sim dunif\,(0.05, 1)$
$\tau_\theta = \sigma^{-2}$
$\alpha \sim \mu_\theta\, \tau_\theta$
$\beta = (1 - \mu_\theta)\, \tau_\theta$
$\mu_\lambda \sim dunif(-2, -0.5)$
$\sigma_\lambda \sim dunif\,(0.2, 1)$

Table 4. Sites identified in Seton River during high flow periods in May and June 2016.

Site	Length (m)	Mean Wetted Width (m)	Wetted Area (m^2)
OCH-01	117.5	4.1	482
OCH-02	106.2	7.8	831
OCH-08	34.1*	11.6	396
OCH-09	184.6	5.4	1137

*OCH-08 is a wetland area isolated from Seton River. When site was surveyed in 2016 the downstream sections had been backwatered by the Seton River. Only the backwatered area that fish could access and where fish were found is reported.

Table 5. Total number of fish caught during juvenile growth sampling surveys, 2016.

	Sample Size (n) at Site						
Species	**Seton**	**LSC**	**USC**	**OCH1**	**OCH2**	**OCH8**	**OCH9**
Bridgelip Sucker	4	18	1	0	1	1	1
Bull Trout	0	0	0	0	1	0	0
Cottus aleuticus	10	4	53	0	0	0	2
Cottus asper	90	16	107	0	0	0	0
Chinook	130	20	6	0	12	10	12
Peamouth Chub	0	0	0	0	5	0	0
Coho	88	29	7	0	11	1	0
Longnose Dace	137	103	14	13	6	3	29
Mountain Whitefish	5	0	0	0	0	0	0
Northern Pikeminnow	16	1	0	0	0	0	0
Rainbow Trout	621	19	17	0	5	2	11
Red-sided Shiner	8	28	10	0	10	0	0
Sockeye	4	0	0	0	0	0	0

Table 6. Length data for various age classes of Rainbow Trout, Coho and Chinook sampled in main-stem Seton River and the Spawning Channels, 2016.

			Seton River					Spawning Channels				
Species	Age Class	Sampling Month	n	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Sd FL (mm)	n	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Sd FL (mm)
RB	0	June	1	27	27	27	NA	-	-	-	-	-
		August	31	46.4	30	67	8.6	6	52.7	50	56	2.5
		September	31	64.2	39	88	13.7	4	86.8	65	112	19.4
		October	21	74.6	59	90	9.8	6	80.7	77	87	3.5
	1	April	13	86.3	69	115	14.8	3	101.7	93	111	9
		May	12	102.5	49	129	14.5	-	-	-	-	-
		June	1	113	113	113	NA	-	-	-	-	-
		August	-	-	-	-	-	1	87	87	87	NA
		September	4	110.5	97	123	10.7	2	144	135	153	12.7
		October	1	145	145	145	NA	1	148	148	148	NA
	2	April	4	129.5	110	147	18.7	10	137.4	104	187	27.6
		May	2	120	110	130	14.1	-	-	-	-	-
		June	2	137	120	154	24	1	156	156	156	NA
		August	2	120	113	127	9.9	1	124	124	124	NA
		September	-	-	-	-	-	1	176	176	176	NA
		October	1	154	154	154	NA	4	170.5	127	210	34.1
	3	April	-	-	-	-	-	1	200	200	200	NA
		October	-	-	-	-	-	1	216	216	216	NA
CO	0	April	22	33.9	22	43	4.9	3	34.7	33	36	1.5
		May	33	37.4	30	46	4.1	-	-	-	-	-
		June	12	57	31	68	9	1	47	47	47	NA
		August	3	51.7	40	73	18.5	5	71.8	67	75	3.3
		September	7	85	46	103	10	5	96.8	86	105	9
		October	2	70	69	71	1.4	18	86.1	77	100	5.5
	1	April	4	90.2	82	94	5.6	6	97.8	89	107	6.2
		August	-	-	-	-	-	1	90	90	90	NA
		September	-	-	-	-	-	2	108	105	111	4.2
CHK	0	April	4	37.8	37	39	1	-	-	-	-	-
		May	33	40.5	31	54	5.4	-	-	-	-	-
		June	23	51.5	25	69	11.5	-	-	-	-	-
		August	11	77.6	61	91	10.3	2	74.5	70	79	6.4
		September	29	82.1	49	105	15.4	12	84.1	76	93	6.3
		October	5	82	69	89	8	13	94.2	88	104	5.2
	1	April	1	103	103	103	NA	4	107.8	94	120	11
		May	2	94.5	93	96	2.1	-	-	-	-	-
		September	3	101	97	106	4.6	1	83	83	83	NA
		October	-	-	-	-	-	4	110.8	101	129	13.2

Table 7. Weight data for the various age classes of Rainbow Trout, Coho and Chinook salmon sampled in main-stem Seton River and the Spawning Channels, 2016.

			Seton River					Spawning Channels				
Species	Age Class	Sampling Month	n	Mean W (g)	Min W (g)	Max W (g)	Sd W (g)	n	Mean W (g)	Min W (g)	Max W (g)	Sd W (g)
RB	0	August	29	1.6	0.5	4.0	0.9	6	2.2	2.0	3.0	0.4
		September	30	3.8	0.5	8.5	2.2	4	8.9	3.0	18.0	6.4
		October	21	4.9	2.5	7.5	1.6	6	5.4	4.5	6.0	0.6
	1	April	13	7.3	4.0	15.0	3.4	3	12.3	9.0	14.0	2.9
		May	12	14.5	5.6	25.3	5.2	-	-	-	-	-
		June	1	17.3	17.3	17.3	NA	-	-	-	-	-
		August	-	-	-	-	-	1	9.0	9.0	9.0	NA
		September	4	14.5	10	17.5	3.5	2	35.5	30.0	41.0	7.8
		October	1	33.5	33.5	33.5	NA	-	-	-	-	-
	2	April	4	24.8	15.0	32.0	8.4	10	32.0	14.5	68.5	18.7
		May	2	22.5	18.7	26.3	5.4	-	-	-	-	-
		June	2	32.0	19.5	44.6	17.7	1	44.0	44.0	44.0	NA
		August	2	20.0	16.0	24.0	5.7	1	20.0	20.0	20.0	NA
		September	-	-	-	-	-	1	63.5	63.5	63.5	NA
		October	1	39.5	39.5	39.5	NA	3	67.3	22.5	129.0	55.2
	3	April	-	-	-	-	-	1	80	80	80	NA
CO	0	April	3	0.7	0.5	1.0	0.3	3	0.5	0.5	0.5	0
		May	33	0.7	0.3	1.3	0.3	-	-	-	-	-
		June	11	2.6	1.6	4.0	0.6	1	1.3	1.3	1.3	NA
		August	3	2.3	1.0	4.0	1.5	5	4.2	3.0	5.0	0.8
		September	7	8.0	5.0	13.5	3.3	5	10.8	7.5	13.5	2.9
		October	2	3.8	3.5	4.0	0.4	18	7.2	4.5	10.5	1.6
	1	April	4	8.5	6.5	10	1.5	6	10.3	9.0	12.5	1.5
		August	-	-	-	-	-	1	8.0	8.0	8.0	NA
		September	-	-	-	-	-	2	16.5	15.0	18.0	2.1
CHK	0	April	2	0.5	0.5	0.5	0	-	-	-	-	-
		May	33	0.7	0.3	1.4	0.3	-	-	-	-	-
		June	18	2.0	0.3	3.4	0.7	-	-	-	-	-
		August	11	6.1	3.0	9.0	2.1	2	5.5	4.0	7.0	2.1
		September	29	7.1	1.5	15.5	3.8	12	6.7	4.5	9.0	1.6
		October	5	6.0	4.0	7.0	1.2	13	10	7.0	13.5	1.9
	1	April	1	12.0	12.0	12.0	NA	4	16.0	9.0	27.0	7.7
		May	2	11.8	10.6	12.9	1.6	-	-	-	-	-
		September	3	12.8	11.0	16.0	2.8	1	6.0	6.0	6.0	NA
		October	-	-	-	-	-	4	15.8	12.0	25.5	6.5

Table 8. Growth of PIT-tagged juvenile Rainbow Trout, 2016.

PIT ID	Growth period (days)	Length (mm) at t1	Length (mm) at t2	Age	Growth rate (mm day-1)	Weight (g) at t1	Weight (g) at t2	Growth rate (g day-1)
656752	May to Jun (42)	93	115	1	0.52	12.2	19.8	0.18
656809	May to Jun (42)	93	121	1	0.67	12.3	20.6	0.20
657570	May to Jun (42)	82	105	1	0.55	7.9	14	0.15
656886	Aug to Sep (42)	113	115	2	0.05	16	17	0.02
657804	Sep to Oct (33)	77	81	0	0.12	5	6	0.03
657836	Sep to Oct (35)	80	82	0	0.06	5.5	5.5	0.00
657839	Sep to Oct (32)	81	82	0	0.03	5.5	6	0.02
657877	Sep to Oct (34)	76	79	0	0.09	5	5.5	0.01
657900	Sep to Oct (33)	74	79	0	0.15	4	5.5	0.05
657902	Sep to Oct (34)	70	75	0	0.15	4	4	0.00
657910	Sep to Oct (32)	80	82	0	0.06	5.5	6	0.02
657979	Sep to Oct (34)	87	90	0	0.09	7	8	0.03

Table 9. Summary of fish observed during juvenile snorkel surveys in Seton River, 2016

Species	N	Mean FL (mm)	SD	Min FL (mm)	Max FL (mm)
Bridgelip Sucker	1	130	NA	130	130
Bull Trout	1	175	NA	175	175
Coho	42	90.1	14.8	60	120
Sculpin	4	127.5	84.2	60	250
Lamprey	1	110	NA	110	110
Mountain Whitefish	16	243.1	75.3	40	320
Rainbow Trout	129	121.5	42.7	60	280
Steelhead	1	600	NA	600	600

Table 10. Seton River Rainbow Trout age 0 densities, 2016.

Site	Density (fish/m)	5 % CI	95 % CI
6	0.12	0.03	0.41
7	0.25	0.09	0.7
8	1.38	0.59	3.1
9	0.61	0.25	1.43
11	0.22	0.06	0.67
15	0.5	0.19	1.3
16	0.11	0.03	0.37
17	0.1	0.03	0.34
18	0.29	0.09	0.9
20	1.08	0.47	2.61
26	1.42	0.62	3.32
27	0.15	0.04	0.49
28	0.66	0.27	1.62
29	0.3	0.11	0.84
30	1.06	0.46	2.64
34	0.07	0.01	0.26
43	0.09	0.02	0.34
44	1.52	0.7	3.49
44.2*	0.68	0.29	1.68
46	0.77	0.32	1.8
46.2*	0.27	0.08	0.8
47	0.07	0.01	0.26
51	0.11	0.03	0.38
54	0.19	0.06	0.59

*The .2 represents a second site surveyed on same habitat unit.

Table 11. Seton River Steelhead and Coho catch data for individuals detected in the Seton River, 2016

Date	Location	Species	Sex	Length (mm)	Catch (A/R)	Frequency	Code	PIT #
8-Mar-16	Seton Con	SH	F	625	A	149.32	55	183225426
9-Mar-16	Seton Con	SH	F	740	A	149.78	63	230000010022
8-Apr-16	Seton Con	SH		600	A	149.78	60	230000010016
16-Oct-16	Bridge R. Bridge	COA	F	535	A	149.740	171	230000010052

Table 12. Seton River Coho visual count data – 2016. S. Dam = Seton Dam, IPT = Inclined Plane Trap at Picnic area, Cay.Con = Cayoosh Creek confluence, Halfway = 1.7 R.km from Dam, Intake = Lower Spawning Channel intake, and S.Bridge = HWY 99 Bridge at 3.8 R.km from Dam.

Date	Cloud Cover %	S. Dam-IPT	IPT-Cay.Con	Cay.Con-Halfway	Halfway-Intake	Intake-S.Bridge	USC	LSC	Total
10/07/16	100	0	0	0	0	0	2	0	2
10/14/16	100	0	0	0	0	0	1	0	1
10/21/16		0	0	0	0	0	0	0	0
10/28/16		0	0	0	0	0	4	0	4
11/04/16		0	0	0	0	0	2	26	28
11/11/16	100	4	0	0	0	0	7	19	30
11/18/16		0	0	0	0	0	6	7	13
11/25/16	95	0	0	0	0	0	1	8	9
12/02/16	100	0	0	0	0	0	2	4	6
12/09/16		0	0	0	0	0	0	0	0
12/16/16		NA	NA	NA	NA	NA	0	0	0
Subtotal		4	0	0	0	0	25	64	93

Table 13. Seton River Chinook visual count data – 2016. S. Dam = Seton Dam, IPT = Inclined Plane Trap at Picnic area, Cay.Con = Cayoosh Creek confluence, Halfway = 1.7 R.km from Dam, Intake = Lower Spawning Channel intake, and S.Bridge = HWY 99 Bridge at 3.8 R.km from Dam.

Date	Cloud Cover %	S. Dam-IPT	IPT-Cay.Con	Cay.Con-Halfway	Halfway-Intake	Intake-S.Bridge	USC	LSC	Total
08/26/16	80	0	0	0	0	0	0	0	0
09/02/16	100	0	0	0	0	0	0	0	0
09/09/16	100	0	0	0	0	0	0	0	0
09/16/16	100	0	0	0	0	0	0	0	0
09/23/16	100	0	0	0	0	0	0	0	0
09/30/16	0	0	0	0	0	0	0	0	0
10/07/16	100	0	0	0	0	0	0	1	1
10/14/16	100	0	0	0	0	0	0	0	0
11/10/16	100	2	0	0	0	0	0	0	2
12/02/16	100	0	0	0	0	0	0	0	0
Subtotal		2	0	0	0	0	0	1	3

Table 14. Seton River Resident Fish Species Data – 2016. Fish were either collected through angling at the Seton/Fraser Confluence (Seton Con) or at the Penstock forebay during trash-rack cleaning and released at the Seton Lake Boat Launch (Seton Con).

Capture Location	Species	Count	Mean FL (mm)	SD	Min (mm)	Max (mm)
Penstock Forebay	Rainbow Trout	13	295	58.2	222	440
Seton Con	Bull Trout	17	427.1	72.5	340	580
Seton Con	Rainbow Trout	11	373.5	47.7	310	482

Table 15. D50 (and dominant size class) substrate size (mm) at four transects in the Seton River between 2014 and 2015. LG = Large gravel (16-64 mm), SC = Small cobble (64-128 mm), LC = Large cobble (128-256 mm), B = Boulder (256-400 mm)

Transect	2014	2015	Net change
G1B	43 mm (LG)	260 mm (B)	Larger
G1D	171 mm (LC)	141 mm (LC)	No change
G1F	128 mm (LC)	172 mm (LC)	No change
G1G	259 mm (B)	118 mm (SC)	Smaller

7.0 FIGURES

Figure 1. Bridge & Seton Watersheds

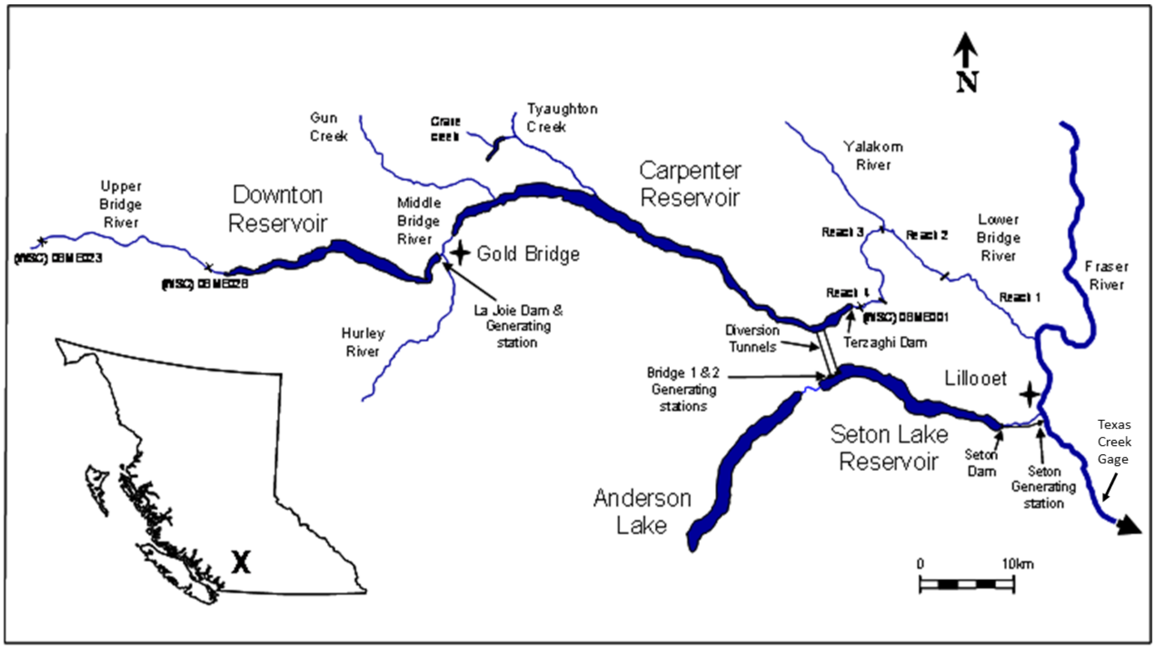


Figure 2. Seton River Study Area bound by Seton Lake to the West and the Fraser River to the East. Included on the map, but not included in the study, is Seton power canal and Cayoosh Creek. Reach 1 extends from the dam to the confluence of Cayoosh Creek. Reach 2 extends from the confluence of Cayoosh Creek to the intake of the lower spawning channel. Reach 3 extends from the lower spawning channel intake to the Fraser River.

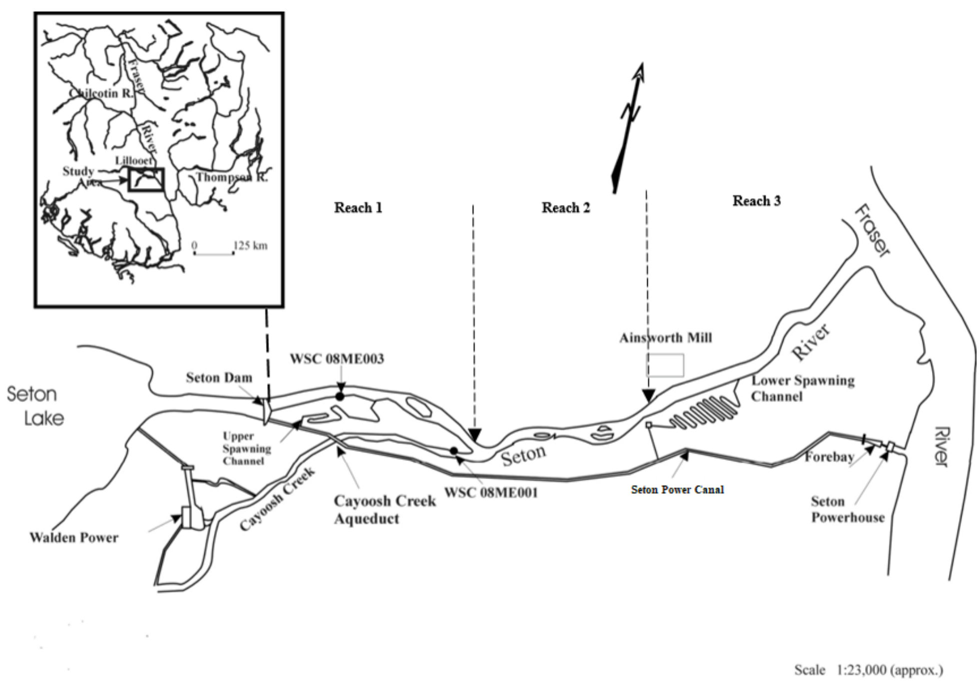


Figure 3. Location of juvenile growth sampling sites in A) Reach 1, Seton River, 2014 - 2016. For reference, Seton Dam can be seen on the far-left side of the map; B) Reach 2; C) Reach 3, Seton River Bridge can be seen adjacent to GS-11. Sites are distributed on both river right and river left throughout each reach. GS = Growth Sampling site, USC = Upper Spawning Channel, LSC: Lower Spawning Channel.

Figure 4. Discharge curve for reach 1 of Seton River at Water Survey of Canada gauge (08ME003). Black line represents 2014 data, blue 2015 data and red 2016 data. The dashed-grey line shows proposed WUP target flows.

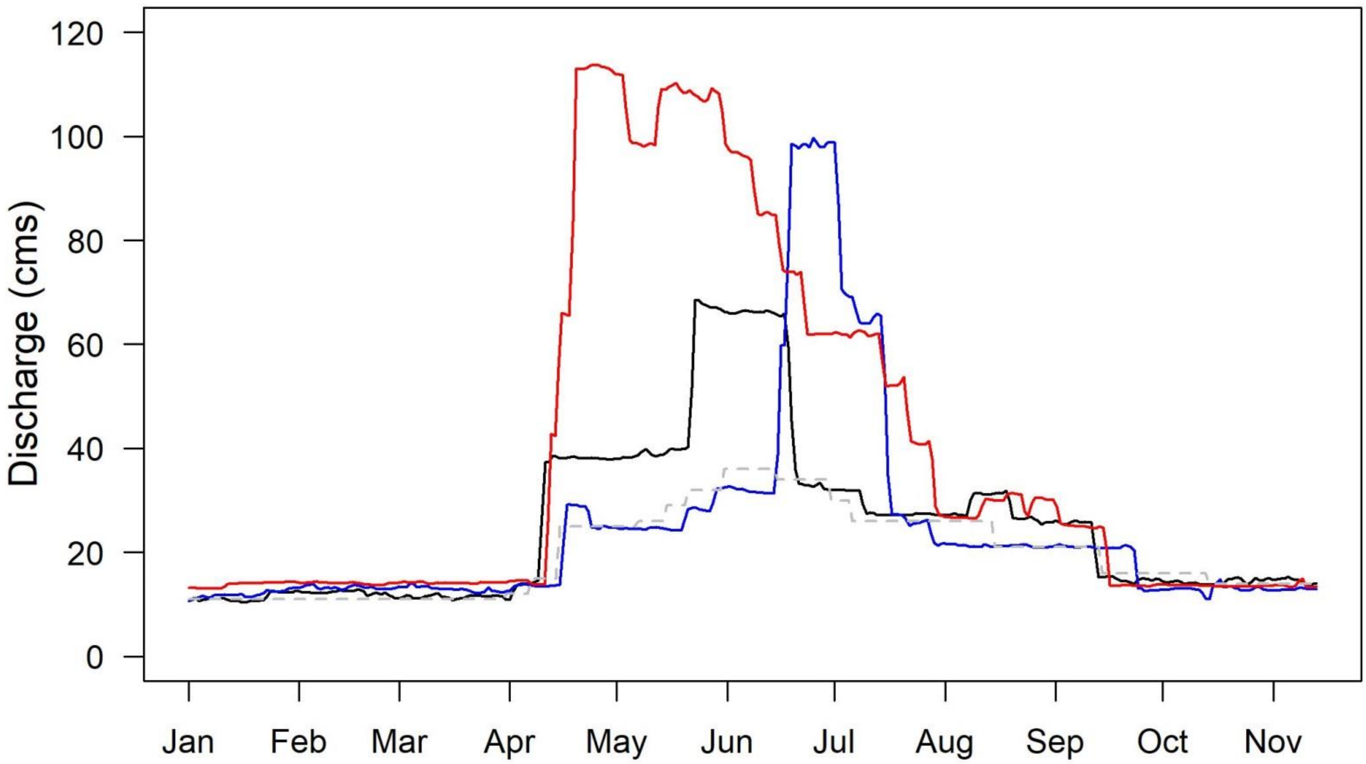


Figure 5. Side-channel habitat identified in 2016 during high flow periods in May and June of 2016.

Figure 6. Location of juvenile standing crop electrofishing sites in each reach. Sites were chosen randomly and cover both river right and river left. Red points represent index- electrofishing sites, blue points represent mark-recapture electrofishing sites. Green points represent snorkel survey sites.

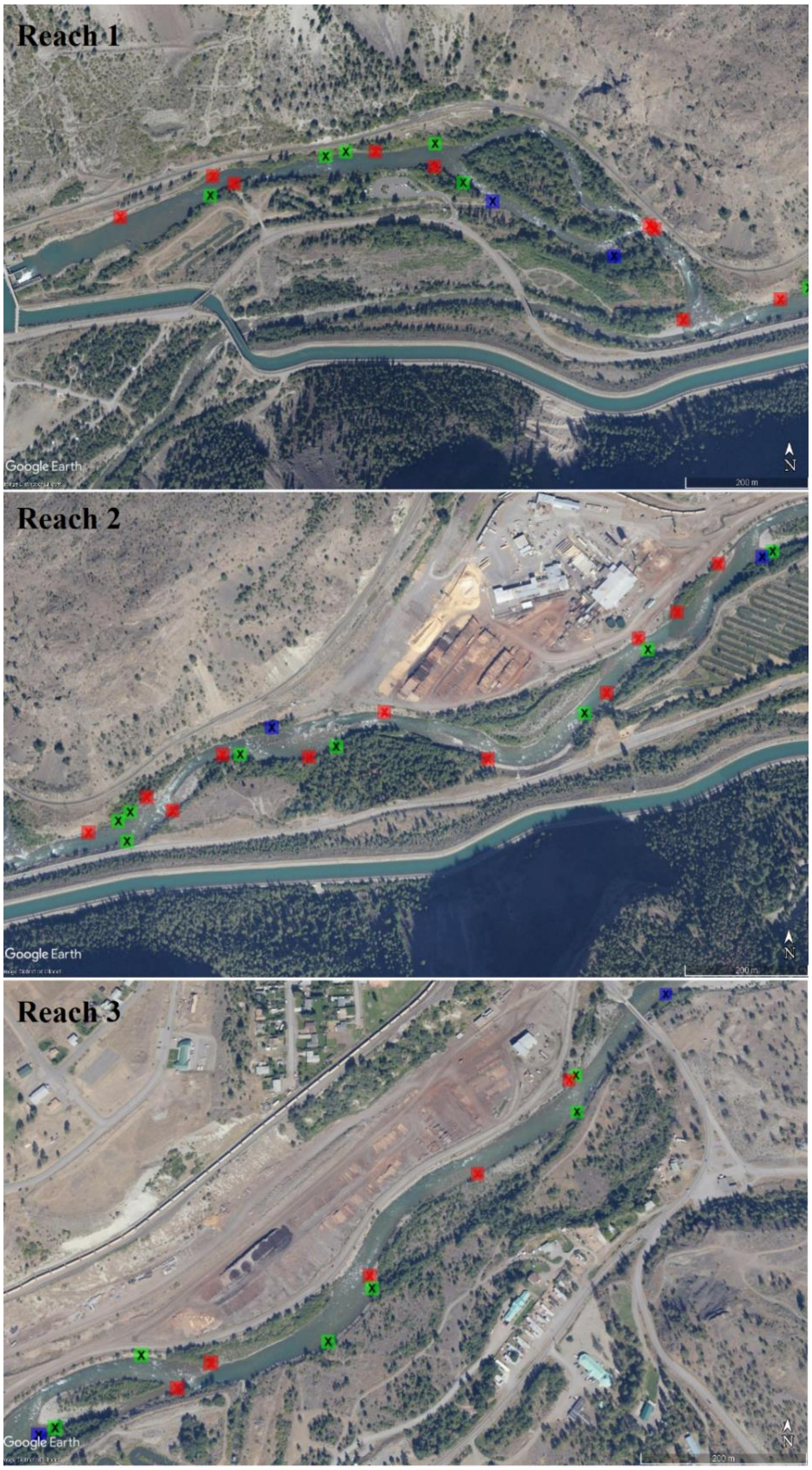


Figure 7. Location of fixed radio telemetry station and fixed PIT station, Seton River (outlined in green) 2014 – 2016.

Figure 8. Location of Fraser River stranding sites (flow reduction monitoring).

Figure 9. Site of riverbed topographic surveys 2013 & 2015

Figure 10. Length at age frequency distributions for Seton River and Spawning Channel Rainbow Trout April to October 2016.

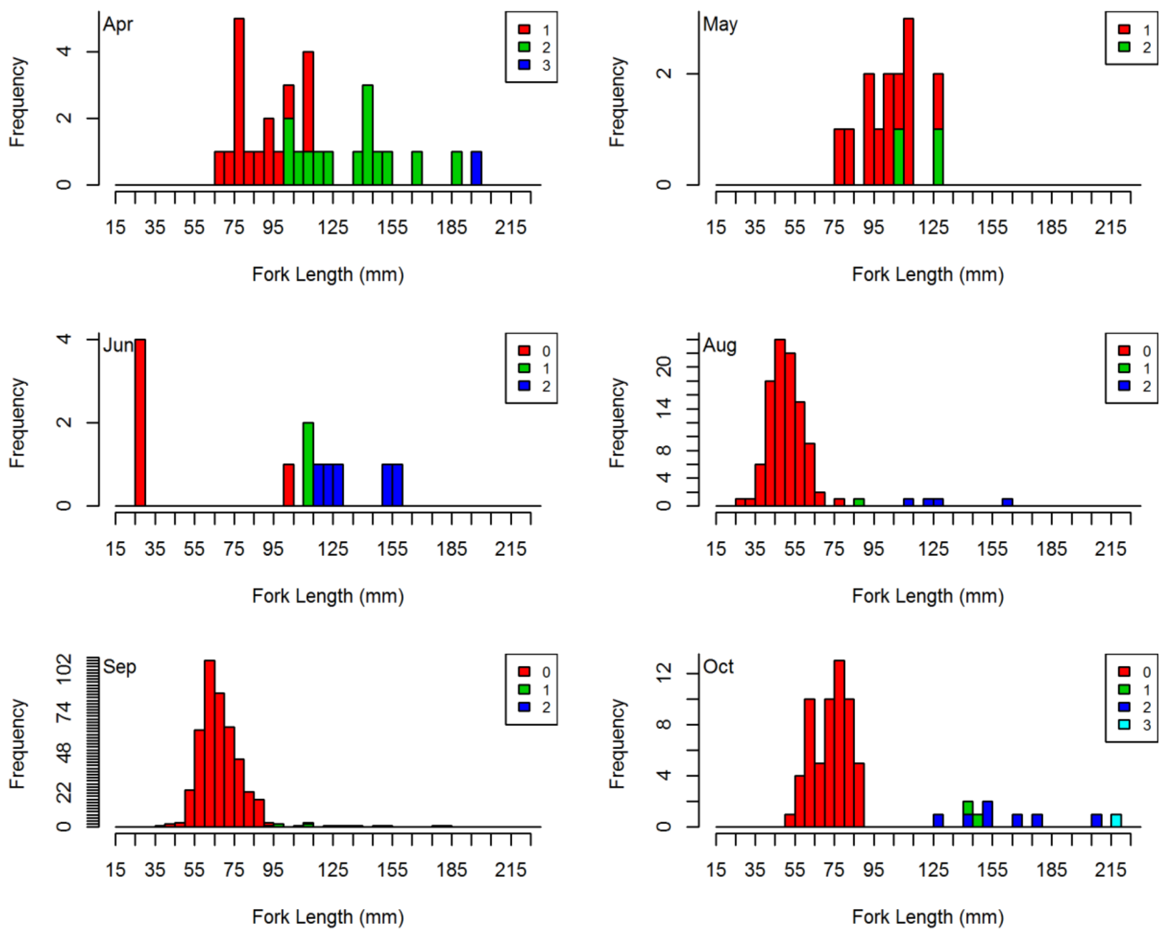


Figure 11. Length-at-age for Seton River Rainbow Trout sampled in April to October 2016. Mean lengths are connected by blue line.

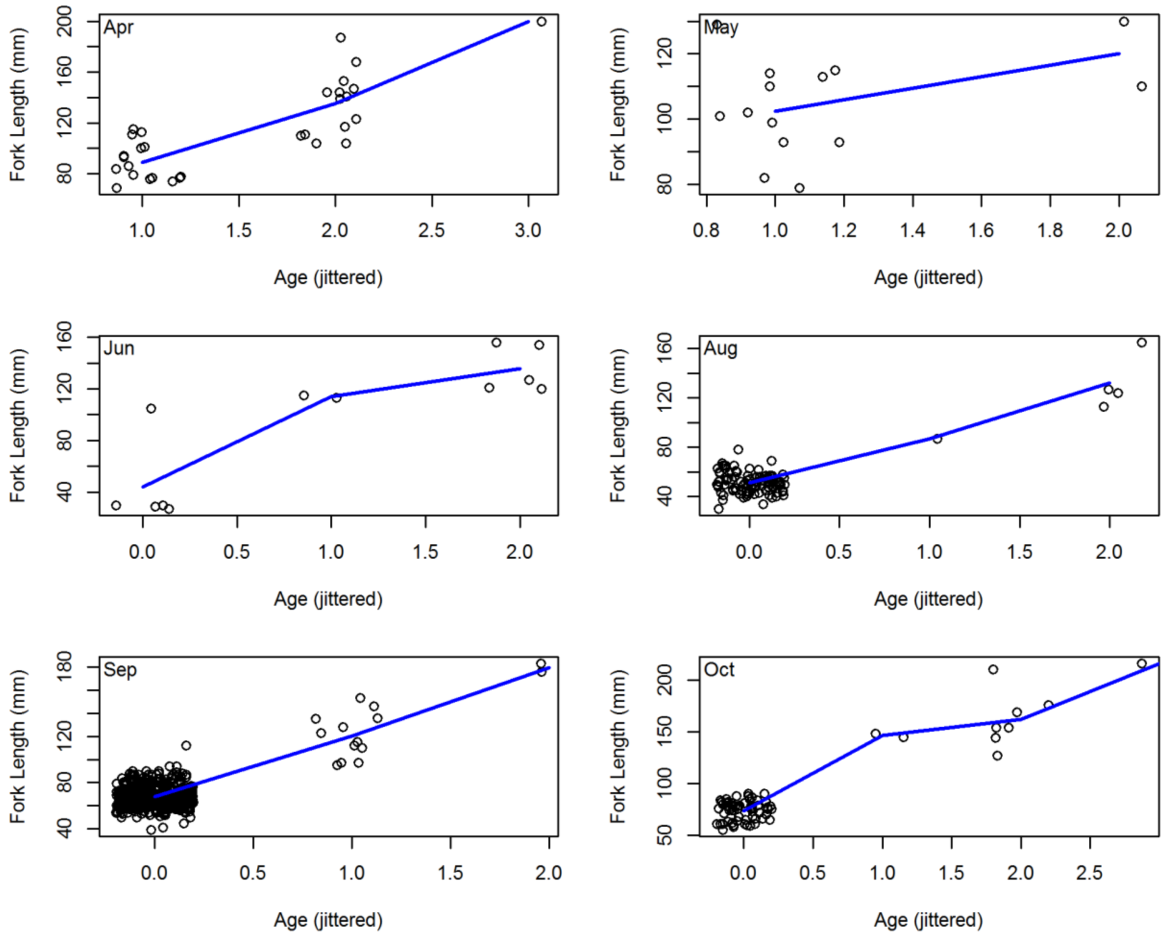


Figure 12. Length-weight relationship for Seton River Rainbow Trout sampled in 2016.

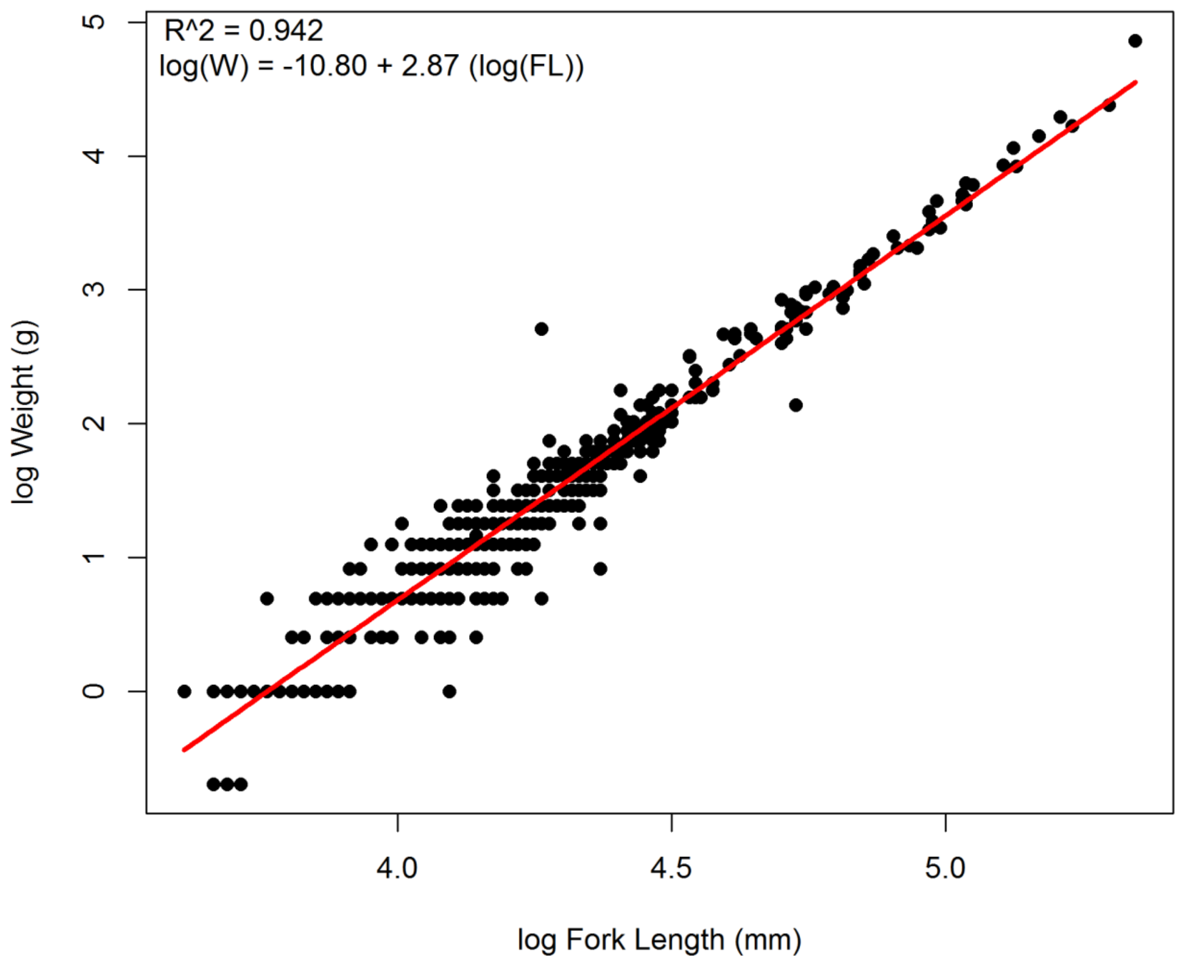


Figure 13. Length boxplot of Seton River Rainbow Trout (Age 0 to Age 2) from April -October 2016

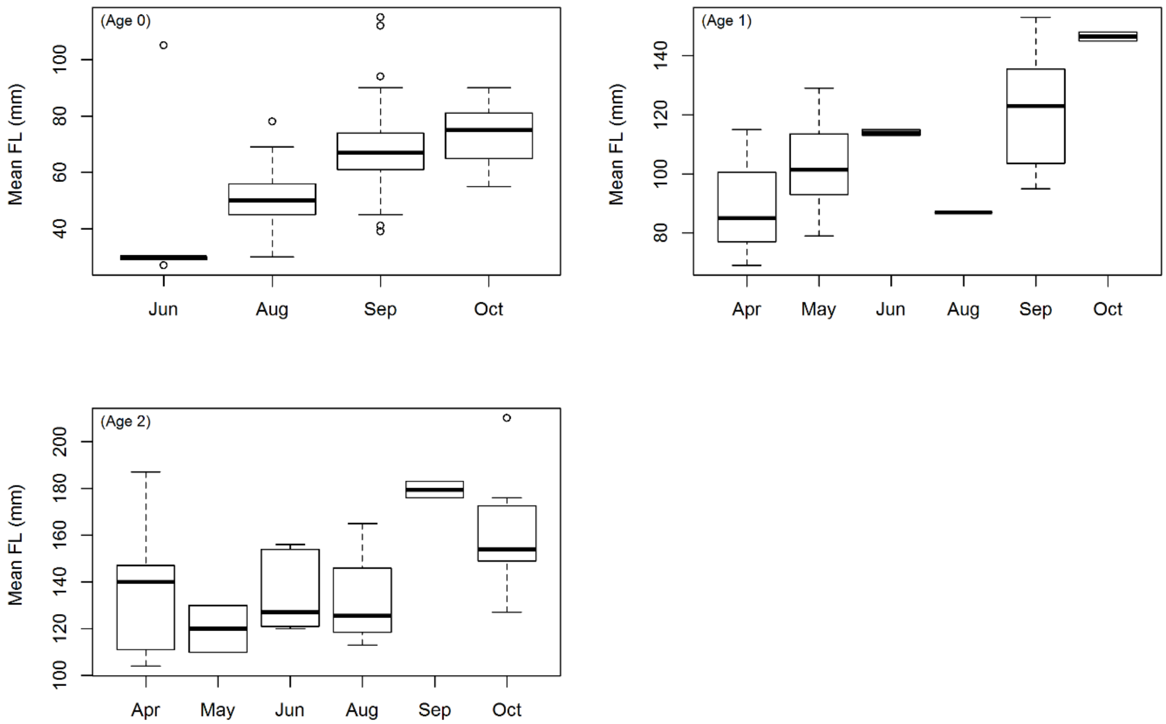


Figure 14. Weight boxplot of Seton River Rainbow Trout (Age 0 to Age 2) from April - October 2016

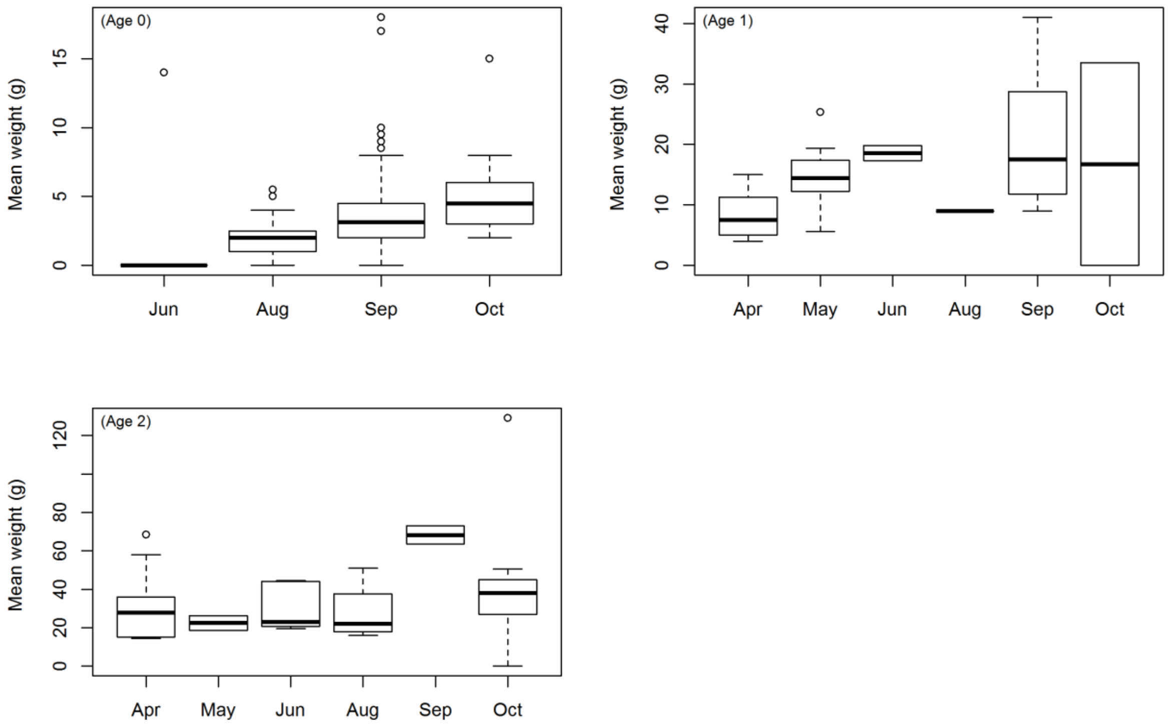


Figure 15. Growth of PIT-tagged juvenile rainbow trout from April to October 2016. Each panel represents the growth of an individual fish. LSC and USC are the Lower and Upper Spawning Channels, respectively. Red box represents initial tagging day and the black box represent recapture date.

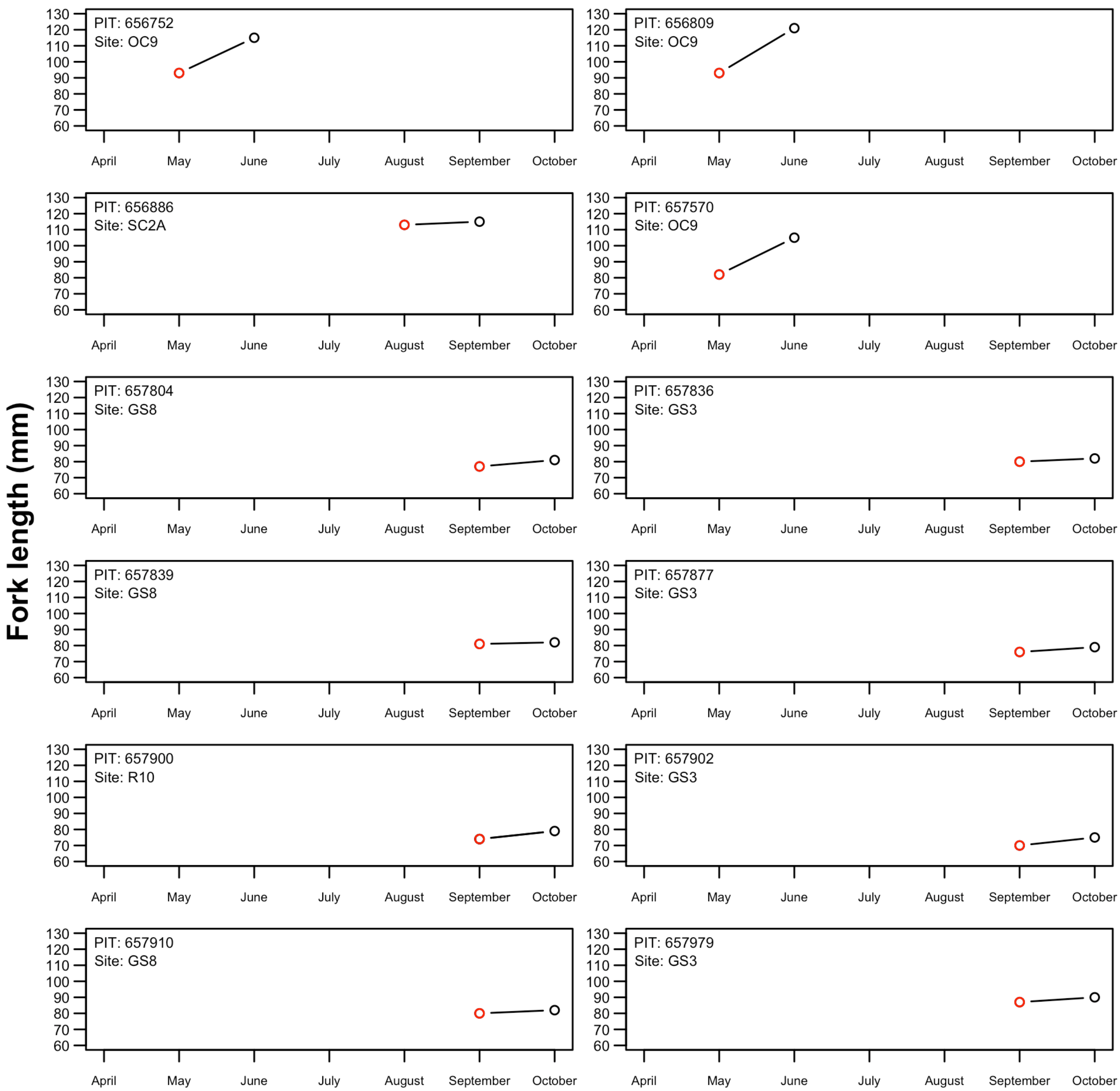


Figure 16. Length and age frequency for Seton River juvenile Coho Salmon in 2016.

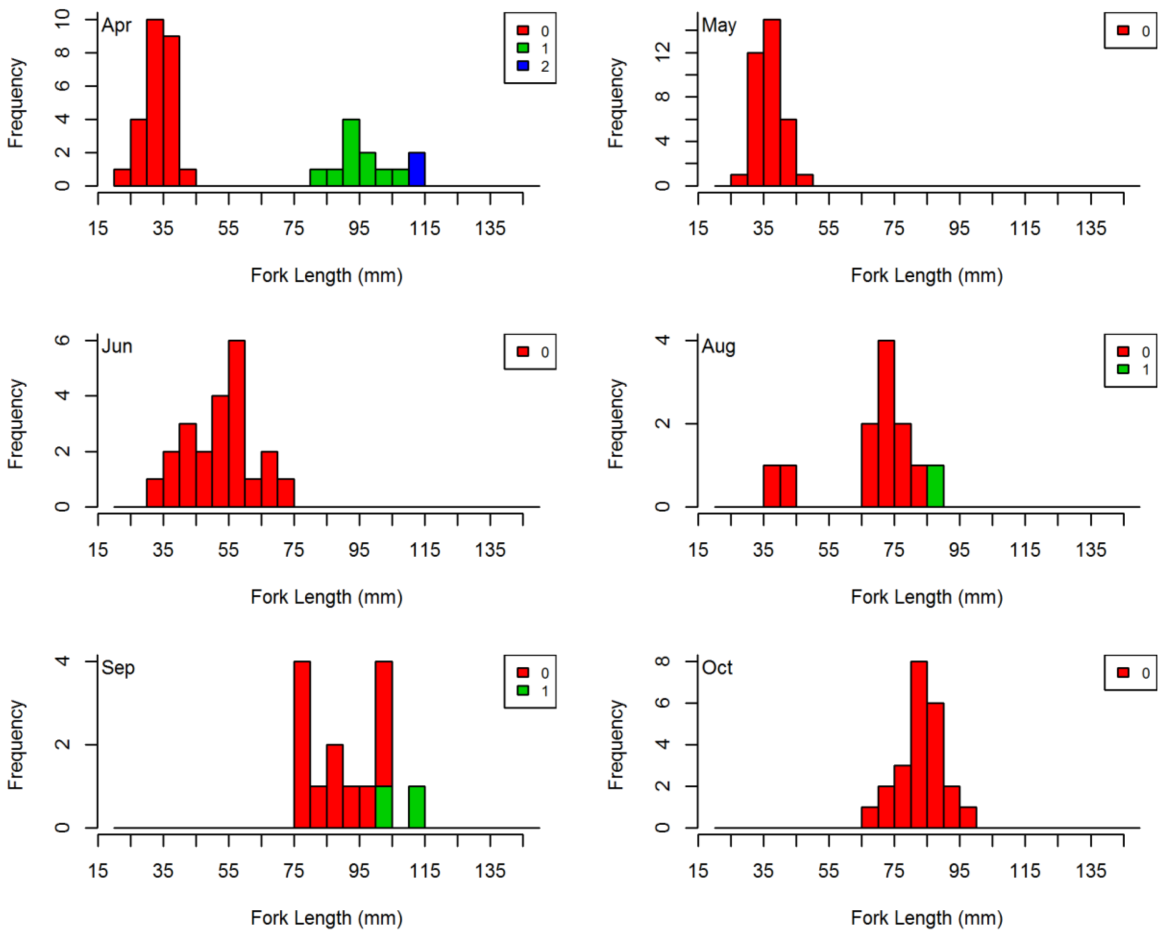


Figure 17. Length-at-age for Seton River Coho Salmon sampled in April to October 2016. Age is jittered, and mean lengths are connected by blue line.

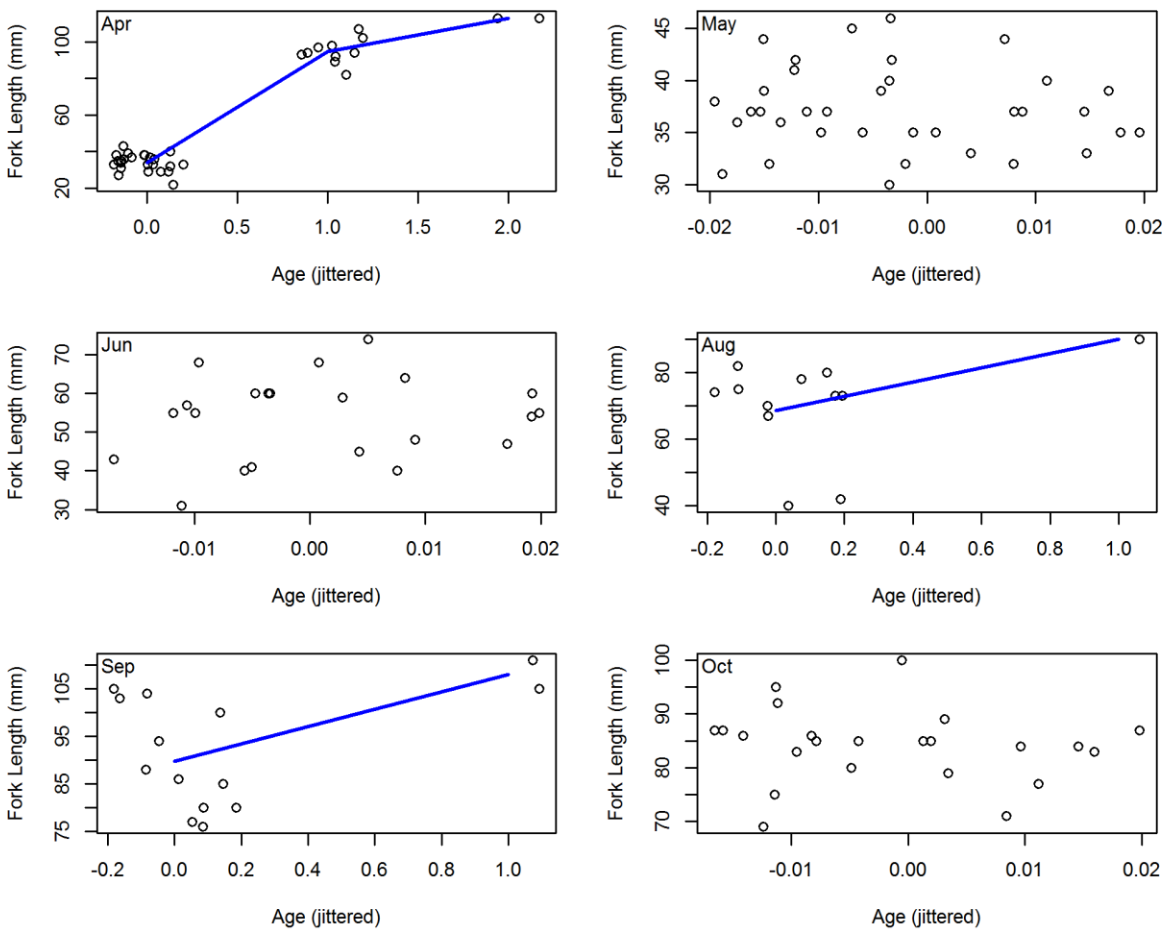


Figure 18. Length-weight relationship for Seton River juvenile Coho Salmon sampled in 2016.

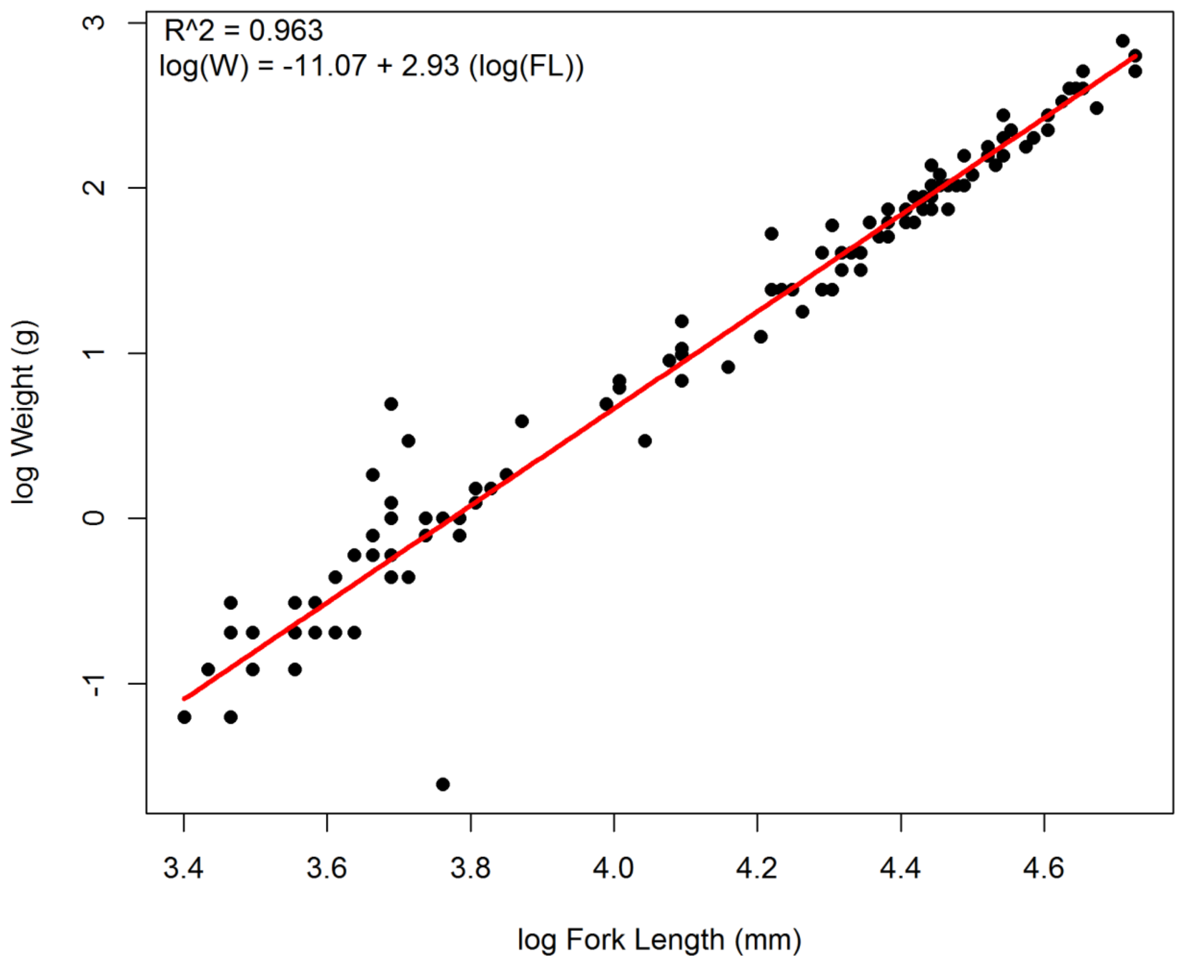


Figure 19. Length boxplot of Seton River age 0 Coho from April -October 2016.

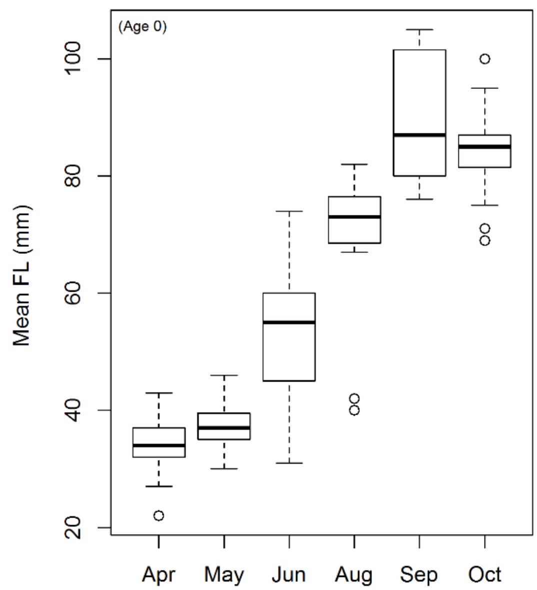


Figure 20. Weight boxplot of Seton River age 0 Coho from April -October 2016.

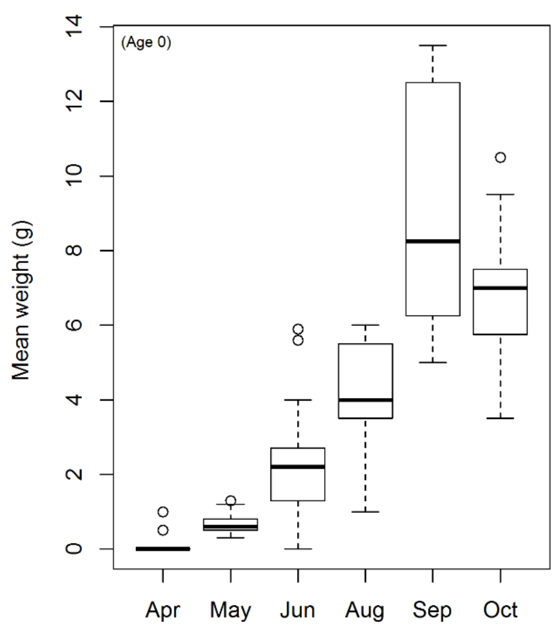


Figure 21. Length and age frequency for Seton juvenile Chinook Salmon in 2016.

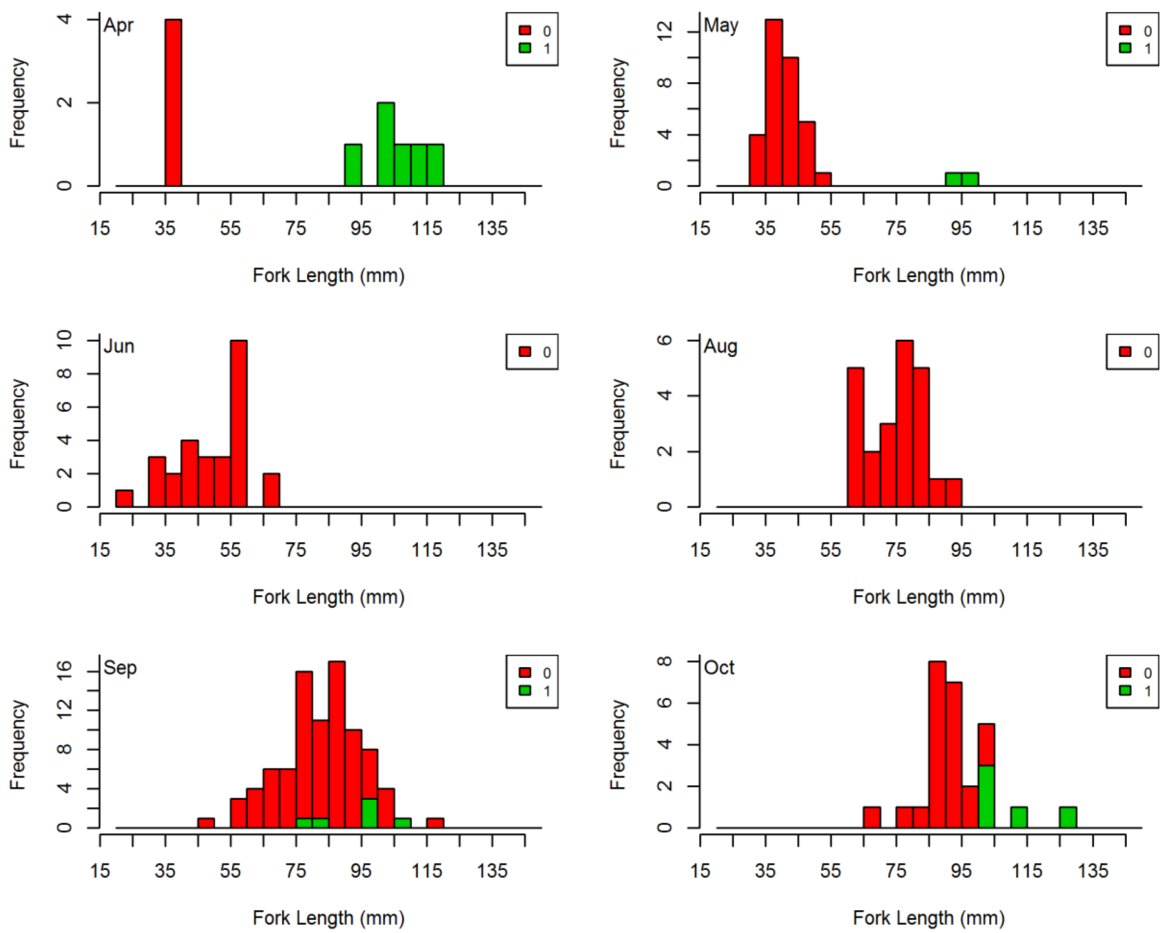


Figure 22. Length-weight relationship for Seton River juvenile Chinook salmon sampled in 2016.

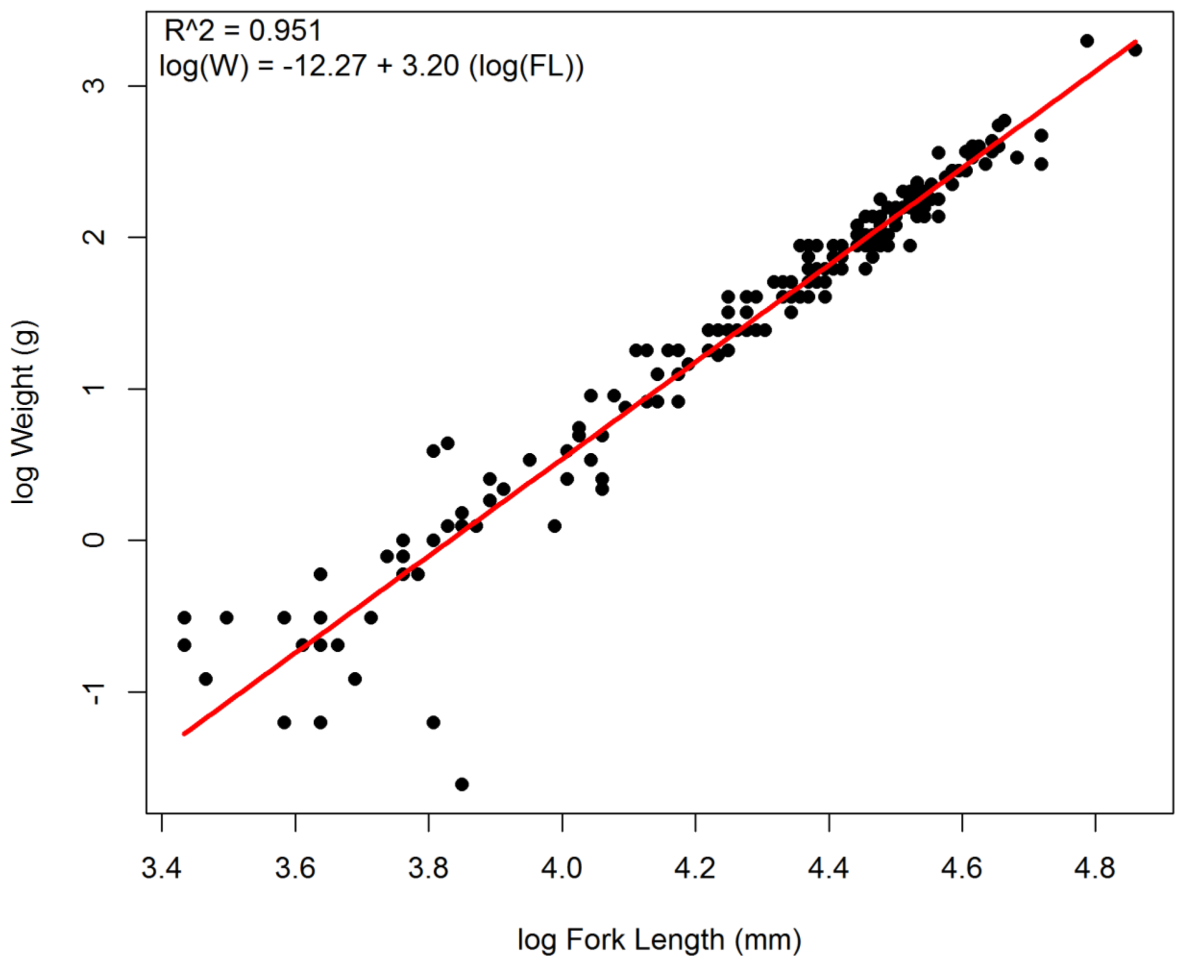


Figure 23. Length boxplot of Seton River age 0 Chinook from April to October 2016.

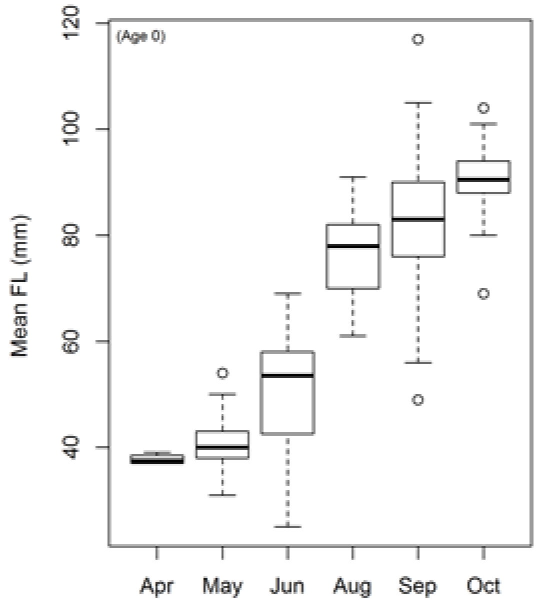


Figure 24. Weight boxplot of Seton River age 0 Chinook from April to October 2016.

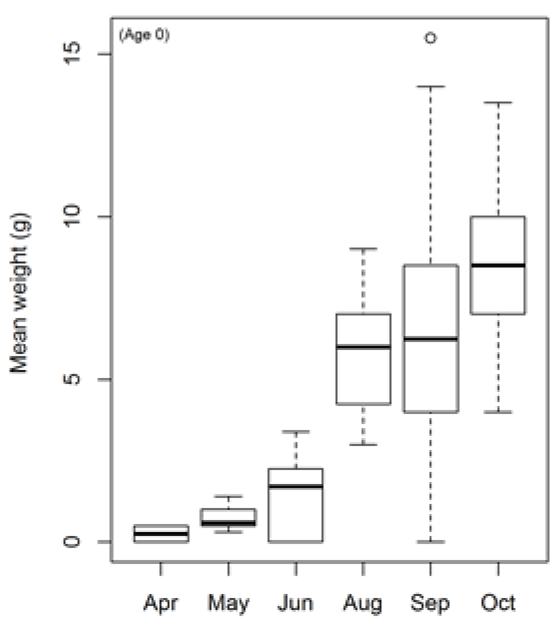


Figure 25. Posterior distributions for capture probability at mark-recapture sites, Seton River 2016.

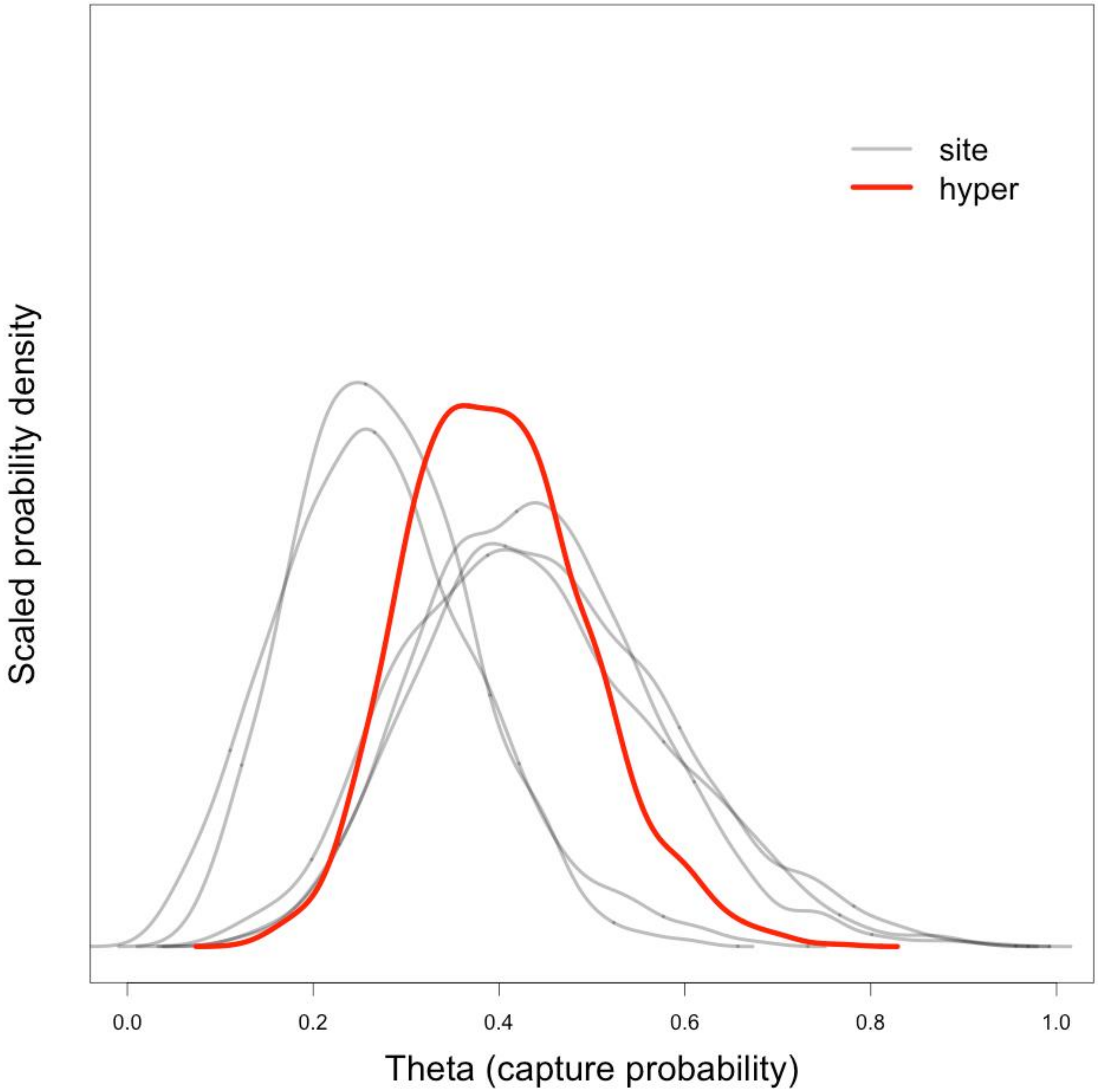


Figure 26. Seton River age 0 Rainbow Trout density estimates. Red open boxes represent 2016 densities. Grey open triangles represent 2014 densities and black open circles represent 2015 densities. Filled symbols represent mark recapture sites.

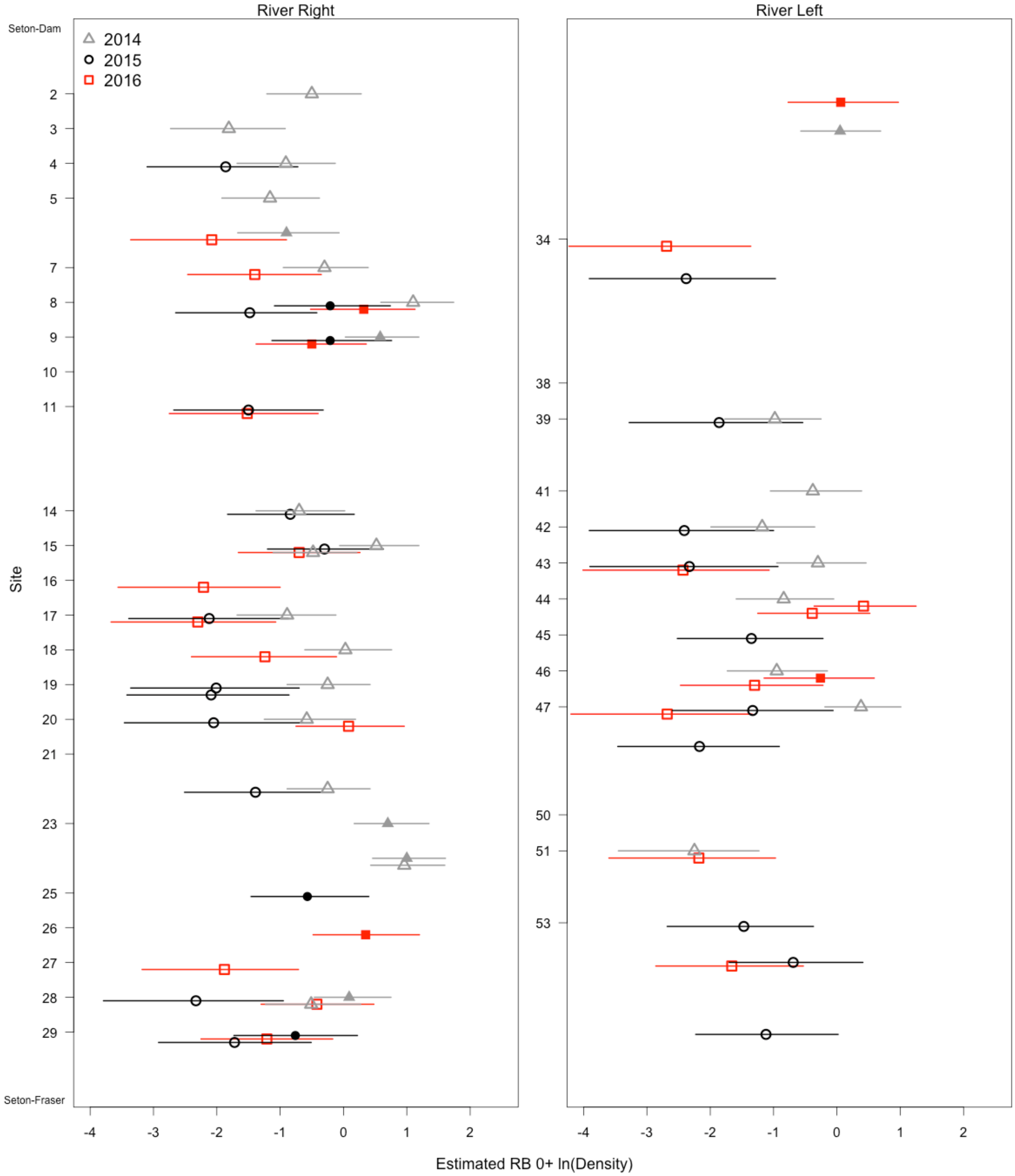


Figure 27. Detection histories of radio-tagged Steelhead Trout in the Seton River in 2016. Grey lines connect the release information (red) and data collected from radio receivers (blue) and PIT readers (black). Successful fish passage at Seton Dam is represented by two vertically-stacked circles at Seton Dam. Water temperature in the Seton River is shown as a black line. FRA = Fraser River, LSC = Lower Spawning Channel, CAY = Cayoosh, USC = Upper Spawning Channel, SON = Seton Dam

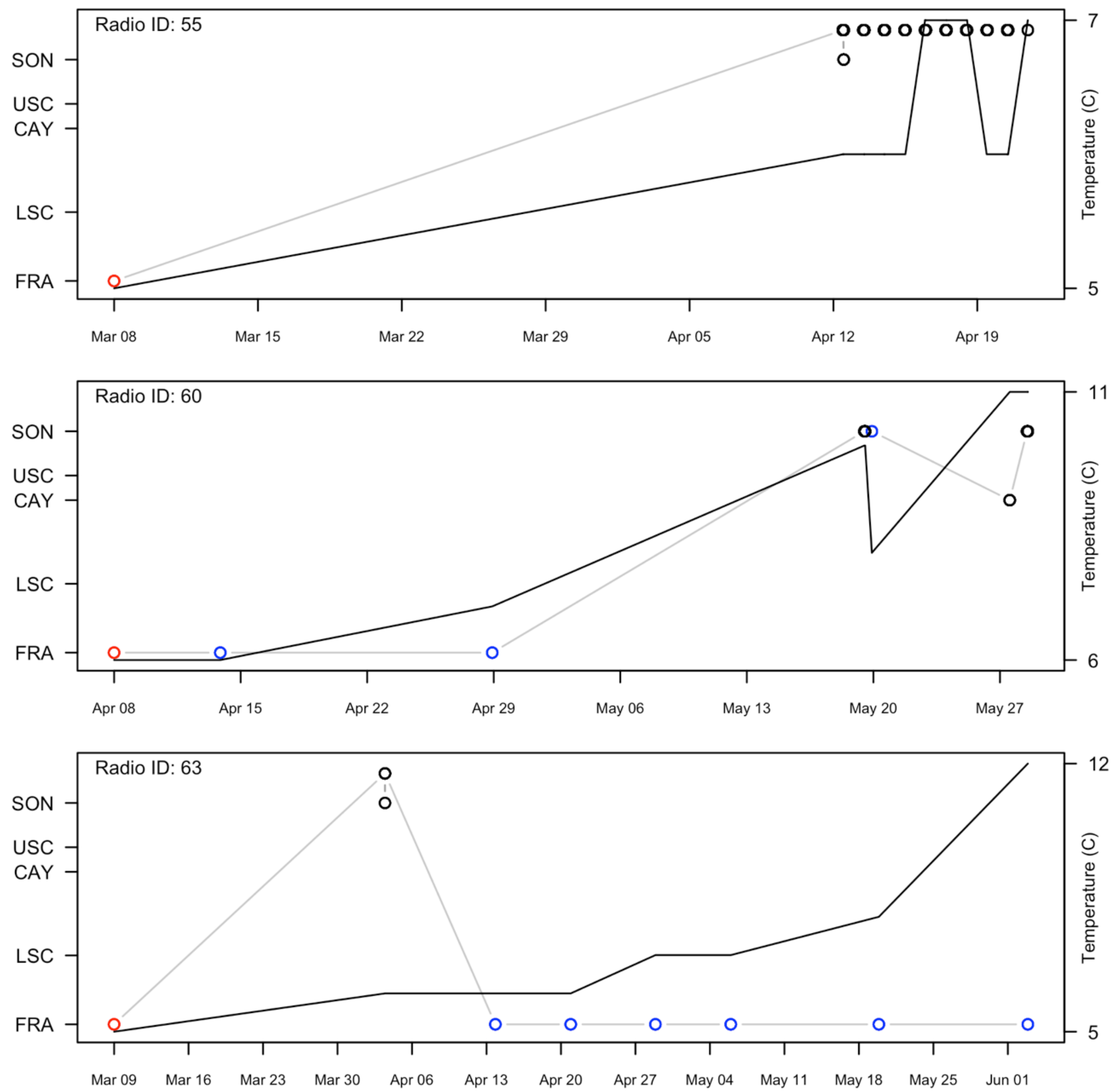


Figure 28. Fraser River discharge at Water survey of Canada Texas Creek gauge (08MF040) – March 23, 2016

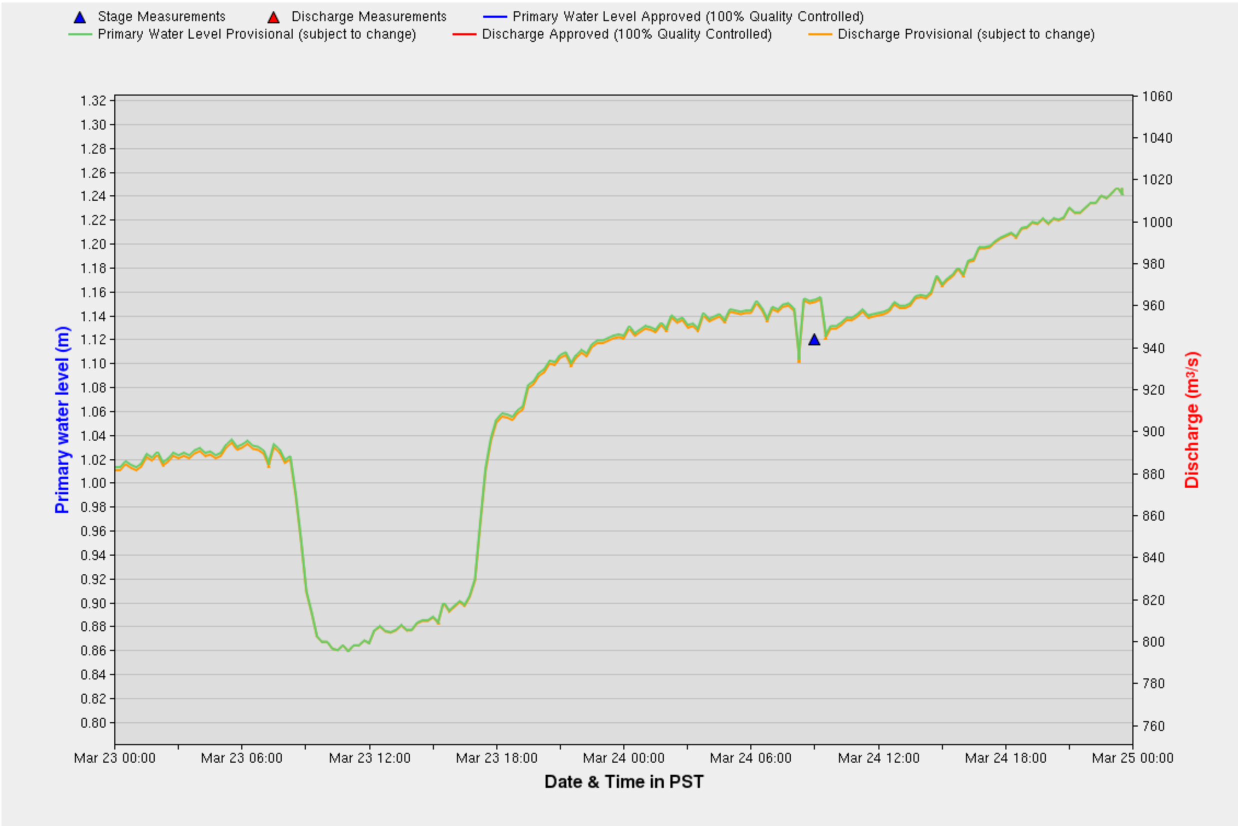
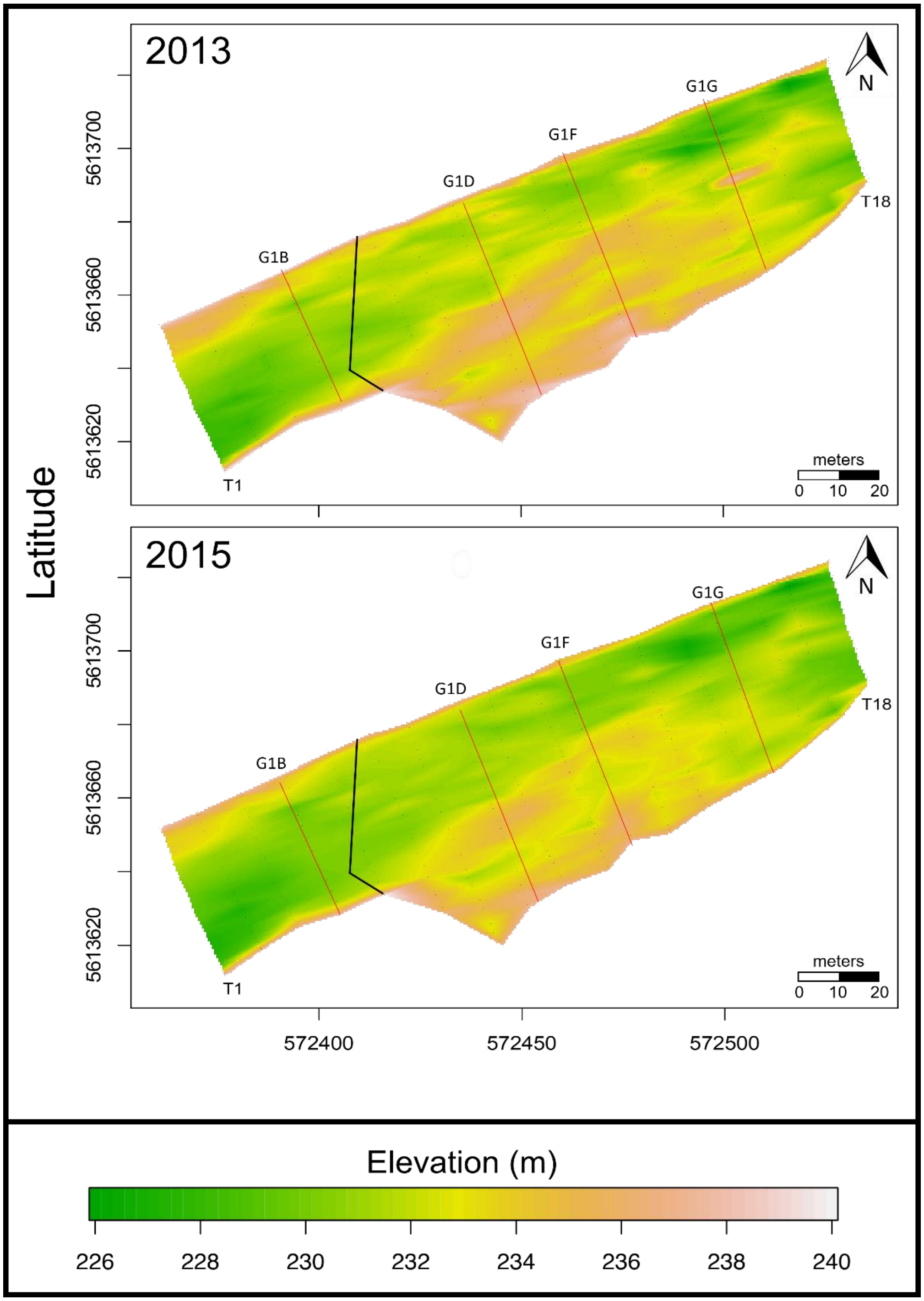


Figure 29. Streambed elevation (m) in the Seton River in 2013 (top panel) and 2015 (bottom panel). Dots represent individual measurement points along 18 transects (T1 to T18) and red lines present substrate transects.



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